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GUN PERFORATOR

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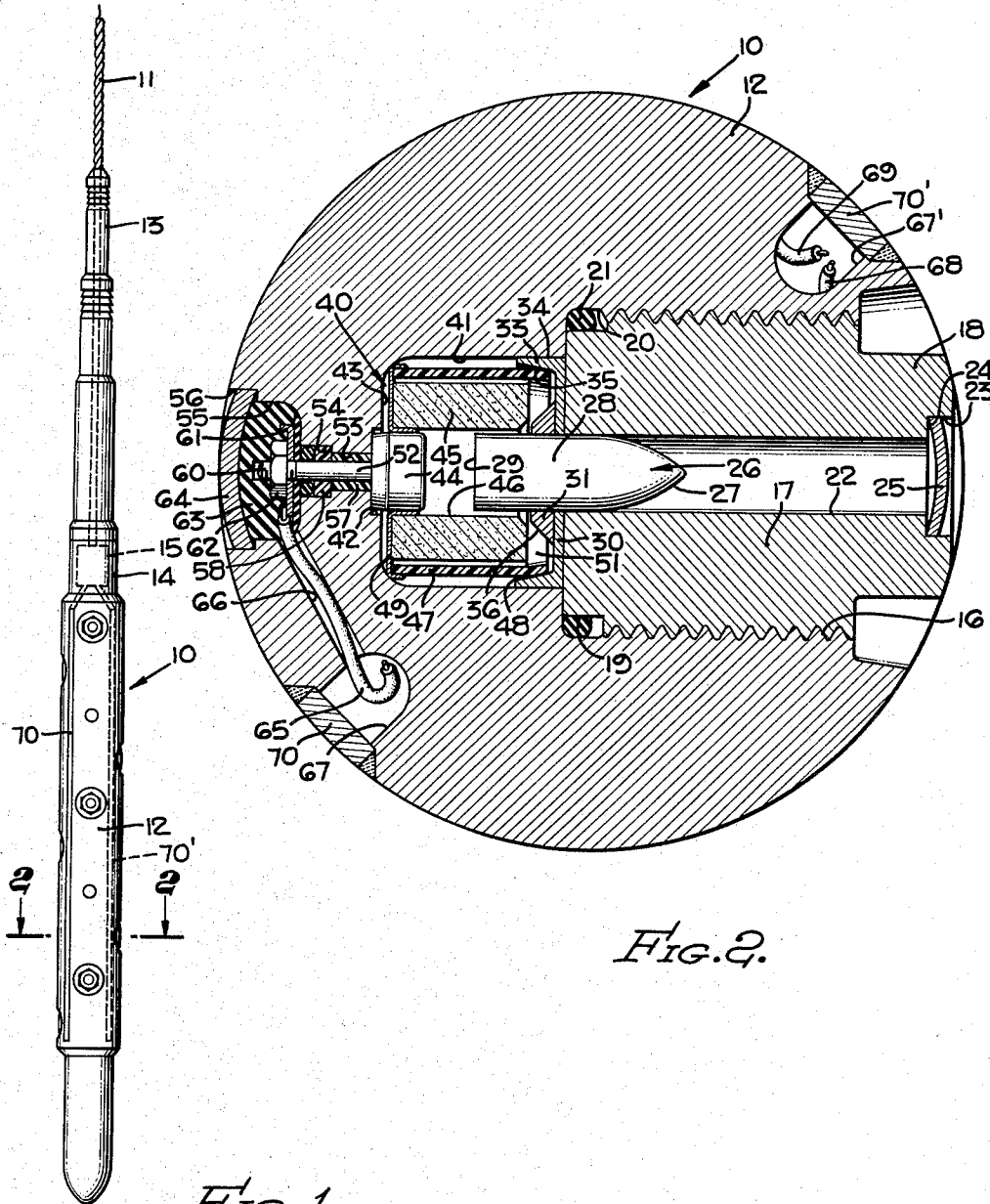


FIG. 2.

FIG. 1.

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2,953,971

GUN PERFORATOR

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Continuation of abandoned application Ser. No. 199,769, Dec. 8, 1950. This application Oct. 4, 1954, Ser. No. 460,086

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This invention relates to gun perforators and particularly to well perforators of the type adapted to be lowered into a well borehole and in which a bullet or projectile is fired from the gun to pierce the surrounding well casing and formation to open the same for the flow of fluid into the well. More specifically, this invention relates to the construction, arrangement, and mounting of the bullets, propellant charges, sealing means and firing mechanism, and to the combination and inter-relation thereof. This is a continuation of copending application Serial No. 199,769 filed December 8, 1950, now abandoned.

Among the numerous problems encountered in the design and construction of uniformly efficient and effective gun perforators, are those of securing adequate effective barrel length for the bullet, the mounting of the bullet in such manner as to provide initial restraint thereof during initiation of combustion of the propellant charge, the sealing of the firing chamber against external fluids, and the precluding of premature firing, particularly in response to external pressures, as well as the relation between bullet and propellant charge for obtaining maximum ballistic efficiency for the gun. It is also desirable to provide a combined charge and bullet loading unit assembly which may be preassembled under factory supervision and control, and which may be safely transported and installed in the perforator gun with a minimum of time and effort and with a resultant maximum of uniformity in characteristics of operation.

These and like problems of perforating gun construction and operation have long been recognized. Noteworthy steps in the solution thereof are exemplified in the prior patents of others skilled in a manner designed solely to improve one particular aspect of the total combination of factors, and in so doing, collateral weaknesses have been ignored. In the present construction, all of the above-mentioned problems and others related thereto have been considered as a whole to the end that improvements in the individual functions combine, without sacrifice one to another, to provide a new and improved combination and interrelation of parts. In such combination, improved efficiency and effectiveness are achieved in a novel, simple manner readily designed to meet the demands of economic manufacture.

It is, therefore, an object of the present invention, to provide a novel and improved perforating gun having a plurality of combining and cooperating features of advantageous character, the sum of which represents a total advance in the art along several heretofore separately considered avenues of progress.

It is also an object of the invention to provide a bullet and propellant charge loading unit for a gun perforator which may be assembled as a unit subassembly under factory supervision with factory economy and precision, and one which may be transported and loaded into a gun with a high factor of safety and with an assured uniformity of firing efficiency and effectiveness.

It is a further object of the present invention to provide new and improved means for mounting a perforat-

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ing bullet in a perforating gun in such manner as to provide in effect a barrel of extended length for the bullet, and to secure the same with a new and improved manner of bullet restraint so as to secure new and improved ballistic efficiency.

Another object of the invention is to provide a bullet and propellant charge combination such that premature firing of the charge will not result from an inadvertent subjection thereof to excessive fluid or mechanical pressure.

Another object is to provide a novel and improved charge to igniter relation and to provide a variable propellant charge to air or gas volume ratio which may be selected, adjusted, and maintained, such being one means by which the ultimate firing force and bullet penetration may be improved.

Another object of the invention is to provide a novel and improved sealing means for the firing chamber of a gun perforator, an improved feature of such sealing means being its responsiveness to pressure within the powder chamber, whereby the greater the propellant gas pressure applied, the greater the sealing effect.

It is another object of the invention to provide a gun perforator construction in which expendable parts are used where the erosion and deteriorating effects of the propellant gases are greatest, thereby in effect maintaining the gun unit in substantially new condition.

It is another object to provide a gun perforator structure in which provision is made for replacing the igniters when reloading the gun, without the necessity of disturbing the breech assembly and associated electrical connections and wiring leading to the igniters.

These and other objects and features of the present invention will be apparent from a consideration of the following specification taken in conjunction with the accompanying drawings, in which:

Figure 1 is a view in elevation of a typical well perforating gun embodying the features of the present invention, and

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

In the drawings, the numeral 10 indicates the gun assembly generally, and the numeral 12, the gun body. The gun comprises a steel cylindrical assembly which is adapted to be lowered into a well bore hole by a conductor cable 11, containing an insulated conductor or conductors, through which the firing of the units may be controlled. As indicated in Figure 1, between the conductor cable 11, and the body 12 of the gun, there are provided a cable socket 13 and various interconnecting subs, one of which, as shown at 14, contains suitable fire control means, as indicated in dotted lines at 15, with respect to which the present invention is not specifically concerned, but which will be referred to in more detail hereinafter.

Referring more particularly to Figure 2, the gun body, indicated by the numeral 12, comprises a generally elongated substantially solid steel cylinder of sufficient strength and solidity to withstand the explosive forces of the firing of the gun charges. Laterally directed gun units are mounted in the cylindrical gun body at longitudinally spaced intervals and preferably in a spiral arrangement, as shown in Figure 1. Each unit comprises an internally threaded, laterally directed barrel opening 16, which receives the threaded barrel member 17. In the form of a barrel member here illustrated, the outer end portion 18 is reduced in external diameter and given a hexagonal shape in order to receive a suitable tool or wrench for its installation and removal. Preferably, the lateral depth of the barrel opening 16 and the length of the barrel member 17 are such that the barrel member is wholly received within the open-

ing, flush with the surface of the gun body, when fully seated and tightened therein, so as not to present any laterally projecting parts when the gun is fully assembled in the manner shown in Figures 1 and 2. The inner end of the barrel member 17 is formed with a smooth thread-free end 19, of slightly reduced external diameter, adapted to be received concentrically within an inner thread-free, counterbored end recess 20, of the barrel opening 16, thereby forming therebetween a short annular end recess. An O ring 21 is seated within the beforementioned annular end recess, between the surfaces 19 and 20, in order to seal the barrel member within the barrel opening and to preclude leaking of any well fluid inwardly from between the threaded portion of the gun barrel opening 16 and the external surface of the barrel member 17. The barrel member 17 is formed with a concentric barrel bore 22 of generally uniform inside diameter, but having, at the outer or muzzle end thereof, a short portion of slightly enlarged diameter, forming a shallow recess 23, having an annular shoulder 24. Seated within the recess 23, and making sealing engagement against the shoulder 24, there is provided a sealing disc 25 for preventing admission of well fluid into the barrel bore. The disc 25 may be seated and sealed in any suitable manner well known in the art, and may be formed of any suitable material, such as brass or steel. In operation, when the propellant charge is detonated and the bullet fired, the seal 25 is ejected from the recess 23, either as a unit or as fragments, and forms substantially no obstacle to the discharge of the bullet.

The well casing or formation piercing projectile or bullet of the present gun unit is indicated at 26, and preferably comprises a forward piercing nose portion 27 of substantially conical or ogival form, and a body or rearward shank portion 28, preferably of uniform diameter, extending from the nose portion 27 to the transverse rear end or butt 29. The bullet 26 is usually made of hardened steel or steel jacketed in a manner well known in the industry to provide adequate casing or formation piercing ability. While a bullet of the shape here shown is now believed preferable in the present combination, it will be understood that the invention is not limited to this specific design of bullet. Various types of nose formations and shapes may be resorted to as desired, in accordance with the dictates of the particular perforation operation to be performed. The bullet 26 is mounted through a central opening formed in a sealing plate or diaphragm 30, and also through a frusto-conical restraining annulus 31, both of which engage the cylindrical midsection of the bullet approximately midway between the forward end of the nose portion 27 and the butt 29. While the plate 30 and the annulus 31 are here shown as separate parts, they may be integral. The openings through both plate 30 and annulus 31 are preferably such as to form a tight press fit upon the bullet 26, the annulus 31 and plate 30 being either in juxtaposition or of integral construction to form a holding unit, from which the bullet is dislodged only upon firing of the propellant charge and the building up of a sufficient initial pressure within the charge chamber. The periphery of the diaphragm 30 has formed thereon and integral therewith a rearwardly directed annular flange or lip 33, the outer face 34 of which is cylindrical and coaxial with the disc portion and centrally contained bullet, while the inner surface 35 is slightly tapered in a rearwardly diverging direction, forming thereby a frusto-conical surface disposed at opposite angularity to the rearwardly converging frusto-conical outer surface 36 of the annulus 31.

A cylindrical firing charge chamber is shown at 40, formed by a bore 41 of inside diameter reduced relative to that of threaded barrel 16 but uniform throughout its length and extending concentrically inward from the innermost end of the barrel opening 16. A concentric

bore or recess 42, of still smaller diameter, is formed in the inner end wall 43 of the firing charge chamber 40 to receive an igniter head 44 of the firing means further referred to hereinafter during the final loading operation in the field. The internal diameter of the bore 41, forming the side walls of the firing charge chamber 40, is such as to snugly receive, by a hand press fit, the outer cylindrical walls 34 of the annular flange 33 of the diaphragm 30. The firing charge comprises a compressed, molded, or otherwise consolidated or pelletized, tubular shaped body of combustible propellant material 45, formed with an opening or passage 46 extending centrally therethrough from end to end. The charge body 45 is surrounded and contained within a container sleeve or shell 47, which may be composed of suitable material, preferably nonmetallic, such as, for example, a paper or cloth base, phenolic-impregnated tubing. The propellant charge body makes a loose fit within the container sleeve 47, preferably with a substantial annular clearance space between the outside surface of the charge body and the inside surface of the sleeve. The container sleeve 47 preferably extends a short distance forward of the forward end of the propellant charge body and fits within the flange 34 of the diaphragm 30, being preferably glued or cemented or otherwise suitably secured in coupling engagement within the frusto-conical inner surface thereof, as shown at 48. The rearward end of the cylindrical charge body is initially closed by an impervious paper or cloth sealing membrane or wafer 49, which extends fully across the rearward end of the charge, and is secured by gluing or cementing its edges to the end margin of the container sleeve 47. The central opening 46, extending through the charge 45, has an internal diameter slightly greater than the external diameter of the cylindrical body portion 28 of the bullet 26. When the charge and bullet are assembled, the bullet extends within the central opening 46 for approximately one-half the length of the cylindrical portion 28 of the bullet 26, which is here shown as approximately one-third the length of the charge 45. In this arrangement, it will also be seen that, as assembled, the rearward end of the annulus 31 is spaced from the forward end of the charge 45. Since the cylindrical propellant charge assembly terminates at each end in plane, transverse surfaces, except for the chamfered, forward edge of the passage 46, it will be noted that an annular air or gas space 51 is formed between the charge and the plate 30 surrounding the annulus 31. In the present instance, the space 51 is approximately equal in depth to the thickness of the annulus 31. The character, size, density, and shape of the propellant charge may, of course, be varied to suit varying conditions and requirements, the relationships here suggested being only by way of example as having been found effective and efficient in certain perforating practices. It is important to note that the present assembly provides the combustion clearance space 51, and that such space is variable, depending upon the density and quantity of a given charge, so that the ballistic characteristics and penetrating ability of the unit may be varied by change in size of the charge and position of the bullet loading unit. Thus, by change of density of a given quantity of charge, the ballistic characteristics of the unit may be altered somewhat without change in the outer dimension of the charge and bullet assembly, and without alteration or adjustment of the size and shape of the gun parts.

It is also important to note that in the present assembly, the bullet is retained within the firing chamber without direct contact with the charge. By virtue of the fact that the maximum bullet diameter is slightly less than the minimum inside diameter of the opening 46 through the propellant charge body 45, the bullet 26 is freely mounted therein. Thus, should pressure accidentally be applied to the bullet in such manner as to press the

same rearwardly, as by a premature rupture of the sealing disc 25, and the admission of well fluid pressure to the nose of the bullet, rearward movement of the bullet will not act to compress the charge and, by such compression and the resultant friction and heat thereof, prematurely explode the charge. An important safety factor is, in this manner, incorporated in the present design.

A further important feature of the present invention is the fact that the bullet 26, plate 30, annulus 31, charge 45, and container sleeve 47 may be readily assembled at the factory and under factory supervision and control, as a sealed loading unit protected from external moisture or other contamination. Such units may then be transported to the field or other loading locations and conveniently loaded into the gun with a minimum of time, effort and of danger, and with maximum insurance of uniformity of operation. The individual charge and bullet loading unit assembly is formed by press fitting the bullet 26 through the plate 30 and annulus 31 respectively. Preferably, such fitting may be accomplished as a single operation. The charge, having been suitably formed and placed within the container sleeve 47, is then sealed over at the rearward end by the paper wafer 49, and the forward free end of the container sleeve 47 is then fitted within the frusto-conical walls 35 of the flange 33 and secured there by gluing, cementing, or the like, at 48, as beforementioned. The loading unit, thus formed, may be transported with relative safety, it being noted that the igniter is not included in this loading unit but is applied to the unit as an incident to the final loading of the gun. Safety, convenience, and uniformity of performance are thus insured.

As will be hereinafter referred to, the securing of the forward end of the container sleeve 47 within the lip 33, provides against dislodgment of the container 47 from the plate 30 under the high pressure resulting from combustion of the propellant charge, and will not only force the container sleeve end more tightly outward against the inner surface of the flange 33, but will also expand the flange 33 more tightly outward against the inner wall 41 of the bore 40, and thereby effectively prevent leakage of the propellant charge gases outwardly to the space between the rearward end face of the barrel member 17, and the adjacent forwardly directed face of the annular end surface surrounding the charge chamber bore opening, which might otherwise result in dislodgment of the gun barrel member 17 from the gun upon firing of the charge.

In the present embodiment of the invention, firing of the charge 45 is provided for by an igniter 44, which is preferably a cup-like head member, containing a combustible powder and an electrical resistance element therein (not shown). One example of an igniter of this type, well suited to the present purposes, is that disclosed in the patent of Robert A. Phillips, Patent No. 2,649,736, to which reference may be had for further details of its construction and operation. The head of the igniter 44 is seated by the operator during final preparation in the field for firing, within the recess 42, and extends forwardly therefrom into the firing charge chamber 40. When the loading unit is inserted into the firing chamber, the head of the igniter 44 ruptures the paper membrane or cover 49, and extends into the end portion of the passage 46 of the propellant charge 45.

Prior to installation of the loading unit, including the propellant charge body 45, in the charge chamber 40, the igniter head 44 is secured in the position shown, by means of a metal stem 52, which extends rearwardly therefrom, coaxially with the recess 42 and chamber 40, through an interconnecting passage 53, and a counter-bored section 54, rearwardly into a cylindrical recess or cavity 55 bored into the surface of the gun body diametrically opposite the barrel opening 16 and rounded at

its rearward end. An annular seal receiving recess 56 is formed at the rearward edge of the recess or cavity 55 at the surface of the gun barrel opposite the muzzle. Within the passage 53, the igniter stem 52 is surrounded by an insulating sleeve 57 and a similar insulating spacer 58 is provided in the counterbored portion 54; the threaded extremity 60 of the stem 52 receives a conductor-connecting washer 61, and a securing nut 62. The washer 61 and nut 62 are preferably embedded together within a sealing and retaining body 63 composed of rubber or the like resilient insulating material, tightly fitted, preferably under pressure, within the recess 55. For sealing the recess 55, and retaining the member 63 therein, a seal disc 64 is tightly pressed or driven into the shallow annular recess 56 surrounding the outer or rearward edge of the recess 55.

By this construction, it will be noted that the retaining member 63, with its nut 62 and washer 61, are held relatively stationary within the recess 55, in axial alignment with the passage 53, while the igniting head and its threaded conductor stem 52 may be inserted through and removed from the muzzle end opening of the gun unit as desired, without disturbing the sealing body 63, the electrical wiring and connections and the seal disc 64. Thus, after each firing of the gun, the igniters may be replaced prior to reloading, through the barrel opening and charge chamber with a minimum of time and difficulty.

Energization of the igniter 44 is provided for by an insulated conductor 65 which is connected to the igniter stem 52 through washer 61, and extends from the recess 55 through a lateral duct 66 to a longitudinally extending conductor passage 67, formed in the side of the gun barrel and thence up through the passage 67 to the ignition control device 15, which may be contained in the top of the gun assembly 10, as hereinbefore mentioned. In case it is desired to fire each gun unit in the gun body separately, separate conductors are provided for each gun unit, which conductors make connection with and extend from each of the igniters of each gun unit, in the manner shown in Figure 2, and extend through their respective lateral passages into the longitudinal passages 67 and 67', as shown in part at 68 and 69, and thence up to the beforementioned firing controller 15. Two diametrically opposite longitudinal passages 67 and 67' are preferably provided in the gun body, to which the several lateral ducts of the type shown at 66 may conveniently make connection from the gun units which are directed at different angles along the length of the gun body. It will be noted that the arrangement of recesses 55, ducts 66, and intercommunicating passages 67 and 67', provides internal, fluid tight passages for the controlling conductors, and, therefore, the possibility of accident and damage thereto is minimized, so that they will not be subjected to pressures of or contact with well fluid. By this arrangement, repeated firings and reloadings of the gun may be accomplished without disturbing the conductors or opening the recess 55 and without removal of the insulating and positioning member 63, or seal disc 64, all of which may be semipermanently installed and sealed upon the original assembly of the gun body.

In the assembly of the gun proper prior to loading, conducting wires, as shown at 65, 68, and 69, are located within the passages 67 and 67' and led through the lateral ducts 66 as desired, the grooves having been closed and permanently sealed by welding the cover plates 70 and 70' in place. The individual conductors 65, 68, and 69, are then attached to their respective conductor washers, as shown at 61, in Figure 2, which are embedded with the nuts 62 in the insulating and positioning member 63. After such connection, the members 63 are inserted in the recesses 55, preferably with a tight fit and with the threaded bores of the nut axially arranged with respect to the axis of the passage 53 and the firing chamber bore 41, so as to threadedly receive the stems of the igniters. The assembled and wired nuts 62, washers

61, and members 63, are then sealed within the recesses 55 preferably under compression or pressure applied by the seal discs 64 and may thus be retained in such position through repeated firings of the gun.

The next step in preparing the gun for operation prior to loading is installing the igniters, which may be done at any time after the assembly of the wiring and the nuts 62, as beforedescribed. Installation of the igniters is readily accomplished by inserting the stems thereof through the passages 53, 54, and threading the stem into the nuts, as shown at 62, by which the heads 44 are securely fastened within the recesses 42 of the firing chambers. As an incident to thus installing the igniters, they are each electrically connected with their individual conductors, which extend to the firing control apparatus, as beforedescribed.

Independently of the fabrication and assembly of the gun proper, the charge 45, bullet 26, plate 30, and annulus 31, are preferably assembly within the container sleeve 47 and sealed by the sealing member 48 to form a gun loading unit. Preferably, although not necessarily, the charge 45 is formed and compressed within the sleeve 47 and the paper membrane or seal 49 is applied as beforementioned, to seal one end thereof. In a separate operation, the bullet 26 is press fitted through the central apertures of the diaphragm 30 and annulus 31, which, as hereinbefore suggested, may be formed together as a single integral unit if desired. In securing the bullet in the annulus 31 and the plate 30, it will be understood that either or both, and preferably the annulus, grips the bullet with sufficient force to hold the same against the initial pressure following ignition of the propellant charge to allow the pressure to build up behind the bullet to some extent before the bullet is expelled from the barrel, in order to insure a maximum bullet velocity. Mounting of the plate and annulus directly against the rear end of the barrel member with the rear end portion of the bullet extending into the charge chamber, provides an effective increase in the barrel length.

With the bullet 26 thus assembled with plate 30 and restraining annulus 31, and with the charge 45 mounted within its container sleeve 47, the forward end of the container sleeve is then placed within the flange 33 of the plate 30 and is sealed thereto at 35, either by a press fit or with a suitable adhesive or cement, or the like sealing means as beforedescribed. Thus, the plate 30 and bullet 26 cooperate with the container 47 and its end seal 49 to form a complete bullet and charge loading unit package, fully sealed and protected from contamination and the elements, and readily transported with relative safety, since the more easily exploded igniting element is not included in the unit thus formed. In thus forming the loading unit, it will be noted that the volume or density of the propellant charge 45 relative to the air space provided in the loading unit and in the surrounding charge chamber of the gun unit, may be predetermined and controlled, as well as the restraining force between the bullet 26 and the plate 30 and annulus 31. One of the important reasons for control of these relations between the charge and clearance spaces around the charge is to allow for expansion of the charge body due to temperature rise upon lowering of the gun perforator into a deep well bore hole where temperatures are high. All of such factors may be determined and controlled in the manufacture and assembly of the loading unit. In this manner, uniformity in operation of the gun perforator in the field is insured. Numerous variations in the ballistic characteristics of the loading units may thus be built into them in the factory, and the units may then be marked so as to permit selection of the desired ones upon loading of the gun at the place of use.

In the field, when the gun is to be used, one of the igniters 44, which may be separately stored and transported, is first inserted and screwed into place, and a loading unit is then placed in the firing chamber, suf-

ficient force being applied to rupture the sealing wafer 49, thus permitting the opening 46 of the charge 45 to be forced over the head of the igniter 44. As hereinbefore noted, the internal diameter of the bore 41 of the charge chamber 40 and that of the external face 34 of the flange 33 of the diaphragm 30 is such as to provide a snug fit therebetween. As indicated, the tubular container 47 is of uniform external diameter, and since it fits within the flange of the diaphragm 30, the remaining outer wall of the tubular container 47 is loosely contained within the charge chamber 40, and is thus free to expand outwardly under the force of the pressure of the propellant charge gases upon firing of the charge. However, such outward expansion of the shell container 47 will act to force the contained marginal portion thereof more tightly against the inner surface of the flange 33 and will thereby act to expand the flange more firmly against the inner surface of the firing chamber bore to automatically increase the effectiveness of the seal therebetween and around the periphery of the diaphragm 30 to prevent leakage of gases from the charge chamber to the inner annular end portion of the barrel member 17, which surrounds the charge chamber.

After the loading unit has been inserted in the firing chamber, the barrel member 17 is threaded into the barrel opening 16 and tightened into place, the barrel bore thereby being positioned about the forward end portion 27 of the bullet 26, and being securely sealed at the inner end of the O ring 21.

While the assembly of parts is preferably made in the manner herein set forth, and in the sequence indicated, it will be understood that the invention is not restricted to such manner of assembly. For example, the complete gun, fully loaded and ready for firing, may be prepared in the factory. While it is a feature of the invention to provide independent and transportable loading units of the type hereinbefore described, the invention is not so limited, but obviously includes the assembly of the separate components, either in the factory or in the field if desired.

After complete assembly, and with the gun lowered into the well bore or casing, the individual gun units may be fired either simultaneously or selectively, in any desired sequence, in any suitable manner well known in the gun perforating art. For example, the gun units may be fired electrically by employing an electrically controlled selector switch of a type such as that disclosed in the patent to Johnson No. 2,048,451. In using a selector switch of this type, the separate conductors, shown at 55 in Figure 11 of the beforementioned patent and leading from the several switch contact points therein, would correspond to or be connected to the conductors shown at 65, 68, and 69, shown in Figure 2 of the present application, leading to each of the fusible resistance wires incorporated in each of the ignition units 44. Other firing control means well known in the art may obviously be used in the same or similar manner. As beforementioned, this firing control apparatus connected to the insulated conductor contained in cable 11, may be located in the perforator gun assembly 10, in the position shown in dotted lines at 15. Upon ignition of the propellant charge 45, pressure will rapidly build up in the charge chamber, tending to propel the bullet outwardly through the barrel. Such outward movement of the bullet 26 is initially restrained with a predetermined holding force applied by the gripping action of diaphragm 30 and annulus 31, as beforementioned, until the accumulation of force behind the bullet desired for the required ballistic efficiency and effectiveness is reached, whereupon the bullet will be forced on through the diaphragm and annulus and will be discharged from the gun bore with the desired muzzle velocity for penetration of the well casing or formation. After firing, the gun may be withdrawn from the borehole, the barrel member 17 unscrewed from the gun body, and suitable tools may be applied to

remove, by unscrewing, the empty igniter 44, after which a new igniter may be applied in the same manner and a new loading unit, including charge and bullet, inserted, and the barrel member 17, including the sealing member 25, again screwed into place. The gun is then ready for further perforating operations.

The portion of the gun unit which is subjected to the most erosion and other deterioration by the propellant gases is the rearward end of the bore 22 of the gun barrel adjacent the charge chamber. In the present invention, the diaphragm 30 and annular ring 31 form in effect a rearward extension of the barrel bore 22. These parts, especially the ring member 31, therefore are subjected to most of the erosive action of the propellant gases and thereby serve to shield and protect the adjacent and rearward portions of the barrel bore 22 from these damaging effects. Each time the gun is reloaded, these parts are replaced by new ones, as hereinbefore described, and thus this vital portion of the gun assembly is maintained in good condition.

It is to be understood that the foregoing is illustrative only, of a preferred embodiment and use of the invention; and that the invention is not limited thereby, but may include various modifications and changes made by those skilled in the art, without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. In a perforating gun for wells having a body formed with an outer barrel opening, a bore of reduced diameter extending coaxially inward from the inner end of said outer barrel opening and constituting a firing charge chamber, a cylindrical recess of still further reduced diameter extending axially inward from the inner end of said firing charge chamber for receiving the head of an igniter, and a barrel threaded into said barrel opening, said barrel having a coaxial bullet bore, the combination of: a bullet having its forwardly projecting portion fitted into said bullet bore; an igniter head mounted in said recess and extending therefrom into said firing charge chamber; a consolidated tubular-shaped propellant charge body having a passage extending concentrically therethrough from end to end thereof and positioned coaxially within said firing charge chamber with the rearward portion of said passage encircling the inwardly extending portion of said igniter head; a transverse diaphragm at the junction of said outer barrel opening and said charge chamber bore to seal the latter, said diaphragm having a peripheral rearwardly directed flange, the external diameter of which is such as to be received within said charge chamber with a light press fit, said flange having an internal surface of rearwardly diverging frusto-conical form; a cylindrical shell surrounding said charge body and fitted at its forward end within said inner frusto-conical surface of said flange, said shell being of less external diameter than said internal diameter of said firing charge chamber bore forming an annular clearance space therebetween, with said bullet being mounted concentrically through said diaphragm and extending therefrom into said firing charge chamber; and a restraining annulus mounted on said bullet intermediate the ends thereof and positioned on the rearward side of said diaphragm and adjacent thereto, said annulus having an external frusto-conical surface the inclination of which is opposite to that of the frusto-conical surface of said flange.

2. In a perforating gun for wells having a body formed with an outer barrel opening, a bore of reduced diameter extending coaxially inward from the inner end of said outer barrel opening and constituting a firing charge chamber, a cylindrical recess of still further reduced diameter extending axially inward from the inner end of said firing charge chamber for receiving the head of an igniter, and a barrel threaded into said barrel opening and having a coaxial bullet bore, the combination of: a bullet having its forwardly projecting portion fitted into

said bullet bore; an igniter head mounted in said recess and extending therefrom into said firing charge chamber; a consolidated tubular-shaped propellant charge body having a passage extending concentrically therethrough from end to end thereof and positioned coaxially within said firing charge chamber with the rearward portion of said passage encircling the inwardly extending portion of said igniter head; a transverse diaphragm at the junction of said outer barrel opening and said charge chamber bore to seal the latter, said diaphragm having a peripheral rearwardly directed flange the external diameter of which is such as to be received within said charge chamber with a light press fit, and said diaphragm being formed with a central opening; a cylindrical shell concentrically surrounding said charge body and making coupling engagement at its forward end within the inner surface of said flange, said shell being of less external diameter than the internal diameter of said firing charge chamber bore forming an annular clearance space therebetween, with said bullet being mounted concentrically in and extending through said central opening formed in said diaphragm, the rearward portion of said bullet extending into said firing charge chamber; and a restraining annulus encircling and gripping said bullet intermediate the ends thereof and positioned adjacent the rearward side of said diaphragm.

3. In a perforating gun for wells having a body formed with an outer barrel opening, a bore of reduced diameter extending coaxially inward from the inner end of said outer barrel opening and constituting a firing charge chamber, a cylindrical recess of still further reduced diameter extending axially inward from the inner end of said firing charge chamber for receiving the head of an igniter, and a barrel mounted in said barrel opening and having a coaxial bullet bore, the combination of: a bullet having its forwardly projecting portion fitted into said bullet bore; an igniter head mounted in said recess and extending therefrom into said firing charge chamber; a consolidated tubular-shaped propellant charge body having a passage extending concentrically therethrough from end to end thereof and positioned coaxially within said firing charge chamber with the rearward portion of said passage encircling the inwardly extending portion of said igniter head; a transverse diaphragm means at the juncture of said outer barrel opening and said firing charge chamber to seal the latter, said diaphragm means having a peripheral rearwardly directed flange, the external diameter of which is such as to be received snugly within said charge chamber bore, said diaphragm means also being formed with a central opening; and a cylindrical shell concentrically surrounding said charge body and making coupling engagement at its forward end within the inner surface of said flange, said shell being of less external diameter than the internal diameter of the said firing charge chamber, with said bullet fitting with a hard press fit concentrically through said central opening formed in said diaphragm means and having the rear end portion thereof extending coaxially therefrom into said firing charge chamber and into the forward portion of said passage of said charge body.

4. In a perforating gun for wells having a body formed with an outer bullet bore, an inner bore of increased diameter relative to that of said bullet bore extending coaxially inward from the inner end of said bullet bore and constituting a firing charge chamber, the combination of: a bullet; a tubular-shaped propellant charge positioned coaxially within said firing charge chamber, said charge having a passage extending axially therethrough from end to end thereof; transverse diaphragm means located at the juncture of said bullet bore and said firing charge chamber bore, said diaphragm means being formed with a central opening, said bullet being supported at an intermediate relatively short section thereof by means of said central opening, with said bullet being positioned with its rear end portion exposed to and extending from

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said diaphragm means coaxially into said firing charge chamber for a substantial portion of the length of said bullet, said bullet making a press fit in said central opening sufficiently tight to delay initial movement of said bullet therefrom into said bullet bore following ignition of said charge; and igniter means in said firing charge chamber and positioned in communication with said passage through said propellant charge body, said passage being unobstructed intermediate said igniter means and the rear end portion of said bullet therein.

5. In a perforating gun for wells having a body formed with an outer bullet bore, an inner bore of increased diameter relative to that of said bullet bore extending coaxially inward from the inner end of said bullet bore and constituting a firing charge chamber, the combination of: a bullet; a tubular-shaped propellant charge body positioned coaxially within said firing charge chamber, said body having a passage extending axially therethrough from end to end thereof; a transverse diaphragm located at the juncture of said bullet bore and said firing charge chamber bore, said diaphragm being formed with a central opening, said bullet being supported at an intermediate relatively short section thereof by means of said central opening, with said bullet being positioned with its rear end portion exposed to and extending from said diaphragm coaxially into said firing charge chamber for a substantial portion of the length of said bullet; a restraining annular member separate from said diaphragm encircling and gripping said bullet intermediate the ends thereof and positioned adjacent to and on the rearward side of said diaphragm, said bullet making a press fit in said annular member sufficiently tight to delay initial movement of said bullet therefrom into said bullet bore following ignition of said charge; and igniter means in said firing charge chamber and positioned in communication with said passage through said propellant charge body, said passage being unobstructed intermediate said igniter means and the said rear end portion of said bullet therein whereby said igniter means is effective to ignite initially the inner portion of said propellant charge in said passage.

6. In a perforating gun for wells having a body formed with an outer barrel opening, an inner bore of reduced diameter relative to that of said barrel opening extending coaxially inward from the inner end of said barrel opening and constituting a firing charge chamber, a barrel threaded into said barrel opening and having a coaxial bullet bore therethrough, the combination of: a bullet; a tubular-shaped propellant charge body positioned coaxially within said firing charge chamber, said propellant charge body having a passage extending axially therethrough from end to end thereof; transverse diaphragm means located at the juncture of said outer barrel opening and firing charge chamber bore adjacent the rear end of said barrel, said diaphragm means being formed with an opening, with said bullet being supported at an intermediate relatively short section thereof through said opening and said bullet being positioned with its rear end exposed to and extending from said diaphragm means coaxially into said firing charge chamber for a substantial portion of the length of said bullet, said bullet making a press fit in said opening sufficiently tight to delay initial movement of said bullet from said opening into said bullet bore following ignition of said charge; and combustible igniter means in said firing charge chamber and positioned within said passage through said propellant charge body, said passage being unobstructed intermediate said igniter means and the said rear end portion of said bullet therein whereby said igniter means is effective to ignite initially the inner portion of said propellant charge in said passage.

7. In a perforating gun for wells having a body formed with an outer barrel opening, an inner bore of reduced diameter relative to that of said barrel opening extending coaxially inward from the inner end of said barrel opening

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and constituting a firing charge chamber, a barrel threaded into said barrel opening and having a coaxial bullet bore therethrough, the combination of: a bullet; a tubular-shaped propellant charge positioned coaxially within said firing charge chamber, said charge having a passage extending axially therethrough from end to end thereof and having an external diameter less than the internal diameter of said firing charge chamber; transverse diaphragm means located at the junction of said outer barrel opening and firing charge chamber bore adjacent the rear end of said barrel, said diaphragm means being formed with a central opening, with said bullet being supported at an intermediate relatively short section thereof through said central opening and said bullet being positioned with its rear end exposed to and extending from said diaphragm means coaxially into said firing charge chamber for a substantial portion of the length of said bullet, said bullet making a press fit in said central opening sufficiently tight to delay initial movement of said bullet from said central opening into said bullet bore following ignition of said charge; and combustible igniter means in said firing charge chamber and positioned within said passage through said propellant charge, said passage being unobstructed intermediate said igniter means and the said rear end portion of said bullet therein whereby said igniter means is effective to ignite initially the inner portion of said propellant charge in said passage.

8. In a perforating gun for wells having a body formed with an outer barrel opening, an inner bore of reduced diameter relative to that of said barrel opening extending coaxially inward from the inner end of said barrel opening and constituting a firing charge chamber, a barrel threaded into said barrel opening and having a coaxial bullet bore therethrough, the combination of: a bullet; a tubular shaped propellant charge positioned coaxially within said firing charge chamber, said charge having a passage extending axially therethrough from end to end thereof and having an external diameter less than the internal diameter of said firing charge chamber; transverse diaphragm means located at the junction of said outer barrel opening and firing charge chamber bore adjacent the rear end of said barrel, said diaphragm means being formed with a central opening, with said bullet being supported at an intermediate relatively short section of said bullet through said central opening and said bullet being positioned with its rear end exposed to and extending from said diaphragm means coaxially into said firing charge chamber for a substantial portion of the length of said bullet, said bullet making a press fit in said central opening sufficiently tight to delay initial movement of said bullet from said central opening into said bullet bore following ignition of said charge; and igniter means in said firing charge chamber and positioned within and located at an intermediate portion of said passage through said propellant charge body, said passage being unobstructed intermediate said igniter means and the rear end of said bullet therein whereby said igniter means is effective to ignite initially the intermediate portion of said propellant charge in said passage.

9. In a perforating gun for wells having a body formed with an outer barrel opening, an inner bore of reduced diameter relative to that of said barrel opening extending coaxially inward from the inner end of said barrel opening and constituting a firing charge chamber, a barrel threaded into said barrel opening and having a coaxial bullet bore therethrough, the combination of: a bullet; a tubular-shaped propellant charge positioned coaxially within said firing charge chamber, said charge having a passage extending axially therethrough from end to end thereof and having an external diameter less than the internal diameter of said firing charge chamber; transverse diaphragm means located at the juncture of said bullet bore and firing charge chamber bore, said diaphragm means being formed with a central opening, with said bullet being supported at an intermediate

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relatively short section of said bullet through said central opening and positioned with its rear end exposed to and extending coaxially from said central opening into said firing charge chamber and into said passage in said propellant charge for a substantial portion of the length of said bullet, said bullet making a press fit in said central opening sufficiently tight to delay initial movement of said bullet therefrom into said bullet bore following ignition of said charge; and combustible igniter means in said firing charge chamber and positioned within and located at an intermediate portion of said passage through said propellant charge body, said passage being unobstructed intermediate said igniter means and the rear end of said bullet therein whereby said igniter means is effective to ignite initially the intermediate portion of said propellant charge in said passage.

10. In a perforating gun for wells having a body formed with an outer bullet bore, an inner bore of increased diameter relative to that of said bullet bore and extending coaxially inwardly from the inner end of said bullet bore and constituting a firing charge chamber, the combination of: a bullet; a tubular-shaped propellant charge body positioned coaxially within said firing charge chamber, said charge having a passage extending axially there-through from end to end thereof and having an external diameter less than the internal diameter of said firing charge chamber; transverse diaphragm means located at the juncture of said bullet bore and firing charge chamber bore, said diaphragm means being formed with a central opening, with said bullet being supported at an intermediate relatively short section of said bullet through said central opening and positioned with the rear end portion thereof exposed to and extending from said diaphragm means coaxially into said firing charge chamber and into said passage in said propellant charge for a substantial portion of the length of said bullet, said bullet making a press fit in said central opening sufficiently tight to delay initial movement of said bullet therefrom into said bullet bore following ignition of said charge; and combustible igniter means in said firing charge member and positioned within and located at an intermediate portion of said passage through said propellant charge, said passage being unobstructed intermediate said igniter means and the rear end of said bullet therein whereby said ignited means is effective to ignite initially the intermediate portion of said propellant charge in said passage.

11. In a perforating gun for wells having a body formed with an outer bullet bore, an inner bore of increased diameter relative to that of said bullet bore and extending coaxially inward from the inner end of said bullet bore and constituting a firing charge chamber, the combination of: a bullet; a tubular-shaped propellant charge positioned coaxially within said firing charge chamber, said charge having a passage extending axially there-through from end to end thereof and having an external diameter less than the internal diameter of said firing charge chamber; a transverse diaphragm located at the juncture of said bullet bore and firing charge chamber bore, said diaphragm being formed with a central opening, with said bullet being supported at an intermediate relatively short section of said bullet through said cen-

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tral opening and positioned with the rear end portion thereof exposed to and extending from said diaphragm coaxially into said firing charge chamber and into said passage in said propellant charge for a substantial portion of the length of said bullet; a restraining annular member encircling and gripping said bullet intermediate the ends of said bullet and positioned adjacent to and on the rearward side of said diaphragm, said bullet making a press fit in said annular member sufficiently tight to delay initial movement of said bore therefrom into said bullet bore following ignition of said charge; and combustible igniter means in said firing charge chamber and positioned within and located at an intermediate portion of said passage through said propellant charge, said passage being unobstructed intermediate said igniter means and the rear end of said bullet therein whereby said igniter means is effective to ignite initially the intermediate portion of said propellant charge in said passage.

12. In a perforating gun for wells having a body formed with an outer bullet bore, an inner bore of increased diameter relative to that of said bullet bore extending coaxially inward from the inner end of said bullet bore and constituting a firing charge chamber, the combination of: a tubular-shaped propellant charge body positioned coaxially within said firing charge chamber, said body having a passage extending axially therethrough from end to end thereof; a transverse diaphragm located at the juncture of said bullet bore and said firing charge chamber bore, said diaphragm being formed with a central opening therethrough; a bullet supported at an intermediate relatively short section thereof through said central opening, with its rear end portion exposed to and extending from said diaphragm opening coaxially into said firing charge chamber for a substantial portion of the length of said bullet; a restraining annular member encircling and gripping said bullet intermediate the ends thereof and positioned on the rearward side of said diaphragm, said bullet making a press fit in said annular member sufficiently tight to delay initial movement of said bullet therefrom into said bullet bore following ignition of said charge; and igniter means positioned in communication with said passage extending through said propellant charge body, said passage being unobstructed intermediate said igniter means and the said rear end portion of said bullet therein whereby said igniter means is effective to ignite initially the inner portion of said propellant charge in said passage.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,953,971

September 27, 1960

Forrest V. Porter

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 7, line 19, for "assembly" read -- assembled --;
column 8, line 29, for "end of" read -- end by --; column 11,
line 42, for "wheels" read -- wells --; column 12, line 68, for
"with" read -- within --; column 13, line 29, for "beans" read
-- means --; line 45, for "ignited" read -- igniter --.

Signed and sealed this 25th day of April 1961.

(SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

DAVID L. LADD
Commissioner of Patents

UNITED STATES PATENT OFFICE
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1960
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