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A. D. WHIPPLE

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MEANS FOR COMPRESSING FINELY DIVIDED SUBSTANCES AND PROCESS THEREFOR

Filed March 18, 1938

3 Sheets-Sheet 1

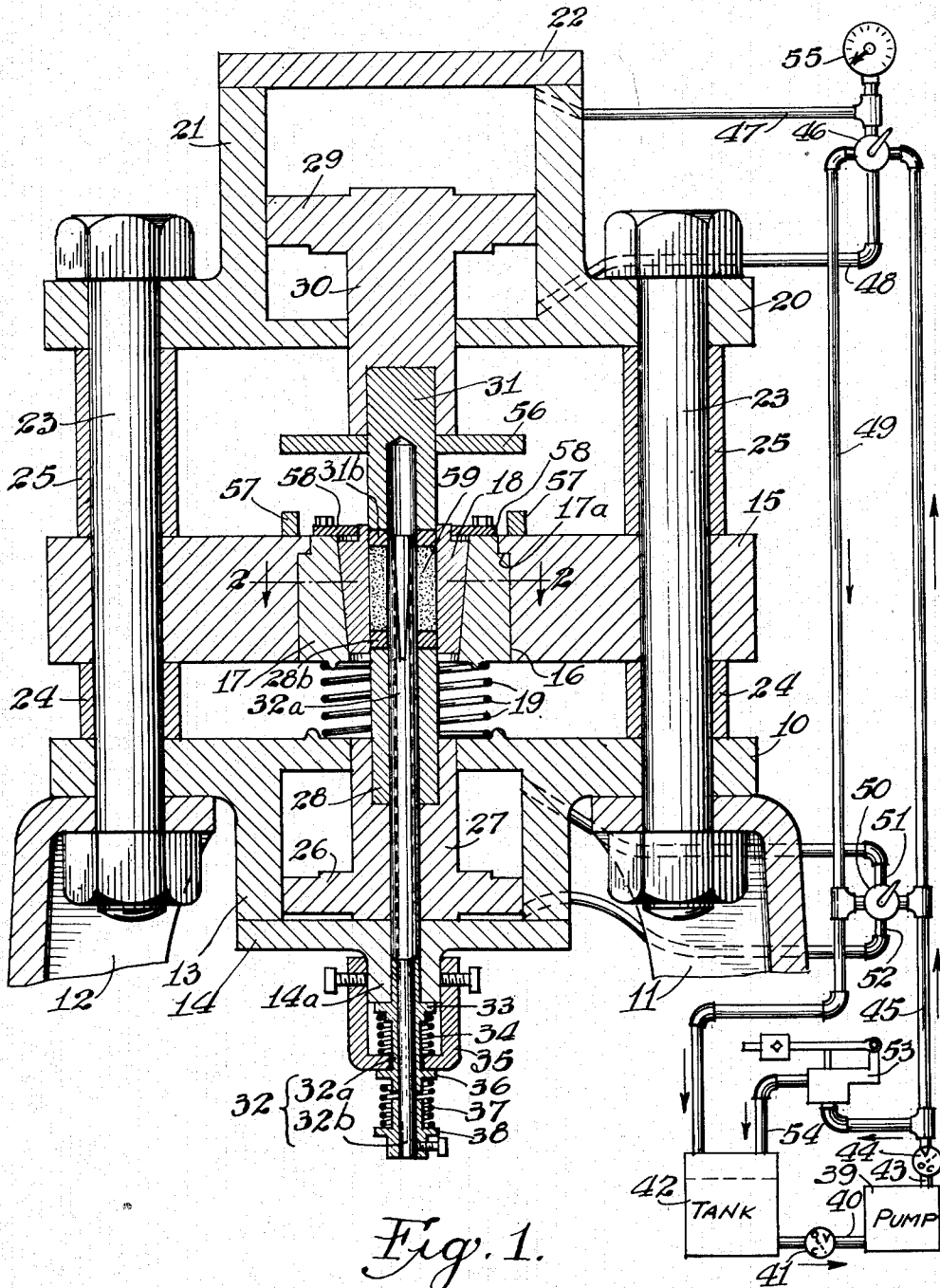


Fig. 1.

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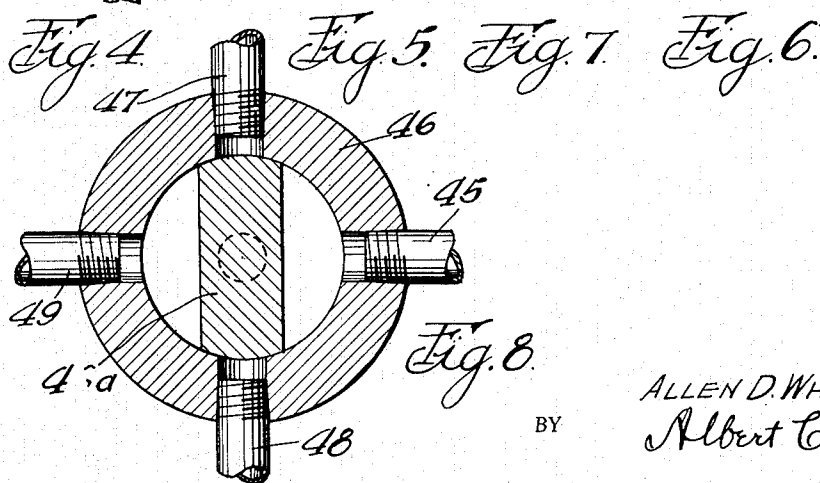
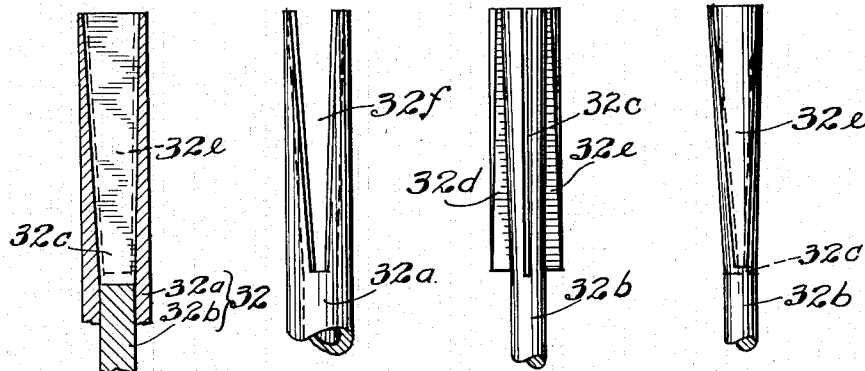
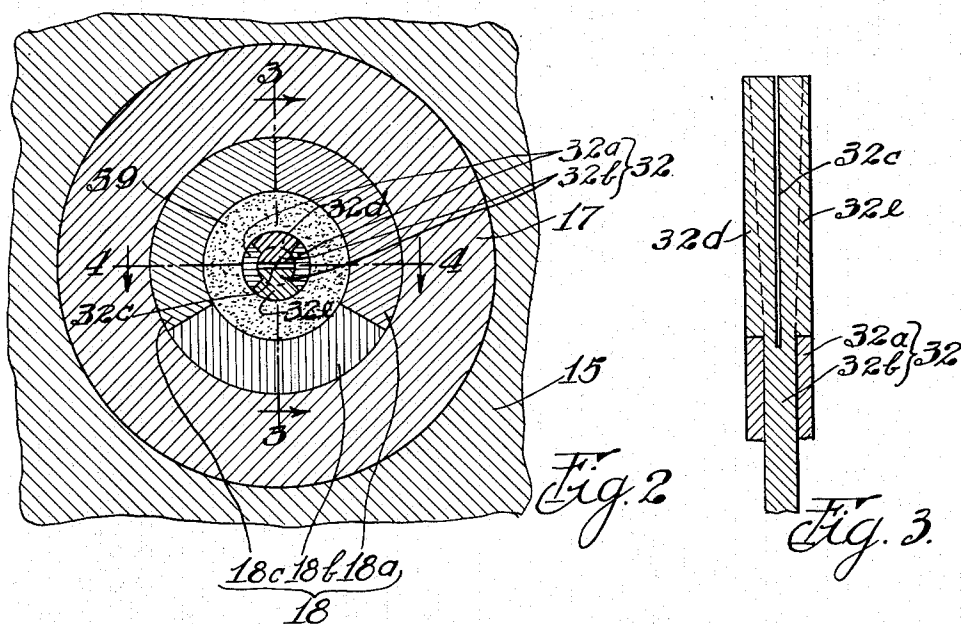
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3 Sheets-Sheet 2



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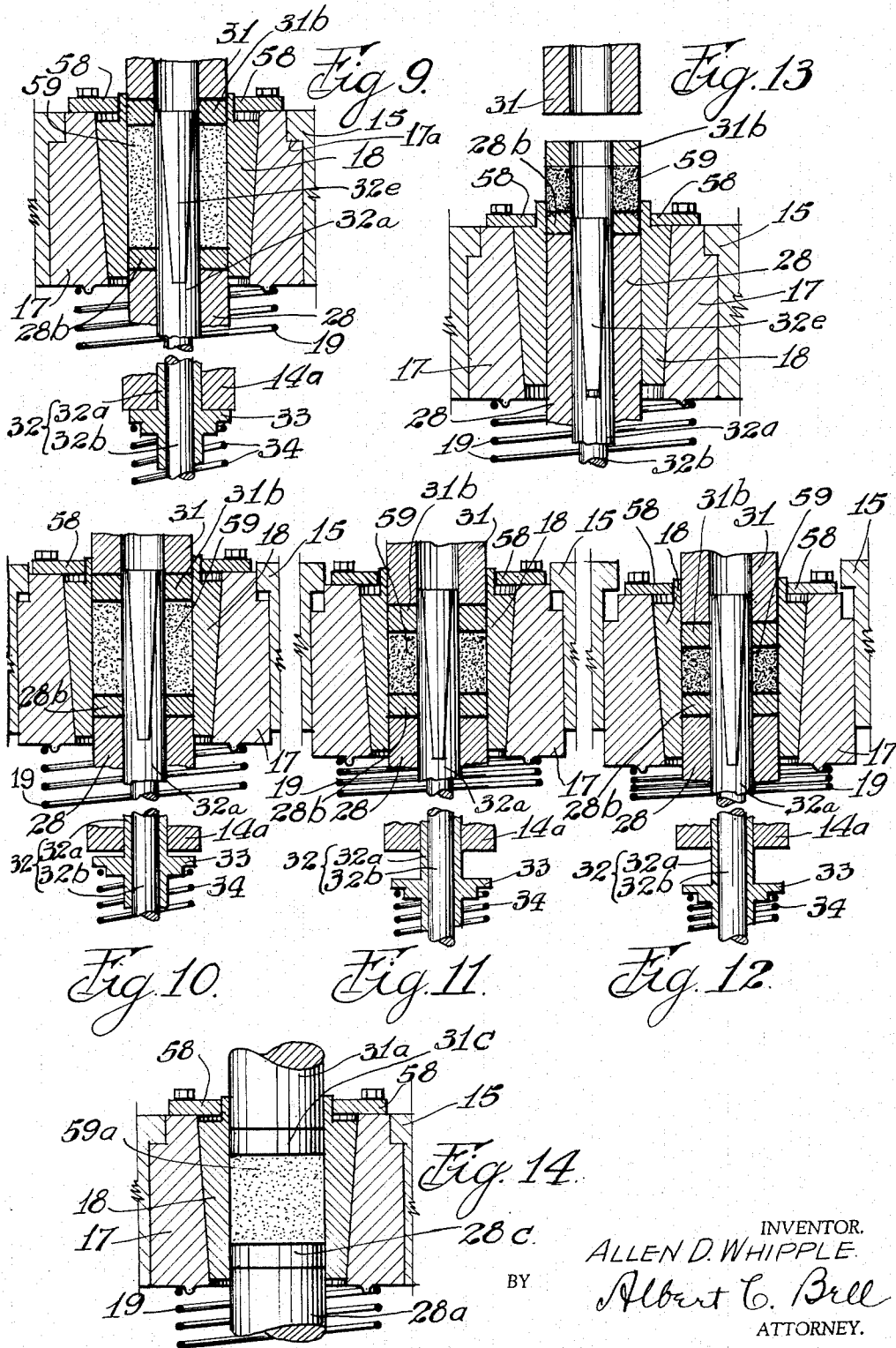
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MEANS FOR COMPRESSING FINELY DIVIDED SUBSTANCES AND PROCESS THEREFOR

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

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MEANS FOR COMPRESSING FINELY DIVIDED
SUBSTANCES AND PROCESS THEREFORAllen D. Whipple, Alexandria, Ind., assignor to
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Application March 18, 1938, Serial No. 196,653

10 Claims. (Cl. 29—1)

My invention pertains to compressing finely divided substances in metal molds, particularly where large pressures are exerted upon the finely divided material being compressed. In so compressing finely divided substances, particularly where the minute particles are metallic and microscopic in size, difficulty has been experienced in the past in producing uniform compression throughout the compressed pieces, and difficulty has also been experienced in removing the compressed pieces from the mold after compression, without distorting or damaging the compressed pieces, due to the considerable adhesion developed between the compressed pieces and the adjacent surfaces of the metal mold. These difficulties are experienced particularly in compressing powdered iron consisting of minute particles of iron, frequently as small as 300 or 400 mesh, or smaller, to form solid magnetic cores adapted for electrical work and particularly for cooperation with high frequency inductance coils. For such purposes it is often desirable that the compressed pieces shall be uniformly dense and furthermore that the pieces shall have exact and uniform dimensions when ejected from the mold in which they are compressed. As far as I am aware, it has heretofore been impossible to remove such highly compressed magnetic bodies or pieces from the molds in which they are compressed, without exerting such high pressure on them, due to the high degree of adhesion between the surfaces of the compressed bodies and the mold containing them, that the compressed bodies are damaged by the ejecting operation, particularly where the compressed bodies are of substantial length relatively to their diameters or cross-sectional areas, so that frequently instead of being straight-sided after ejection, as they should be, they are distorted into curved conformations longitudinally, which makes them useless for the purpose for which they are intended.

By my present invention I avoid the difficulties referred to, by first providing a metal mold to receive compressing plungers at its opposite ends, the mold being free to move axially during the compressing operation, so that irregularities in adhesive action between the minute particles being compressed and the surfaces of the mold retaining said particles, are equalized and prevented from cumulating at any particular point or points in the mold, so that the condition of the compressed body at the end of the compressing operation, is substantially uniform throughout the body. The difficulty heretofore experienced

in ejecting such compressed bodies from the mold is overcome by my invention, by providing in the mold a cell containing a mold cavity, which cell has an outer surface that is tapered longitudinally, said cell being split longitudinally so that it is made up of a plurality of parts. During the compressing of the finely divided substance in the mold cavity, the parts of the tapered cell are tightly held together by mounting the cell in a tapered bore in a housing employed to support the cell, said housing having a floating support in the press employed, so that the tapered cell and its housing move longitudinally during the compressing operation, to equalize the compressive forces throughout the body being compressed during the compressing operation. The housing of the cell is supported by a light spring which serves to hold the housing in its uppermost position unless and until the cell and housing are moved during a compression operation to equalize the compressive forces throughout the body being compressed. The tapered cell is thus never forced into the tapered bore in the housing with a force greater than the force of the spring supporting the cell housing. During the compression operation, the lower plunger may be stationary and the upper plunger may be forced downwardly until the desired degree of compression is reached. To eject the compressed body from the mold, the upper plunger is raised sufficiently to clear the compressed body as it is ejected from the mold, and the lower plunger is moved upwardly to raise the compressed body out of the mold and sufficiently above the mold so that it may be removed from the machine. At the beginning of the ejecting operation, the adhesion between the compressed body and the conical cell is sufficient to raise the conical cell slightly relatively to the housing supporting it; this relieves the lateral pressure between the compressed body and the cell and the compressed body is readily moved upwardly in and from the cell, without exerting destructive pressure on it and without distorting it, even though the compressed body may have a length equal to several times its outer diameter. Compressed bodies of powdered iron formed in this way, are found to have substantially uniform density, indicating substantially uniform distribution of the compressive forces throughout the bodies during compression, and they are found to be true as to size and shape.

By my invention, I am also able to produce tubular compressed bodies, the difference in this case being that a core rod extends longitudinally

through the mold, which core rod is provided with a collapsible construction where it extends through the mold, so that during the ejecting operation a part of the core rod is moved relatively to the remaining portion of said rod, by the adhesions existing between the compressed body and the core rod, the parts of the core rod being so constructed as will be described below, that the relative movement of the parts of the core rod permits the part of the core rod in the mold to collapse somewhat and thus relieve the lateral pressure between the compressed body and the core rod to facilitate ejecting the compressed body without damage or deformation. The core rod employed is preferably given a floating support in a manner to be described, to equalize the compressive pressures along the inner surface of the compressed body in substantially the manner above referred to for the equalizing of the compressive pressures in the outer portions of the compressed body, where it engages the conical cell.

My invention includes the mechanism used to produce the compressed bodies described, and also the process of so doing including the operation of ejection described.

My invention will be best understood by reference to the accompanying drawings illustrating a preferred embodiment thereof, in which

Fig. 1 illustrates schematically a press for producing the requisite compressive pressures, and the improved conical cell and collapsible core construction,

Fig. 2 is a horizontal, sectional view to an enlarged scale, of a part of the structure shown in Fig. 1, taken along the line 2—2,

Fig. 3 shows in vertical, central, sectional view, the core construction illustrated in Figs. 1 and 2, this view being taken along the line 3—3 in Fig. 2,

Fig. 4 is a vertical, central, sectional view of the core construction shown in Figs. 1 and 2, this view being taken along the line 4—4 in Fig. 2,

Fig. 5 shows in front elevation, the upper end of the outer portion of the core rod illustrated in Figs. 3 and 4,

Fig. 6 shows in front elevation, the upper end portion of the inner part of the core rod shown in Figs. 3 and 4,

Fig. 7 shows in side elevation the structure illustrated in Fig. 6,

Fig. 8 is a sectional view through one of the valves employed to control the operation of the press illustrated in Fig. 1,

Figs. 9 to 13 inclusive, illustrate in views to an enlarged scale, different positions of the conical cell and core rod during the compression and ejection of the compressed body, each of these views showing the parts in vertical, central, sectional view, the parts in Fig. 9 being in the position assumed at the beginning of the compression of a charge, Fig. 10 being illustrative of one position the parts may assume when the compression of the charge has been begun, Fig. 11 showing in a similar view a different position the parts may assume at nearly the end of compressing the charge, Fig. 12 showing in a similar view a position the parts may assume at the end of compression of the charge, and Fig. 13 showing the position assumed by the parts at the end of the ejection of a compressed body from the mold, and

Fig. 14 shows in a view similar to Fig. 9, a similar mold construction for use with solid plungers to produce solid compressed bodies.

Similar numerals refer to similar parts throughout the several views.

As shown in Fig. 1, my machine consists of a base 10 supported on legs 11 and 12, said base having extending downwardly therefrom a cylinder 13 open at its lower end and engaged by a head 14 to enclose said cylinder. A bed plate 15 is supported in horizontal position above and spaced from the base 10, which bed plate is provided with a cylindrical bore 16 coaxial with the cylinder 13, containing with a sliding fit an annular housing 17 having a conical inner surface fitting the conical outer surface of a cell 18 containing the mold cavity in which the compressed body 59 is to be formed. The housing 17 is provided with a shoulder 17a near its upper end, engaging a similar surface on the bed plate 15 to limit upward movement of said housing, in which position said housing is normally held by a light spring 19 between the lower end of said housing and the base 10. The strength of the spring 19 is sufficient to support the housing 17 and parts carried thereby, in their uppermost position, when the mold is open to receive a charge of the finely divided material to be compressed, but it is insufficient to appreciably interfere with downward movement of the housing 17 and cell 18 to equalize the compression strains on a charge while being compressed. A top plate 20 is supported above and spaced from the bed plate 15 and from the said top plate, a cylinder 21 extends upwardly and coaxially with the cylinder 13 and housing 17, the upper end of said cylinder being closed by a cover plate 22. The base 10, the bed plate 15 and the top plate 20 are held in the positions indicated by retaining bolts 23, also extending through the upper ends of the legs 11 and 12, spacing tubes 24 being provided on said bolts 23 between the base 10 and the bed plate 15, and similar spacing tubes 25 being provided on said bolts between the bed plate 15 and the top plate 20, to maintain the base, the bed plate and the top plate in the spaced relation illustrated.

The cylinder 13 contains a piston 26 having a central, cylindrical extension 27 extending upwardly with a sliding fit through the base 10, which extension engages and supports the lower plunger 28 of the machine. The cylinder 21 contains a piston 29 provided with a downwardly projecting cylindrical extension 30 which extends with a sliding fit through the top plate 20 and carries the upper plunger 31 of the machine. The plungers 28 and 31 are coaxial and enter the lower and upper ends of a cylindrical bore in the cell 18 forming the mold cavity to receive the finely divided material to be compressed. The machine illustrated in Fig. 1 is arranged to produce tubular compressed bodies by providing in the mold cavity a core structure 32 coaxial with the mold cavity, which core structure extends with a sliding fit into a bore in the lower end of the plunger 31, and also with a sliding fit through the lower plunger 28, and also through the piston 26 and its extension 27, and also through the head 14 of the cylinder 13. The core structure 32 consists of a tubular member 32a, containing with a sliding fit, a rod 32b, the lower end portion of the member 32a having an outwardly extending flange 33 formed thereon for engagement by the upper end of a supporting spring 34, the lower end of which spring engages an inwardly extending flange on a tubular member 35 extending downwardly from and supported by a

central hub 14a on the head 14. The spring 34 is of sufficient strength to positively hold the core structure in its uppermost position, with the flange 33 against the lower end of the hub 14a, when the mold is open to receive a charge of the finely divided material to be compressed, but not of sufficient strength to appreciably prevent downward movement of the core structure during the compressing of the finely divided material, to equalize the strains of compression throughout the compressed body. Below the member 35, the member 32a carries a flange member 36 engaging the upper end of a spring 37, the lower end of which rests on a second flange member 38 carried by and rigidly secured to the lower end of the rod 32b. The spring 37 permits the rod 32b to have limited movement upwardly relatively to the tubular member 32a during an ejecting operation, to permit the upper end portion of the core structure to collapse to a limited extent during such ejection in a manner to be described, said spring being sufficiently strong to positively hold the core parts in their relative positions indicated in Fig. 1, excepting during the ejection of a compressed body from the mold.

As shown in Fig. 1, the lower end portion of the plunger 31 consists of a bushing 31b having butting engagement with the body portion of said plunger, and the upper end portion of the plunger 28 consists of a bushing 28b having butting engagement with the latter plunger, which bushings are not secured to the body portions of their respective plungers. By this construction, the said bushings may be accurately ground to fit the mold cavity and the core structure 32, and the body portions of the plungers may have external diameters slightly smaller than the mold cavity, and they may also have clearance bores slightly larger in diameter than the external diameter of said core structure, which eliminates friction and wear between the body portions of the plungers and the mold and between said body portions and said core structure. Further and marked advantages secured by the use of said bushings, particularly where heat is employed in connection with compressing and solidifying the molded cores, are as follows: the compressed cores adhere with considerable force to the plunger surfaces engaging them, making it difficult to separate the plungers from the compressed cores immediately after the latter are ejected from the mold, without breaking or damaging the cores, to avoid which, where single-piece plungers are used, the entire machine must remain idle and at rest until the compressed core has cooled sufficiently to permit safely separating the compressed core from the plungers. By the use of the plunger bushings described, such delays are avoided, the compressed cores may be removed from the machine with their adhering bushings immediately after ejection from the mold, and as many of said bushings may be provided as desired, to insure continuous operation of the machine.

To operate the pistons 26 and 29, I diagrammatically illustrate a pump 39, intended to receive its supply of operating liquid, for example oil, through a pipe 40 and a check valve 41 from a tank 42, said pump having a delivery connection 43 through a check valve 44, to a pipe 45 for supplying the liquid under pressure to operate said pistons. The pipe 45 is connected with a control valve 46, which is also connected with pipes 47 and 48, extending to the upper and low-

er ends respectively of the cylinder 21, so that when the control valve 46 is moved to one position, liquid under pressure is supplied to the pipe 47 to move the piston 29 and plunger 31 downwardly, and when said control valve is moved to another position, the pipe 48 is connected with the pipe 45 to move the piston 29 and the plunger 31 upwardly.

As shown in Fig. 8, the control valve 46 contains a valve member 46a, which by its rotation establishes communication within the valve body between the pipes 45 and 47 for one position of the valve handle, at which time the pipe 48 is connected with pipe 49; for a second position of the valve member 46a, the pipes 45 and 48 are connected within the valve body and at the same time the pipes 47 and 49 are connected. In this way the liquid under pressure may be supplied either to the pipe 47 or to the pipe 48, and at the same time the liquid contained in the cylinder 21 in the path of movement of the piston 29 is directed from one of the pipes 47 and 48, as the case may be, to the drain pipe 49, which as shown in Fig. 1 extends to the tank 42. A second and similar control valve 50 is connected with the pipes 45 and 49 and also with pipes 51 and 52 extending to the upper and lower ends of cylinder 13, to move the piston 26 downwardly or upwardly, as desired, by liquid under pressure, the liquid in the cylinder and required to be drained therefrom for either movement of the piston 26, finding its way through the control valve 50 to the drain pipe 49 in the manner above described. To permit the pump 39 to operate continuously, a pressure relief valve 53 is connected with the pipe 45 and also with a discharge pipe 54 extending to the tank 42, so that when both of the control valves 46 and 50 are closed, to prevent liquid flow to the cylinders 13 and 21, the pump 39 may remain in operation and the liquid delivered under pressure from the pump finds its way through the valve 53 back into the tank 42.

In operating the machine, the piston 26 and plunger 28 are first moved to their lowermost position by means of the control valve 50, for which position the upper end of the plunger 28 just enters the mold cavity in the conical cell 18. The piston 29 and plunger 31 are raised to their uppermost position to afford free access to the upper end of the mold, a bushing 28b is inserted in the mold to rest on the body portion of the plunger 28, the mold is filled to a desired point with the subdivided material to be compressed to form the compressed body, and a bushing 31b is inserted in the mold, preferably with its upper end just below the upper end of the mold. The piston 29 and plunger 31 are then forced downwardly by the liquid under pressure in the upper end of the cylinder 21, by operation of the control valve 46, and the compression is continued until the desired degree of compression of the finely divided substance is effected. If it is desired to compress the finely divided substance until a predetermined pressure is exerted upon it, a pressure gauge 55 connected with the pipe 47 may be employed, so that by manipulation of the control valve 46, the pressure indication of the gauge 55 is increased until the desired pressure corresponding with the maximum pressure to be exerted on the charge being compressed is reached, at which time the control valve 46 is moved to stop the operation of the piston 29, and the piston is moved upwardly to its uppermost position to raise the plunger 31 to permit the ejection of the compressed body. If

preferred, the compression of the finely divided substance may be continued until the amount of compression is determined by a definite decrease of volume of the material being compressed, which is found in some cases to give more uniform results than where compressing the finely divided material to a definite pressure, is relied upon to secure uniformity. In this case, the extension 30 may be provided with a cross bar 56 secured to said extension and movable vertically with the plunger 31. Spacing blocks 57 are placed on the bed plate 15 below the ends of the bar 56, the height of the blocks 57 determining the possible amount of travel downwardly of the plunger 31, and in this way, any desired amount of vertical movement of the plunger 31 may be permitted. With this system of controlling the amount of compression, the pressure exerted downwardly on the piston 29 is increased until the possible travel of the bar 56 is effected, after which no increase in pressure above the piston 29 is necessary or desirable, and the control valve 46 is moved to its alternate position, raising the plunger 31 to permit ejection.

After the compressed body has been formed in the conical cell 18, and with the plunger 31 in its uppermost position, and the control valve 46 in a neutral position, for example as illustrated in Fig. 8, the plunger 28 is raised by supplying liquid under pressure to the pipe 52 by operation of the control valve 50. This raises the compressed body, and in doing so, at the beginning of its upward movement, by the adhesion between the compressed body and the conical cell 18, the conical cell is raised in its housing 17 and freed from the lateral pressure between the conical cell and the compressed body. Stop bars 58 carried by the housing 17, limit the upward movement of the conical cell 18 relatively to the housing 17, after which, with the shoulder 17a in contact with the corresponding surface of the bed plate 15, continued movement upwardly of the plunger 28 raises the compressed body in the conical cell 18, and with small opposition from the conical cell, because of its slightly expanded condition, as will be described, the core structure 32 being also released from lateral pressure of the compressed body by its collapsed condition, to be described.

It will be borne in mind that during the compression of the divided material in the conical cell, the lower plunger 28 may be in its lowermost position and may be stationary, in which position it just enters the lower end of the mold cavity in the conical cell 18. As a result, when the upper plunger 31 is moved downwardly to compress the charge in the mold cavity, adhesions develop between the material being compressed and the inner surface of the conical cell, which adhesions may cumulate either at the upper part of the charge, at its lower portion, or any other portion thereof, on the inner surface of the conical cell, the manner in which these adhesions develop and accumulate being entirely unpredictable. In one case the adhesions may develop at the lower part of the charge and just above the plunger 28. In this case, there is no disturbance in connection with effecting distribution of compression throughout the charge, and no movement of the conical cell 18 results. In another case, the adhesions between the finely divided material and the conical cell may develop and accumulate in the upper portion of the charge, in which case the tendency is to move the conical cell downwardly with the plunger 31, which movement is

not opposed by the lower portion of the charge, since adhesions have not developed to an appreciable extent between the charge and the lower part of the conical cell. This downward movement of the conical cell is freely permitted by the manner of supporting the housing 17 above described. When the conical cell and the plunger 31 have moved downwardly together a certain distance, the tendency is to develop adhesions between the subdivided material and the lower portion of the conical cell, which accumulates until the latter adhesions are greater than the former adhesions at the upper portion of the cell, at which time the upper plunger 31 forcibly moves the upper part of the charge relatively to the conical cell, breaking down the adhesions first formed and effecting a redistribution of the pressure of compression throughout the charge. The cell 18 and its supporting housing may thus be regarded as floating during the compression of a charge, since the pressures involved are usually much greater than the weight of the conical cell and its supporting housing. A similar action takes place as to the adhesions between the charge being compressed and the core structure 32, the spring 34 affording a floating support for the core structure which effects distribution of the pressures of compression throughout the charge being compressed, as far as adhesions developed between the core structure and the charge are concerned.

As shown in Fig. 2, the conical cell 18 consists of a plurality of longitudinally extending sections 18a, 18b and 18c, the edge surfaces of which are in radial planes and so closely fitted to each other that when the cell is seated in its housing 17, the bore of the conical cell is a continuous surface. From this relation it will at once appear that relieving the conical cell from lateral restraint by the housing 17, by slightly raising the cell relatively to the housing as above described, frees the compressed charge 59 from lateral pressure on its outer surface so that the ejecting operation may be readily effected.

As shown in Figs. 3 and 4, the inner or rod portion 32b of the core structure is conically formed at its upper end portion for a length preferably somewhat greater than the length of the mold cavity, said conical portion being of increasing diameter upwardly. The upper end portion of the part 32a of the core structure is provided with a conical bore closely fitting the conical upper end of the rod 32b when the latter is in its lowermost position relatively to the tubular portion 32a of the core structure. The upper end portion of the rod 32b is longitudinally slotted as shown at 32c for a distance from the upper end of the core structure to a point somewhat below the lower end of the conical portion of said rod. The slot 32c permits the upper portion of the rod 32b to collapse or yield laterally, when the rod portion is raised from its lowermost position relatively to the tubular portion 32a, for which position the upper portion of the rod 32b may yield or collapse laterally to free the inner surface of the compressed body 59 during an ejecting operation. The upper end portion of the rod 32b is provided with longitudinally extending wedge-shaped members 32d and 32e having a length substantially equal to the tapered upper end portion of said rod, the wider portions of said wedge members being uppermost. The tubular member 32a is provided at its upper end portion with tapered slots, the edges of which closely fit the edges of said wedge members, when

the rod 32b is in its lowermost position relative to the tubular member 32a, at which time the upper end portion of the rod 32b is restrained from collapsing by the engagement of the edge surfaces of the wedge members 32d and 32e with the adjacent surfaces of the tubular member 32a, as indicated in Fig. 2. In Fig. 5, I show the upper end portion of the tubular member 32a with the rod 32b removed therefrom, to more clearly illustrate one of the slots 32f therein to engage the corresponding one of the wedge members 32d and 32e. In Figs. 6 and 7, I illustrate the upper end portion of the rod 32b to more clearly show the relation of the wedge members 32d and 32e to the upper tapered end portion of the rod.

In Figs. 9 to 12 inclusive, I illustrate various positions assumed by the upper plunger 31, the mold cell 18, its housing 17 and the core structure 32 during the compression of a charge. In Fig. 9, the plunger 31 has just entered the filled mold cavity and the parts are in substantially the position shown in Fig. 1, the cell 18 and its housing 17 being in their uppermost position against the shoulder 17a under the action of the spring 19, the lower plunger 28 being in its lowermost position which is maintained during the compressing operation, and the core structure 32 being in its uppermost position under the action of the spring 34, with the flange 33 against the lower end of the hub 14a. In Fig. 10, the upper plunger 31 is shown in the position assumed by it after accomplishing the first part of the compressing operation, during which it is assumed that sufficient adhesion has occurred between the upper portion of the charge 59 and the inner surface of the conical cell 18 to move the cell and the housing 17 downwardly a small amount against the action of the spring 19, although this amount of movement is assumed to be less than the plunger movement on account of the adhesions at the upper end of the charge not being great enough to prevent redistribution of the adhesion during the movement of the plunger. It is also assumed that the adhesion between the charge being compressed and the core structure 32 has slightly developed, but only to a sufficient extent to move the core structure downwardly a small amount and less than the downward movement of the housing 17, against the action of the spring 34. In Fig. 11, the upper plunger 31 is shown in the position assumed by it as it nears the end of the compressing operation. In its travel from the position shown in Fig. 10, it is assumed that the adhesions developed between the charge 59 and the conical cell 18 and the redistribution of these adhesions, have effected further substantial movement downwardly of the conical cell and its housing resulting in further compression of the spring 19, and that for this particular movement of the plunger 31, adhesions between the charge 59 and the core structure 32 have developed to a greater extent at the upper part of the compressed charge, as a result of which the core structure 32 has moved downwardly to a much greater extent than the downward movement of the housing 17, correspondingly separating the flange 33 from the hub 14a and compressing the spring 34. In Fig. 12, the upper plunger 31 is shown in its lowermost position assumed at the end of a compressing operation, and in this case the adhesions developed between the compressed charge and the conical cell 18 are assumed as having imparted substantial movement to the conical cell and its housing against the action of the spring 19, and

that further movement as a result of adhesions between the compressed charge and the core structure, has moved the core structure downwardly, but not to as great an extent as the downward movement of the housing 17. It will be noted that during the entire operation of compression of the charge there is no movement of the conical cell 18 relatively to its housing 17, and no movement of the parts of the core structure relatively to each other. It will also be noted that regardless of the adhesions developed between the charge being compressed and the conical cell 18, the cell cannot be pressed downwardly into its housing under any circumstances with a force greater than the upward thrust exerted by the spring 19, also that the rod portion 32b of the core structure cannot be forced downwardly into the tubular portion 32a of said structure with any greater force than the upward thrust exerted by the spring 34. As a result, assuming that the tapers of the conical surfaces and wedge members are sufficient to prevent it, the cooperating wedge-shaped members are never forced together so tightly that it is difficult to separate them. While the degrees of taper may be widely different to meet the requirements of different constructions mechanically, I find in practice that a taper of not over six-tenths of an inch per foot is ample to prevent the downward forces exerted on the cell 18 and on the rod portion 32b, from tightly locking the cell and the housing together and from tightly locking the parts of the core structure together, as a result of which, during the ejecting operation, the conical cell is readily raised relatively to the housing 17, and the rod portion 32b of the core structure is readily raised relatively to the tubular portion 32a thereof.

After the compression operation has been completed as illustrated in Fig. 12, ejection of the solidified compressed charge is effected by first raising the upper plunger 31 to the position illustrated in Fig. 13, and then raising the lower plunger 28 by the action of the piston 26 as above described. In Fig. 13, I show the solidified compressed body 59 just before it is completely ejected from the mold cavity, and in this figure I also illustrate the positions assumed by the conical cell 18 and by the rod member 32b of the core structure, due to the upward movement of the compressed body. As shown in this figure, the upward movement of the compressed body 59, by its friction or adhesion with the conical cell 18, has raised the conical cell against the stop bars 58 at the beginning of the ejecting operation, in which position the conical cell remains under the slight friction still existing between it and the compressed charge, to the end of the ejecting operation, and by the adhesion or friction of the compressed charge with the wedge-shaped members of the rod portion 32b of the core structure, the rod portion is raised against the action of the spring 37, a small amount relatively to the tubular portion 32a of said core structure, thus freeing the upper end of the rod portion so that it may collapse slightly, and also freeing the upper end of the tubular portion 32a of the core structure so that it may collapse slightly and thus permit the ready removal of the compressed body 59 with the adhering bushings 28b and 31b, from the mold, so that said bushings may be subsequently removed from the compressed body, as desired. Where in the past it has been attempted to eject such compressed bodies of powdered iron from the

molds in which they were compressed, without relieving the lateral forces involved, I have found that large pressures were required to effect the ejecting operation, many times amounting to several times the pressure required to compress the charge, and where, as is frequently the case, compressing pressures of from fifteen to twenty tons are required to properly compress the charge, it will at once be appreciated how difficult it has been heretofore to eject the compressed bodies from the mold without damaging the compressed bodies and without deforming them, particularly when the compressed bodies have substantial length relative to their diameters or lateral dimensions. By my improved construction, however, the lateral pressures on the compressed bodies are released at the beginning of the ejecting operation, and as a result the pressure required to eject the compressed body from the mold is small relatively to the pressure used in compressing the body, and I find that compressed bodies of finely divided iron originally in powdered form, can be successfully removed from the molds after exerting very large compressing pressures on them, without in any way damaging the compressed bodies and without in any way distorting them, even though the compressed bodies may be as long as eight or ten times their diameters or lateral dimensions.

In Fig. 14, I illustrate the use of solid plungers 31a and 28a instead of hollow plungers 31 and 28, where it is desired to produce compressed bodies 59a which are solid instead of tubular, solid bushings 31c and 28c being here employed instead of the tubular bushings 31b and 28b above described. The only other change required to produce such solid compressed bodies by my invention, is to remove the entire core structure above described and the head 14, and to replace said head with a solid head of the kind shown at 22 for the cylinder 21. The conical cell structure 18 and its housing 17 remain the same as before and operate in the same manner to secure the same results as above described.

From the above it will appear that by my invention I may produce solidified compressed bodies of desired shape and proportions from finely divided material, either with or without the use of a binder, depending upon the nature of the material, and that even where very high compression pressures are required, the solidified compressed bodies may be readily delivered from the mold of the machine in undamaged condition.

In referring above to the plungers 31 and 28 as being respectively the upper and lower plungers of the machine, it will be understood that said designations and the directions of motion described, apply when the machine is used with the center line of said plungers in vertical position or nearly so, and that the same considerations apply to the plungers 31a and 28a illustrated in Fig. 14. It is pointed out, however, that in some cases, if desired, the machine may be erected and operated with the said center line in any other position than vertical, in which cases the designations of location and motion will be appropriately changed. In any event, the plunger 31 or 31a as the case may be, may be considered as the first of the plungers of the machine, and the plunger 28 or 28a as the case may be, may be considered as the other or second plunger of the machine.

By the operation of the apparatus above described, I am able to produce long and slender compressed bodies or cores of comminuted ma-

terial including magnetic material such as powdered iron, which are straight and true when they are ejected from the molds or dies in which they are compressed, and which due to the release of the lateral pressures on the compressed body or core at the beginning of the ejecting operation, are free from appreciable burnishing or polishing effects which would occur if they were forced from the mold while subjected to large lateral pressures. The last named result is important, for, particularly in making cores from comminuted magnetic material, surface portions forming closed paths for electric current flow result from heavy burnishing during ejection, which, even if the compressed bodies were straight and true when ejected, materially decrease the efficiency of the compressed bodies, and this effect with compressed magnetic cores, has frequently been sufficient to ruin such cores for their intended purposes. By my invention these undesirable results are avoided by releasing the lateral pressures on the compressed bodies before ejecting movement of said bodies from the molds is begun, thus practically eliminating the burnishing and polishing of the compressed bodies during ejection. My invention includes the apparatus used to secure the novel results described, and also the process of compressing bodies of comminuted material, which includes the novel ejection of the compressed bodies above set forth.

It will be understood that the mechanisms shown are largely schematic, and that I do not limit myself to any particular sizes, proportions or forms of mold cavities and compressed bodies formed therein, since the structure disclosed may readily be adapted to meet the requirements of any conditions to which my invention is applicable. It will also be understood that I may employ equivalents of the structure and operations described without departing from the scope of the appended claims.

Having thus described my invention, what I claim is:

1. In a machine of the class described, the combination of a split and expansible cell containing a mold cavity, opposed plungers coaxial with said mold cavity for entering opposite ends of said cavity with a close fit, means for forcing a first one of said plungers into said cavity towards the other of said plungers to compress and solidify a charge in said cavity, said cell having a tapered outer surface of self-locking angle and increasing in size laterally towards said first plunger, a housing having a tapered bore fitting said cell and freely movable axially, said cell having limited movement axially in said tapered bore to free said cell for expansion, and freely yielding light spring means tending to hold said housing towards said first plunger with a pressure inappreciable relatively to said compressing pressures, whereby said cell and said housing are free to move to equalize the compressing and solidifying of a charge and the pressure forcing the tapered cell into said housing is limited to the holding force of said freely yielding means.

2. In a machine of the class described, the combination of a split and expansible cell containing a mold cavity, opposed plungers coaxial with said mold cavity for entering opposite ends of said cavity with a close fit, means for forcing a first one of said plungers into said cavity towards the other of said plungers to compress and solidify a charge in said cavity, said cell

having a tapered outer surface of self-locking angle and increasing in size laterally towards said first plunger, a housing having a tapered bore fitting said cell and freely movable axially, said cell having limited movement axially in said tapered bore to free said cell for expansion, freely yielding light spring means tending to hold said housing towards said first plunger with a pressure inappreciable relatively to said compressing pressures, whereby said cell and said housing are free to move to equalize the compressing and solidifying of a charge and the pressure forcing the tapered cell into said housing is limited to the holding force of said freely yielding means, and means for forcing said other plunger into the mold cavity to eject a solidified charge with said first plunger withdrawn, thereby moving and freeing said cell for expansion in said housing and freeing said charge from lateral pressure during ejection.

3. In a machine of the class described, the combination of a split and expansible cell containing a mold cavity, opposed plungers coaxial with said mold cavity for entering opposite ends of said cavity with a close fit, means for forcing a first one of said plungers into said cavity towards the other of said plungers to compress and solidify a charge in said cavity, said cell having a tapered outer surface of self-locking angle and increasing in size laterally towards said first plunger, a housing having a tapered bore fitting said cell and freely movable axially, said cell having limited movement axially in said tapered bore to free said cell for expansion, freely yielding light spring means tending to hold said housing towards said first plunger with a pressure inappreciable relatively to said compressing pressures, whereby said cell and said housing are free to move to equalize the compressing and solidifying of a charge and the pressure forcing the tapered cell into said housing is limited to the holding force of said freely yielding means, and a core structure extending through said mold cavity and adapted to enter said first plunger.

4. In a machine of the class described, the combination of a split and expansible cell containing a mold cavity, opposed plungers coaxial with said mold cavity for entering opposite ends of said cavity with a close fit, means for forcing a first one of said plungers into said cavity towards the other of said plungers to compress and solidify a charge in said cavity, said cell having a tapered outer surface of self-locking angle and increasing in size laterally towards said first plunger, a housing having a tapered bore fitting said cell and freely movable axially, said cell having limited movement axially in said tapered bore to free said cell for expansion, freely yielding light spring means tending to hold said housing towards said first plunger with a pressure inappreciable relatively to said compressing pressures, whereby said cell and said housing are free to move to equalize the compressing and solidifying of a charge and the pressure forcing the tapered cell into said housing is limited to the holding force of said freely yielding means, a core structure extending through said mold cavity and adapted to enter said first plunger, said core structure being freely movable axially towards said other plunger, and second freely yielding light spring means tending to hold said core structure towards said first plunger with a pressure inappreciable relatively to said compressing pressures, whereby said core structure is free to

move to equalize the compressing and solidifying of a charge.

5. In a machine of the class described, the combination of a split and expansible cell containing a mold cavity, opposed plungers coaxial with said mold cavity for entering opposite ends of said cavity with a close fit, means for forcing a first one of said plungers into said cavity towards the other of said plungers to compress and solidify a charge in said cavity, said cell having a tapered outer surface of self-locking angle and increasing in size laterally towards said first plunger, a housing having a tapered bore fitting said cell and freely movable axially, said cell having limited movement axially in said tapered bore to free said cell for expansion, freely yielding light spring means tending to hold said housing towards said first plunger with a pressure inappreciable relatively to said compressing pressures, whereby said cell and said housing are free to move to equalize the compressing and solidifying of a charge and the pressure forcing the tapered cell into said housing is limited to the holding force of said freely yielding means, a core structure extending through said mold cavity and adapted to enter said first plunger, said core structure including a tubular portion and a rod portion movable longitudinally in said tubular portion, said core portions having cooperating tapered members of self-locking angle holding said core structure against collapse during the compression of a charge and permitting collapse of said core structure during the ejection of a compressed and solidified charge, said core structure being freely movable axially towards said other plunger, and second freely yielding light spring means tending to hold said core structure towards said first plunger with a pressure inappreciable relatively to said compressing pressures, whereby said core structure is free to move to equalize the compressing and solidifying of a charge.

6. In a machine of the class described, the combination of a split and expansible cell containing a mold cavity, opposed plungers coaxial with said mold cavity for entering opposite ends of said cavity with a close fit, means for forcing a first one of said plungers into said cavity towards the other of said plungers to compress and solidify a charge in said cavity, said cell having a tapered outer surface of self-locking angle and increasing in size laterally towards said first plunger, a housing having a tapered bore fitting said cell and freely movable axially, said cell having limited movement axially in said tapered bore to free said cell for expansion, freely yielding light spring means tending to hold said housing towards said first plunger with a pressure inappreciable relatively to said compressing pressures, whereby said cell and said housing are free to move to equalize the compressing and solidifying of a charge and the pressure forcing the tapered cell into said housing is limited to the holding force of said freely yielding means, a core structure extending through said mold cavity and adapted to enter said first plunger, said core structure being collapsible and including tapered members of self-locking angle holding said core structure in expanded condition during the compressing and solidifying of a charge, said core structure being freely movable axially towards said other plunger, and second freely yielding light spring means tending to hold said core structure towards said first plunger

er with a pressure inappreciable relatively to said compressing pressures, whereby said core structure is free to move to equalize the compressing and solidifying of a charge.

7. In a machine of the class described, the combination of an expansible cell containing a mold cavity for a charge of material to be compressed and solidified, a plunger movable into said mold cavity to compress a charge therein, means for ejecting a compressed charge from said mold cavity, a member holding said cell against expansion during the compression of a charge and freeing said cell for expansion during the ejection of a compressed charge, said cell comprising a plurality of separate pieces having a conical outer surface of self-locking angle, and said holding member having a bore fitting said conical outer surface, and light spring means supporting said cell with a pressure inappreciable relatively to said compressing pressures and yielding freely during the compression of a charge and thereby effecting substantially uniform distribution of compression throughout said charge.

8. In a machine of the class described, the combination of an expansible cell containing a mold cavity for a charge of material to be compressed and solidified, a plunger movable into said mold cavity to compress a charge therein, means for ejecting a compressed charge from said mold cavity, a member holding said cell against expansion during the compression of a charge and freeing said cell for expansion during the ejection of a compressed charge, said cell comprising a plurality of separate pieces having a conical outer surface of self-locking angle, and said holding member having a bore fitting said conical outer surface, and light spring means supporting said cell with a pressure inappreciable relatively to said compressing pressures and yielding freely during the compression of a charge and thereby effecting substantially uniform distribution of compression throughout said charge, the friction of the charge against

the wall of the mold cavity being instrumental in the freeing of said cell for expansion.

9. In a machine of the class described, the combination of a laterally expansible cell containing a mold cavity for a charge of material to be compressed and solidified, a first plunger movable into said mold cavity to compress a charge therein, a second plunger movable to eject a compressed charge from said mold cavity, an axially movable member holding said cell against lateral expansion during the compression of a charge, and light spring means supporting said cell and said member with a small pressure of the order of the combined weight of said cell and said member in comparison with the large pressure of compression and yielding throughout the compression of the charge without appreciable opposition to the pressure of compression, said light spring means being the sole support of said axially movable member and said cell during the entire compression of the charge, said axially movable member and said cell having co-operating conformations freeing said cell for lateral expansion only by initial movement of said second plunger to eject a compressed charge and before the compressed charge is moved in the mold cavity.

10. The process of making cylindrical bodies of compressed comminuted material, including placing a cylindrical body of comminuted material in a surrounding zone and laterally restraining said body to cylindrical form and applying to the body a compressing pressure substantially perpendicular to the directions of said lateral restraint and at the same time restraining said body in a direction opposite to the direction of application of said compressing pressure, then removing said compressing pressure, and then releasing said body from lateral restraint with said body still in the zone of lateral restraint by pressure on said body in a direction opposite to the direction in which said compressing pressure was applied.

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