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APPARATUS FOR SUPPORTING EXPLOSIVE CHARGES IN JET TYPE PERFORATING GUNS

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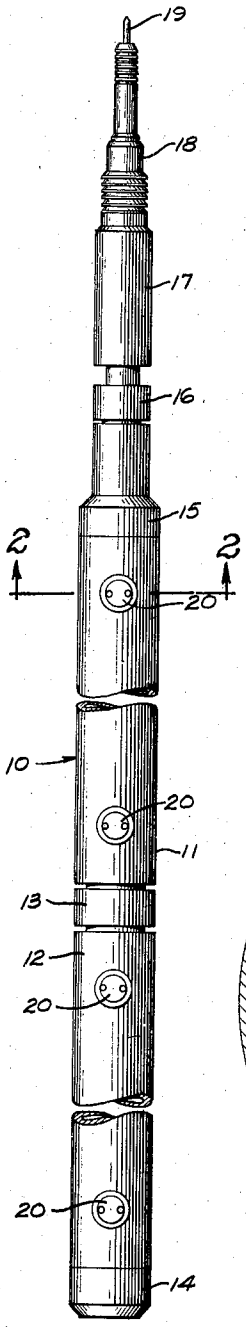


Fig. 1

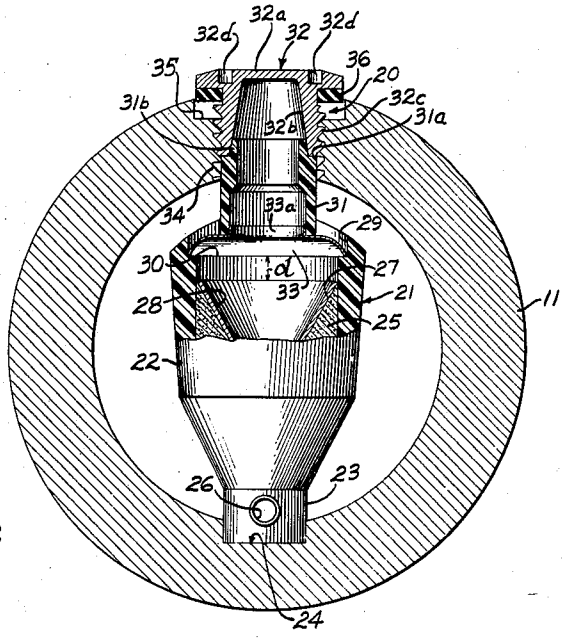


Fig. 2

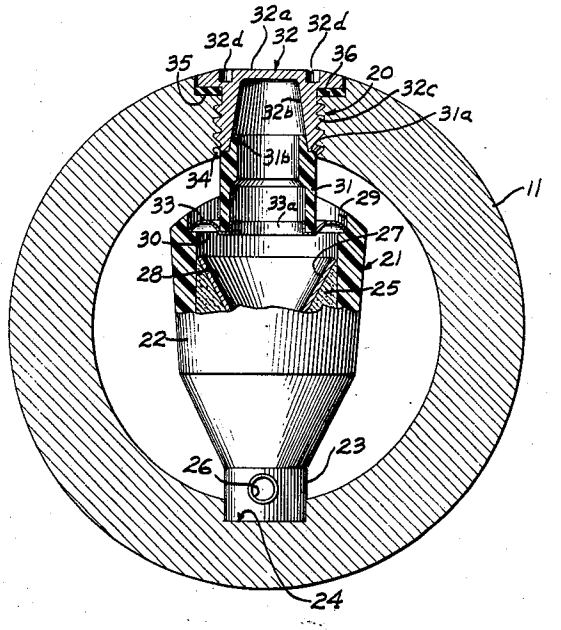


Fig. 3

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APPARATUS FOR SUPPORTING EXPLOSIVE CHARGES IN JET TYPE PERFORATING GUNS

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3 Claims. (Cl. 102—20)

The present invention relates to perforating guns of the type used for casing perforation work in oil field recovery and well completion operations and more particularly to an improved method and apparatus for supporting an explosive charge in the barrel of a so-called jet type perforating gun, by which is meant a perforating device that employs shaped explosive charges designed to produce the "jet effect" or "Munroe effect."

Conventionally, a jet type perforating gun comprises a tubular gun barrel having explosion ports extending through the wall thereof at spaced points. A shaped jet producing explosive charge is positioned within the gun barrel opposite each explosion port so that the explosive forces developed upon detonation of the charge are discharged through the port. In accordance with present operating practices, the explosive charges disposed in any given section of the gun barrel are detonated substantially simultaneously by means of a detonating cord, which extends longitudinally of the barrel and is threaded through the explosive charges. All parts of the explosive charge units and the assemblies for supporting the same in the gun barrel are expendable and must be replaced each time the gun is fired. However, the gun barrel sections, to be satisfactory, must be machined to close tolerances from special alloy steels and hence are quite expensive. Accordingly, every effort must be made to prevent the directionalized explosive forces developed upon detonation of the explosive charges from damaging the gun barrel sections. This can only be achieved if each explosive charge unit is firmly and accurately held in the gun barrel so that the cavitied end of the charge is in exact alignment with the opposed explosion port. In order to achieve the desired alignment with conventional charge supporting assemblies, certain dimensions of the gun barrel must be held to tolerances as close as plus .015 inch and minus .000 inch. Moreover, such conventional supporting assemblies do not include facilities for positively protecting the explosion ports against damage from the explosive forces discharged therethrough.

Accordingly, it is an object of the present invention to provide an improved supporting assembly for firmly and accurately holding a jet producing explosive charge in the barrel of a jet type perforating gun.

It is another object of the invention to provide an improved explosive charge supporting assembly of the character described which provides the desired accuracy of charge alignment with an explosion port of the gun barrel regardless of relatively large variations in the physical dimensions of the gun barrel.

It is a further object of the invention to provide an improved explosive charge supporting assembly of the character described which includes an expendable part arranged to remain in an explosion port of the gun barrel during detonation of the charge opposite the port, thereby to protect the port against damage from the explosive forces discharged therethrough.

It is still another object of the invention to provide an improved explosive charge supporting assembly of the

character described which is of simple and economical construction and may be easily and quickly mounted in the gun barrel.

According to a still further object of the invention, an improved method is provided for securing a cavitied explosive charge unit in a tubular gun body which may be easily and quickly carried out in the field and insures exact alignment of the charge with an explosion port in the gun body.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the specification taken in connection with the accompanying drawings, in which:

Fig. 1 is a side perspective view of a perforating gun having embodied therein explosive charge supporting assemblies characterized by the features of the present invention;

Fig. 2 is a view partially in section taken along the lines 2—2 in Fig. 1 illustrating the details of one of the charge supporting assemblies embodied in the gun shown in Fig. 1; and

Fig. 3 is a sectional view identical with that of Fig. 2 but illustrating the parts of the charge supporting assembly in their fully assembled positions.

Referring now more particularly to the drawing, the present improved charge supporting assembly is there illustrated in its embodiment in a jet type perforating gun indicated generally at **10**. This gun, together with the facilities provided therein for detonating the various explosive charges thereof, is preferably of the improved form disclosed and claimed in copending application Serial No. 219,480, filed April 5, 1951 by Jacques H. Castel and assigned to the same assignee as the present invention. Briefly, the gun **10** comprises a plurality of tubular barrel sections **11** and **12** which are joined together at their adjacent ends by means of a firing subassembly **13**. At its upper end the gun section **11** is connected to a second firing subassembly **15**, which in turn is connected with a contact subassembly **16**. The upper end of the latter subassembly is connected to the lower end of a cable head sealing subassembly **17** which in turn is connected to the lower end of a rope socket assembly **18**. The latter assembly is employed to anchor the lower end of a cable **19** which is employed to lower and raise the gun into and out of the cased well which is to be perforated. At its lower end, the lower gun barrel section **12** is closed by an end closure cap **14**. All of the described parts of the gun are preferably secured together by means of threaded connections therebetween in order to provide a rigid overall assembly and to facilitate assembly and disassembly of the gun structure.

Each of the two gun sections **11** and **12** is provided with a plurality of explosion ports **20** spaced apart along the length thereof. These ports may also be spaced circumferentially of each gun section in any desired manner. As disclosed more fully in the above-referred to copending application, the firing facilities for detonating the explosive charges disposed in the gun sections **11** and **12** opposite the ports **20** are preferably so arranged that the explosive charges of each gun section may selectively be fired in sequence. In this connection, it is noted that the detonating cords, which extend longitudinally of the gun sections **11** and **12** and are threaded through the explosive charges disposed in these gun sections are preferably electrically ignited from the surface of the earth over an electrical circuit which comprises an insulated conductor forming a part of the cable **19**.

Referring now more particularly to Figs. 2 and 3 of the drawing, the present improved explosive charge supporting assembly is there illustrated in its use to support a cavitied explosive charge unit indicated generally at **21**

in the gun barrel section 11 opposite one of the explosion ports 20. The explosive charge unit or cartridge 21 comprises a generally cylindrical container 22 preferably formed of a molded plastic insulating material, such as a phenol-formaldehyde resin (e. g. Bakelite), and having a neck 23 of reduced diameter which is adapted to seat in a recess 24 accurately formed in the wall of the gun barrel 11 directly opposite the explosion port 20. The casing 21 is partially filled with a suitable explosive material 25 which extends well into the hollow interior of the neck 23 to surround a metallic sleeve 26 extending transversely of the casing 21 through aligned openings in the neck 23. This sleeve is adapted to receive a detonating cord, such as Primacord or the like, which is threaded through the sleeves 26 of all of the charges provided in the barrel 11, and is arranged for electrical ignition from the surface of the earth to serve as the detonating element for all of the charges through which it is threaded.

At the end thereof which faces the port 20, the explosive charge 25 is provided with a conical cavity 27 which is lined with an inert liner 28 of conical configuration, formed, for example, of a metal such as copper, brass, steel, aluminum or the like, or of other inert material, such as glass. Provision of this lined conical cavity in the explosive charge 25 has the well known effect of directionalizing the explosive forces developed upon detonation of the charge along a confined path having the axis of the conical cavity 27 as its center. This directionalization effect is commonly referred to as the "Munroe Effect" or "jet effect." At the end thereof which faces the explosion port 20, the casing 22 is provided with a counterbore 29 which terminates in an annular seat 30 for supporting one of the components of the supporting assembly in the manner more fully explained below. The seat 30 is spaced outwardly from the base of the conical cavity 27 in the explosive charge 25 to provide a minimum standoff distance *d*.

Referring now more particularly to the present improved facilities for supporting the unit 21 in the barrel 11, it is pointed out generally that these facilities comprise a positioning sleeve 31, a closure plug 32 and a deformable positioning disk 33. As best shown in Fig. 2, the positioning disk 33 is normally in the form of an inverted dish-shaped annular ring and is provided with a flange 33*a* along the inner edge thereof which fits snugly into the lower end of the positioning sleeve 31. The outside edge of the disk 33 is adapted to fit snugly in the counterbore 29 formed in the casing 22 and to seat on the annular seat 30. Prefearbly, the disk 33 is constructed of a lightweight metal, such as aluminum or magnesium, and is of appropriate thickness to be readily deformable and to have a reasonable amount of resiliency.

The plug 32 is arranged to perform three functions, namely, that of closing the explosion port 20, that of holding the unit 21 in place within the gun barrel 11, and that of protecting the port 20 against damage by the explosive forces developed upon detonation of the explosive charge 25 in the unit 21. Specifically, the plug 32 is provided with a frangible end wall 32*a* which is adapted to be ruptured upon detonation of the explosive charge 25 and with a tubular portion 32*b* which is adapted to be threaded into the explosion port 20. As shown, the explosion port 20 is provided with internal threads 34 for receiving the external threads 32*c* formed around the tubular portion 32*b* of the plug 32. The head of the plug 32 is adapted to seat within a counter-bore 35 formed in the external wall of the barrel 11 coaxially with the threaded portion of the port 20. This plug head is provided with spaced tool receiving recesses 32*d* or equivalent means that may be engaged by a suitable tool to thread the plug 32 into place. For the purpose of sealing the port 20 against the admission of well fluid to the interior of the barrel 11, a soft rubber gasket 36 is provided which is clamped between the head of the plug 32 and the bottom wall of the counter-bore 35 when the plug is fully threaded into the port 20. The plug 32 may be formed of any suitable material, and is preferably of a metal having adequate strength that is at the same time readily pierced by the explosive forces of the shaped charge unit. Aluminum and various aluminum base alloys are suitable for this purpose, although brass, copper and other metals can be used. The end wall 32*a* may be formed of one material and the tubular portion 32*b* of another, if desired, but the entire plug 32 is preferably of unitary construction.

At its inner end the tubular portion 32*b* of the plug 32 engages the outer end of the positioning sleeve 31. More particularly, the upper end of the sleeve 31 is provided with an external shoulder 31*a* for seating the inner end of the plug. Further, that portion 31*b* of the positioning sleeve 31 which extends beyond the shoulder 31*a* is provided with an inwardly tapering outer surface which seats within the correspondingly tapered inner surface of the tubular plug part 32*b* to insure exact axial alignment of the two components 31 and 32.

In accordance with the present improved method of securing the explosive charge unit 21 and the described components of the supporting assembly in the gun barrel 11, the positioning disk 33 is first inserted in the counter-bore 29 of the casing 22 until the outer edge thereof is firmly seated against the seat 30. Frictional engagement between the outer edge of this disk 33 and the wall of the counter-bore 29 is sufficient to hold the disk assembled with the unit 21. The next operation is that of threading the detonating cord through the sleeve 26, following which a pair of tongs may be employed to insert the unit 21 in the barrel 11 and position the end of the neck 23 in the recess 24 opposite the explosion port 20. The operator may now insert the positioning sleeve through the explosion port 20 and by manipulating the unit 21 may telescope the inner end of this sleeve over the flange 33*a*. In this connection, it will be noted that prior to insertion of the plug 32 into the explosion port, a substantial portion of the positioning sleeve 31 remains in the port to minimize the likelihood of this sleeve passing through the port and falling to the bottom of the gun barrel 11.

After the sleeve 31 is thus brought into position with the inner end thereof resting against the inner edge surface of the disk 33, the plug 32 with the gasket 36 thereon may be threaded into the port 20. As the plug 32 is threaded into the port, the end portion 31*b* of the positioning sleeve 31 enters the tubular portion 31*b* of the plug, following which the inner end of the plug engages the shoulder 31*a* of the positioning sleeve. During the continued inward movement of the plug, the sleeve 31 is forced axially inward to press the end of the casing neck 23 into firm seating engagement with the bottom of the recess 24. Also during the final inward movement of the plug 32 and positioning sleeve 31, the disk 33 is deformed by moving the inner edge thereof inwardly while holding the outer edge thereof in seating arrangement with the annular seat 30 provided at the end of the casing 22. After the plug 32 is fully threaded into the port 20 to compress the gasket 36, the port 20 is completely sealed off to prevent well fluid from entering barrel 11. After the components are fully assembled in the manner explained above, the disk 33 is deformed in the manner illustrated in Fig. 3, so that it is effectively held under stress between the seat 30 and the inner end of the positioning sleeve 31. By making the disk 33 of a lightweight deformable metal having a reasonable amount of resiliency, and of the shape and size illustrated, uniform deformation of this disk is produced around the entire annulus thereof so that tilting of the explosive charge unit 21 out of axial alignment with the explosion port 20 is positively prevented. Moreover, and as will be apparent from the above explana-

tion, the permissible amount of deformation of the positioning disk **33** is such that there is no necessity for holding the dimensions of the plug **32** and the positioning sleeve **31** or the distance between the bottom of the recess **24** and the bottom of the counter-bore **35** to extremely close tolerances.

As indicated above, when the explosive charge **25** is detonated, all parts of the unit **21** and the described supporting assembly, with the possible exception of the sealing gasket **36**, are expended. More specifically, detonation of the charge **25** results in the production of a highly directionalized jet of explosive forces which is directed outwardly through the tubular portion **32*b*** of the plug **32**. These forces rupture the frangible end wall **32*a*** of the plug and penetrate the casing adjacent the port **20** as well as the earth's strata which surrounds this casing. The extremely violent nature of the explosive forces accounts for the requirement that the axis of the conical cavity **27** in the explosive charge **25** be precisely coincident with the exact center of the explosion port **20**. Such precision alignment of the conical cavity axis axially of the port **20** is obtained by employing the described supporting assembly to support the unit **21** in the manner just described.

In accordance with another important feature of the invention, the tubular portion **32*b*** of the plug **32** is also so arranged as to remain in the port **20** during detonation of the explosive charge **25** to act as a liner for the port and prevent the explosive charges from "nicking" or otherwise damaging the walls of the gun barrel which define the port. Specifically, buttress threads **34** and **32*c*** are respectively provided in the port **20** and on the tubular portion of the plug **32** to hold the plug in position within the port **20**. As shown, the threads **34** in the walls defining the port **20** in the barrel **11** are arranged with the thrust sides thereof facing inwardly, so that maximum resistance to thread shearing is obtained. It has been found that by employing threads of the character specified arranged in the manner described, the tubular portion **32*b*** of the plug **32** is positively prevented from being blown out of the explosion port **20** upon detonation of the explosive charge **25**. Thus the tubular portion **32*b*** of the plug remains in place to protect the side walls of the port **20** against damage.

To understand the importance and scope of the present invention, it should first be understood that in perforating guns of the general character here involved, it has previously been proposed to use explosion port closures and assemblies of expendable components intended to align the explosive charge units with the ports that superficially correspond to some of those constituting the essentials of this invention. The prior devices, however, have been found by test to be incapable of providing uniform and positive alignment of the explosive charge with the ports, and hence have failed to protect the gun barrels from damage. Additionally, these prior devices are more expensive in use because they are more difficult to assemble, and they require more elaborate and costly machining of the various parts and the gun barrel itself in order to enable them to function.

A direct comparison of the previously used port closures and explosive unit alignment systems with those of this invention will probably best demonstrate the conclusions just expressed. For example, a common form of gun body section (such as **11** of the present drawings) may have a nominal outside diameter of four inches and a nominal inside diameter of two and three-quarters inches. The alignment system of the type heretofore known depends upon a rigid disk, corresponding generally to the deformable disk **33**, and a sleeve corresponding roughly to the sleeve **31**, either as a separate part or formed integrally with the rigid disk. These members are disposed to cooperate with the open end of the container for the explosive charge and the inner end of the port in the gun body to align the explosive charge unit, whose opposite end is seated in a recess in the gun body, as in the case of the invention above-described. The outer end of the port is then sealed by a plug and gasket generally corresponding in purpose, and even in appearance, to the plug **32** of this invention. Because these previously used components depend for their proper functioning solely on their fixed dimensions, they must be accurately made, and the dimensions of the gun body in which they are used must also be fixed within close limits. In the prior devices described, for example, a nominal four-inch gun body must have its actual outside diameter formed throughout its entire length within the limits of 4.000 inches and 4.015 inches, while the critical dimension from the bottom of each of the recesses opposite the ports to the seating shoulder for the port-closing plug must be in each case within the limits of 3.243 inches and 3.257 inches. The maintenance of such close tolerances in forming massive alloy steel tubular bodies many feet in length with numerous pairs of ports and recesses and with a wall thickness of more than one-half inch is obviously laborious and expensive. Moreover, the necessity of maintaining such close tolerances defeats itself in practice, because repeated use of the gun body involve the firing of many explosive charges within it, with the inevitable result that the gun body, despite its massive construction, is expanded and distorted so that the dimensions of the device, no matter how closely controlled initially, are changed in use. A necessary concomitant of a change is that accurate alignment of the charges becomes uncertain.

By contrast, a gun body of four inches nominal size in which is embodied the features of this invention need not be made to such close tolerances, and the outside diameter of the body need be maintained only within $\frac{1}{32}$ inch of its nominal diameter, while the dimension from the bottom of the counter-bore **35** to the bottom of the recess **24** may vary by as much as $\frac{1}{16}$ inch. Even these limits could be widened were it not for the change of dimensions of the gun body in use, as noted above.

Moreover, because the components that insure alignment of the explosive charges and ports in the present improved structure are deformable, the sleeve **31** when initially located in its place in the assembly extends well into the port itself, and this distance is only reduced as the charge is seated by threading the plug **32** into place. This allows speed and ease in assembling the components and in loading the gun bodies without danger of a "cocked" or misaligned charge. This possibility of a misaligned charge is ever present in the previously used system, since it depends on elements of fixed dimensions, and the part corresponding to the sleeve **31** cannot initially intrude any farther into the port than its final position, which is necessarily a very small distance, since it is essential that a maximum of its available thread length be used to secure the sealing plug in the port.

Turning now to a comparison of the plugs that seal the ports, there is one small but vital structural difference in these, although there are other important distinctions in the way that they coact in combination with the associated elements of the invention. As previously constructed, the closure plugs were threaded to their full length with standard machine threads, and it was intended that the explosive forces be directed through the closed end of the plugs to effect perforation of the well wall while leaving roughly an annulus of each plug, including its threaded portion, in place in each port. It is highly desirable to achieve this result for two reasons: First, it is obvious that if the threaded portion remains in the ports, the whole of the effective explosive forces are exerted through the frangible ends of the plugs and will not injure the gun body; second, and most important, if the threaded body of the plugs are not retained in the ports but are carried away, or partly so, by the explosive forces, there would be a quantity of the deformed metal plug bodies left in the well. Any scrap or so-called

"junk," particularly metal fragments, in a well constitute a hazard to operations in the well, since this may cause damage to tools, such as swabs and packers, and may become jammed between a tool and the well wall or casing to necessitate an expensive fishing job. Portions of the port plugs that are only partly carried out of the ports frequently require fishing of the gun body itself.

Experience in the field has shown that the usual machine threads heretofore used frequently shear or strip on the plug bodies to allow these to be carried away, or partly so. Surprisingly, however, the adoption of buttress threads as disclosed above has proved effective to eliminate this completely for all practical purposes. In field operations involving thousands of shots using the buttress threaded port plugs of this invention, the proportion of plug bodies carried away has been negligible.

The second advantage of the plugs of this invention is the way in which these cooperate with the other elements of the aligning system to insure positive alignment of the axis of the explosive charge with the port. Because the sleeve **31** is ultimately forced inward to deform the positioning disk **33** and all of the ports are thus held under stress, no necessity exists for holding the dimensions of the sleeve, the disk and the threaded body of the plug within fixed limits as is true in the case of the previously used devices, and the benefits thereby gained will be apparent.

Finally, it will be seen that all of the advantages and novel features that contribute to the value of this invention are gained without departing from the fundamental physical arrangement of the corresponding devices heretofore known, so that a minimum change in the related structure is involved. Thus, the shaped explosive charge units, gun bodies, loading and firing tools and systems and other associated parts used conventionally before the advent of the present improvements are incorporated without alteration in the practice of this invention. The advantages and economies accruing from this compatibility of the invention with that which has been heretofore used are obviously significant.

While one embodiment of the invention has been described, it will be understood that various modifications may be made therein which are within the true spirit and scope of the invention as defined in the appended claims.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. In a perforating gun which includes a gun barrel provided with an explosion port in a wall thereof, an assembly for holding a cavitied explosive charge unit in said barrel in axial alignment with said port with the cavitied end of the explosive charge facing said port, comprising a positioning sleeve, means closing said port and supporting said positioning sleeve in axial alignment with said port, said unit being provided with an annular seat adjacent the inner end of said sleeve, and a dish-shaped annular member deformably held between said sleeve and said unit and provided with an outer edge seated on said annular seat, said member having an inner edge surface seating against the inner end of said sleeve and being provided with a flange around said inner edge which projects into said sleeve.

2. In a perforating gun which includes a gun barrel provided with a buttress threaded explosion port through the wall thereof, an assembly for holding a cavitied explosive charge unit in said barrel in axial alignment with said port with the cavitied end of the explosive charge facing said port, comprising a hollow plug closing said port and provided with a frangible end wall which is adapted to be ruptured upon detonation of the explosive charge, said plug including a tubular portion having external buttress threads engaging the buttress threaded explosion port of said barrel and coacting therewith to hold the tubular portion of said plug in place upon detonation of the explosive charge, a positioning sleeve engaging said plug at the inner end thereof, said unit being provided with an annular seat adjacent the inner end of said sleeve, and a dish-shaped annular member deformably held between said sleeve and said unit and provided with an outer edge seated on said annular seat, said member having an inner edge surface seating against the inner end of said sleeve and being provided with a flange around said inner edge which projects into said sleeve.

3. In a perforating gun which includes a gun barrel provided with an explosion port through the wall thereof, the walls defining said port having buttress threads extending inwardly from the outer side of said barrel with the thrust sides of said threads facing inwardly, a cavitied explosive charge unit adapted to be supported in said barrel with the cavitied end of the explosive charge facing and aligned with said port, a hollow plug closing said port and provided with a frangible end wall which is adapted to be ruptured upon detonation of the explosive charge, said plug including a tubular portion having external threads engaging the buttress threads of said explosion port and coacting therewith to hold the tubular portion of said plug in place upon detonation of said explosive charge, a positioning sleeve provided with a shouldered outer end which projects within and engages the inner end of the tubular portion of said plug, said unit being provided with an annular seat adjacent the inner end of said sleeve, and a dish-shaped annular member deformably held between said sleeve and said unit and provided with an outer edge seated on said annular seat, said member having an inner edge surface seating against the inner end of said sleeve and being provided with a flange around said inner edge which projects into said sleeve.

References Cited in the file of this patent

UNITED STATES PATENTS

2,142,583	Yarbrough	Jan. 3, 1939
2,494,256	Muskat	Jan. 10, 1950
2,517,560	Hambly	Aug. 8, 1950
2,565,788	Tow	Aug. 28, 1951
2,662,474	Turechek et al.	Dec. 15, 1953

OTHER REFERENCES

Article entitled, The Jet Perforation Process by W. T. Box and R. F. Meiklejohn published in World Oil, March 1950, vol. 130, No. 4, pages 112, 116, 118, 121 and 122. Editor's note, on last page of article, refers to presentation date of Jan. 17, 1950.

Mechanical Engineer's Handbook by Lionel S. Marks, third edition, 1930, page 870.