June 10, 1958 J. H. CASTEL 2,837,995

UNSYMMETRICALLY ENCASED SHAPED EXPLOSIVE CHARGES

Filed Dec. 26, 1952 2 Sheets-Sheet 1

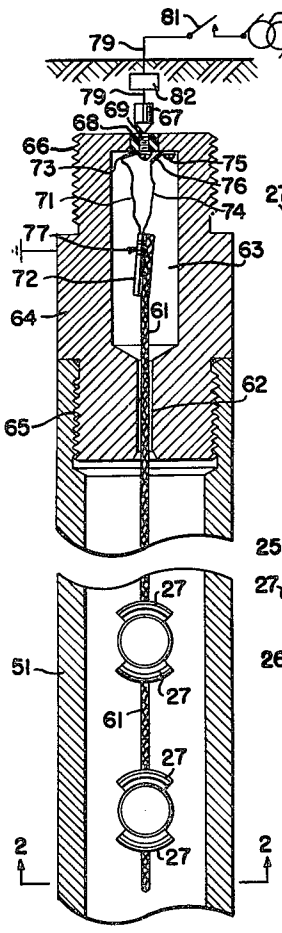


FIG. 1

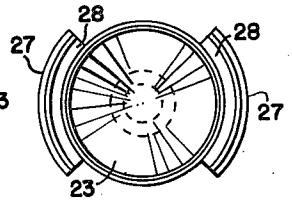


FIG. 5

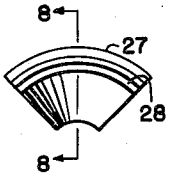


FIG. 7

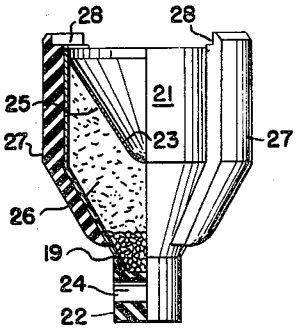


FIG. 4

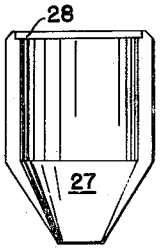


FIG. 6

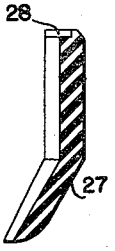


FIG. 8

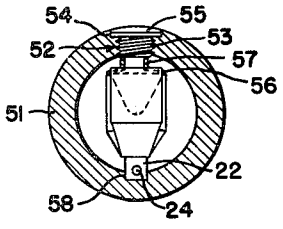


FIG. 2

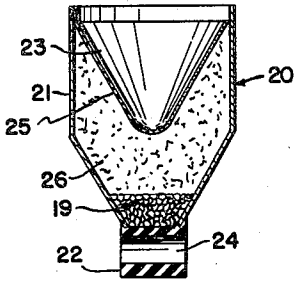


FIG. 3

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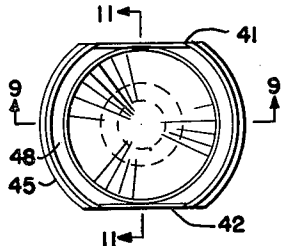


FIG. 10

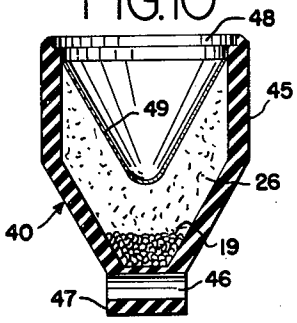


FIG. 9

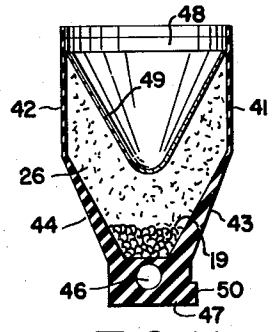


FIG. 11

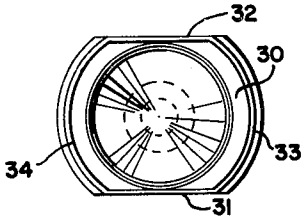


FIG. 13

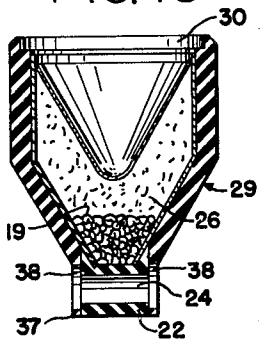


FIG. 12

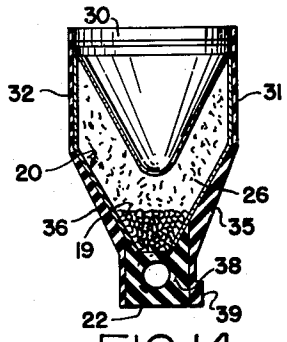


FIG. 14

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2,837,995

UNSYMMETRICALLY ENCASED SHAPED EXPLOSIVE CHARGES

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Application December 26, 1952, Serial No. 328,026

3 Claims. (Cl. 102—20)

This invention relates to explosive charges and more particularly to encased shaped explosive charges designed to produce the so-called "jet effect" or "Munroe effect," especially for oil well "jet type" perforating guns.

Conventional jet type perforating guns primarily comprise a tubular gun barrel having explosion ports extending radially through its walls at spaced points and behind each of which in axial alignment therewith a so-called "jet explosive" or encased shaped charge is positioned so that upon detonation the explosive forces that produce the jet effect are directed through the ports against the target to be penetrated. Additionally, means manipulable from the surface are provided for suspending the device in a borehole and for firing the shaped charges.

In accordance with present operating practice, 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 an aperture in each of the explosive charges for that purpose. Furthermore, all parts of the explosive charge units and the assemblies for supporting the same in the gun barrel, together with closures for the explosion ports, are usually expendable and must be replaced after each time the gun is fired. On the other hand, the gun barrel section or sections, in order to be satisfactory must be carefully machined to close tolerances from special alloy steels and are accordingly quite expensive with a desideratum that they not be expendable. Unfortunately, in operations heretofore, after a relatively small number of firings, these gun barrels become sufficiently bulged from the forces exerted by the explosive charges when detonated therewithin to cause them to have become so deformed and misshapen as to render them useless and necessitating that they be scrapped. After only a comparatively few firings or salvos, that varies with the size of the gun, but which is generally in the neighborhood of from 12 to 14 firings for a 4 inch diameter gun and from 16 to 20 firings in the case of a 5 inch diameter gun, the bulging out of the gun barrel sections caused either misalignment of the axes of the encased shaped charges with the firing ports so that the boundaries of the ports themselves become nicked and the gun barrel damaged by the misaligned jet streams, or probably even worse, enlargement or bulging may cause the gun to become lodged in the borehole necessitating costly fishing operations and involving the possibility of damage to the well or to otherwise reusable portions of the gun itself.

I have now discovered that for the most part, this bulging is caused by the impact of the material making up the case or shell of the jet charge against the internal wall of the gun sections upon detonation of the charges. With this knowledge, it would appear only to be necessary in order to lengthen the useful life of the gun merely to reduce the thickness of the charge case material and thereby proportionally reduce the impact damage to the

guns. By such reasoning the simple use of an extra-thin or extra-light material for the charge case would be indicated. There is, however, a major drawback to this approach by reason of which it is unacceptable. A thin charge case material may result in both sympathetic detonation between charges and movement and misalignment of adjacent charges due to uncushioned or unbroken shock waves directed thereagainst, and which is otherwise known in the art as inter-charge "interference." In an effort to alleviate this interference, it has heretofore been proposed to fill the spaces between charges in a jet type perforating gun with granular material to break or cushion the shock, and such materials as paper scraps, sand, vermiculite, popcorn and other expanded cereals, have been used or suggested for this purpose. This is unnecessary with the instant invention. As for the former, notwithstanding that the composition of the detonating cord provides a substantially simultaneous series detonation of the group of charges through which it is threaded, there is nevertheless a finite although very small time interval between individual detonation of the charges. The lighter or thinner the charge casing material is for given distance between charges therefore, the greater will be the possibility of inter-charge interference which primarily causes misalignment of charges with consequent damage to the gun ports and the gun barrel proper.

This invention has overcome to a markedly substantial degree the objectionable bulging of the gun barrel sections thereby prolonging the useful life of the guns many times without the drawbacks of increasing interference between charges upon detonation or promoting the possibility of sympathetic or premature detonation of the charges. This has been achieved by providing a new and different form of casing for the shaped jet charges, which principally consists of so shaping or molding the charge casing that two opposite approximately ninety degree circumferential portions thereof are either eliminated entirely or are reduced to the minimum thickness required to contain the charge. In this manner, there is either substantially no mass or a minimum of casing material in the regions referred to, and thus there is virtually eliminated the material that otherwise would be acted upon and driven outwardly upon detonation of the charge. The provision of shaped charge casings in such form constitutes the principal object of this invention.

Another object of this invention is the provision of methods of reducing damage to jet perforating guns thereby prolonging their useful life as well as maintaining interference between charges at a minimum, and still another object resides in the adaptability of the new form of charge casing to either cartridge type charges or directly loaded charges.

Additional features and advantages will become apparent as the following description proceeds, particularly when taken in conjunction with the accompanying drawings in which:

Fig. 1 is a central longitudinal sectional view partly in elevation to show a portion of a jet perforating gun barrel and immediately associated members.

Fig. 2 is a sectional view of the gun of Fig. 1 taken on the line 2—2.

Fig. 3 is a central longitudinal section through a cartridge for a shaped charge of this invention.

Fig. 4 is a view partly in central longitudinal section and partly in elevation of an embodiment of a shaped charge of this invention employing the cartridge of Fig. 3.

Fig. 5 is an end view of the charge of Fig. 4.

Fig. 6 is an elevation of one of the members forming a part of the shaped charge of Fig. 4.

Fig. 7 is a top view of the member of Fig. 6.

Fig. 8 is a sectional view taken on line 8—8 of Fig. 7.

Fig. 9 is a central longitudinal sectional view of another embodiment of a shaped charge according to the present invention.

Fig. 10 is an end view of the charge of Fig. 9 and showing the section lines on which Figs. 9 and 11 are taken.

Fig. 11 is a central longitudinal view similar to that of Fig. 9 but taken on a plane perpendicular to the plane of Fig. 9.

Fig. 12 is a central longitudinal sectional view of a third embodiment of a shaped charge in accordance with this invention.

Fig. 13 is an end view of the charge of Fig. 12.

Fig. 14 is a central longitudinal sectional view similar to that of Fig. 12 but taken on a plane at right angles to the plane of Fig.12.

Referring now particularly to Fig. 3, a thin walled cartridge **20** is provided for the embodiments of charges illustrated in Figs. 4–8 and 12–14. The cartridge **20** has an outer shell preferably of thin metal which is generally funnel shaped tapering down to a neck portion **22** of circular cross section. The shell **20** contains an explosive charge **26** of a detonating type high explosive material formed with a cavitied end **25** of generally conical shape the apex of which extends approximately to the central portion of the charge. This cavity causes a directed stream of explosive forces of a "Munroe effect" upon detonation. The space within the cartridge shell **20** immediately adjacent the neck **22** is provided with a booster charge **19** designed to promote detonation of the remainder and major poriton of the explosive **26**. Into the open end of cartridge shell **20** and closely fitting within the conical cavity **25** of the explosive charge **26** there may be pressed or otherwise fitted a correspondingly shaped conical liner **23** of non-explosive material, such as one of a ductile metal. The provision of the liner is optional, and the penetrating effects obtainable through the use of shaped charges of the general type described with or without liners for the cavities of such charges are well known, as are the types of explosives and other features of such charges. Further description of these details which form no part of the novelty of this invention is accordingly unnecessary. The cartridge charge is completed with a diametrical bore **24** through the narrow neck portion **22** adjacent the booster portion of the charge for the reception of a detonating cord. Thus it will be seen that an entirely symmetrical cartridge for a shaped charge is provided.

The cartridge **20** may be employed in the fabrication of a shaped charge according to this invention as follows:

Referring to the embodiment of this invention illustrated in Figs. 4–8, two charge case segments **27** are affixed to opposite sides of the thin walled cartridge **20** by any suitable means such as cement. Segments **27** are preferably approximately quarter or 90° segments of a charge casing shaped to otherwise conform to the entire outer shape of cartridge **20** and having an external funnel shape complementary to the funnel shape of cartridge **20** but terminating short of necked portion **22**. The segments **27** are all provided adjacent their upper ends with an annular shoulder **28** which when they are affixed to the cartridge **20**, extend slightly above the cavitied end of the cartridge, the purpose for which will be described later. The segments **27** may be formed of any suitable material and conveniently may comprise a molded thermosetting resin base plastic composition such as "Bakelite." In affixing the segments **27** to cartridge **20**, they are oppositely placed on either side of the cartridge in longitudinal alignment with the axis of detonating cord bore **24** in the neck portion **22**.

Another embodiment of a shaped explosive charge employing cartridge **20** is illustrated in Figs. 12–14 wherein cartridge **20** is inserted into a fully formed casing **29** which is of general funnel shape and internally formed to snugly receive the entire length of cartridge **20**, including its necked portion **22**. The casing **29**, as with the casing segments previously described, is provided with an annular shoulder or counter bore **30** adjacent its open end which extends slightly beyond the cavitied end of cartridge **20**. As best illustrated in the top view (Fig. 13), the casing **29** is unsymmetrical in that two opposite sides **31** and **32** of the cylindrical portion of the casing are shaped or molded so that the thickness of the casing material is reduced to the greatest extent practicable in two opposite approximately 90° circumferential portions thereby presenting a substantially lesser mass of casing material than is present in the remaining or intermediate portions of the casing. In the embodiment illustrated, reduced sides **31** and **32** are formed parallel and flat whereby the longitudinal centers of said flat sides **31** and **32** have very little thickness while curved sides **33** and **34** therebetween have a substantial thickness. Opposite sides **35**, **36** of the conical portion of the casing which form continuations of flat sides **31** and **32** are also flat and present a wall decreasing in thickness from the neck portion **37** toward flat sides **31**, **32**. The flat portions **31**, **32**, **35** and **36** are so formed relative to cartridge **20** that their planes are all parallel to the axis of bore **24** in neck **22** and the sides **31** and **32** are in planes parallel to a plane also extending through the longitudinal or jet axis of cartridge **20**. It will be apparent that instead of the flat sides described, curved sides of greater radius and thus lesser mass could be provided as well. A necked portion **37** of the oppositely flat sided casing **29** is provided with a pair of registering bores **38** of slightly larger diameter than that of cartridge neck bore **24** and which overlappingly register therewith. Casing **29** consists of any suitable material, such as referred to before.

A third embodiment illustrated in Figs. 9–11 is adapted for direct loading and contains no cartridge such as that shown in Fig. 3. Casing **40** is generally of the same shape as cartridge **20** but preferably consists of molded plastic material in its entirety. In this embodiment as illustrated, two opposite walls **41**, **42** of the cylindrical portion thereof are parallel and flat with corresponding portions of the conical portion **43**, **44** being flat and of decreasing thickness from a necked portion **45** to the line of joinder with flat parallel sides **41**, **42**. The flat sides **41**, **42** are parallel to a plane through the axis of a bore **46** in a necked portion **47** and the longitudinal axis of the casing proper, and flat tapering sides **43**, **44** are in planes parallel to the axis of bore **46**. Here again, instead of flat sides, equivalent portions of greater radius and lesser mass could as well be provided. As referred to in the embodiments previously described, the open end of the casing **40** is provided with an annular shoulder or counter bore **48** and the entire casing is unitary. A liner **49** which can be pressed in place immediately below counter bore **48** is provided for completing the cavitied end of the charge casing after it has been suitably loaded with explosive material formed with a cavity corresponding in shape to that of the liner and adapted for its reception. As with the cartridge **20**, the narrow portion adjacent the neck **47** is charged with a booster material **19** and the remaining portion between the casing and the liner is filled with a suitable detonating material **26**. It will be seen that this embodiment likewise provides a charge having a casing of unsymmetrical shape, being thin walled on sides parallel to the axis of the neck bore **46** but which is capable of being directly loaded with explosive material.

Referring now to Figs. 1 and 2, the gun barrel portion **51** is provided with radial ports **52** at longitudinally spaced intervals throughout the length of the gun barrel. The ports **52** need not of necessity all be in longitudinal alignment but may be alternated at 180 degrees or

spiralled in longitudinal spaced relation. The ports 52 are each threaded as indicated at 53 and counterbored at 54 for the reception of a port plug 55 of a suitable material such as aluminum. A disc 56 of any suitable material such as plastic or aluminum for positioning the conical axis of the charge cavity in central alignment with its port 52 fits into any of the charge counterbores or annular shoulders 28, 30, 48 at the cavitied ends of the various embodiments of charges previously described, and between the positioning disc 56 and port plug 55, the threaded portion of which may be partially hollow, a positioning sleeve 57 is placed. All of these positioning expedients are well known and shown only for purposes of illustration and need not be further detailed herein. It is furthermore not intended nor is it necessary to limit this invention to any particular type of positioning means.

Opposite the ports 52 within the gun barrel wall, charge mounting recesses 58 are provided into which the necked portions 22, 37 or 47 of the various embodiments of the charges snugly fit. When the charges are mounted in this manner, it is necessary that they be properly oriented so that the reduced thickness portions of the charge casings are directed toward the adjacent gun barrel walls and the thicker or unreduced portions of the charge casings are directed toward adjacent charges, that is to say, longitudinally of the gun barrel rather than laterally of the gun barrel axis as for the reduced thickness portions.

In order to achieve this orientation of the charge casings relative to the gun barrel, each charge may be rotated to proper orientation by hand, or manipulated for example, by pulling the detonating cord which is threaded through the small bore in the necked portion until the proper orientation is achieved which, due to the structure previously described, occurs when the axis of the detonating cord bore is longitudinal of the gun barrel. Also, as illustrated with regard to certain of the embodiments presented, an indexing means such as a fin or projection 39 and 50 (Figs. 11 and 14) on the necked portion of the charge may be provided along with a corresponding keyway (not shown) adjacent each positioning recess 58 into which such projections fit for convenient preselected orientation of the charge casing relative to the gun barrel. In the event that indexing means of this type is employed, it should be arranged so that the detonating cord bores of the charges extend longitudinally of the gun barrel 51. Obviously indexing means are unnecessary and if employed may be provided in numerous other forms and it is not here intended to limit the invention to the necessity for an indexing means or any particular indexing means.

The charges are thus positioned in the gun barrel in alignment with their respective ports and with a suitable detonating cord 61, such as Primacord, threaded through the various detonating cord bores 24 or 46 in the necked portions of the charges. The detonating cord 61 extends upwardly from the gun barrel 51 through an opening 62 into a chamber 63 both within a detonating cord subassembly member 64 threaded at 65 to the upper end of gun barrel 51. The other end of detonating cord subassembly 64 is also threaded at 66 for engagement with the next adjacent portion of the gun, generally the firing sub-assembly, not shown, other than the schematic showing of certain well known members of a typical firing sub-assembly such as contact member 67 and this is in turn connected to a closure member or bell for connection to the wire line by which it is transported or suspended within the borehole. Likewise, the lowermost gun barrel section is closed off by a bull plug (not shown) so that the entire gun is sealed or fluid tight. The upper end of chamber 63 is closed by a plug 68 of electrically insulating material through the center of which threadably extends a metal contact screw 69 preferably of brass. To the head of screw 69 and within chamber 63 one electrical lead 71 of a blasting cap 72 is secured by means of a suitable electrical connector 73. The other electrical contact lead 74 of the blasting cap 72 is secured to the body of the detonating cord sub-assembly 64 which may be considered electrically as ground by means of a screw 75 and lead connector 76. The blasting cap 72 thus connected is secured by any suitable means 77 such as tape for instance, to the end of the detonating cord 61 within chamber 63.

The manner in which the blasting cap 72 is electrically ignited to detonate cord 61 to in turn detonate the various charges through which cord 61 is threaded is also well known and is only shown schematically as a suitable power source 78 above the surface of the ground suitably grounded on one side and on the other connected by lead 79 through switch 81 and suitable transformer means 82 to contact 67 which when the firing sub-assembly (not shown) is screwed in place to the detonating cord sub 64 by means of threads 66, will be pressed into electrical contact with screw 69 so that when switch 81 above the ground is closed, an electrical circuit is closed and the charges are detonated.

It will also be understood that although not shown, lead 79 represents an electrical conductor of an armored cable by which the perforating gun is lowered into, suspended within and withdrawn from the borehole. As is also well known, the cable sheath may serve as the ground connection or an earth ground may be employed.

When the charges are detonated as just referred to, the casing portions such as 27 or the entire casing in the case of 29 or 40 are fragmented but due to the unsymmetrical shape of the charge casings, either thin walled or nonexistent on the sides adjacent the wall of gun barrel 51 depending upon the embodiment considered, only a minimum of the fragmented casing particles impinge against the gun barrel to cause bulging or deformation thereof whereas maximum casing thickness is provided in the direction of adjacent charges so that so-called intercharge interference is substantially prevented.

The following specific example will serve to illustrate the invention and to demonstrate its efficacy in achieving its objects as set out above:

Comparative tests were conducted using on the one hand shaped charges of a type that is commercially available, and, on the other, shaped charges made in accordance with this invention as illustrated in Figs. 9 to 11. The commercial charges were contained in molded plastic cases and the charges illustrating the present invention also were encased in the same material. The wall thickness of the commercial charges was uniform about the entire circumference of the charge, while the charges of this invention had this same thickness of molded plastic in the sections indicated at 45 of Figs. 9 and 10, but with its thickness reduced in the portions indicated at 41 and 42 of Figs. 10 and 11 by the proportion illustrated in these figures. All of the charges contained identical amounts of identical explosive material, and the cavities of all the charges were provided with identical liners formed of copper.

A like number of charges of both types were detonated under identical circumstances in gun bodies that had not been previously used and which were fabricated to the same specifications from the same lot of alloy steel. These gun bodies were of the size designated as 4 inch guns.

Accurate measurements of the outside diameters of the gun bodies were made before their use in this test and the results of the test are indicated as the increase in this diameter after use.

In the case of the gun body in which the commercially available shaped charges were detonated, it was found that after firing ten salvos of such charges, the diameter of the gun had increased by 0.070 inch. In the case of the gun body in which were fired shaped charges in accordance with this invention as illustrated by Figs. 9 to 11, and in which the charges were positioned so that the

thin portion of the case indicated at 41 and 42 of these figures faced the wall of the gun, it was found that after ten salvos, the increase in diameter was only 0.011 inch, and with continued firing of the charges in accordance with this invention in the same gun body, it was found that after twenty salvos, the increase in diameter was only 0.022 inch. In no case using either type of charge was there any apparent interference between the charges fired in any salvo.

It will be evident from these test data that the present invention sharply reduces the damage to jet perforating gun bodies and serves to increase the useful life of these guns many fold. At the same time, none of the other advantages of shaped charges heretofore known are sacrificed through the employment of the features of my invention.

Notwithstanding the fact that preferred embodiments of the shaped charges of this invention have been described in detail, it will be understood that numerous modifications within the spirit of this invention will suggest themselves to those skilled in the art and it is intended that all such modifications be included within the scope of the invention as defined in the appended claims.

I claim:

1. The combination with a reusable jet type perforating gun barrel having at least one radially extending port, of a shaped explosive charge suitable for producing penetration of target objects by means of the jet or Munroe effect obtained on detonation of the charge carried transversely within the gun barrel, said charge comprising a shaped body of explosive material provided with at least one cavity adapted to be directed toward the target to be penetrated through said port and contained within a casing for said explosive material, the side walls of said casing being unsymmetrical in thickness about the longitudinal axis of the charge, the wall portions of said casing of lesser thickness being relieved over substantially the extent of the explosive material and positioned toward the walls of said gun barrel.

2. The combination with a reusable jet type perforating gun barrel having at least one radially extending port, of a shaped explosive charge suitable for producing penetration of target objects by means of the jet or Munroe effect obtained on detonation of the charge carried transversely within the gun barrel, said charge comprising a shaped body of explosive material provided with at least one cavity adapted to be directed toward the target to be penetrated through said port and contained within a casing for said explosive material, the side walls of said casing being unsymmetrical in thickness, the wall portions of said casing of lesser thickness being relieved over substantially the extent of the explosive material and positioned toward the walls of said gun barrel, and means for orienting the wall portions of said casing of lesser thickness toward the walls of said gun barrel.

3. The combination with a reusable jet type perforating gun barrel as claimed in claim 1, in which said side wall portions of the charge casing of greater thickness extend in the direction of the longitudinal axis of the gun barrel.

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