Nov. 2, 1937. G. T. SOUTHGATE 2,097,502

METHOD OF AND APPARATUS FOR PRODUCING RODS AND THE LIKE OF COMMINUTED MATERIAL

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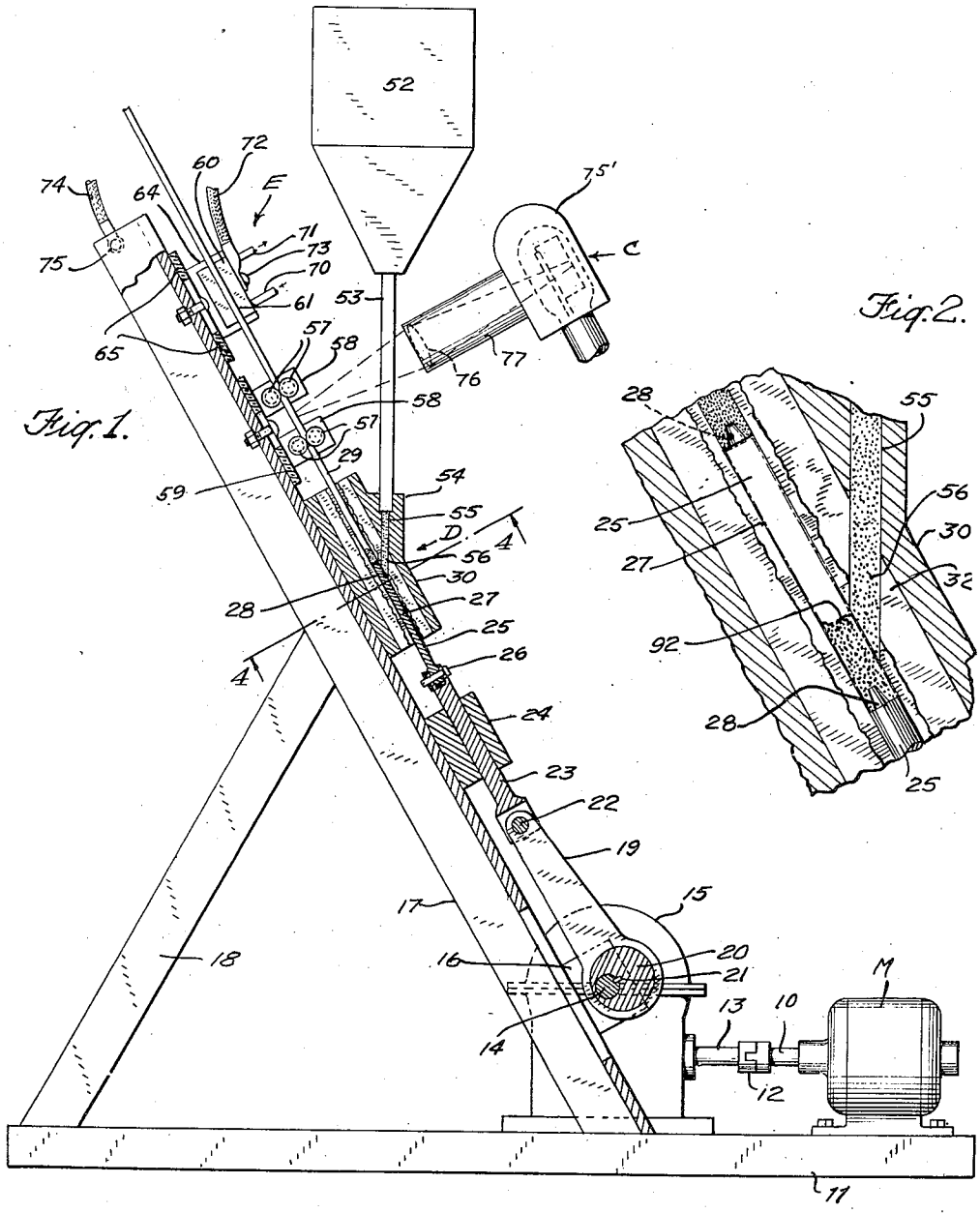


Fig. 1.

Fig. 2.

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Fig. 3.

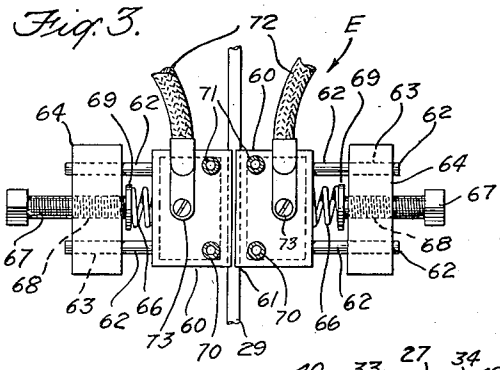


Fig. 4.

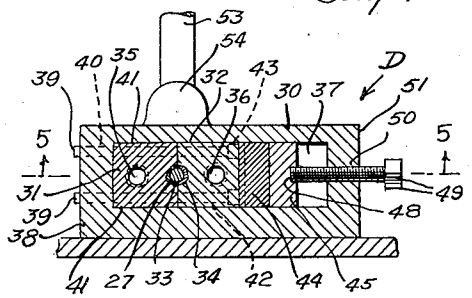


Fig. 5.

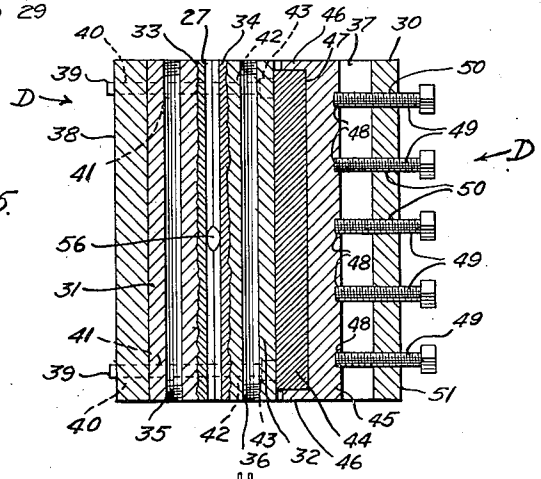
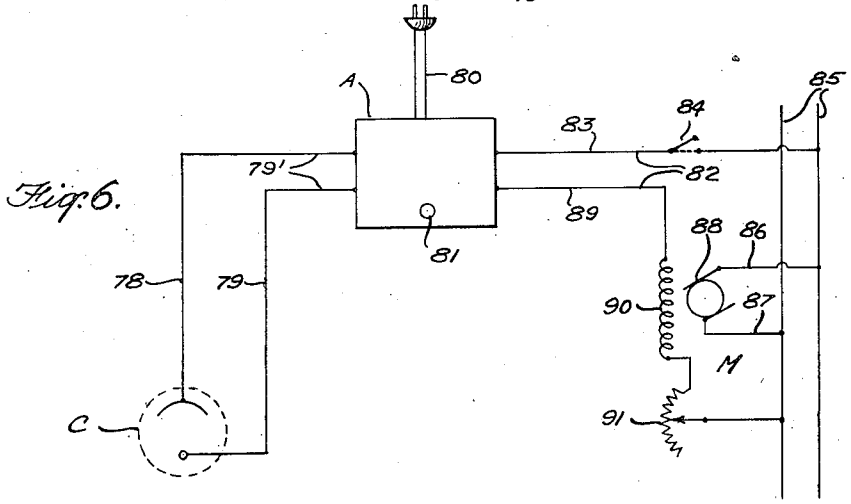


Fig. 6.



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Fig. 7.

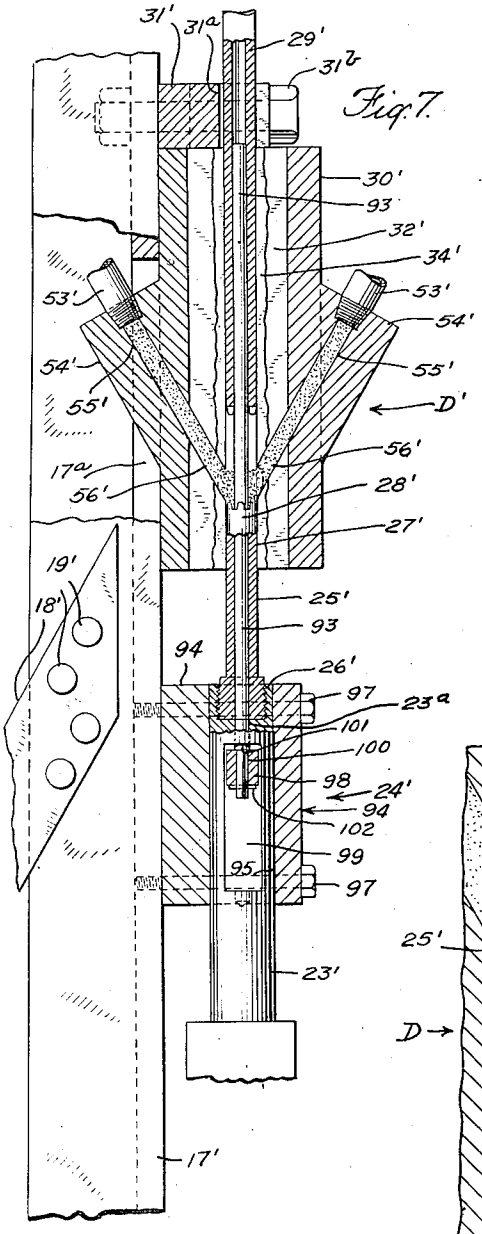


Fig. 8.

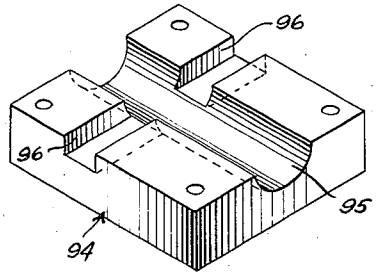
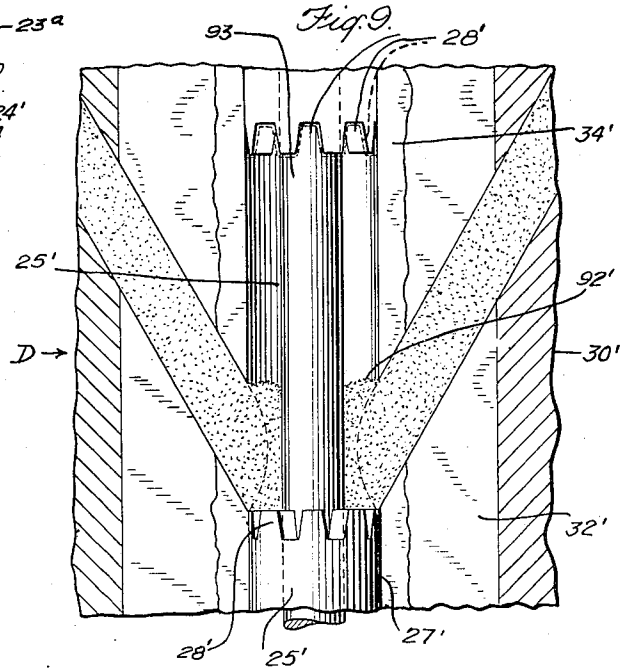


Fig. 9.



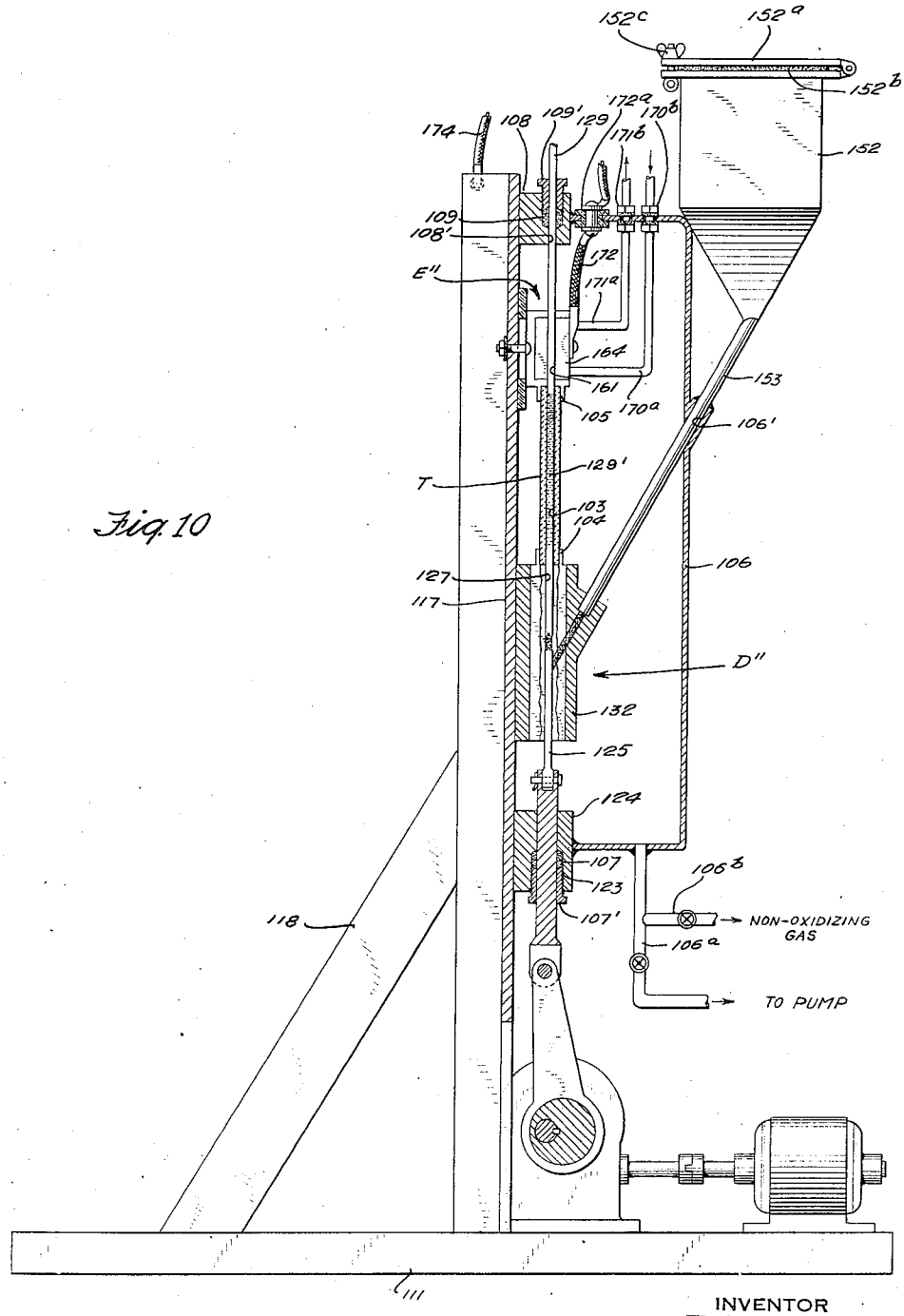
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Fig. 10



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METHOD OF AND APPARATUS FOR PRODUCING RODS AND THE LIKE OF COMMINUTED MATERIAL

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Application March 18, 1933, Serial No. 661,493

22 Claims. (Cl. 75—22)

This invention relates to a method of and apparatus for producing solid and hollow rods and wires and the like of comminuted or powdered material. More particularly this invention relates to a method of and apparatus for producing such articles by compacting the material in a die, and extruding the compacted material continuously therefrom. As a rod is being extruded from a die, it may be progressively heated to increase the cohesion or bonding of the powdered material through the agency of sintering, semi-fusion or fusion.

Although not limited thereto, this invention is applicable to the production of alloys of substantially uniform composition from the powders of metals; the formation, from powders, of alloys and mixtures of metals that ordinarily combine with great difficulty, such as copper and tungsten, which have large differences in their melting points; the production of rods or wires from the powders of refractory metals, such as tungsten; the production of rods that are mixtures of metals and non-metals, such as copper and graphite; and the production of bearings and bushings from powders of suitable materials, such as a mixture of graphite, copper and tin.

In this invention the comminuted or powdered material is preferably fed continuously into a die in such a manner that predetermined quantities or slugs thereof are successively or intermittently impacted by means of a plunger. As the material is advanced in the die by the plunger, the frictional resistance of the die causes the material to be compacted to a dense homogeneous mass which is extruded from the die in the form of a rod. The rod may then be progressively heated after extrusion from the die, as stated above, so as to provide a simple, continuous and economical method of producing the finished article.

In order to provide means whereby a rod could be formed in the manner above described, difficulty was experienced in using solid dies because of the tendency of the compacted material to jam in the die opening after the die had been in operation only for a short time. This difficulty was probably due to the fact that no radial relief was obtained in the die opening to insure the compacted material extruding from the die.

I have found that the above difficulties can be overcome by using a split die, the respective elements of which are resiliently held together under high pressure and provided with aligned and cooperating longitudinal grooves at their contacting faces to form the die opening. By this construction, when the frictional resistance of the die opening becomes very great and the longitudinal movement of the compacted material tends to be retarded, the elements of the die will separate so as to relieve the radial pressure of the compacted material on the walls of the die opening. The separation of the split die is very slight, but nevertheless sufficient to separate the walls of the die, so that sufficient radial relief in the die opening is obtained to insure the extrusion of the compacted material from the die, without any jamming of the material during continuous use of the die, to produce a rod as above described.

One object of my invention, therefore, is to provide an improved apparatus for continuously producing solid and hollow rods and the like of comminuted or powdered material.

Another object of my invention is to produce solid and hollow rods of comminuted or powdered material by compacting the material and extruding the same substantially continuously from a split die, the respective elements of which are resiliently held together under high pressure.

A further object of my invention is to produce solid and hollow rods and the like of comminuted material, which may include comminuted metal, by compacting the material in a die and extruding the same therefrom continuously, and progressively heating successive portions of the rod after they are formed.

A further object of my invention is to heat progressively to a fusing temperature successive portions of a rod of compacted comminuted material, and subsequently to cool such fused portions to cause definite structural changes in the rod material.

A further object of my invention is to provide means for substantially uniformly heating successive portions of a rod of compacted comminuted material as they are continuously extruded from a die.

The above and further objects of my invention will become apparent from the following description and accompanying drawings, in which

Fig. 1 is a side view, partly in section, of an apparatus embodying the principles of this invention;

Fig. 2 is an enlarged fragmentary sectional view of certain parts of Fig. 1;

Fig. 3 is a plan view illustrating details of the electrical contact shown in Fig. 1 for passing a current through a rod;

Fig. 4 is a sectional view taken on line 4—4 of Fig. 1;

Fig. 5 is a view taken on line 5—5 of Fig. 4;

Fig. 6 diagrammatically illustrates a control system that may be applied to the apparatus shown in Fig. 1;

Fig. 7 is a side view, in section, of a modification of the apparatus illustrated in Figs. 1 to 5 inclusive;

Fig. 8 is an enlarged perspective view of a portion of the apparatus shown in Fig. 7;

Fig. 9 is an enlarged sectional view to show more clearly details illustrated in Fig. 7; and

Fig. 10 is a side view, partly in section, of a further modification of the apparatus illustrated in Fig. 1.

Referring to Fig. 1, the apparatus illustrated as embodying the principles of this invention comprises a driving motor M having a shaft 10 and mounted on a base plate 11. The shaft 10 is connected by a coupling 12 to a shaft 13 which drives, through suitable reduction gearing, a shaft 14. The reduction gearing is enclosed in a housing 15 mounted on the base plate 11, and the shaft 14 is journaled in an opening in the wall of the housing and an opening in a bracket 16 which is fixed to a frame plate 17. The frame 17 is preferably straight and is mounted on the base plate 11 at an acute angle to the horizontal base 11, and is provided with one or more brace members 18, the ends of which are secured to the frame 17 and base plate 11, respectively.

The rotary motion of the shaft 14 is converted into rectilinear reciprocatory motion by a connecting rod 19, one end of which is mounted on an eccentric 20 fixedly secured at 21 to the shaft 14. The opposite end of the connecting rod 19 is pivotally connected at 22 to a thrust rod 23, which reciprocates in a guide block 24 that is mounted on the frame 17.

This rectilinear reciprocatory motion is imparted to a plunger 25 by connecting the outer end thereof in the socket 26 at the end of the thrust rod 23. The plunger 25 is received in an opening 27 of a die D, which is mounted on the frame 17, so that the die opening 27 is at an acute angle to a vertical line perpendicular to the horizontal base plate 11. The impacting end 28 of the plunger 25 is preferably reduced and tapered to insure a strong joint between successive quantities of powdered material as they are compacted and compressed together by the plunger 25, to form a solid rod 29.

In accordance with this invention, the die D is preferably a split die, the respective die elements of which are resiliently held together under high pressure. Referring more particularly to Figs. 4 and 5, the die D preferably comprises a housing 30 having an opening 37 in which are positioned cooperating die elements 31 and 32 provided with cooperating longitudinal grooves that form the die opening 27. The grooves of the die elements 31 and 32 may be nitrided or lined with a metal having a high degree of hardness, such as an alloy composed of cobalt, chromium and tungsten, as indicated at 33 and 34, so that the die elements will withstand wear and the high temperatures which result from continuous operation of the apparatus. The metallic linings may be formed in the die elements in any suitable manner, such as by electroplating or by welding. The die elements 31 and 32 may also be provided with longitudinal openings 35 and 36, through which a cooling medium such as water may be circulated in any suitable manner for dissipating the heat produced by the compacting and compressing of powdered material to form a rod thereof, and for dissipating the heat conducted to the die elements as a result of the heating of the rod, hereinafter to be described.

In order to maintain the die opening 27 in alignment with the plunger 25 and the parts of the apparatus to be described, the die elements 31 and 32 are preferably positioned at one side within the opening 37 of the housing 30, with the die element 31 abutting the inside face of the end wall 38. Longitudinal movement of the die elements 31 and 32 within the housing 30 is prevented by guide pins 39 which extend through openings 40 in the end wall 38 and transverse openings 41 and 42 in the die elements 31 and 32, the heads 43 of which guide pins fit into the counterbored ends of the openings 42 in the die element 32.

The die elements 31 and 32 are resiliently held together under high pressure against the end wall 38 by means comprising a rubber pad 44, which is of substantially the same area as the outside wall of the die element 32, and disposed within the opening 37 of the housing 30. A pressure equalizer plate 45 arranged within the opening 37 is provided with shoulders 46 which form, with the side walls of the housing 30, a large recess 47 for receiving the rubber pad 44 on one side of the plate. The opposite side of the plate 45 is provided with a plurality of small recesses 48 to receive the ends of pressure adjusting screws 49 which extend inwardly into the opening 37 through openings 50 in the end wall 51 of the housing 30. By providing the plate 45, the pressure of the screws 49 thereon is uniformly distributed over the rubber pad 44 which contacts the outside wall of the die element 32 and causes the same to be resiliently held together with the die element 31.

The powdered material may be fed to the die D in any suitable manner, and as shown in Figs. 1 and 5 is fed by gravity from a hopper 52 having the outlet opening at the bottom thereof connected to the upper end of a conduit 53, the lower end of which is connected at a boss 54 to communicate with an aperture 55 formed in the upper side wall of the housing 30. The aperture 55 is in direct alignment with an aperture 56 which is formed by cooperating grooves in the upper parts of the die elements 31 and 32, so that the powdered material may flow into the die opening 27 intermediate its ends. When it is desired to form automatically a rod composed of a mixture of powdered materials, the hopper 52 may be provided with an agitator and form a main hopper into which may be fed different powdered materials from several other hoppers.

The powdered material is compacted and compressed in the die D and extruded therefrom in the form of the rod 29. The rod 29 passes through guide rolls 57 supported on spaced blocks 58, which are mounted on and insulated from the frame 17 at 59. The guide rolls 57 are provided to prevent any bending of the rod 29 between the die D and an electrical contact E through which the rod 29 passes.

As shown in Figs. 1 and 3, the contact E may comprise a pair of contact shoes 60 having cooperating longitudinal grooves which form an opening 61 to accommodate the rod 29. Each of the shoes 60 is provided with guide pins 62, which pass through openings 63 in blocks 64 that are mounted on and insulated from the frame 17 at 65. The shoes 60 are guided by the pins 62, and, in order to obtain good electrical contact, they may be slightly and firmly pressed against

the rod 29 by helical springs 66 attached at one end to the backs of the shoes 60. The tension of the springs 66 may be adjusted by threaded studs 67 that extend through openings 68 in the blocks 64, the ends of which studs have bearing surfaces 69 to contact the free ends of the springs. The shoes 60 may be hollow and provided with inlet and outlet openings 70 and 71 for circulating a cooling medium therethrough to dissipate the heat the shoes receive as a result of heating the rod 29, to be described.

An electrical conductor 72 connected to one terminal of a source of supply of electrical energy, not shown, is connected at 73 to the shoes 60. The opposite terminal of the source of supply is connected by a conductor 74 to the upper end of the frame 17 at 75, thereby completing an electrical circuit for passing a current through a portion of the rod 29 to heat the same progressively as it is extruded from the die. The electrical circuit formed comprises one terminal of the source of supply, conductor 72, contact E, the portion of the rod 29 extending between the contact E and the die D, the die D, the frame 17, and conductor 74 back to the opposite terminal of the source of supply.

By introducing a current of sufficient magnitude in the rod 29 in this manner, the current preferably being an alternating current, the bonding of the particles of the comminuted material may be increased by sintering or semifusion. Moreover, the heating of the rod 29 may drive off any undesirable volatile matter in the material.

In order to insure the production of a rod having substantially constant physical properties, it is desirable to heat successive portions of the rod to a predetermined value of temperature. For this purpose, means may be provided to control the rate at which the rod 29 is extruded from the die D as the temperature of the rod varies from a predetermined temperature.

As shown in Fig. 1, I prefer to use a photoelectric apparatus C comprising a photoelectric cell 75', which may be focused on the heated rod 29 in any suitable manner, as by a lens 76 positioned in a tube 77. This apparatus may be mounted in any suitable manner on one side of the conduit 53. The cell 75' is responsive to changes in the radiant energy emitted by the heated rod 29, and may be connected to control automatically the speed of the driving motor M which actuates the plunger 25 of the die D.

Referring to Fig. 6, this may be accomplished by connecting the photoelectric cell 75' by conductors 78 and 79 to the input terminals of a suitable amplifying unit A, which may have a filament-current supply connection 80 and an amplification control knob 81. The circuit 82 of the amplifying unit A includes a conductor 83 that is connected through a switch 84 to one side of the main supply circuit 85 to which is connected, by conductors 86 and 87, the armature 88 of the driving motor M. The conductor 89 of the circuit 82 is connected through the field winding 90 of the motor M and variable resistor 91 to the opposite side of the main supply circuit 85.

This photoelectric cell 75' reacts to changes in the radiant energy emitted by the heated rod 29 to effect changes in the value of current flowing in the input circuit 79'. The amplifying unit A, with such changes of current in the input circuit 79', varies, in a well known manner, the value of current in the circuit 82 to change the field excitation produced by the field winding 90. This changes the speed of the motor M to increase or decrease the rate of reciprocation of the plunger 25, and thus extrude the rod 29 faster or slower from the die D.

In order to start producing a rod of comminuted material, the motor M is rotated until the plunger 25 is at the end of a compression stroke, as indicated in dotted lines in Fig. 2. The upper end of the die opening 27 is then filled with compacted comminuted material. This may be done by alternately pouring comminuted material and compacting the same, by means of a ramrod, until the frictional resistance between the walls of the die opening 27 and the section of compressed material thus formed approximates the frictional resistance of the compressed material when it is formed during normal operation of the apparatus.

The operation of the above described apparatus is substantially as follows: It will be assumed that the upper end of the die opening 27 has been filled with compacted powdered material, as described above; that the hopper 52 is filled with the powdered material; that the conductors 72 and 74 are connected to a source of electrical energy which will deliver approximately constant current; that the switch 84 in the circuit 82 is in closed position; that the supply lines 85 are energized to drive the motor M; and that the photoelectric apparatus C is temporarily rendered inoperative.

With the above assumed conditions, the motor M will drive the shaft 14 through the shaft 10, coupling 12, shaft 13, and reduction gearing in the housing 15, and impart a rectilinear reciprocatory motion to the plunger 25 through the thrust rod 23 and connecting rod 19.

When the plunger 25 is at the beginning of a compression stroke, as shown in solid lines in Fig. 2, a predetermined quantity of the powdered material will flow by gravity from the hopper 52 through the conduit 53, aperture 55 and aperture 56, and occupy the space 92 in the die opening 27, between the lower end of the aperture 56 and the impacting end 28 of the plunger 25. At the beginning of the compression stroke of the plunger 25, the powdered material in the space 92 is merely forced upward. Compacting of this material does not begin until the impacting end 28 of the plunger 25 has passed the aperture 56. By delaying the compacting of the material in the space 92 until the plunger 25 has closed the lower end of the aperture 56, this material is prevented from being forced back into the aperture 56 again. Stated another way, until the impacting end 28 of the plunger 25 moves past the aperture 56, there will always be a space in the die opening 27 between the lower end of the material previously compressed and the quantity of loose material being forced upward by the plunger 25.

After the plunger 25 has closed the lower end of the aperture 56, the quantity of loose material moved upward is forced against the previously compressed material. During the remainder of the compression stroke of the plunger 25, the quantity of loose material in the space 92 is compacted and compressed with the material previously compressed, and an increment of the rod thus formed is extruded from the die opening 27.

The return stroke of the plunger 25 then takes place, and another predetermined quantity of powdered material fills the space 92 in the die opening 27, between the lower end of the aper-

ture 56 and the impacting end 28 of the plunger 25. This quantity of material is then moved upward in the die opening 27 by the plunger 25, and compacted and compressed with the material compressed during the previous compression stroke of the plunger.

Compacting and compressing of the powdered material is obtained in this manner because of the frictional resistance between the walls of the die opening 27 and the compressed material. The density of the compressed material may be readily controlled by the pressure adjusting screws 49 that maintain the die elements 31 and 32 together. When the die elements 31 and 32 separate to relieve the radial pressure of the compacted material and permit the same to move through the die opening 27, the separation is so slight that particles of powdered material cannot flow into the spaces between the die elements and tend to cause them to remain separated after the radial pressure is relieved.

The extruded rod passes between the guide rollers 61, and through the opening 61 of the contact E. This completes an electric circuit between the conductors 72 and 74, so that an electric current will flow through the rod 29 between the die D and contact E, as described above, to heat the same and increase the cohesion or bonding of the powdered material, and to drive off any volatile vapor matter that may be present in the material.

The electric current supplied to the conductors 72 and 74 is preferably from a source of approximately constant current. After the heated rod 29 has reached a predetermined normal value of temperature, the photoelectric cell 75' is then rendered operative. When the heated rod 29 is at the predetermined value of temperature, the value of current flowing in the field winding 90, and hence the speed of the motor M, are substantially at normal. Any variation of the heated rod 29 from the predetermined value of temperature produces a corresponding change in the amount of radiant energy that reaches the photoelectric cell 75'. This produces a change in the value of current in the input circuit 79', which in turn varies, through the amplifying unit A, the value of current flowing in the field winding 90 in the circuit 82 to increase or decrease the speed of the motor M. The change in motor speed varies the rate of compacting the predetermined quantities of powdered material by the plunger 25, thereby tending to reestablish the predetermined value of temperature of the heated rod 29.

Thus, when the temperature of the heated rod 29 becomes higher than the predetermined normal value of temperature, the radiant energy emitted by the rod 29 increases and effects, through the photoelectric cell 75' and amplifying unit A, a decrease in the value of current flowing in the field winding 90. Lowering the value of field excitation increases the speed of the motor M, thereby extruding the rod 29 faster from the die D. This tends to reestablish the predetermined value of temperature of the heated rod 29 by lowering the length of time the current is permitted to flow through the successive portions of the rod as they pass from the die D to the contact E.

Conversely, when the temperature of the rod 29 becomes lower than the predetermined value of temperature, the amount of radiant energy emitted by the heated rod decreases, and effects, through the photoelectric cell 75' and amplifying unit A, an increase in the value of current flowing in the field winding 90. Raising the value of field excitation decreases the speed of the motor M, thereby extruding the rod 29 slower from the die D. This tends to reestablish the predetermined value of temperature in the rod 29 by increasing the length of time the current is permitted to flow through successive portions of the rod 29 as they pass from the die D to the contact E.

After successive portions of the rod 29 pass through the contact E, they immediately begin to cool naturally. If it is desired to hasten the cooling of the rod, a cooling medium, such as a jet of air, may be applied to the rod as it passes from the contact E. For producing rods of uniform length, automatic means may be provided to cut the extruded rod at definite intervals of time. Since the rate of extrusion of the rod from the die D may vary, it will be desirable to provide cutting means which will vary with the rate the rod is produced. This may be accomplished by providing a rotatable burner which is adapted to cut the rod when the flame produced thereby passes over the rod. The burner may be mounted on a hollow rotatable spindle supplied with a suitable combustible gas, and the speed of rotation of the spindle may be arranged to be responsive to the rate of extrusion of the rod 29, as by driving the same from the motor M.

In Figs. 7 to 9, I have shown a modification of the apparatus illustrated in Figs. 1 to 5 for producing hollow or tubular rods of comminuted material. In this embodiment of my invention, the parts of the apparatus, hereinafter to be described, are mounted on a frame 17' which is preferably extended vertically. This may be accomplished by mounting the frame 17' on a base plate similar to the base plate 11 shown in Fig. 1, and providing suitable brace members secured to the base plate and frame 17', respectively. In Fig. 7, the upper end of one such brace member 18' is shown secured at 19' to the frame 17'.

Apparatus similar to that shown in Fig. 1 may be provided to impart a rectilinear reciprocatory motion to a thrust rod 23', which reciprocates in a guide block 24' that is mounted on the frame 17'. The end of the thrust rod 23' is recessed and internally threaded at 26' to receive the externally threaded outer end of a hollow plunger 25'. The plunger 25' reciprocates in an opening 27' of a die D', which is mounted on the frame 17'. The impacting end 28' of the plunger 25' is notched or castellated, as clearly shown in Fig. 9, so as to insure a strong joint between successive quantities of powdered material as they are compacted and compressed together by the plunger 25' to form the hollow rod 29'.

The die D' is a split die similar to the one shown in Figs. 4 and 5, described above, and comprises a housing 30' having an opening in which are positioned cooperating die elements resiliently held together under pressure, one of which is indicated at 32' in Figs. 7 and 9. The die elements are provided with cooperating longitudinal grooves, which may be nitrided or lined at 34' with a hard metal to form the die opening 27'. In order to provide a rigid structure, a thrust plate 31', having an opening 31*a* in alignment with the die opening 27', may be secured by bolts 31*b* to the frame 17' adjacent the upper end of the die D'.

The powdered material may be fed from hoppers (not shown) which are connected to conduits 53', the lower ends of which are connected at bosses 54' to communicate with a plurality of

apertures which are formed in the side walls of the housing 30'. As indicated at 55' in Fig. 7, two such apertures are shown. The frame 17' is provided with an opening 17a, through which the left hand boss 54' projects. The apertures 55' are in direct alignment with apertures 56', which are formed by cooperating grooves on the contacting faces of the die elements 32'. The apertures 56' communicate with the die opening 27', intermediate the ends thereof, and are disposed at diametrically opposite points of the die opening.

In order to produce hollow or tubular rods of comminuted material, a mandrel 93 is centrally disposed in the die opening 27' and extends substantially the length thereof. The mandrel 93 may be made integral with the hollow plunger 25' and reciprocate therewith, or may be fixedly secured in a suitable manner, so as to remain stationary with respect to the reciprocating hollow plunger 25'. As shown, the mandrel 93 extends through the hollow plunger 25' and an opening 23a at the end of the thrust-rod 23', and the lower end thereof is fixedly secured to the guide block 24'. This may be accomplished by making the guide block 24' a split block, and having the respective halves 94 thereof provided with co-operating longitudinal grooves 95 to form an opening in which the thrust rod 23' reciprocates.

As shown in Fig. 8, each half 94 of the guide block 24' is transversely recessed at 96. When the two halves 94 of the guide block 24' are secured together and mounted on the frame 17' by cap screws 97, the recesses 96 cooperate to form a transverse opening which receives a bar 98.

As shown in Fig. 7, the bar 98 extends through a longitudinal slot 99 in the thrust rod 23', so that the latter is free to move up and down in the guide block 24' and impart a reciprocatory motion to the plunger 25'.

The lower reduced end of the mandrel 93 extends through a central opening 100 in the bar 98, and in this manner is shouldered at 101 against the upper side of the bar 98 so that downward movement thereof is prevented. Upward movement of the mandrel 93 is prevented by keying the same at 102 against the lower side of the bar 98. By this construction, longitudinal movement of the mandrel 93 is prevented, the thrust rod 23' freely reciprocates in the guide block 24', and the hollow plunger 25' freely reciprocates in the die opening 27' and slides up and down along the mandrel 93.

Guide rolls, an electrical contact, connections to a source of supply of electrical energy, and apparatus for controlling the rate of compacting and compressing of powdered material may be provided in the same manner as illustrated in Figs. 1 to 6, and described above.

The operation of the apparatus just described for producing hollow rods is substantially the same as the first described embodiment of my invention:

In order to start producing hollow rods, the plunger 25' is moved to the end of a compression stroke, as indicated in dotted lines in Fig. 9, and the upper end of the die opening 27' is filled with compacted powdered material. The motor for reciprocating the plunger 25' is then connected to the supply lines.

When the plunger is at the beginning of a compression stroke, as indicated in solid lines in Fig. 9, a predetermined quantity of powdered material will flow through the apertures 56' and occupy the space 92' in the die opening 27'. By providing two apertures 56', a uniform distribution of powdered material is obtained about the mandrel 93.

As in the first described embodiment of my invention, compacting and compressing does not begin until the plunger 25' has moved past the apertures 56', thereby insuring complete compaction of each predetermined quantity of powdered material that flows by gravity into the space 92'.

After the plunger 25' has closed the lower end of the apertures 56' during a compression stroke, the powdered material is compacted and compressed with the material previously compressed, and an increment of the hollow rod 29' thus formed is extruded from the die opening 27'. Heating of successive portions of the rod 29' and varying of the rate of producing the rod to obtain substantially uniform heating may be accomplished in the same manner as in the first described embodiment of this invention.

In Fig. 10 I have illustrated apparatus for progressively fusing or melting successive portions of a rod after they are extruded from a die, and for subsequently cooling such fused portions. Since many of the parts of this apparatus are similar to those described above and illustrated in Figs. 1 to 5 inclusive, only the essential differences will be pointed out for a complete understanding of this embodiment of my invention.

In this modification a plate 111 is mounted vertically on a base plate 111, and provided with one or more brace members 118. Apparatus similar to that shown in Fig. 1 is provided for imparting a rectilinear reciprocatory motion to a plunger 125 for compacting comminuted material in the form of a rod 129 and extruding the same from a split die D'' into a tube T of refractory material, such as alundum or carborundum. In cases where carburization of the material fused is not objectionable, graphite may be employed as the refractory material. This tube T extends between the upper end of the die D'' and the lower end of the electrical contact E'', and its bore 103 is substantially the same size as that of the rod 129.

In order to maintain the tube T in alignment with the opening 127 in the split die D'' and the opening 161 in the contact E'', each of the die elements 132 and the shoes 164 of the contact E'' are provided with flanges 104 and 105 of semicircular shape for gripping the upper and lower ends, respectively, of the refractory tube T. The contact E'' is similar to the contact E described above and clearly shown in Fig. 3, with helical springs for firmly holding the shoes 164 together. Because of this construction of the contact E'', the flanges 105 on the shoes 164 will also firmly hold the upper end of the refractory tube T in alignment with the opening 161 in the contact E''. The lower end of the tube T rests firmly on the upper end of the die elements 132, and lateral movement thereof is prevented by the flanges 104.

The electrical circuit for progressively heating successive portions of the rod 129 comprises an electrical conductor 172 which is connected to one terminal of a source of supply of electrical energy, contact E'', the portion of the rod 129 extending between the contact E'' and the die D'', the die D'', the plate 117, and conductor 174, which is connected to the opposite terminal of the source of supply.

Although the apparatus just described may be

employed where it is desired to introduce a current of such magnitude that the particles of comminuted material are bonded together by sintering or semi-fusion, it is particularly adaptable where it is desired to fuse or melt a rod of compressed comminuted material, and subsequently to freeze it quickly to produce definite structural changes in the material. It is known that the micrographic structure of many cast metals and alloys, such as brasses and bronzes, is refined and improved by such quick freezing. For producing such rods of an improved and refined nature, the operation of the apparatus described is substantially as follows:

The feeding of the comminuted material into the die opening 127, the compacting and compressing of the material into the form of a rod, and the extrusion thereof from the die D'' are the same as in the previously described embodiments of my invention, and will therefore not be repeated here. After the rod 128 has moved past the electrical contact E'', the electric circuit is completed between the conductors 172 and 174, and an electric current will flow through the material between the upper end of the die D'' and the electrical contact E''. The electric current is of such magnitude that the comminuted material is heated to its fusing temperature. The comminuted material will not completely fuse until it has moved upward a slight distance from the bottom of the refractory tube T. Thus, the compacted comminuted material is still in its solid form as it enters the lower end of the tube T, and fused material 129' above it cannot flow from the tube T and into the space between the tube and the flanges 104 of the die elements 132. If it becomes necessary to cool the die elements, they may be provided with longitudinal openings through which a cooling medium or refrigerant can be circulated.

As the fused material 129' in the tube T is moved upward and approaches the bottom of the electric contact E'' by the continuous reciprocation of the plunger 125, the material freezes quickly. This is due to the cooling of the contact E'' by circulating a cooling medium or refrigerant through the hollow shoes 164.

The temperature and circulation of the cooling medium or refrigerant can be so controlled that as the fused rod nears the contact E'', heat is rapidly conducted along and from the rod so that the rod is solidified when it enters the opening 161 of the contact E''. In this manner any tendency of the fused material to leak from the tube T into the space between the tube and the flanges 105 of the contact E'' is prevented.

Although I have illustrated the passing of an electric current through a rod to heat the same, such heating may be accomplished by introducing or inducing a high frequency current in the rod. The rod may also be heated in other ways, as by hot gases directed and confined about the rod as it is extruded from the die; or by a furnace, such as a small electric furnace, disposed about the rod in any suitable manner. With substances that combine with a strongly exothermic reaction, such as a mixture of 85% chromium and 15% aluminum, a portion or all of the heat required for heating the material may be supplied by such a reaction. Thus, with the apparatus illustrated and described, current of a sufficient magnitude may be passed through the compressed material to raise the same to a temperature at which the reaction will start. After such an exothermic reaction begins, all of the heat required for fusing the material may be supplied by the reaction, or such heating may be utilized in conjunction with the heating produced by the electric current.

In making rods of powdered metals, it has been found that the ohmic heating, as above described, heats the rods formed so rapidly that very little oxidation of the metallic particles takes place. Where it is desired to produce a rod having a bright finish, or to protect a product that oxidizes readily, it may be necessary to arrange all or a portion of the apparatus in an enclosure through which a non-oxidizing gas, such as hydrogen or carbon monoxide, may be circulated. In certain applications, it may be desirable to evacuate such an enclosure to minimize the trapping of air in the compacted material, and thereby increase the density of the rods produced.

In the apparatus illustrated in Fig. 10, this is accomplished by providing a housing 106 which may be secured, as by welding, to the plate 117 so as to enclose the die D'', refractory tube T and electric contact E''. In order to provide an air-tight enclosure, the guide block 124, which extends through an opening at the lower end of the housing 106, may be provided with packing material 107 which is retained in position about the thrust rod 123 by a packing gland 107'. Likewise, a guide block 108 mounted on the plate 117 and extending through an opening at the upper end of the housing 106 is provided with packing material 109 which is retained in position about the rod 129 by a packing gland 109' The opening 108' in the guide block 108 serves to guide the rod 129 from the electric contact E'' and out of the housing 106.

The conduit 153, through which comminuted material is fed from the hopper 152 and into the die opening 127, extends through an opening 106' in the housing 106. The hopper 152 is maintained air-tight by a hinged cover 152*a* having a gasket 152*b* and a screw and clamping nut 152*c*.

The conduits 170*a* and 171*a* for circulating a cooling medium through the hollow shoes 164 extend through insulating bushings 170*b* and 171*b* in the wall of the housing 106. In a similar manner, the electric conductor 172 is connected to one terminal of the source of supply of electric energy through an insulating connection 172*a* in the wall of the housing 106.

With the above described construction, an air-tight enclosure is provided which may be evacuated by a pump connected by a conduit 106*a* to the housing 106; or filled with a non-oxidizing gas from a suitable source of supply through a conduit 106*b* connected to conduit 106*a*. In operating the apparatus illustrated in Fig. 10 when the material is fused in the refractory tube T, it may be desirable to purge the housing with a gas, such as hydrogen, and then evacuate the housing. By evacuating the housing, all of the occluded gases in the compressed material are drawn out so that dense homogeneous rods are produced.

In preparing comminuted material for producing rods, it may be desirable in some cases to employ a temporary fugitive constituent in the powdered material. This constituent may be of such a nature as to provide temporary adhesion of the particles until they are finally bonded, as by sintering; or to provide a lubricating effect for the sliding of the compacted and compressed material through a die; or, in some instances, to give both of the above mentioned actions.

This adhesive or lubricative constituent preferably should be of such a nature that it may be driven off by decomposition or vaporization when the rod is heated. Dry soaps, such as zinc stearate, possess excellent lubricating properties, and in powdered form may be readily mixed with powders of metals. It has been found that as little as 0.25% of zinc stearate produces sufficient lubrication in a mixture of copper, tin and nickel powders, and that the zinc stearate leaves no objectionable residue, in the rod formed of the above materials, after it has been sintered.

The temporary constituent added may be a substance of a viscous type, such as a soap; or it may be of a type which is corrosive in its action, so as to form metallic compounds that bridge between all or a portion of the particles, and subsequently harden as a matrix. Chemical binders which have been found suitable for this purpose are phosphoric anhydride, sulphuric acid, and chromic anhydride. Certain temporary binders, such as phosphoric anhydride, readily mix with metallic powders while in a dry state. After mixing such binders with the powdered material, sufficient moisture is absorbed from the air to produce a corrosive action on the particles of comminuted metal.

It is to be understood that in the claims which follow, the term "rod" broadly includes solid rods, hollow or tubular rods, and wires and the like.

While I have shown and described particular embodiments of my invention, it will be obvious to those skilled in the art that modifications may be made, and that certain features may be used independently of others without departing from the spirit and scope of my invention.

I claim:

1. The method of producing rods of comminuted material including substances which combine with an exothermic reaction, which comprises compressing the material into the form of a rod; progressively heating successive portions of the rod to a fusing temperature after it is formed; at least a portion of such heat being supplied by the exothermic reaction of the comminuted substances; and thereafter progressively cooling the heated portions of the rod below their fusing temperature.

2. The method of producing rods which comprises compacting predetermined quantities of comminuted material including comminuted metals which combine with an exothermic reaction; compressing each added quantity of compacted material against the material previously compacted so as to form a rod of the compacted material; progressively heating successive portions of the rod to a fusing temperature after it is formed; at least a portion of such heat being supplied by the exothermic reaction of the comminuted metals; and thereafter progressively cooling the heated portions of the rod below their fusing temperature.

3. The method of producing rods of comminuted material including substances which combine with an exothermic reaction, which comprises compressing such material into the form of a rod and heating the same to a fusing temperature, at least a portion of such heat being supplied by the exothermic reaction of the comminuted substances.

4. Process for producing a continuous rod from comminuted material which includes at least one metal component, which process comprises compressing and shaping successive predetermined quantities of said comminuted material by ramming each such successive quantity against the next preceding compressed and shaped quantity thereof whereby to form a continuous rod of said material, and passing the rod, immediately as formed, into and through a heated zone wherein the continuous rod is progressively heated to a temperature at which an at least partial bonding of the particles of comminuted material in the continuous rod occurs.

5. The continuous method of producing a rod which comprises mixing a lubricant with comminuted material to reduce the coefficient of friction between said material and an elongated die having an open end; successively compacting predetermined quantities of said lubricated material in said die against the quantity of material previously compacted; pushing the compacted material through the open end of said die; and heating the rod after it is formed so as to drive off such lubricant.

6. The method of producing rods of comminuted material which comprises substantially continuously compacting and compressing comminuted material so as to form a rod of the compacted material; progressively heating to a predetermined temperature successive portions of the rod as they are formed; and varying the rate of forming the rod in accordance with variations in the heated condition of the rod from the predetermined temperature.

7. The method of producing rods of comminuted material which comprises compacting predetermined quantities of the comminuted material and compressing each added quantity of compacted material against the material previously compacted so as to form a rod of the compacted material; progressively heating approximately to a predetermined value of temperature successive portions of the rod as they are formed; and varying the rate of compacting the predetermined quantities of the comminuted material as the temperature of the heated portions of the rod changes from the predetermined value, such variations in the rate of compacting the predetermined quantities of material being responsive to such temperature changes and tending to reestablish such predetermined value of temperature.

8. The method of producing rods of comminuted material which comprises compacting predetermined quantities of the comminuted material and compressing each added quantity of compacted material against the material previously compacted so as to form a rod of the compacted material; progressively heating approximately to a predetermined temperature successive portions of the rod as they are formed so as to bond together the particles of comminuted material; and varying the rate of compacting the predetermined quantities of the comminuted material in accordance with changes in radiant energy emitted by such heated portions of the rod.

9. Apparatus for producing rods of comminuted material in powdered form which comprises the combination of a die having an opening, means for providing a continuous supply of the material to the opening of said die; means for intermittently compressing successive predetermined quantities of the material in the opening of said die and for extruding the compressed material from said die in the form of a continuous rod; said compressing means including a reciprocatory plunger movable in the opening of said die and adapted to compress with each compressive stroke

a predetermined quantity of material in the opening of said die against the material previously compacted; a refractory conduit having an opening aligned with said die opening to continuously receive said rod as it is extruded from said die; and means for progressively heating successive portions of the rod as they pass through said refractory conduit.

10. Apparatus according to claim 9, in which said die and said heating means are arranged in an enclosed housing; and means for evacuating said housing.

11. Apparatus for producing rods from comminuted material in powdered form, which comprises the combination of a die; means for feeding the material into said die; means for compressing the material in said die and extruding the compressed material substantially continuously therefrom in the form of a rod; and means for progressively heating successive portions of the rod as they are extruded from said die; said last mentioned means comprising an electric circuit which includes the said die, a pair of cooperating grooved contact shoes and the portion of the extruded rod lying between the said die and contact shoes; and yielding means operatively associated with the said shoes and adapted to urge the latter into contact with each other and with the said rod.

12. Apparatus for producing rods of comminuted material comprising the combination of a split die including cooperating die elements provided with cooperating grooves to form a die opening adapted to receive a plunger, and means for holding said die elements together under pressure; said last-mentioned means including resilient means to provide radial relief for said cooperating die element when the material tends to jam in said die opening.

13. Apparatus for producing rods of comminuted material comprising the combination of a split die, the respective elements of which die are provided with cooperating longitudinal grooves at their contacting faces to form a die opening adapted to receive a plunger, and means including at least one rubber pad for resiliently holding said die elements together under pressure.

14. Apparatus for producing rods and the like of comminuted material including the combination of a housing having an opening, a split die positioned within said opening and comprising a plurality of cooperating die elements provided with cooperating grooves to form a die opening, and means positioned in the opening in said housing for resiliently holding said die elements together under pressure.

15. Apparatus for producing rods of comminuted material comprising the combination of a die having an opening, a material compacting plunger adapted to be received in the die opening and having a bore, a mandrel disposed in the die opening and extending through the bore of said plunger, said plunger having the impacting end thereof notched, and means for intermittently reciprocating said plunger in said die.

16. Apparatus for producing rods of comminuted material comprising the combination of a split die including cooperating die elements provided with cooperating grooves to form a die opening adapted to receive a plunger, and means for resiliently holding said die elements together under pressure, at least one of said die elements having an aperture communicating with the die opening at a point intermediate the ends thereof for introducing the comminuted material into the die opening.

17. Apparatus for producing rods of comminuted material comprising the combination of a support; a split die mounted on said support; such split die including cooperating grooves to form a die opening in a substantially vertical plane; means for resiliently holding said die elements together under pressure; a plunger adapted to be received at the lower end of the die opening; and means for imparting a rectilinear reciprocatory motion to said plunger in the die opening; at least one of said die elements having an aperture for introducing the material by gravity into the die opening; such aperture being disposed above the impacting end of said plunger when the latter is at the beginning of a compression stroke.

18. Apparatus for producing rods of comminuted material, which comprises the combination of a die; means for feeding the material into said die, means for compressing the material in said die and extruding the compressed material substantially continuously therefrom in the form of a rod; means for progressively heating successive portions of the rod as they are extruded from the die; and means responsive to the heated condition of the rod for controlling the quantity of heat applied to such successive portions of the rod.

19. Apparatus for producing rods of comminuted material, which comprises the combination of a die; means for compressing the material in said die and extruding the compressed material substantially continuously therefrom in the form of a rod; means for progressively heating successive portions of the rod as they are extruded from the die; and means responsive to the heated condition of the rod for controlling the rate at which the rod is extruded from said die.

20. Apparatus according to claim 19, in which said means for controlling the rate at which the rod is extruded from said die comprises a device sensitive to variations in radiant energy emitted by the heated portion of the rod.

21. Apparatus for producing rods of comminuted material which comprises the combination of a die having an opening; a plunger adapted to be received in the die opening; means for feeding predetermined quantities of the material into the die opening; means for operating said plunger to exert a high pressure to compact intermittently the predetermined quantities of the material, to compress each quantity of compacted material against the quantity of material previously compacted, and to extrude an increment of the compacted material from the die in the form of a rod; means for progressively heating successive portions of the rod as they are extruded from the die; and means responsive to the heated condition of the rod for controlling said plunger operating means.

22. Apparatus according to claim 21, in which said means for controlling said plunger operating means includes a device sensitive to variations in radiant energy emitted by the heated portion of the rod.

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