

Sept. 15, 1953

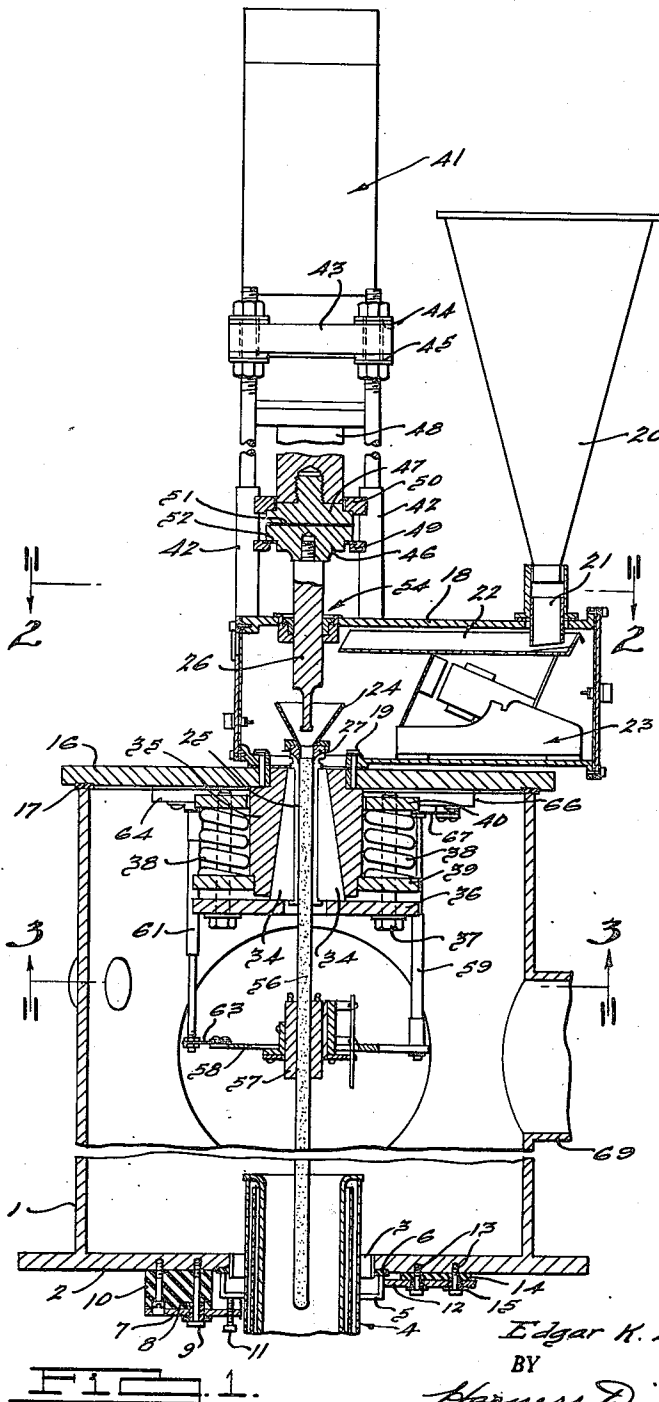
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2,651,952

DIE FOR EXTRUDING COMPRESSED POWDER RODS

Filed Nov. 24, 1947

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

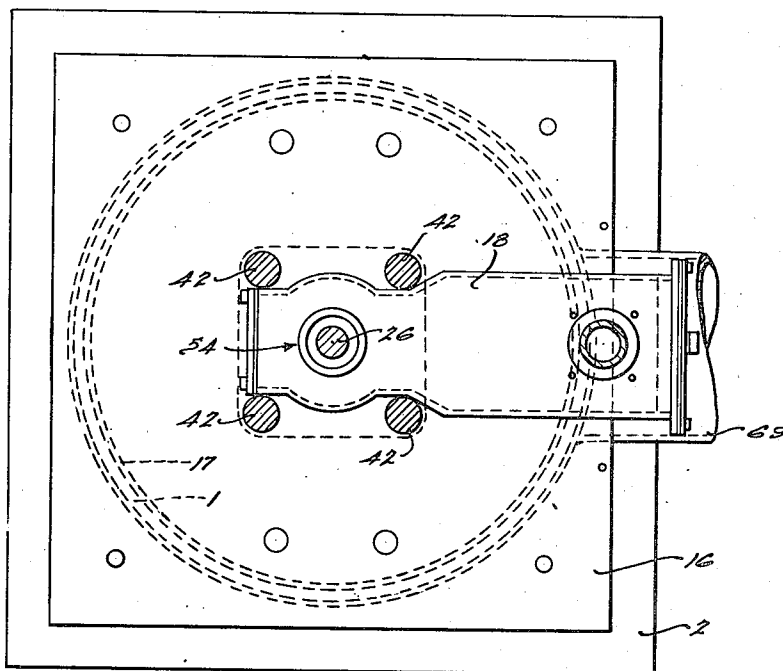


FIG. 2.

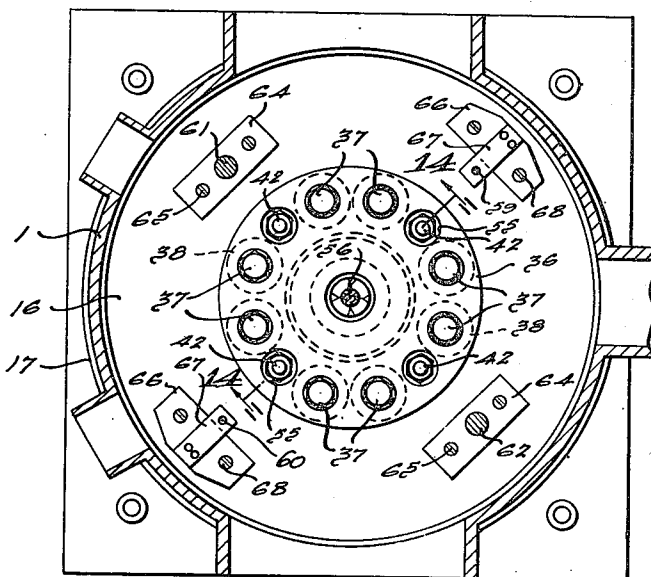


FIG. 3.

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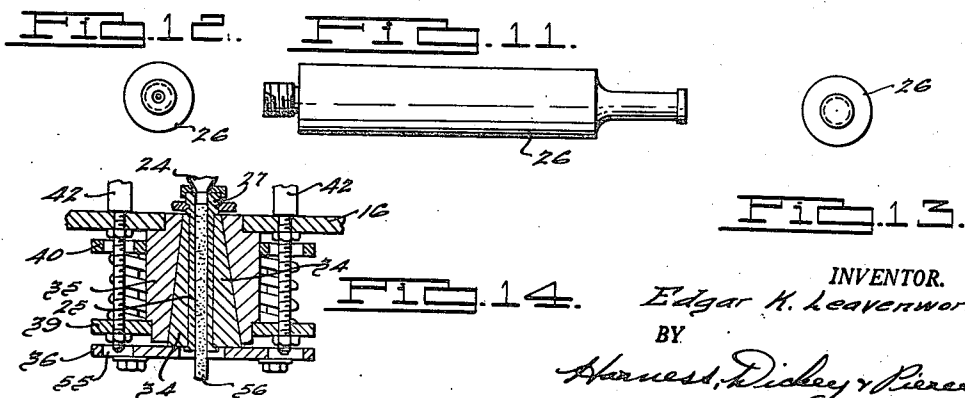
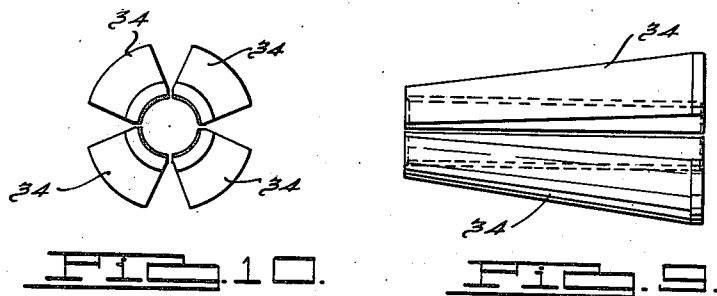
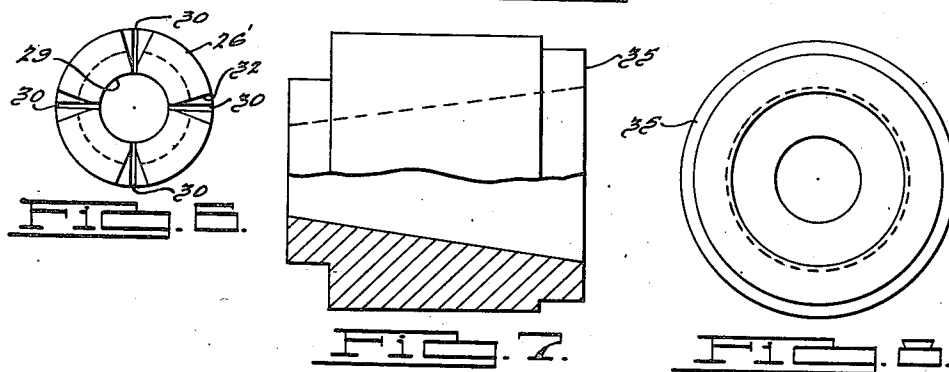
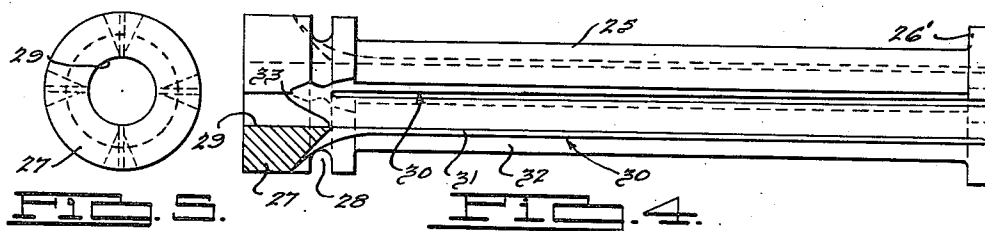
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DIE FOR EXTRUDING COMPRESSED POWDER RODS

Filed Nov. 24, 1947

3 Sheets-Sheet 3



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## UNITED STATES PATENT OFFICE

2,651,952

DIE FOR EXTRUDING COMPRESSED  
POWDER RODS

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Application November 24, 1947, Serial No. 787,797

12 Claims. (Cl. 78—0.5)

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The present invention relates to a die mechanism for compressing powdered metal to form a continuous rod which may be sintered into a relatively rigid structure; and this application is a continuation-in-part of applicant's copending application, Serial No. 776,091, filed September 25, 1947.

The invention may be employed in conjunction with any desired powdered metals, but is peculiarly suited for use in forming a self-sustaining rod from the powders of refractory metals such as molybdenum and tungsten and their alloys without the use of any binder. Such rods require high compacting pressures and are relatively fragile. They have a relatively low elastic limit; and, when that limit is exceeded, they break down into small fragments.

The object of the invention is to provide an improved die for the purpose mentioned above.

Other objects and advantages of the invention will become apparent from the following specification, the accompanying drawings, and the appended claims.

In the drawings:

Figure 1 is a cross-sectional view of a complete apparatus suitable for forming a continuous rod of compressed and sintered powdered metal;

Figure 2 is a section taken on the line 2—2 of Figure 1;

Figure 3 is a section taken on the line 3—3 of Figure 1;

Figure 4 is an elevational view partly in section and Figures 5 and 6 are upper and lower end views of the inner die nozzle;

Figure 7 is an elevation and Figure 8 is a lower end view of the conical die-supporting member;

Figure 9 is an elevation and Figure 10 is an upper end view of the die-supporting shoes;

Figure 11 is an elevation and Figures 12 and 13 show upper and lower end views of the plunger; and

Figure 14 is a fragmentary section taken on the line 14—14 of Figure 3.

Referring to Figure 1, the invention is illustrated in connection with a vacuum arc melting furnace in which the continuously formed sintered powdered metal rod produced by the mechanism of the present invention acts as a consumable electrode and the collecting pot or mold which receives the molten metal acts as the other electrode. The mechanism of the present invention compresses powdered metal and extrudes it in a continuous rod, and thus continuously supplies the consumable electrode material. The

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compressed rod is sintered by the passage of an electric current or otherwise in order to impart sufficient strength to enable the rod to sustain its own weight.

5 The complete apparatus includes a housing 1 having a bottom plate 2 provided with a central opening 3 to receive the upper end of a water-cooled copper mold 4, of any desired length. The mold 4 is provided with an integral channel-shaped flange 5, the upper edge of which is adapted to seat against a sealing ring 6 in order to seal the interior of the housing 1 against the admission of atmospheric air. The mold is secured to the bottom plate 2 by means of a plurality of clamps 7, one of which is illustrated in Figure 1. Each clamp 7 consists of an arm which is pivotally mounted upon an insulating bushing 8 surrounding a bolt 9 which is threaded into the lower plate 2 and holds the clamp against a block of electric insulation 10. The inner end of the clamp arm carries a screw 11 which is adapted to engage the flange 5 and hold the flange against the sealing strip 6. When the screw clamps 11 are released and the clamps 15 rotated about their pivotal mountings, the mold 4 may be removed from the housing 1.

A plurality of circumferentially spaced locating lugs 12 is likewise secured to the underside of the plate 2 by screws 13 and engages the outer periphery of the flange 5 in order to rotate the mold in proper axial alignment with the consumable electrode, hereinafter described. The lugs 12 are insulated from the plate 2 by means of a layer of insulation 14 and insulating bushings 15 surrounding the screws 13.

The upper end of the housing is closed by means of a flat plate 16 which seats upon a sealing ring 17 and which is provided with a central opening communicating with a powder feed housing 18 which is secured to the upper surface of the plate 16 by means of screws 19. A magazine 20, of any desired size, is secured to the housing 18 with its discharge opening 21 overlying the feed tray 22 of a conventional vibratory feeder, indicated generally at 23.

In accordance with the present invention, the metal powder which is fed from right to left along the tray 22 of the vibratory feeder is discharged into a funnel 24 and thus to the upper end of an extrusion die 25, within which it is compressed by a reciprocating plunger 26, the plunger also acting to feed the compressed powder downwardly through the die.

As best shown in Figures 4, 5 and 6, the die 25 is generally cylindrical in form, except that

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it is provided with a flange 26' at its lower end and a head 27 at its upper end, the head being provided with a circumferential groove 28. The die 25 is provided with an axial cylindrical bore 29. For reasons hereinafter stated, it is essential that the die opening 29 be of the same diameter from one end to the other, the maximum permissible variations in diameter being less than one one-thousandth of an inch and preferably in the order of one ten-thousandths of an inch. The side walls of the opening are preferably provided with a hard chromium plate and thereafter finish ground to the final dimensions.

The head portion 27 of the die 25 comprises a circumferentially continuous cylinder, but the remainder of the die is provided with two or more longitudinally extending circumferentially spaced slots 30, four being illustrated in the drawings. Each of the slots 30, as best shown in Figures 4 and 5, comprises an inner portion 31 which is quite narrow and has parallel sides and an outer portion 32 which flares outwardly.

As best indicated in the lower half of Figure 4, the slots 32 terminate on the interior walls of the opening 29 at the point indicated by the numeral 33, thus leaving an unslotted top or head portion in which, as hereinafter set forth, the powdered metal is compacted. The slots 30 permit radial expansion of the lower portion of the die, and in that connection the groove 28, which is located adjacent the upper ends of the slots, facilitates flexure of the die segments by reducing the thickness of the metal at the upper ends of the slots.

In the complete assembly shown in Figure 1, the die 25 is held against expansion by means of four circumferentially spaced shoes 34, the construction and arrangement of which are best shown in Figures 9 and 10. Each of the shoes has a cylindrical inner surface adapted to fit the cylindrical surface of one of the segments of the die 25 between the flange 26 and the head 27. The outer surfaces of the shoes 34 form a common cone adapted to fit the internal cone surface formed in a holder 35. The lower ends of the shoes 34 seat against a plate 36 which is constantly urged upwardly by means of eight circumferentially spaced bolts 37 and associated helical springs 38. The bolts 37 pass freely through an annular fixed plate 39 and their upper ends are threaded into an annular plate 40 which is free to move axially with respect to the holder 34. The helical springs 38 surround the bolts between the plates 39 and 40 and thus urge the plate 40, bolts 37, plate 36 and shoes 34 upwardly with respect to the fixed plate 39.

The reciprocating plunger 26 may be operated by any suitable mechanism, but as illustrated is actuated by a hydraulic piston and cylinder unit 41 which is supported in elevated position above the plate 16 by four long bolts or rods 42. The bolts 42 pass through suitable openings in a flange 43 formed on the lower end of the cylinder. Flanged bushings 44 and 45 formed of electrical insulating material are fitted within the openings in the flange 43 and surround the bolts. Nuts threaded on the bolts engage the bushing flanges on the upper and lower sides of the flange 43, in the manner best shown in Figure 1. As a result, the bolts 42 support the piston and cylinder unit, but are electrically insulated therefrom. The plunger 26 is provided with a head 46 which is secured to a correspondingly shaped head 47 formed on the piston rod 48 of the piston and cylinder unit 41 by means of a pair of an-

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nular flanges 49 and 50, which flanges are connected together by a plurality of circumferentially spaced bolts (not shown). A layer of electric insulation material 51 is positioned between the heads 46 and 47 and an annular ring of electric insulation 52 is positioned between the flange 49 and the head 46, as a result of which it will be apparent that the plunger 26 is connected to the piston rod of the cylinder and piston unit 41 but is electrically insulated therefrom. In that connection, it will be noted that since the diameter of the flanges 49 and 50 is less than the space between diagonally opposite bolts 42, the flanges do not engage the bolts.

The point at which the plunger 26 enters the feed chamber 18 is sealed by a packing box, indicated generally at 54.

While any desired means may be provided for securing the holder 35 and the stationary plate 39 in fixed position, in the preferred arrangement illustrated this function is performed by the lower ends of the bolts 42, which, as illustrated in Figure 3, are located between each pair of bolts 37. As best illustrated in Figure 14, the lower ends of the bolts 42 are reduced in diameter to provide a shoulder which seats upon the upper surface of plate 16. The reduced lower extremities of the bolts are threaded and project through the plate 16, enlarged openings in the movable annular ring 40, and the stationary plate 39. Nuts are threaded on the lower extremities of each of the bolts 42 beneath the plate 16 and the stationary plate 39, thus fixing the bolts in position with reference to the plate 16 and securing the stationary plate 39 in fixed position. The plate 36 is preferably provided with openings 55 slightly larger than the nuts on the lower ends of the bolts 42, for clearance purposes.

The extruded rod of compressed powder, indicated by the numeral 56, extends downwardly from the die 25 and is engaged by two or more electrical contacts 57 which are carried by a horizontal plate 58. The plate 58, in turn, is supported from the plate 16 by four vertical rods, two of which, namely rods 59 and 60, are fixed at their lower ends to the plate 58, and the remaining two, namely rods 61 and 62, are connected to the plate 58 by resilient leaf springs 63. The upper ends of rods 61 and 62 are fixed in any suitable manner to blocks of insulation 64, which, in turn, are secured to the undersurface of the plate 16 by means of screws 65. The upper ends of rods 59 and 60 are connected to similar blocks of insulation 66 by resilient leaf springs 67, and the insulating blocks 66 are likewise secured to the underside of the plate 16 by screws 68. As a result of this construction, the electrical contacts 57 are resiliently supported for limited vertical movement but are held against lateral movement.

After the magazine 20 is loaded, it is closed and sealed, thus completely sealing the magazine, the interior of the feed chamber 18, and the interior of housing 1. The entire apparatus is then preferably evacuated to an exceedingly high degree by any suitable form of vacuum pump which may be connected to the chamber 1 by means of a conduit 69.

The operation of the apparatus is as follows. The vibratory feeder 23 is energized, thus operating to feed the powder along the tray 22 and into the funnel 24, which directs the powder into the cylindrical die 25. Assuming that the apparatus has previously been operating, the major portion

of the length of the die 25 will contain a column of compressed powder, as indicated in Figure 1. The plunger 26 is reciprocated continuously by means of the hydraulic piston and cylinder unit 41, any suitable control mechanism being provided for controlling the actuation and reciprocation of the piston within the cylinder in accordance with conventional practice. The stroke of the plunger and the rate of feed of powder to the die may be varied as desired, except that in no case should the plunger advance into the die beyond the point 33 in Figure 4. The tension of springs 38 is so adjusted by means of bolts 37 that they hold the tapered shoes 34 and, consequently, the die 25 against downward movement under the influence of the force exerted by plunger 26 until the force exerted by the plunger reaches that value which will provide the required degree of compression and compacting of the loose powder in the upper end of die. In this connection, it will be noted that since the head of the die 25 is, in effect, a flange overlying the upper ends of the tapered shoes 34, the die and the shoes 34 will move downwardly when the force exerted by the plunger 26 overcomes the force exerted by the springs 38 and any friction between the shoes 34 and the holder 35.

As a result of the above described mode of operation, all of the compressing or compacting of the powder by the plunger will occur within the head 27 of the die 25 which provides a circumferentially continuous cylindrical die opening, and no movement of the compacted powder into the lower slotted portion of the die 25 will occur until after the powder has been compacted to the maximum degree. Thus, all of the successive segments of the extruded rod are formed within the head of the die, and the lower slotted portion of the die operates only to exert sufficient frictional resistance upon the compressed column of powder to hold it against movement under the powder compacting force. In this connection, it may be noted that the head portion of the die is so short that the frictional resistance exerted by its side walls is insufficient to prevent bodily movement of the powder through the die before the powder is compressed to the desired degree. It has been found that if a circumferentially continuous die is made sufficiently long to impose the necessary degree of frictional resistance to the column of powder, no amount of force exerted by the plunger will advance the powder column through the die, and it is for this reason that the lower portion is slotted to permit radial expansion.

An important feature of the invention resides in the fact that the die and tapered shoes 34 will always move downwardly, permitting expansion of the lower portion of the die 25, when an exact predetermined pressure is exerted by the plunger. Thus, all portions of the rod will be compressed and compacted to the same degree. This is no possibility of expansion of the die in response to radial forces exerted by the powder column on the die member until the axial force exerted by the plunger exceeds the pressure exerted by the springs because the angle of the conical interior surface of the holder 35 is substantially equal to or less than the frictional angle of repose of the engaging surfaces of the shoes and holder. Thus, the shoes and springs 38 constitute an irreversible or self-locking force transmitting mechanism for exerting a radial pressure on the powder column.

The functioning of the die to hold the powder

column against movement during the compacting of the top segment of the column and then release it at a predetermined axial pressure results from the fact that the powder column, as compressed in the head of the die to a relatively high degree, has an appreciable strength and hence acts within the lower portion of the die as a solid elastic body, such as a solid bar of steel having a definite capability of limited deformation within the elastic limit. The springs 38, in combination with the tapered shoes 34, thus exert a radial compressive force upon the powder column tending to reduce its diameter but without exceeding the elastic limit of the powder column. This radial force produces sufficient friction between the powder column and the walls of the die to prevent downward movement of the column so long as the die remains stationary in the holder.

The required radial force is applied without exceeding the elastic limit of the compressed rod by distributing the force over a sufficient surface area on the rod. It is for that reason that the split portion of the die is relatively long compared with the solid portion in which the powder is first compressed. However, a slight downward movement of the die permits expansion of the lower portion and a resultant reduction in the pressure exerted by the column upon the die walls. If when the die expanded the powder column had no inherent compression strength, it would act as a liquid and thus expand equally with the die without any reduction in the pressure exerted by the column upon the die walls. However, since the column has compression strength, an expansion of the die walls by an amount within the elastic limit of the column results in a reduction in the radial pressure and, therefore, in the friction between the column and the die. As soon as the friction reduces to a value equal to the pressure exerted by the plunger, the column will advance downwardly through the die until the plunger reaches the end of its stroke. During this downward movement of the column relative to the die, a state of equilibrium exists between the force exerted by the springs 38 and the friction force exerted on the die walls by the powder column. On the return stroke of the plunger, springs 38 will return the die and shoes 34 to their uppermost position and thus reduce the lower portion of the die to its initial diameter, at which it tightly clamps the column. The total downward movement of the die is limited to only a few thousandths of an inch, since only a minute expansion of the die is necessary to reduce the radial pressure exerted by the column on the die walls.

It will be appreciated from the above why it is essential that the die be of uniform diameter from one end to the other. Thus, if the column which is completely formed in the head of the die is subsequently forced through an opening which is slightly smaller than the opening in the head but nevertheless is sufficiently small to compress the column beyond its elastic limit, the column will at that point be crushed and will thus lose all of its inherent strength. Therefore, at the point at which the column is crushed, the powder column cannot act as an elastic solid in the manner described above. In addition, it is not possible to reduce the cross section of the compressed column of powder beyond the elastic limit in an expendable die for the reason that such a reduction would cause the powder to pack in the longitudinal slots of the die and, therefore,

render the die inoperative. Since in accordance with the present invention the column is completely formed in the head of the die which is not slotted, the column will have sufficient inherent strength to bridge across the slots in the lower portion. In as much as the powder column at best has only limited strength and a very low elastic limit of deformation, it is necessary to avoid even minute changes in the diameter of the die from one end to the other.

While in the preferred form of die mechanism illustrated and described herein the tapered shoes 34 are formed as separate pieces from the die 25, it will be obvious that the shoes may form an integral part of the radially expandable sections of die 25 without altering the mode of operation or the results achieved.

In the above description of the operation of the device, it was assumed that at the start of the operation the die was filled with compressed powder. If this is not the case, it is necessary to manipulate the apparatus until the die is filled with powder before the normal operation can start. This can be done in several ways. For example, an accurately made cylindrical plug of the same diameter as the die opening and of the same length as the slotted portion of the die may be inserted within the die opening while the tension on the springs 38 is relieved. Thereafter, the spring tension is applied by tightening the bolts 37. The apparatus may then be started, the plug, which may be formed of copper or any other suitable metal, performing the function of compressed powder column in resisting downward movement of the column during the powder compacting portion of the plunger stroke.

In order to increase the strength of the powdered rod extruded from the die 25, it is preferred to sinter the powdered particles together by raising their temperature in any suitable manner to a sintering temperature. This is most readily accomplished by passing an electric current through the powdered column, and, in accordance with the form of apparatus illustrated in Figure 1, the sintering current is supplied to the rod by connecting the terminals of a source of electric current to the plate 16 which is in electrical communication with the die 25 and to the contact shoes 57. It has been noted that there is a tendency on the passage of an electric current through the compressed powdered rod for the current to produce nonuniform heating of the rod and, consequently, it is necessary to support the rod for a sufficient period to enable the heat to flow equally to all portions and complete the sintering operation. The frictional effect of the contact shoes 57 will ordinarily be sufficient for that purpose. However, it has been found that in the production of rods of relatively large diameter and particularly when the rod is extruded at a relatively high rate of speed, it is necessary to provide additional friction shoes located beneath the contact shoes 57. These merely serve to exert an upward force on the rod and help sustain it until a uniform sinter is effected.

If, as in the illustrated embodiment of the invention, the extruded rod is to constitute the consumable electrode of a vacuum arc furnace, a second electric arc current is imposed upon the rod by connecting the terminals of a suitable source of electricity to the shoes 57 and the mold 4, so that the bath of molten metal produced by the arc constitutes the second electrode of the system.

While only one form of the invention is illustrated and described herein, it will be apparent that variations in the design and details of construction may be indulged in without departing from the spirit of the invention or the scope of the appended claims.

What is claimed is:

1. Apparatus for forming a continuous rod of compressed powdered metal in successive increments, comprising a die having an opening there-through which normally is of the same cross section throughout its length, means for supplying powdered metal to the die opening at one end thereof, powder compressing means including a reciprocating plunger operable to compress the powder within said opening against the previously formed portion of the rod and thus compact to final form successive increments of said rod in a portion of the die opening adjacent said one end, the remaining and major portion of the length of said die opening receiving a length of the fully formed rod and being radially expandable, and mechanism normally clamping the expandable portion of the die with a radial force insufficient to stress the compressed rod beyond its elastic limit, the radial clamping force normally exerted by said mechanism being sufficient to develop a frictional resistance to movement of the compressed rod through the die opening which will prevent such movement in response to the force exerted by the plunger until after the radial clamping force is reduced, said mechanism including pressure responsive means operated by the powder compressing means for reducing the radial clamping force exerted by said mechanism and thus permitting expansion of said expandable portion of the die and movement of the compressed rod through the die opening after the plunger has completed only a portion of its stroke in the powder compressing direction.

2. Apparatus for forming a continuous rod of compressed powdered metal in successive increments, comprising a die having an opening there-through which normally is of the same cross section throughout its length, means for supplying powdered metal to the die opening at one end thereof, powder compressing means including a reciprocating plunger operable within said one end of the die opening to compress the powder against the previously formed portion of the rod and thus compact to final form successive increments of said rod in a portion of said die opening adjacent said one end, the remaining portion of said die opening receiving a length of the fully formed rod, at least a portion of said remaining portion of said die being radially expandable, and mechanism normally clamping the expandable portion of the die with a radial force insufficient to stress the compressed rod beyond its elastic limit, the radial clamping force normally exerted by said mechanism being sufficient to develop a frictional resistance to movement of the compressed rod through the die opening which will prevent such movement in response to the force exerted by the plunger until after the radial clamping force is reduced, said mechanism including pressure responsive means operated by said powder compressing means for reducing the radial clamping force exerted by said mechanism and thus permitting expansion of the expandable portion of the die and movement of the compressed rod through the die when the total force exerted by the plunger on the compressed rod increases to a predetermined maximum value.

3. Apparatus for forming a continuous rod of compressed powdered metal in successive increments, comprising a die having an opening there-through which normally is of the same cross section throughout its length, means for supplying powdered metal to the die opening at one end thereof, powder compressing means including a reciprocating plunger operable within said one end of the die opening to compress the powder against the previously formed portion of the rod and thus compact to final form successive increments of said rod in a portion of said die opening adjacent said one end, said portion of the die opening having circumferentially continuous walls and being inexpandible radially, the remaining and major portion of said die opening being radially expandible and receiving a length of the fully formed rod, and mechanism normally clamping the expandible portion of the die with a radial force insufficient to stress the compressed rod beyond its elastic limit, said mechanism including pressure responsive means operated by said powder compressing means for reducing the radial clamping force exerted by said mechanism and thus permitting expansion of the expandible portion of the die and movement of the compressed rod through the die when the total force exerted by the plunger on the compressed rod increases to a predetermined maximum value, the radial clamping force normally exerted by said mechanism being unimpaired by changes in the plunger pressure below maximum plunger pressure and being sufficient to develop a frictional resistance to movement of the compressed rod through the die opening which will prevent such movement in response to the force exerted by the plunger until after the radial clamping force is reduced.

4. Apparatus for forming a continuous rod of compressed powdered metal in successive increments, comprising a die having an opening there-through which normally is of the same cross section throughout its length, means for supplying powdered metal to the die opening at one end thereof, powder compressing means including a reciprocating plunger operable to compress the powder within said opening against the previously formed portion of the rod and thus compact to final form successive increments of said rod in a portion of the die opening adjacent said one end, said portion of the die opening having circumferentially continuous walls and being inexpandible radially, the remaining and major portion of the length of said die opening receiving a length of the fully formed rod and being radially expandible, and mechanism normally clamping the expandible portion of the die with a radial force insufficient to stress the compressed rod beyond its elastic limit, the radial clamping force normally exerted by said mechanism being sufficient to develop a frictional resistance to movement of the compressed rod through the die opening which will prevent such movement in response to the force exerted by the plunger until after the radial clamping force is reduced, said mechanism including pressure responsive means operated by the powder compressing means for reducing the radial clamping force exerted by said mechanism and thus permitting expansion of said expandible portion of the die and movement of the compressed rod through the die opening after the plunger has completed only a portion of its stroke in the powder compressing direction.

5. Apparatus for forming a continuous rod of

compressed powdered metal in successive increments, comprising a die having an opening there-through which normally is of the same cross section throughout its length, means for supplying powdered metal to the die opening at one end thereof, powder compressing means including a reciprocating plunger operable to compress the powder within said opening against the previously formed portion of the rod and thus compact to final form successive increments of said rod in a portion of the die opening adjacent said one end, the remaining and major portion of the length of said die opening receiving a length of the fully formed rod and being radially expandible, means supporting at least the expandible portion of the die for movement in a direction parallel to the opening, said means confining the expandible portion of the walls of the die to a path of movement which expands outwardly from the axis of the opening as the die moves in the direction in which the plunger moves during compression of the powder, and yielding means exerting a predetermined force on said die portion in the opposite direction and of a magnitude insufficient to stress said compressed rod radially beyond its elastic limit but sufficient to develop a frictional resistance to movement of said rod relative to said die portion which will prevent such movement of the rod until after the die is moved in said direction against the force exerted by said yielding means.

6. Apparatus for forming a continuous rod of compressed powdered metal in successive increments, comprising a die having an opening there-through which normally is of the same cross section throughout its length, means for supplying powdered metal to the die opening at one end thereof, powder compressing means including a reciprocating plunger operable to compress the powder within said opening against the previously formed portion of the rod and thus compact to final form successive increments of said rod in a portion of the die opening adjacent said one end, the remaining and major portion of the length of said die opening receiving a length of the fully formed rod and being radially expandible, means supporting at least the expandible portion of the die for movement in a direction parallel to the opening, said means confining the expandible portion of the walls of the die to a path of movement which expands outwardly from the axis of the opening at an angle not more than the frictional angle of repose between the engaging surfaces of the die and said supporting means as the die moves in the direction in which the plunger moves during compression of the powder, and yielding means exerting a predetermined force on said die portion in the opposite direction and of a magnitude insufficient to stress said compressed rod radially beyond its elastic limit but sufficient to develop a frictional resistance to movement of said rod relative to said die portion which will prevent such movement of the rod until after the die is moved in said direction against the force exerted by said yielding means.

7. Apparatus for forming a continuous rod of compressed powdered metal in successive increments, comprising a die having an opening there-through which normally is of the same cross section throughout its length, means for supplying powdered metal to the die opening at one end thereof, powder compressing means including a reciprocating plunger operable within said one end of the die opening to compress the powder

against the previously formed portion of the rod and thus compact to final form successive increments of said rod in a portion of said die opening adjacent said one end, the remaining portion of said die opening receiving a length of the fully formed rod, at least a portion of said remaining portion of said die being radially expansible, both of said portions of said die being fixed together against movement relative to each other, means supporting said die for movement in a direction parallel to the opening, said means confining the expansible portion of the walls of the die to a path of movement which expands outwardly from the axis of the opening as the die moves in the direction in which the plunger moves during compression of the powder, and yielding means exerting a predetermined force on said die portion in the opposite direction and of a magnitude insufficient to stress said compressed rod radially beyond its elastic limit but sufficient to develop a frictional resistance to movement of said rod relative to said die portion which will prevent such movement of the rod until after the die is moved in said direction against the force exerted by said yielding means.

8. Apparatus for forming a continuous rod of compressed powdered metal in successive increments, comprising a die having an opening therethrough which normally is of the same cross section throughout its length, means for supplying powdered metal to the die opening at one end thereof, powder compressing means including a reciprocating plunger operable to compress the powder within said opening against the previously formed portion of the rod and thus compact to final form successive increments of said rod in a portion of the die opening adjacent said one end, said portion of the die opening having circumferentially continuous walls and being inexpandible radially, the remaining and major portion of the length of said die opening receiving a length of the fully formed rod and being radially expansible, means supporting at least the expansible portion of the die for movement in a direction parallel to the opening, said means confining the expansible portion of the walls of the die to a path of movement which expands outwardly from the axis of the opening as the die moves in the direction in which the plunger moves during compression of the powder, and yielding means exerting a predetermined force on said die portion in the opposite direction and of a magnitude insufficient to stress said compressed rod radially beyond its elastic limit but sufficient to develop a frictional resistance to movement of said rod relative to said die portion which will prevent such movement of the rod until after the die is moved in said direction against the force exerted by said yielding means.

9. Apparatus for forming a continuous rod of compressed powdered metal in successive increments, comprising a die having an opening therethrough which normally is of the same cross section throughout its length, means for supplying powdered metal to the die opening at one end thereof, powder compressing means including a reciprocating plunger operable within said one end of the die opening to compress the powder against the previously formed portion of the rod and thus compact to final form successive increments of said rod in a portion of said die opening adjacent said one end, the remaining portion of said die opening receiving a length of the fully formed rod, at least a portion of said remaining portion of said die being radially expansible, said

portions of said die being fixed together against axial movement relative to each other, means supporting said die for movement in a direction parallel to the opening, said means confining the expansible portion of the walls of the die to a path of movement which expands outwardly from the axis of the opening at an angle not more than the frictional angle of repose between the engaging surfaces of the die and said supporting means as the die moves in the direction in which the plunger moves during compression of the powder, and yielding means exerting a predetermined force on said die portion in the opposite direction and of a magnitude insufficient to stress said compressed rod radially beyond its elastic limit but sufficient to develop a frictional resistance to movement of said rod relative to said die portion which will prevent such movement of the rod until after the die is moved in said direction against the force exerted by said yielding means.

10. Apparatus for forming a continuous rod of compressed powdered metal in successive increments, comprising a die having an opening therethrough which normally is of the same cross section throughout its length, means for supplying powdered metal to the die opening at one end thereof, powder compressing means including a reciprocating plunger operable to compress the powder within said opening against the previously formed portion of the rod and thus compact to final form successive increments of said rod in a portion of the die opening adjacent said one end, said portion of the die opening having circumferentially continuous walls and being inexpandible radially, the remaining and major portion of the length of said die opening receiving a length of the fully formed rod and being radially expansible, means supporting at least the expansible portion of the die for movement in a direction parallel to the opening, said means confining the expansible portion of the walls of the die to a path of movement which expands outwardly from the axis of the opening at an angle not more than the frictional angle of repose between the engaging surfaces of the die and said supporting means as the die moves in the direction in which the plunger moves during compression of the powder, and yielding means exerting a predetermined force on said die portion in the opposite direction and of a magnitude insufficient to stress said compressed rod radially beyond its elastic limit but sufficient to develop a frictional resistance to movement of said rod relative to said die portion which will prevent such movement of the rod until after the die is moved in said direction against the force exerted by said yielding means.

11. Apparatus for forming a continuous rod of compressed powdered metal in successive increments, comprising a die having an opening therethrough which normally is of the same cross section throughout its length, means for supplying powdered metal to the die opening at one end thereof, powder compressing means including a reciprocating plunger operable within said one end of the die opening to compress the powder against the previously formed portion of the rod and thus compact to final form successive increments of said rod in a portion of said die opening adjacent said one end, said portion of the die opening having circumferentially continuous walls and being inexpandible radially, the remaining portion of said die opening receiving a length of the fully formed rod, at least a portion of said remaining portion of said die being radially expansible, said portions of said

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die being fixed together against axial movement relative to each other, means supporting said die for movement in a direction parallel to the opening, said means confining the expansible portion of the walls of the die to a path of movement which expands outwardly from the axis of the opening as the die moves in the direction in which the plunger moves during compression of the powder, and yielding means exerting a predetermined force on said die portion in the opposite direction and of a magnitude insufficient to stress said compressed rod radially beyond its elastic limit but sufficient to develop a frictional resistance to movement of said rod relative to said die portion which will prevent such movement of the rod until after the die is moved in said direction against the force exerted by said yielding means.

12. Apparatus for forming a continuous rod of compressed powdered metal in successive increments, comprising a die having an opening therethrough which normally is of the same cross section throughout its length, means for supplying powdered metal to the die opening at one end thereof, powder compressing means including a reciprocating plunger operable within said one end of the die opening to compress the powder against the previously formed portion of the rod and thus compact to final form successive increments of said rod in a portion of said die opening adjacent said one end, said portion of the die opening having circumferentially continuous walls and being inexpandible radially, the remaining portion of said die opening re-

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ceiving a length of the fully formed rod, at least a portion of said remaining portion of said die being radially expansible, said portions of said die being fixed together against axial movement relative to each other, means supporting said die for movement in a direction parallel to the opening, said means confining the expansible portion of the walls of the die to a path of movement which expands outwardly from the axis of the opening at an angle not more than the frictional angle of repose between the engaging surfaces of the die and said supporting means as the die moves in the direction in which the plunger moves during compression of the powder, and yielding means exerting a predetermined force on said die portion in the opposite direction and of a magnitude insufficient to stress said compressed rod radially beyond its elastic limit but sufficient to develop a frictional resistance to movement of said rod relative to said die portion which will prevent such movement of the rod until after the die is moved in said direction against the force exerted by said yielding means.

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