May 28, 1946. S. M. DUNN 2,400,878

METHOD OF INSERTING BOLTS INTO CONCRETE

Filed May 10, 1941 3 Sheets-Sheet 1

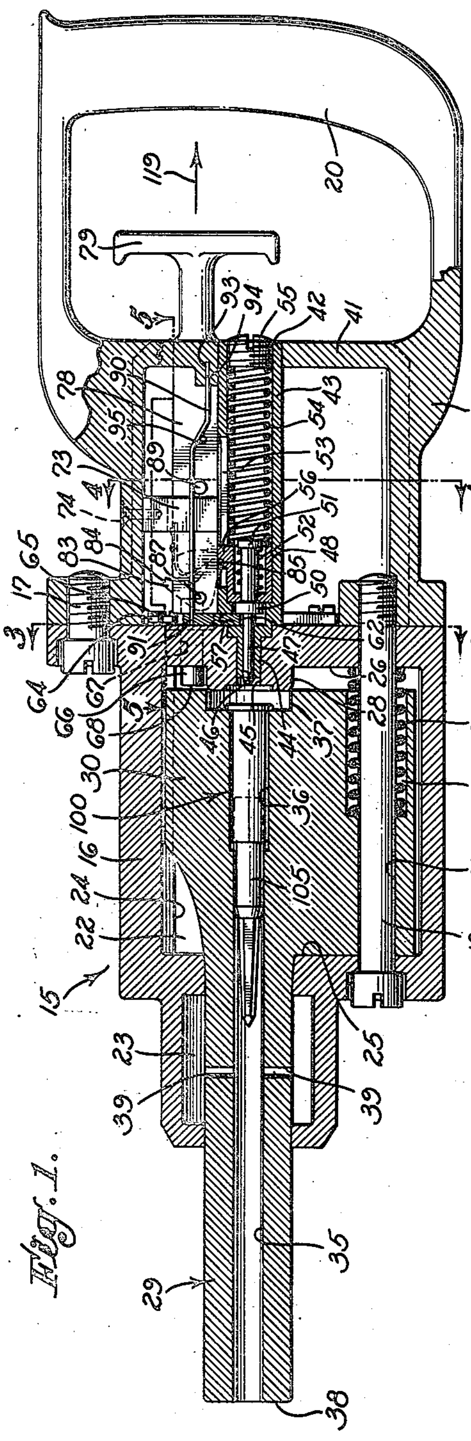

Fig. 1.

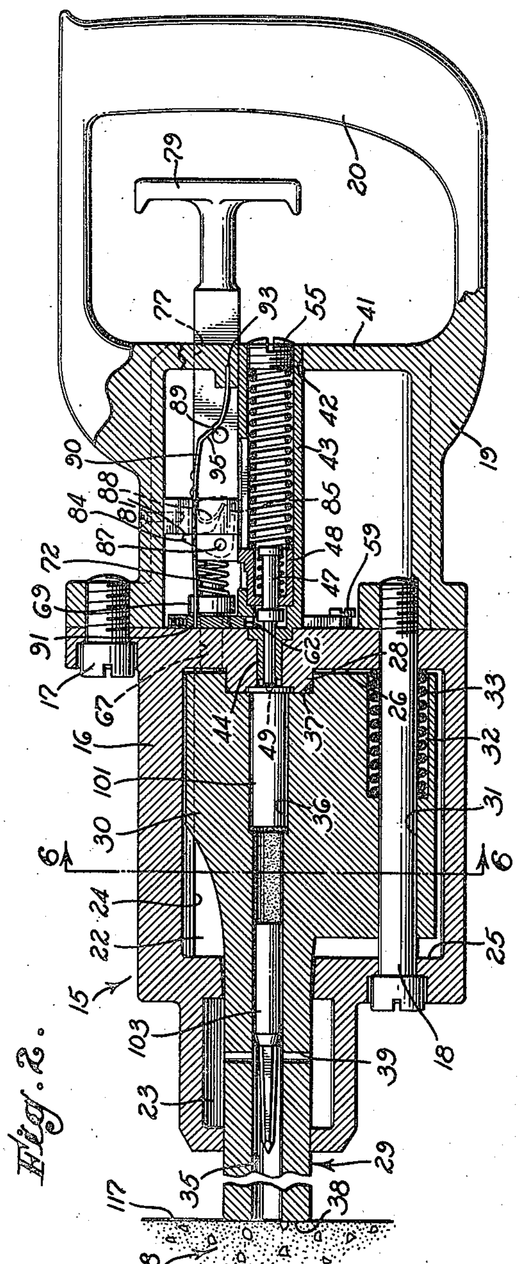

Fig. 2.

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Fig. 7.

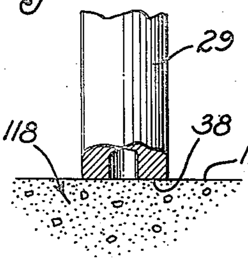

Fig. 8.

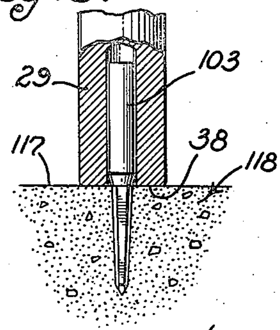

Fig. 9.

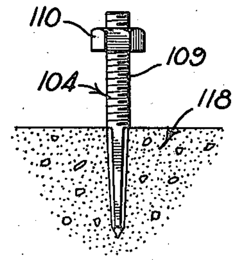

Fig. 3.

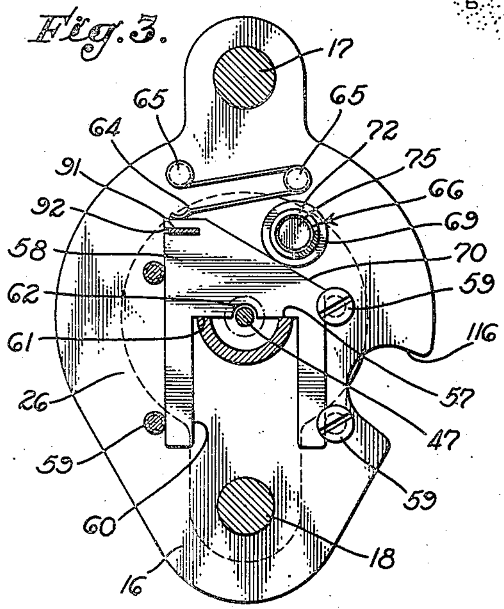

Fig. 4.

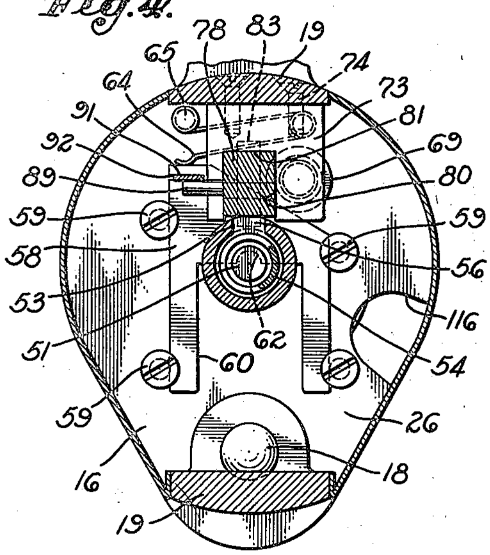

Fig. 6.

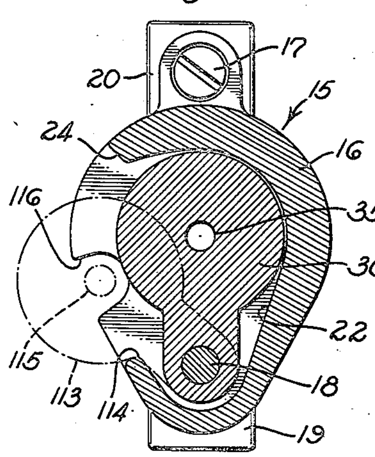

Fig. 5.

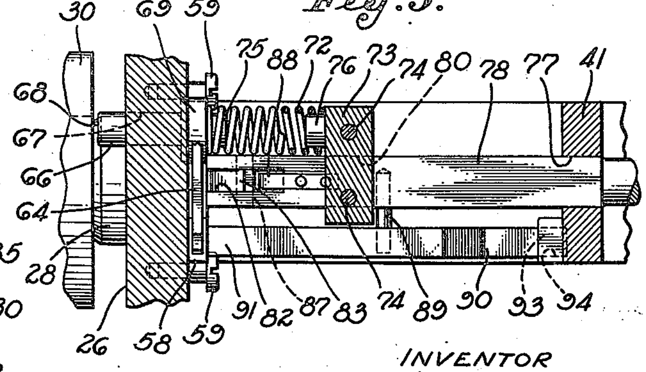

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Fig. 10.

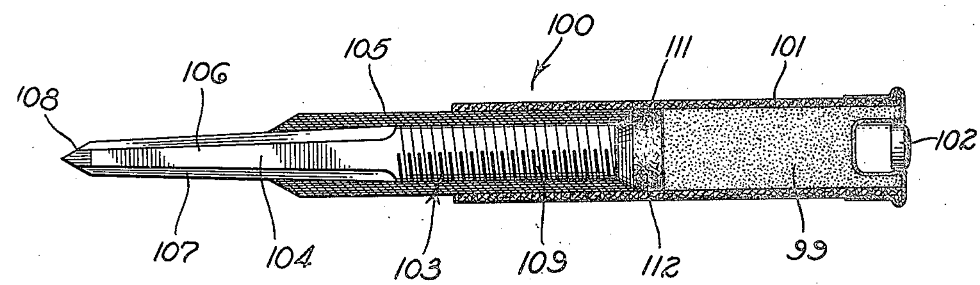


Fig. 11.

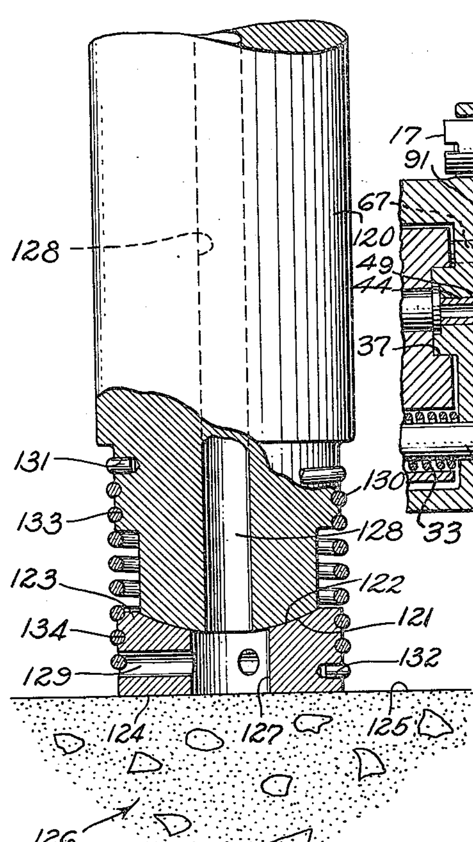
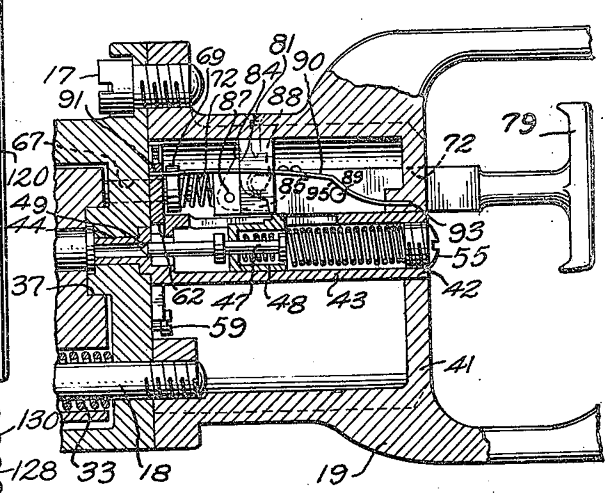


Fig. 12.



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UNITED STATES PATENT OFFICE

2,400,878

METHOD OF INSERTING BOLTS INTO CONCRETE

Stephen M. Dunn, Los Angeles, Calif.

Application May 10, 1941, Serial No. 392,896

4 Claims. (Cl. 1—46)

My invention relates primarily to the art of embedding bolts, studs, or the like in concrete or similar substances, and more particularly to a method for accomplishing this purpose.

My invention is of particular utility in construction work and, accordingly, will be described in connection therewith, although it is to be recognized that my method may be used in other arts without departing from the spirit of my invention.

In the concrete construction art, it is commonly desirable or necessary to set bolts or studs formed of steel or other material so that one end thereof is embedded in a mass of solid concrete. Such embedded bolts or studs are frequently used to provide means whereby other structures may be joined or fastened to such a concrete mass. For example, in the fabrication of concrete building structures it is frequently necessary to provide extensive metal piping systems, such as plumbing, which must be fastened in some manner to the concrete walls of the structure. The standard practice is to partially embed a series of bolts or studs in the concrete walls so as to leave an end thereof projecting, to which the piping may be tied by conventional methods. Heretofore, the embedding of the bolts or studs has been accomplished by either of two methods: (a) bolts or studs are set in the forms in which the walls are originally cast so as to actually cast the studs into the walls; or (b) the walls are first formed complete and then are drilled by conventional methods, as by a pneumatic drill, to form holes to receive the studs which are secured in the holes by anchoring devices or by cementing, or both. These are the only two methods of accomplishing this result known in the art at the present time, and both methods have many marked disadvantages. For example, it is extremely expensive to cast studs directly in the concrete as it is poured as special provision therefor must be made in the concrete forms, and, particularly in the casting of vertical walls, it is very difficult to secure a good bond between the concrete and the studs as voids tend to form below the studs as the concrete is poured. Also, by this standard method errors in location or changes in plans after completion of the pouring of the concrete frequently necessitate the insertion of additional studs, which must then be put in by the second conventional method, which causes delay in construction. The second method, similarly, is expensive as special holes must be drilled in the concrete, and the studs must then be anchored and cemented in the holes, which are labor-consuming operations requiring additional materials such as special anchors and cement, which also increase the cost. By either prior art method, however, only a relatively weak bond can be formed between the studs and the concrete, which allows the studs to pull out of the concrete if large pulling strains are impressed thereon. Thus, such prior art methods are not only expensive to perform but actually produce only a relatively weak bond between the studs and the concrete.

For the purpose of simplicity in this specification and claims, I shall describe my invention as being used in connection with a mass of "aggregated material," which I hereby define as meaning aggregated or fired earthen materials having a low modulus of elasticity and being substantially non-ductile, such as, for example, concrete, cement, brick, clay, and the like, to all of which my invention is applicable.

A primary object of my invention is to provide a method for embedding a stud in a mass of aggregated material which are more economical to use than the prior art methods described above and which form a greatly stronger bond between the stud and the aggregated material than such prior art methods. I intend to accomplish this by shooting a stud directly into a mass of aggregated material so as to rigidly fix the stud therein. I have found that such a method is very economical and attains a result much superior to the standard methods described above. For example, a large number of pulling tests have been run on sand-blasted studs which were carefully tempered and cemented in drilled holes in concrete blocks, in accordance with conventional prior art methods. It was found that all of such studs could be pulled from the concrete by applying a pulling force thereto of 900 pounds per square inch, or less, of circumferential area of the embedded portion of the stud. Similar pulling tests conducted by me on studs embedded in concrete by my method, as described hereinafter, have established that the pulling force required to pull such a stud is commonly over 3800 pounds per square inch of circumferential area of the embedded portion of the stud. In fact, by extensive tests on pulling studs having a diameter of one-quarter inch and which had been embedded in concrete by my process, I have discovered that a bond may be formed between the stud and the concrete of such strength that the stud will break before the bond between the stud and the concrete will break; i. e., the bond between the stud and the concrete is greater than the breaking strength of the stud.

My process includes the use of a gun of special design for firing a stud into aggregated materials. I have found that it is important in the practice of my process to hold the surface of the aggregated material in place while the bolt is shot thereinto, and I prefer to accomplish this by holding the muzzle of my gun solidly against the aggregated material when the gun is fired and until the stud is embedded therein, and this is a feature of my invention. To accomplish this purpose, it is necessary to provide for the exhaust of gases from the gun barrel, to assist in preventing recoil of the gun barrel away from the surface of the aggregated material, and it is another object of my invention to provide a gun capable of accomplishing this result.

It is also important to provide such a gun in which the recoil of the gun resulting from firing the same is put on the breechblock thereof which is allowed to recoil independently of the gun barrel, thus further reducing the possibility of recoil of the muzzle of the gun from the surface of the concrete, and this is another object of the invention.

A further object of my invention is to provide such a gun having a locking mechanism which is so designed that the gun cannot be fired unless the muzzle of the gun is in pressure engagement with a surface. This feature of my gun insures that the desirable supporting pressure is applied to the concrete while the gun is being fired.

Although in carrying out the method of my invention it is important to provide a supporting pressure on the surface of the concrete surrounding the area to be penetrated by the stud during penetration thereof, it is sometimes difficult for an operator to hold a gun barrel against the surface and perpendicular to the surface so as to supply the necessary supporting pressure from the muzzle of the gun. It is therefore another object of my invention to provide means for applying such supporting pressure to such a surface by the gun barrel without requiring the gun barrel to be perpendicular to the surface.

Although any suitable type of stud may be used in carrying out my novel method described above, I have discovered that a particular type of projectile construction, as described hereinafter, gives excellent results, and it is a further object of my invention to provide such a projectile. I prefer to provide a projectile having a body portion which is at least partially covered by a non-metallic sleeve, which may be formed of paper, for example, which projects beyond the rear of the projectile to form an expansible cup. Such a projectile may be used otherwise than in my present method, and I do not intend to be limited to the specific use described for such a projectile.

Other objects and advantages will appear from the following description and from the drawings, which are for the purpose of illustration only and in which:

Fig. 1 is a longitudinal sectional view of my gun loaded with my novel projectile.

Fig. 2 is a view similar to Fig. 1 but illustrating the position of the parts during firing of the gun.

Fig. 3 is an enlarged cross-sectional view taken on the line 3—3 of Fig. 1.

Fig. 4 is an enlarged cross-sectional view taken on the line 4—4 of Fig. 1.

Fig. 5 is a longitudinal fragmentary sectional view, considerably enlarged, taken on the line 5—5 of Fig. 1.

Fig. 6 is a cross-sectional view taken on the line 6—6 of Fig. 2.

Fig. 7 is a diagrammatic view illustrating the gun muzzle in position for firing.

Fig. 8 is a diagrammatic view illustrating the projectile and the gun muzzle at the conclusion of firing.

Fig. 9 is a diagrammatic view showing the bolt at the conclusion of the operation.

Fig. 10 is a longitudinal sectional view of my novel cartridge.

Fig. 11 is a longitudinal sectional view of an alternative form of gun muzzle for my invention.

Referring to the drawings, I show a gun 15 including a breechblock member 16 to which is rigidly secured, as by an upper bolt 17 and a lower bolt 18, a handle frame member 19 having a handle 20 at its outer end. The breechblock member 16 is formed to provide a central chamber 22 and an outer chamber 23, and having an opening 24 in one side thereof, as best shown in Fig. 6. The central chamber 22 is provided with a first wall 25 at one end thereof and a second wall 26 at the other end thereof, the latter being provided with a cylindrical boss 28 projecting into the central chamber.

A gun barrel 29 is provided with a head member 30 which is rotatably supported on the lower bolt 18 which passes through an opening 31 formed in the head member. The opening 31 is provided with a counterbore 32 in which is retained a relatively stiff compression spring 33 which engages the inner end of the counterbore and also the second wall 26 of the breechblock member 16 so as to normally hold the head member 30 forwardly with considerable pressure against the first wall 25 and away from the second wall 26, in the position shown in Fig. 1. The gun barrel 29 is provided with a bore 35, the inner end of which is provided with a cartridge chamber 36, the inner end thereof being chambered at 37 so as to receive the cylindrical boss 28, as best shown in Fig. 2. The outer end of the gun barrel 29 forms a muzzle 38, and the gun barrel is provided with radial ports 39 which communicate between the bore 35 and the outer chamber 23 of the breechblock member 16, the outer chamber in turn communicating through the opening 24 in the side thereof with the atmosphere so as to permit exhaust gases to discharge therethrough from the bore.

The handle frame member 19 is provided with a vertical wall 41 having a central opening 42 therein in which is held the outer end of a guide sleeve 43 having an inner end 44 of reduced diameter which makes a close fit with the walls of an axial bore 45 formed through the second wall 26 of the breechblock member 16. The inner end 44 of the guide sleeve 43 is provided with a firing pin bore 46 through which extends a firing pin 47. The firing pin 47 is supported in an actuating cup element 48 so as to permit restricted relative axial movement therebetween, the firing pin being provided with a firing point 49 and an inner head 50 which limits rightward movement of the firing pin relative to the actuating cup element, and an outer head 51 engaged by a firing pin return spring 52 which is adapted to normally hold the firing pin relative to the actuating cup element 48 in the position shown in Fig. 1. The actuating cup element 48 is adapted for sliding movement in the guide sleeve 43, being guided therein by a lug 56 formed on the top of the actuating cup element and confined in a longitudinal slot 53 formed in the top of the guide sleeve 43. A compression spring 54 is provided in the guide sleeve 43 and engages the outer face of the actuating cup element 48 and a screw plug 55 threaded into the outer end of the guide sleeve, the compression spring 54 exerting a substantial leftward force on the actuating cup element 48 so as to yieldably retain it in the position shown in Fig. 1. The inner end of the guide sleeve 43 is cut away to provide a transverse slot 57.

As best shown in Figs. 3 and 4, against the outer face of the second wall 26 of the breechblock member 16 is provided a vertically movable plate member 58 which is guided for vertical movement by guide screws 59 which are threaded into the second wall 26 of the breechblock member. The plate member 58 has a cutaway central portion 60 providing a horizontal face 61 having a semicircular opening 62 therein. The radius of the semicircular opening 62 is less than the radius of the inner head 50 formed on the firing pin 47, and, as best shown in Fig. 1, when the plate member 58 is in its lowermost position, the semicircular opening 62 partially encircles the firing pin 47 and the inner head 50 engages the plate member to prevent the firing pin from moving to the left from the position shown in Fig. 1. Consequently, the vertically movable plate member 58 comprises a means for preventing actuation of the firing pin 47, and, as will be understood by those skilled in the art, the plate member must be raised before the firing pin can be moved to the left into firing relation. The plate member 58 is normally retained in its lowermost position, as shown in Fig. 3, by a leaf spring 64 which engages the top of the plate member and which is suitably secured to the breechblock member 16 as by screws 65.

Locking means is provided to positively lock the plate member 58 in its lower position, as shown in Figs. 1 and 3, which includes a stud 66 which is slidably mounted in an opening 67 formed in the second wall 26 of the breechblock member and having an inner end 68 projecting into the central chamber 22 into the line of the head member 30, the stud having a head member 69 thereon adapted to engage an angled top surface 70 formed on the plate member 58. The stud 66 is normally urged toward locking position by a compression spring 72, one end of which engages the head member 69 and the other end of which engages a bracket element 73 rigidly fixed to the handle frame member 19 as by screws 74, the compression spring 72 being centered by the outer end 75 of the stud 66 and by a boss 76 formed on the bracket element 73.

As best shown in Fig. 5, a rectangular opening 77 is provided in the vertical wall 41 and acts as a guide for a trigger bar 78 passing therethrough, to the outer end of which is fixed a trigger handle 79, the trigger bar 78 also being guided by passing through a rectangular slot 80 formed in the bracket element 73, as best shown in Fig. 4, the rectangular slot 80 providing an engagement shoulder 81 at the top thereof for a purpose to be described hereinafter. The inner end of the trigger bar 78 is provided with a vertical slot 82 in which is disposed an L-shaped releasing dog 83 having an upper leg 84 and a lower leg 85 and being pivoted to the trigger bar by a suitable pivot pin 87 passing therethrough. Resiliently engaging the lower leg 85 of the releasing dog 83 is the free end of a leaf spring 88 suitably fixed to the trigger bar 78, so as to tend to rotate the releasing dog in a clockwise direction as seen in Fig. 1. Also secured in the trigger bar 78 is a cross pin 89 which engages beneath a spring plate 90, the inner end 91 of which is press-fitted into a suitable slot 92 formed in the plate member 58, as best shown in Fig. 2, and the outer end 93 of which is press-fitted into a slot 94 formed in the vertical wall 41 of the handle frame member 19, the spring plate being bent toward the rear thereof so as to form a cam face 95 thereon. The spring plate 90 is preferably formed of resilient material, such as spring steel.

Adapted to be inserted into the cartridge chamber 36 of the gun barrel 29, as shown in Fig. 1, is a cartridge 100, the details of which are best shown in Fig. 10. The cartridge 100 includes a cartridge case 101 having a primer 102 in the end thereof, the cartridge case and primer being of any standard construction well known in the art. Inserted into the open end of the cartridge case 101 is a projectile 103 which includes a stud 104 and a piston means 105 thereon. The stud 104 is preferably formed of a relatively hard metal, such as steel, and is formed with a tapered outer end 106, on the sides of which longitudinal flutes 107 are preferably formed, the lower end terminating in a sharp point 108 which is preferably treated so as to render it extremely hard. Of course, if desired, the entire stud 104 may be hardened, in which case the point 108 does not need to be separately hardened. The inner portion 109 of the stud 104 is cylindrical and is externally threaded so as to accommodate a nut 110 after the stud has been embedded in a surface, as best shown in Fig. 9. If it is not desired to attach a nut, such as the nut 110, to the stud 104, the threads on the upper portion 109 may be omitted without departing from the spirit of the invention. It is important, however, to provide a pointed penetrating end, such as the point 108, of very hard material, and it is a feature of the invention to provide a stud having such a hard point with a shank formed of tough metal of lesser hardness. Also, if desired, the flutes 107 may be omitted without departing from the invention, although I have found that the provision of such flutes materially contributes to successful operation of the method. The piston means 105 is tightly secured to the inner portion 109 of the stud 104 and is press-fitted into the open end of the cartridge case 101 to seal the same. As will be understood, the inner portion of the cartridge case 101 is filled with powder 99 which is plugged off in conventional manner by a wadding 112. As will be noted from Fig. 1, the piston means 105 is of substantially the same diameter as the bore 35, making a close sliding fit therewith, the piston guiding the projectile 103 through the bore 35 when the gun 15 is fired and keeping the threaded portion 109 out of contact with the bore. Although the piston means 105 may be formed of any desirable or suitable material, such as, for example, metal, wood, or paper, I have discovered that superior results are attained if the piston is formed of paper. In forming such a piston means, I prefer to helically wind a strip of paper directly over the threaded portion 109 of the stud 104, the paper being tightly wound on the stud and the outer end thereof being glued or otherwise secured to the body of the piston so as to provide a cylindrical piston means as shown. In making the piston means 105, I prefer to use a paper which is provided with a glue or cement coat on one side so that the piston may be fixed to the stud 104 and also so that the spiral layers of paper may be secured together to form a more or less homogeneous mass. Good results can also be attained by impregnating the piston 105, when it is made of paper, after winding with a wax, resin, or other similar binding material. By impregnating the piston 105 with wax, paraffine, or other material having good lubricating qualities, a lubricated piston is provided, which is desirable in that it assists in keeping clean the bore 35 of the gun 15. By winding the paper piston 105 directly over the threaded portion 109 of the stud 104, the threads make an excellent anchorage for the piston, thus preventing the stud from being driven out of the piston upon the initial explosion of the cartridge. Due to the helical winding of the strip of paper forming the piston means 105, the piston projects out over the inner end of the stud 104 to form a shallow cup 111, which is expanded outwardly by the combustion gases when the cartridge is fired to form a tight seal between the piston means 105 and the bore 35 of the gun barrel 29, and this is a feature of the invention. Also, since the paper forming the piston 105 has comparatively little weight, substantially all of the energy of the powder explosion is stored in the stud 104, which is important in the practice of the invention as described hereinafter. It is also to be noted that although my projectile 103 has been particularly designed for use in carrying out my novel method, I do not intend to be limited to such use of such a projectile. For example, my conception of providing a paper or non-metallic sleeve, such as the piston means 105, on any standard type of projectile may be very desirable in view of the beneficial results derived therefrom, and this is a part of my invention.

In operation, the gun 15 is first loaded with the cartridge 100, the operating parts of the gun being initially in the position shown in Fig. 1. To accomplish this loading operation, the gun barrel 29 is first rotated on the lower bolt 18 in a counterclockwise direction, as seen in Fig. 6, to the position shown by dotted lines 113 shown therein, rotation of the gun barrel being stopped by engagement thereof with a shoulder 114 formed by one wall of the opening 24 in the breechblock member 16. When the gun barrel 30 is in the position shown by the dotted lines 113 of Fig. 6, it will be noted that the bore, indicated by dotted lines 115 thereof, is aligned with an arcuate opening 116 formed in the breechblock member 16 through which the cartridge 100 may be inserted into the cartridge chamber 36 formed in the gun barrel. The gun barrel is then rotated in a clockwise direction back to the full line position shown in Fig. 6, in which the gun is ready for firing.

Prior to firing of the gun, the muzzle 38 of the gun barrel 29 is firmly pressed against the surface 117 of the mass of aggregated material 118 into which the stud 104 is to be embedded. Force is then applied by the operator through the handle 20 to move the handle frame member 19 and the breechblock member 16 rigidly secured thereto to the left, as seen in Fig. 1, against the action of the compression spring 33 to cause the cylindrical boss 28 formed on the second wall 26 to move into the chambered portion 37 of the cartridge chamber 36 to the position thereof shown in Fig. 2. During such leftward movement of the breechblock member 16, as soon as the head member 30 of the gun barrel 29 engages the inner end 68 of the stud 66, the stud 66 is moved to the right to the position shown in Fig. 2, in which the head member 69 thereof is out of engagement with the angled top surface 70 of the vertically movable plate member 58, permitting the top of the plate member to clear the head member 69. Since the semicircular opening 62 in the plate member 58 normally encircles the firing pin 47 between the inner head 50 formed on the firing pin and the inner wall 26, it will be apparent that the firing pin cannot be moved to the left from the position shown in Fig. 1 into engagement with the primer 102 of the cartridge 100 until the vertically movable plate member 58 has been raised to the position shown in Fig. 2. Consequently, it will be understood that the stud 66, which is normally held in the position shown in Fig. 1 by the compression spring 72, operates as a locking means to prevent firing of the gun until such time as the muzzle 38 of the gun barrel 29 is in strong pressure engagement with the surface 117. This is an important feature of the invention.

With the stud 66 in its unlocking position, as shown in Fig. 2, the trigger handle 79 is then drawn rearwardly in the direction of the arrow 119 of Fig. 1 to the position in which it is shown in Fig. 2. As the trigger handle 79 and the trigger bar 78 move rearwardly from the position shown in Fig. 1, the cross pin 89 secured in the trigger bar moves along beneath the spring plate 90 until it engages the cam face 95 thereof, at which time it exerts a cam action on the spring plate which lifts the same to the position thereof shown in Fig. 2. Since the inner end 91 of the spring plate 90 is secured in the vertically movable plate member 58, lifting of the spring plate 90 causes a similar lifting of the plate member 58 against the action of the leaf spring 64 to move the plate member upwardly to the position shown in Fig. 2, in which the horizontal face 61 and the semicircular opening 62 of the plate member are raised above the inner head 50 of the firing pin 47. As will also be appreciated, rightward movement of the trigger bar 78 causes a similar rightward movement of the actuating cup element 48, due to engagement of the lower leg 85 of the releasing dog 83 with the lug 56 formed on the actuating cup element, thus compressing the compression spring 54 and storing energy therein. Upon continued movement of the trigger bar 78 to the right, the upper leg 84 of the releasing dog 83 engages the engagement shoulder 81 (Figs. 2 and 12) formed on the bracket element 73, so as to cause the releasing dog to rotate in a counterclockwise direction so as to rotate the lower leg 85 thereof out of engagement with the lug 56 formed on the actuating cup element 48. The stored energy of the compression spring 54 is released thereby, which drives the actuating cup element 48 and the firing pin 47 to the left at high speed, the actuating cup element 48 stopping its leftward movement upon engagement with the guide sleeve 43, in the position shown in Fig. 2, but the firing pin 47, due to its inertia, continues its leftward movement and the point 49 thereof pierces the primer 102 of the cartridge case 101 to fire the cartridge in a manner well known in the art. Fig. 2 shows the firing pin 47 having just pierced the primer 102 to fire the cartridge 100, and shows the projectile 103 just starting its travel through the bore 35 of the gun barrel 29.

Under the impact of the explosion of the powder 99, the projectile 103 travels outwardly through the bore 35 of the gun barrel 29 and enters the mass of material 118 to approximately the position shown in Fig. 8. It is to be noted that until after the projectile 103 has penetrated the mass of aggregated material 118 to its desired depth, the muzzle 38 of the gun barrel 29 is held in pressure engagement with the surface 117 of the aggregated material, thus providing substantial support for the surface of the aggregated material around the area of penetration of the projectile 103. This is an important feature of my invention. From extensive tests, I have discovered that unless the muzzle 38 of the gun barrel 29, or some other equivalent support, is provided for the surface 117 of the mass of material 118 around the area of penetration of the projectile 103, the mass of material around such area invariably cracks and shatters, and usually forms a small crater around the embedded stud, which is very undesirable as it mars the surface 117 and weakens the bond between the projectile and the aggregated material 118. Consequently, I believe it is very desirable to maintain a pressure support for the surface 117 directly surrounding the area of penetration of the projectile 103.

To additionally assist in maintaining the muzzle 38 of the gun barrel 29 in pressure engagement with the surface 117 of the mass of material 118 during the firing of the gun 15, several additional features are incorporated in the gun. For example, during firing, after the projectile 103 has passed outwardly through the bore 35 beyond the radial ports 39, the combustion gases from the powder 99 may then pass radially outwardly therethrough to exhaust to the atmosphere, reducing the natural recoil of the gun barrel 29 which would occur if these ports were omitted. Also, since the cartridge case 101 is in solid engagement with the cylindrical boss 28 formed in the breechblock member 16, upon firing of the cartridge 100 the reactive force of the powder 99 is applied directly on the breechblock, tending to move it rearwardly relative to the head 30 of the gun barrel 29, so that the reactive force exerted by the explosion of the powder is never applied to the gun barrel but is applied directly to the breechblock. Both of these features add to the superior results accomplished by my invention. So long as the muzzle 38 of the gun barrel 29 is held in pressure engagement with the surface 117 of the aggregated material 118 during firing of the gun 15, as described, the projectile 103 will cleanly enter into the mass of aggregated material without cracking, shattering, or otherwise marring the surface 117 thereof. A typical test of the invention performed by me was as follows: The stud 104 had an external diameter of 0.25 inch at the upper portion 109 thereof, being provided with a Number 20 thread. A powder charge approximately equal to the powder charge of a standard .410 bore shotgun shell was used in the cartridge 100. The stud used was a steel stud provided with a paper piston 105, as described hereinabove, and the stud was not provided with the longitudinal flutes 107, nor was the point 108 specially hardened. The stud was fired by my gun into a solid concrete floor of standard construction, and the point 108 of the stud penetrated to a depth of 2.12 inches so that the entire tapered end 106 of the stud was embedded in the concrete floor with just the upper threaded portion 109 projecting therefrom. The paper piston 105 remained on the stud during penetration of the concrete and was removed by hand after completion of the firing operation. A pulling machine was connected to the projecting upper portion 109 of the stud and a pulling pressure exerted on the stud thereby, the pressure being gradually increased over a considerable period of time until a force of 2500 pounds was exerted on the upper portion of the stud, at which point the stud broke in half in the upper threaded portion. The portion of the stud embedded in the concrete had not moved relative to the concrete, and the surface of the concrete surrounding the embedded portion of the stud was not cracked or shattered but was perfectly smooth around the stud. Better results have normally been attained by me by the use of a stud having flutes, such as the longitudinal flutes 107, and a hardened point, such as the point 108, and I prefer to incorporate these features in my device, although, as indicated by the above test, they may be omitted if desired.

The depth of penetration of the projectile 103 into the mass of aggregated material 118 depends almost solely on the powder charge 99 used in the cartridge 100, for projectiles of the same dimensions. Extensive tests on firing similar projectiles into generally similar concrete have shown that there is substantially no variation in the depth of penetration of the projectiles. By varying the size or shape of the projectiles, however, or by varying the powder charge employed in the cartridges therefor, the depth of penetration may be controlled as desired.

After the projectile 103 has been fired into the mass of aggregated material 118, as shown in Fig. 8, the cylindrical piston 105 may be readily removed therefrom, as by cutting or otherwise, and a standard nut 110 may be threaded onto the projecting end of the stud 104, as shown in Fig. 9. Thus, the projecting portion 109 of the stud 104 may be used as a tie member for fastening any desired object to the mass of aggregated material 118.

In Fig. 11 I show an alternative embodiment of the invention, which provides means for insuring a solid supporting pressure against the surface of the supporting material around the area to be penetrated by the stud. In this form of the device, a gun barrel 120 is provided for a gun (not shown) which is in all respects similar to the gun 15 except for the muzzle construction to be described. The outer end of the gun barrel 120 is machined to provide a spherically convex muzzle 121 adapted to fit against a spherically concave surface 122 formed in a foot member 123 having a flat engaging end 124 adapted to engage the surface 125 of a mass of aggregated material 126. The foot member 123 is provided with an axial bore 127 of considerably larger diameter than the bore 128 of the gun barrel 120, and is provided with radial exhaust ports 129 which communicate between the axial bore 127 and the atmosphere to permit the exhaust of air ahead of the projectile when it is fired. The foot member 123 is yieldably held in engagement with the muzzle 121 by a tension spring 130, one end of which is bent into a suitable tapped opening 131 in the gun barrel 120 and the other end of which is bent into a suitable tapped opening 132 in the foot member, one end portion of the spring being retained in a helical groove 133 cut in the periphery of the gun barrel and the other end portion of the spring being retained in a helical groove 134 cut in the periphery of the foot member. It will thus be apparent that the gun barrel 120 may deviate several degrees in any direction from the perpendicular to the surface 125 without unseating any portion of the engaging end 124 from the surface 125 of the mass of aggregated material 126. This feature of the invention obviates the necessity of holding the gun barrel 120 exactly perpendicular to the surface 125, as must be done with the gun barrel 28, while retaining an even supporting pressure around the area to be penetrated by the stud. The radial exhaust ports 129 also permit the release of air ahead of the projectile when it is fired, which further reduces the tendency of the gun barrel to recoil from the surface 125 during firing of the gun.

Although I have shown and described a preferred embodiment of my invention, it will be understood that certain parts and elements thereof may be replaced by mechanical equivalents without departing from the spirit of my invention. Consequently, I do not intend to be limited to the specific embodiment shown and described, but desire to be afforded the full scope of the following claims.

I claim as my invention:

1. A method of embedding a stud in a solid mass of concrete, which consists in applying a temporary holding pressure to an area of the surface of the mass of concrete and moving the stud at high velocity so as to cause a portion of the stud to penetrate through said area and into the concrete and form a strong bond therewith.

2. The method of inserting attachment studs in hard fracturable substances such as concrete which comprises shooting a pointed stud into the substance while maintaining a temporary holding pressure on the surface of the substance immediately surrounding the area penetrated by the stud to prevent the shattering of the mass of said substance immediately surrounding the area of entry of said stud.

3. A method of embedding a stud in a solid mass of concrete, which consists in applying a temporary holding pressure to an area of the surface of the mass of concrete and shooting the stud so as to cause a portion of the stud to penetrate through said area and into the concrete and form a strong bond therewith.

4. The method of inserting attachment studs in hard fracturable substances such as concrete which comprises shooting a pointed stud into the substance while maintaining a temporary holding pressure on the surface of the substance in proximity to the area penetrated by the stud to prevent the shattering of the mass of said substance immediately surrounding the area of entry of said stud.

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