

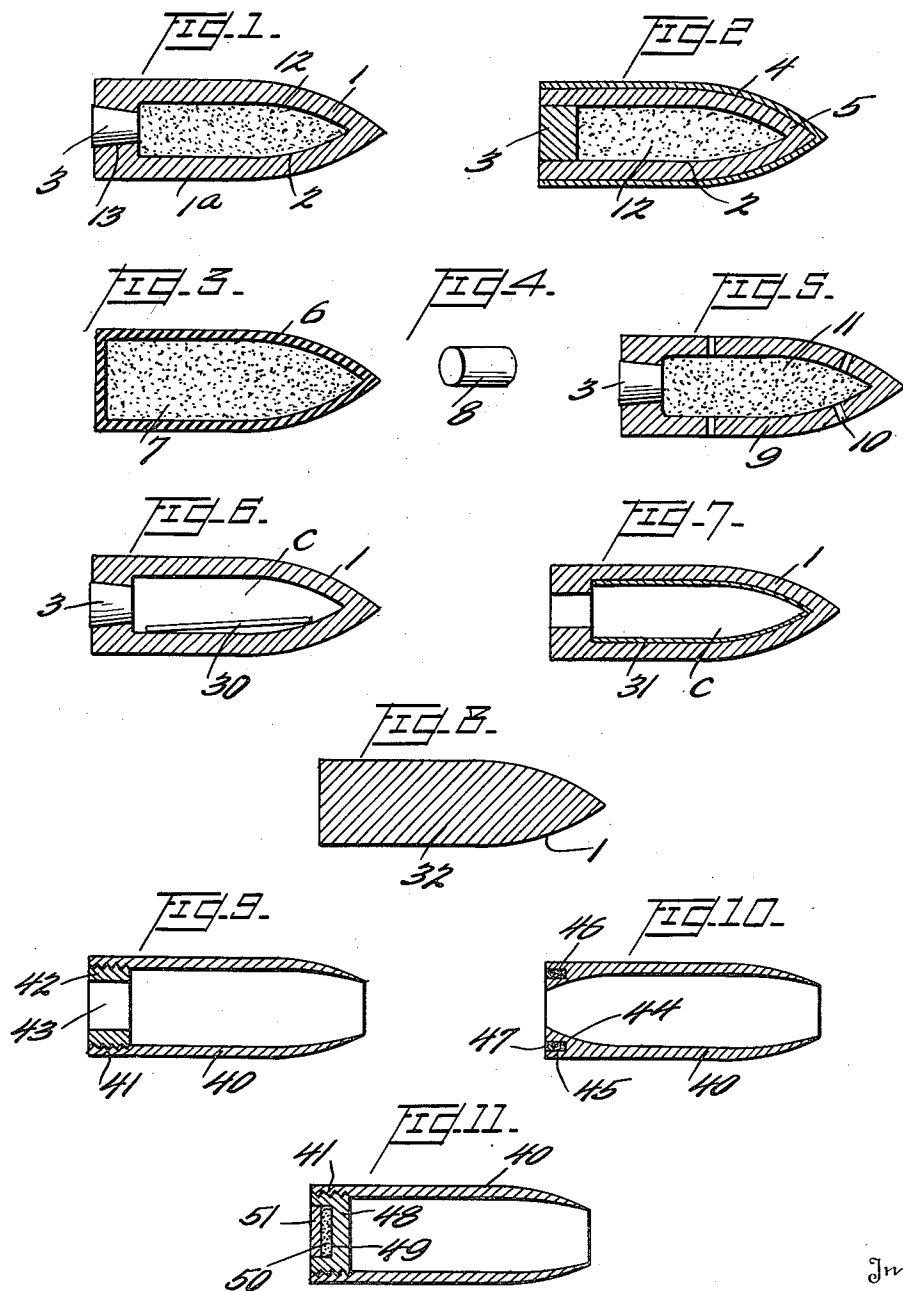
April 8, 1952

S. KRASNOW
RADIOACTIVE MARKER

2,592,434

Filed April 10, 1942

3 Sheets-Sheet 1



Inventor

Shelley Krasnow

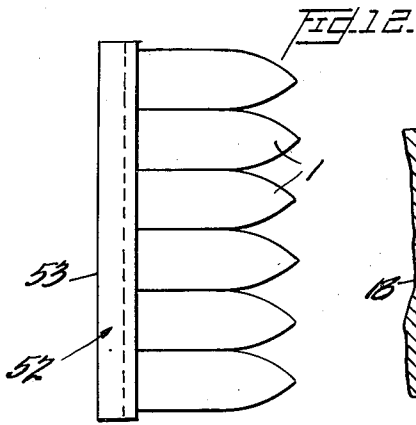
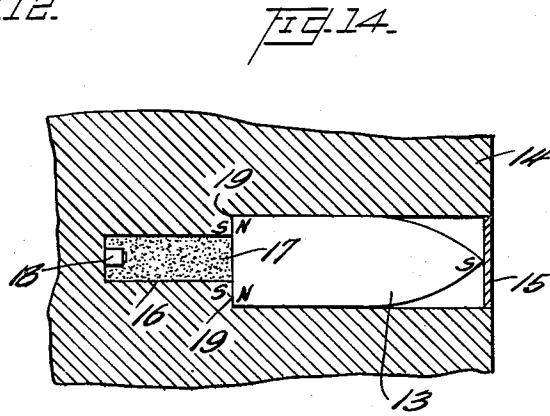
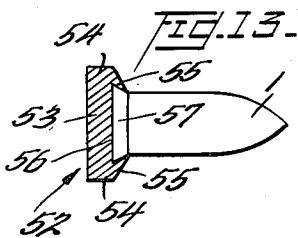
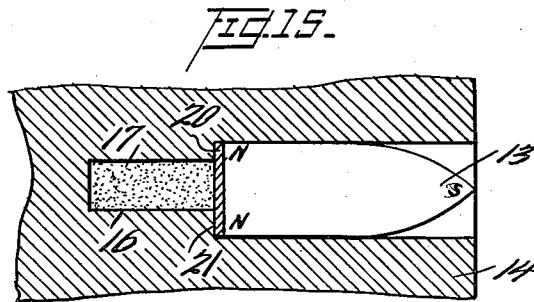
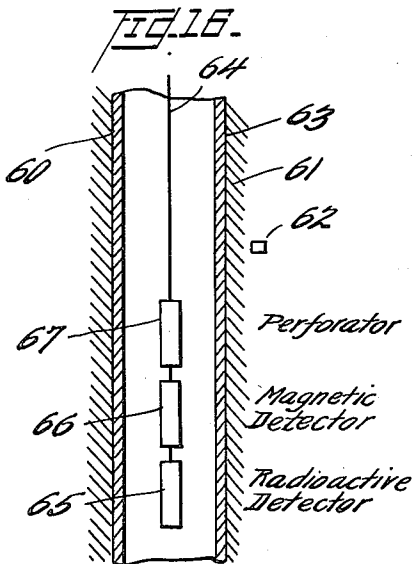
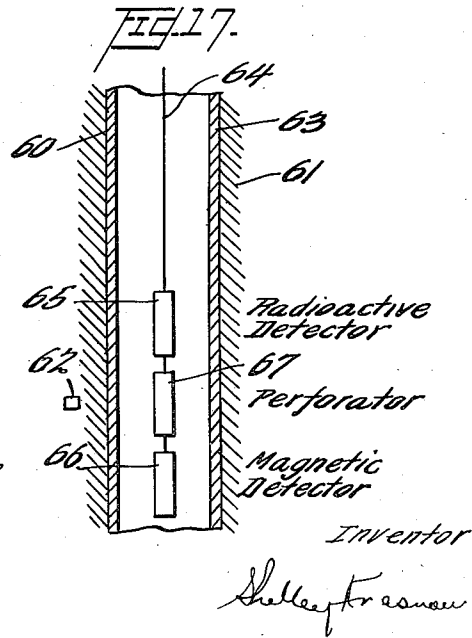
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3 Sheets-Sheet 2



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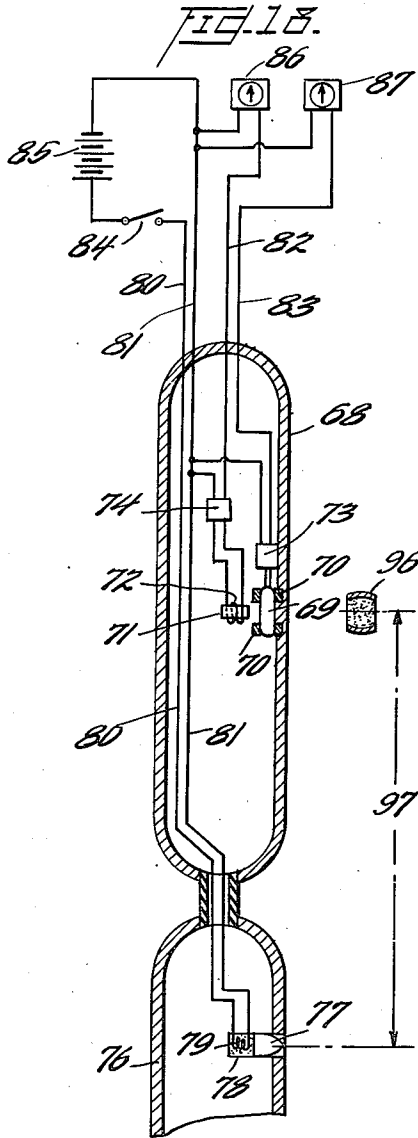
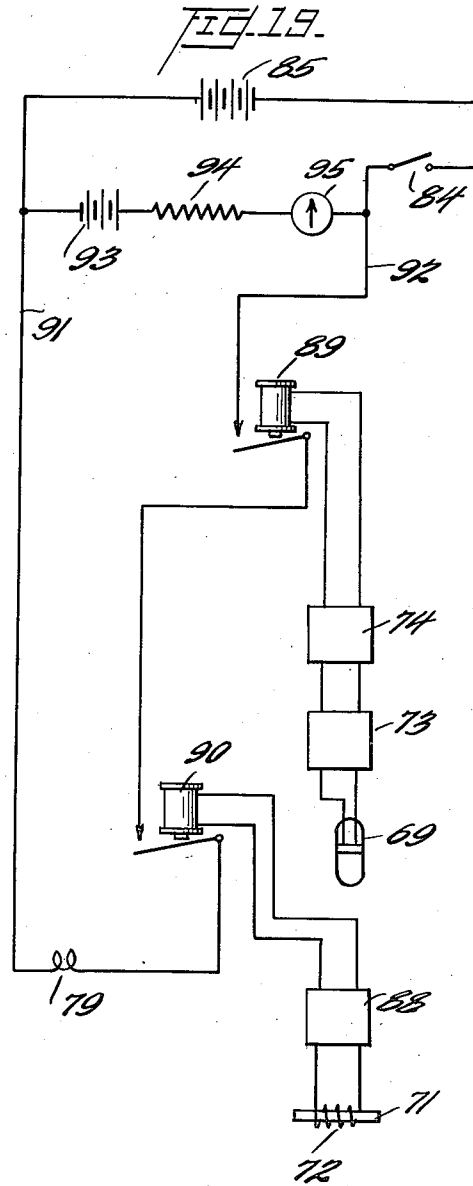
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S. KRASNOW
RADIOACTIVE MARKER

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,592,434

RADIOACTIVE MARKER

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Application April 10, 1942, Serial No. 438,475

3 Claims. (Cl. 102—92.5)

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This invention relates to radioactive markers and particularly to projectiles such as bullets exhibiting radioactive properties either as such or in conjunction with magnetic properties, to compositions useful in making or for incorporation into such projectiles, and to methods of utilizing such projectiles and compositions, specifically in marking substances, articles, objects, localities, and geological formations for subsequent location, detection, or identification.

The invention will be particularly illustrated by referring to borehole operations without any limitation since it is useful in many directions of which borehole use is exemplary. Such illustration by borehole use is particularly valuable since unique results are secured thereby.

Various objects and advantages of the invention may be referred to in this connection.

In connection with operations carried on in boreholes, it is often desirable to mark formations at a given depth within the borehole so that they may afterward be recognized and located with certainty. This is particularly desirable in view of the fact that such formations may be many thousands of feet underground and any capable or other means utilized to lower an apparatus to that point will necessarily have a variable stretch, and will introduce errors by its use.

It is desirable to have a marker which may easily be identified and located, and preferably one which can be located through thicknesses of water, mud, oil, rock and steel casing. One of the most important uses of such a marker will be in cases where it is desired to mark a formation which has been definitely located by borehole logging or geological means, and which is therefore, of a certain and definite nature.

After casing has been driven it is desirable to locate this again so that by its relation to the important strata, other operations may afterwards be conducted.

Other objects and advantages will appear from the more detailed description set forth below, it being understood, however, that this more detailed description is given by way of illustration and explanation only and not by way of limitation since various changes therein may be made by those skilled in the art without departing from the scope and spirit of the present invention.

In connection with that more detailed description, there is shown in the accompanying drawings, in

Figure 1, a cross-section through a bullet provided with radioactive material; in

Figure 2, a similar bullet, but provided with a hard exterior; in

Figure 3, a radioactive pellet with a waterproof covering; in

Figure 4, a shaped radioactive pellet for use in a bullet; in

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Figure 5, a cross-section through a radioactive bullet provided with openings to permit liquid to enter; in

Figure 6, a cross-section through a bullet carrying a radon seed; in

Figure 7, a cross-section through a bullet having a radioactive metal plating thereon; in

Figure 8, a cross-section through a bullet made from radioactive material; in

Figure 9, a cross-section through an earth core sampling bullet, provided with a radioactive insert; in

Figures 10 and 11, modifications of the bullet of Figure 9; in

Figure 12, a clip holding a number of radioactive bullets; in

Figure 13, a cross-section through Figure 12; in

Figure 14, a section through a portion of a gun perforator utilizing a magnetic bullet; in

Figure 15, a modification of Figure 14; in

Figures 16 and 17, sections through a borehole showing instruments in position therein for use in connection with borehole exploration; in

Figure 18, an apparatus for indicating a magnetic and radioactive bullet and performing perforation; and in

Figure 19, a schematic wiring diagram of an apparatus for automatic perforation.

The present invention is particularly concerned with the use of projectiles or markers to be positioned in an article, object, stratum, etc., to mark, identify, or locate such article, object, stratum, etc., with an ineradicable mark which is generally unrecognizable except by instruments constructed for use in connection therewith. The projectiles or markers used are desirably those which exhibit ray emission properties, such as radioactivity, and thus lend them properties readily identified by properly sensitive means. A number of illustrations are set forth below.

Referring now particularly to Figure 1, 1 shows a metallic bullet provided with a cavity 2. Within this cavity is a material 12, undergoing nuclear disintegration, preferably a natural radioactive, or an artificially radioactive, material. The bullet 1 may have a tapered opening 13, into which is fitted as by driving, a metallic tapered plug 3. The outer wall 1a of the bullet may be made of lead, for example, in which case it can have a wall thick enough to protect the user against the adverse effects of the rays from radioactive material.

Within the cavity 2 is placed the radioactive material 12. A suitable material will be carnottite or pitchblende or uranium or thorium ores, exhausted luminous paint or radium salts mixed with a binder or with inert material. It is desirable to use radioactive material diluted with other substances such as barium compounds. Such material is safer to use, since a small amount of it

dropping on the floor or leaking away will not cause such harmful results as would the undiluted material. The concentrated material may be utilized, however, in which case the cavity 2 may be made considerably smaller.

It is understood that rays from radioactive substances may be harmful to human beings, particularly if the bullets are held in the hands of the operator who loads them into the firing mechanism. Furthermore, the bullets might be kept in some number in a bin or container, and the combined effect of the radioactive material of many bullets might be harmful to such users. In order to avoid injury, the wall 1 may be made of an absorbing material like lead, and may be thick enough to reduce the intensity of the rays to a point sufficient to avoid injury to users, still allowing sufficient rays to be given off to permit easy identification by radioactive measuring instruments. It will be noted that particularly the soft gamma rays given off by radium are harmful to human beings, on the other hand, the hard gamma rays are the most useful for the type of measurement described.

In effect, the outer jacket of the bullet acts as a ray filter, filtering out undesired portions of the rays, and passing certain other portions. The plug 3 may be made larger in size and may be made of relatively ray-transparent material, thus allowing the exit of rays in one direction, yet shielding the person handling such bullets through the use of the wall 1. Aluminum is an example of such material.

Figure 2 shows a bullet similar to Figure 1 except that a steel jacket 4 is provided about a lead interior 5. Here again, the cavity 2 holds the radioactive material 12 and plug 3 retains it in place.

The steel jacket 4 serves a dual purpose. It prevents the bullet from spreading upon its striking an object and allows it to penetrate deeper. Thus, the bullet shown in Figure 1 may be utilized where shallow penetration is desired. Under such conditions, it may be provided with a cup nose, as is well known in the bullet making art, to cause spreading and prevent deep penetration of the bullet. On the other hand, the bullet in Figure 2 will penetrate to greater depths because of the hard outer shell. In fact, the portions 5, may be omitted altogether, making the portion 4 thicker and having the bullet of steel or other hard material alone.

Figure 3 shows a shaped pellet of radioactive material mixed with a binder and diluting material, and covered with a waterproof coating 6. Such a shaped insert may be placed conveniently within a bullet such as shown in Figures 1 or 2, and will avoid the necessity of handling loose radioactive material. The pellet may be made of barium sulphate mixed together with a small proportion of radium sulphate, as for example, 0.01% or less, a small amount of Bakelite varnish added as a binder, compressed into the form of a shaped pellet and coated with Bakelite varnish 6 after which baking may take place or combined heat and pressure utilized to form a shaped pellet. Such a pellet may be formed by the usual molding techniques, and will incorporate the radioactive material in permanent and waterproof form. Alternatively, a Bakelite resin itself in powdered form may be admixed with radium salts in powdered form, or the Bakelite material itself may be formed from components containing the desired quantities of radioactive material. In lieu of Bakelite or other phenolaldehyde plastic,

various binders may be used such as the cellulose plastics, and various resins both natural and artificial including copals, polyhydric alcohol-polybasic acid resins, urea-formaldehyde type resins, methacrylate resins, vinyl type resins, etc.

These binders may be combined with radioactive materials, such material being bound either chemically as part of the binder molecule, or in intimate mixture or solution or colloidal dispersion in the substance of the binder. Naturally radioactive materials such as thorium, radium, uranium, etc. may be so combined. Or the binder may be formed of a substance with a radioactive isotope combined either chemically as part of the binder molecule, or in solution, colloidal dispersion or intimate mixture. The material may be first activated to form a radioactive isotope and then combined as taught herein. Alternatively, the activation may take place after the formation of the compound or mixture. If the proper elements are present in the binder, the material may be thus activated and will exhibit radioactive properties for a long enough time to permit placing and subsequent detection. Examples of substances which may be thus combined are sulphur, phosphorus, chlorine, bromine, or arsenic. Other substances such as nickel or yttrium may be combined and serve as suitable sources after activation. Thus, instead of producing the binder from a compound containing a radioactive isotope, the desired composition may be made up and then bombarded with neutrons to induce radioactivity; or a cyclotron may be used to produce ray emission properties. Any such radioactive material may be used in accordance with the present invention.

Such a pellet is also useful for other purposes, as for medical treatment, since it may be placed directly in contact with human tissue, and temporarily fastened in position with adhesive tape or similar material. Being made of waterproof material and being a plastic, it may be washed and sterilized repeatedly. There is no danger of loss of radioactive material as would be the case if a hollow container holding the concentrated material were utilized.

Figure 4 shows a similar pellet made in cylindrical form. This may be formed with any of the binders mentioned previously, or may have some simple binder such as starch or gum arabic. The pellet may be molded in the type of apparatus commonly used by pharmacists for molding pills or tablets. In cases where it is desired to mark with radioactive material, and not to use a metallic projectile, a pellet such as shown in Figure 4 may be utilized, made up of explosive material with radioactive substances intermixed. This may be exploded within the borehole and will spatter the walls of the borehole with radioactive material. This procedure will be useful, for example, where continued erosion or breaking away is suspected. Successive radioactive measurements will indicate whether the material is being eroded, since in such cases the radioactivity will continually diminish more rapidly than would be the case in the absence of erosion.

In the above examples, the radioactive material has been indicated as provided with a waterproof outer covering. This is desirable since corrosive waters in a formation may corrode a steel bullet, for example, leaving the radioactive pellet exposed. If there is any movement of water, there will be a continued solvent action which will spread the radioactive

material through a large volume and make impossible obtaining a sharp indication of the position of the marker.

In other cases, however, advantage may be taken of such action to indicate the presence or absence of water or the movement of such water. A bullet as shown in Figure 5 may be constructed similarly to that shown in Figure 1, but with openings 10 passing entirely through the walls of the bullet 9, and permitting free access to the interior 11. Such a bullet after being fired will be subject to the action of water, and by making the contents easily soluble, the strength of the bullet will diminish with time if waters are present. An immediate spread of radioactivity will be manifested if radium is utilized and oil is present, since the oil will quickly absorb the radon gas given off by the radium. Thus, by the action of the material of the bullet, deductions can be drawn as to the chemical or physical nature thereof.

In another form of bullet as illustrated in Figure 6, the bullet 1 may contain the cavity C closed by plug 3. The radioactive material may be in the form of a pellet 30 as set forth above, or may be a radon seed or any sealed, thin, metallic tube containing radon gas or other radioactive material.

Another modification is illustrated in Figure 7, wherein the bullet carries a plating of a radioactive metal or alloy. As shown, the bullet 1 having cavity C, has the walls of the latter provided with a radioactive coating 31. Such coating may be, for example, an electrically deposited layer of a radioactive material such as radium "C" or a thin deposit of other radioactive material such as polonium.

Os as shown in Figure 8 the bullet 1 may be made of a radioactive metal or alloy 32. Thus the metal may itself be radioactive or radioactive material may be dispersed in the metal. Radioactive alloys are available and may be used. The radioactive alloying element is desirably one which either itself gives off rays, or induces rays, such as gamma rays, in other substances, with sufficient intensity for present purposes. Radioactive metals from the radium, actinium, and thorium families may be used such as radium, polonium, thorium B, ionium, and uranium II. Such metals may be used as the coating in Figure 7 or may be applied as an external coating as on the bullet of Figure 8. Or the bullet of Figure 8 may be made wholly or in part from the still radioactive residues remaining after the extraction of radium from its ores.

The radioactive material mentioned above may be any one of the naturally radioactive materials or may be a substance which has been artificially activated. Thus, as mentioned previously, oil, sand with oil, which has in turn been subjected to radon gas will be radioactive and serve, or materials artificially activated by nuclear bombardment may be utilized. Thus, a considerable number of the ordinarily non-radioactive elements may be utilized, the particular one selected being dependent upon the length of time it is desired to have the bullet identifiable by radio active means. Thus, yttrium will maintain an artificially excited radioactivity for several months, while other substances will maintain such radioactivity for a relatively short time. Sulphur is an example of such a substance. Alternatively, the filling material in Figures 1-5, inclusive, may be of material such as yttrium or sulphur, or the bodies of the projectiles them-

selves may be of material which will respond readily to artificial activating processes. In appropriate cases, the bullet will be fired, an instrument sent down to activate the bullet, and subsequent radioactive measurements made to determine the exact locality. Several different types of material may be utilized for the bullets or the fillings therein in a single borehole, each one marking a separate type of condition. They can then be artificially activated and subsequent measurements will show the different properties of each. The artificial activation mentioned may be caused by bombardment with neutrons and a convenient way of effecting this is to have a substance such as beryllium which gives off neutrons readily on bombardment by radioactive rays intermixed with the material in the bullet. By lowering a radioactive source proximate to the bullet, the rays will excite neutrons in the beryllium, which neutrons will impinge upon the material within the bullet, causing artificial temporary radioactivity therein.

In marking strata in one borehole, bullets having different natural radioactive material incorporated therein may be utilized, each type of material being used to identify a particular condition. Thus, bullets with radium compounds can be used to mark oil layers; while those with thorium compounds can be used to identify water layers. Similarly, certain bullets might have short-life radioactive compounds such as radon; while others might have radium itself. The former bullet would show a rather rapid decrease in radioactive intensity, while the latter would remain practically unchanged over the period of time normally of interest in this type of work. It is well known that different radioactive compounds give off rays of different hardness, and the distribution of intensity in the gamma-ray spectrum is different. This makes possible the differentiation of the different materials by use of filters similar to those described in copending application of Krasnow and Curtiss, Serial No. 301,078.

Figures 9-11 illustrate the adaptation of earth core type bullets to the present invention in which such bullets as ordinarily employed in sampling guns, are given radioactive properties. For example, as shown in Figure 9, the usual type of such bullet illustrated at 40 may have one end thereof internally threaded 41, and a radioactive collar 42 externally threaded, may be positioned in the bullet 40. Such radioactive collar 42 may be radioactive in any way utilizing any of the expedients set forth above. By the use of a collar 42, having the opening 43, the bullet offers less resistance to penetration.

Or, the walls of the bullet may be of greater thickness as shown at 44 in Figure 10, so that a recess 45 may be made therein into which radioactive material 46 may be inserted, and such recess then sealed by a seal 47. Any radioactive material may be used as explained above.

Or, as shown in Figure 11, the ordinary bullet 40, may have one end threaded internally, as at 41, into which a plug 48 is threaded. Such plug may be provided with a recess 49 into which radioactive material 50 either in loose or pellet form may be placed, and a seal 51 then positioned to hold the radioactive material in place.

It is apparent from what has been set forth above, that the projectile or bullet may take any desired form and may be given radioactive properties in a variety of ways. It has been pointed

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out above, that the bullets may be constructed in order to limit the path of emitted rays or to absorb dangerous rays. Another expedient that can be used for this purpose is to mount the radioactive bullets in a clip or container to hold any desired number of them, and to avoid the possibility of injury from handling them.

For example, as shown in Figures 12 and 13, a clip 52 in the form of an elongated channeled member may have a back 53 provided with side walls 54, 54 having in-turned ends 55, 55 forming a channel 56 for reception of a series of bullets 1, 1. The bullets may have a groove 57 into which the edges 55, 55 of the side walls 54, 54 fit the parts being of such size as to hold the bullets frictionally in the clip. A leaf spring can be used if desired to increase such frictional contact. Now if the bullets have lead walls sufficiently heavy to absorb rays, and the clip 51 is also of heavy ray absorbing metal such as lead, the clips can be handled free from any possible danger, and a clip used to load a gun perforator as desired. When such clips are used, all or only a few of the bullets may be radioactive, where in the latter case it is not intended to make each bullet a radioactive marker.

An important feature of the present invention resides in the use of a projectile or bullet which possesses both radioactive and magnetic properties. This usage has great advantages. Other radioactive layers may occur naturally within the borehole and similarly other magnetic effects may be apparent aside from the effect produced by the bullet. Thus, if casing is driven after the bullet has penetrated, it is entirely possible that such casing will have magnetized spots. By the use of a single unit, having both magnetic and radioactive properties a dual indication is possible. The probability of obtaining such a dual indication by accident where the bullet does not exist is so small that it may be dismissed altogether.

In the case of the bullet shown in Figure 1 or Figure 2, the radioactive material may be mixed with the oxide powders commonly used in making permanent magnet material. This may be magnetized after the material has been incorporated in the bullet. In this way, a bullet as shown in Figure 1 may be made simultaneously radioactive and magnetic.

In the case of the combined magnetic and radioactive bullet, oxide material has been mentioned as a suitable permanent magnet material. "Alnico" in particles which may be small or large compared to the size of the radioactive material particles, may also be utilized as a filling material, or the outer jacket of the bullet such as 4 or the inner jacket such as 5 in Figure 2 may be made of "Alnico." Alternatively, the outer jacket 4 or the inner jacket 5 can be made of cobalt magnet steel, tungsten magnet steel or chromium magnet steel. Thus the bullet may be made of a magnetic material having a cavity to contain the radioactive composition, pellet, or seed; or the bullet may contain magnetic and radioactive compositions in the cavity; or a radioactive and magnetic metal plug or collar may be applied to a bullet; or any other expedient used. Where magnetic metals or alloys, etc. are used in the bullet structure, they may be subjected to treatment as by neutrons to induce artificial radioactivity. A variety of expedients are thus available in producing projectiles or markers having both radioactive and magnetic

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properties. And they lend themselves to many different usages.

Figures 14 and 15 show the use of a magnetized bullet in order to retain the bullet in position in the perforating gun. Here 13 is a magnetized bullet with polarity as indicated; 14 is the body of the gun, the portion shown serving as the barrel; 15 is a liquid-tight closure over the bullet; 16 a cavity holding explosive material; 17 the explosive material; 18 the firing means; and 19 a circumferential shoulder serving to maintain the bullet magnetically. The closure 15 may be omitted in cases where provision is made to keep the explosive from being injured by the fluid in the well.

In Figure 15, a disk 20 is driven into the body of the barrel 14 and rests against a shoulder 21. This disk is of magnetic material or is magnetized so as to retain the magnetized bullet 13 by its magnetic attraction by the disk. The disk is driven into place so as to be liquid-tight and the bullet may be easily placed afterward. The magnetized bullets shown in Figures 14 and 15 are most desirably those having radioactive properties as set forth above; but magnetic bullets alone may be used for certain purposes.

In utilizing any of the bullets of the present invention in geological exploration, these bullets may be placed in the usual types of gun perforators and shot into the formation at the desired point. Subsequently their location may be determined either before or after casing has been set. The radioactive bullets are particularly valuable for this purpose, and may be located by any means and methods used for gamma-ray logging, as for example, by the means and methods of the application of Krasnow and Curtiss, Serial No. 137,380, filed April 16, 1937, entitled Method and Apparatus for Measuring Radioactivity. Where magnetic bullets are employed, they may be located by any desired means; as for example, by that disclosed in the U. S. patent to Ennis, No. 2,228,623.

Where bullets are used that exhibit both radioactive and magnetic properties, combinations of the means and methods referred to above may be utilized, thus giving insurance against chance radioactivity or magnetism. Systems for this purpose are illustrated in Figures 16 and 17 showing the use of combinations of radioactive and magnetic detectors and perforators. As shown in Figure 16, a borehole 60 in the stratum 61 has been marked by a radioactive and magnetic bullet 62, and casing 63 has been set. The necessary instruments suspended on cable 64 are lowered into the borehole, depth measurements being made if desired. The instruments are mounted as shown for exemplary purposes, with the radioactive detector 65, magnetic detector 66 and gun perforator 67 in that order. As the radioactive detector passes the location of the bullet, a responsive is sent up the cable 64 to the above-surface instruments. Further movement of the instruments brings the magnetic detector into position to respond to the bullet and here again a response is transmitted to the above-ground apparatus. The operator is then in a position to operate the gun perforator whose position has been defined through the use of both magnetic and radioactive detection. The point of maximum response of the detectors insures proper perforation.

Or as shown in Figure 17, the perforator 67 may be placed intermediate the radioactive detector 65 and the magnetic detector 66.

While Figures 16 and 17 show the use of gun perforators, this is merely illustrative since the radioactive and magnetic detectors may be used to locate the bullet for carrying out any mechanical operation desired at that location. Among such operations there may be mentioned: The locating of apparatus for cementing, the indication of the proper point for operating a whipstock, the start of reaming operations, etc.

Further, all of the desired instruments may be placed in a single container in lieu of separate containers as shown and in this event simultaneous radioactive and magnetic detection carried out. The type of cable employed can be varied to use multiconductor cables of any preferred type. By the use of different frequencies for transmitting the radioactive responses and magnetic indications, the same conductors may be used for both, filtering systems at the surface segregating the responses. The latter may be recorded if desired, as shown in Serial No. 137,380 referred to above.

These systems lend themselves to a variety of adaptations. Since electrical systems are desirably used to transmit the radioactive and magnetic responses, as well as to operate the gun perforator, operation of the latter may be effected automatically by either the radioactive system, or the magnetic system, or by both working simultaneously. For such purposes it is only necessary to connect the radioactive operated circuit to the gun perforator circuit so that the latter is operated when the former responds to a certain minimum radioactive indication. Similarly the magnetic operated circuit may be employed to bring the gun perforator into operation when the magnetic response has exceeded a certain value. More desirably the radioactive controlled circuit and magnetic operated circuit are connected so that they act in series to actuate the gun perforator, responses exceeding a predetermined minimum value from both circuits being necessary to actuate the perforator. This insures against haphazard perforation due to sporadic radioactivity or magnetic disturbance not acting conjointly.

Figure 18 shows an apparatus for location of a radioactive and magnetic marker, and for performing perforation in accordance with the indications obtained from such a marker. A cartridge 68, which is preferably metallic and of non-magnetic material such as brass, Monel metal, or non-magnetic stainless steel, houses a radioactive-sensitive detector such as 69, preferably surrounded by absorbing circumferential shields 70, preferably made of lead. These shields sharpen the indication obtained from the radioactive marker. The radioactive detector is connected to an auxiliary circuit and amplifier shown schematically at 73. This employs apparatus of the type shown in copending application Serial No. 301,078, referred to above, and the responses from such an amplifier and auxiliary circuit are conveyed to the surface of the earth through the intermediacy of common lead 81, and lead 83, both of which feed into an indicating or recording apparatus shown schematically as 87. Preferably at the same level as the radioactive detector, is mounted an iron core 71, surrounded by a coil 72. This will respond to the magnetic material of the bullet such as 96, and the responses caused in the coil 72 thereby will be amplified in amplifier 74, and the amplified responses will be conducted through common lead 81 and lead 82 to indicating instrument

86. The amplifier 74 may be any of a number of familiar and well recognized types available in the art to amplify the pulse produced in coil 72 by its passage in the vicinity of magnetic bullet 96. Leads 80 and 81 pass entirely through cartridge 68, through a rubber bushing 75 connecting cartridge 68 with cartridge 76, and thence to a coil of fine wire 79, adapted to heat and fire an explosive charge 78, thereby driving a perforating bullet 77 through casing.

Battery 85 is connected to the coil 79 by means of switch 84 which is actuated manually when indications are obtained on indicators 86 and 87. The distance between the bullet 96 and the proper point of perforation is indicated as 97, and is predetermined in accordance with the distance between the original indicating instrument discovering the point at which perforation is to be made and the point where the marker 96 is placed.

Figure 19 shows an apparatus employing a simplified circuit, and one which may be operated either manually or automatically. This employs a radioactive detector 69 connected to an auxiliary circuit and amplifier indicated schematically as 73. An additional component 74, similar to that described in copending application, Serial No. 413,241, now Patent No. 2,434,297, issued Jan. 13, 1948, of Test and Krasnow, serves to actuate a relay coil when the radioactivity as indicated by detector 69 equals or exceeds a predetermined value. This value is chosen so as to be above the radioactivity normally encountered in geological formations, since a radioactive bullet such as 96 will have an activity higher than any which will be met in the borehole. Upon an indication of a strong radioactivity, relay coil 89 will be operated, closing the relay contacts associated with the coil. The relay can be constructed either so that it will open once the indication disappears, or remain latched once it has been actuated.

The iron core 71 surrounded by coil 72 will receive an indication of a magnetic object. This will be amplified by amplifier 88, feeding into relay coil 90. When a strongly magnetic object is passed, relay coil 90 will cause the associated contacts to close. This relay may also be made a latching type so that once closed it will remain closed until released by manual or other means. The closing of the two relays will close the circuit composed of conductors 91 and 92 and coil 79 serving to fire the charge behind the bullet. Battery 93, high resistance 94, and milliammeter 95 are provided for indicating purposes. The voltage of battery 93 and the resistance of resistor 94 are so proportioned that upon closure of the circuit in the manner described, the current flowing therethrough will be insufficient to heat coil 79 sufficiently to fire the bullet. However, the current flowing will be sufficient to give an indication on milliammeter 95, so that the operator at the surface of the ground will know that both relays are closed. He can then close switch 84, which will connect battery 85 in circuit, supplying sufficient current to coil 79 to cause firing of the bullet. If key 84 is kept closed throughout the entire operation, then it is seen that the bullet will be fired automatically as soon as the apparatus has passed a radioactive and magnetic marker. A preferred method of using the apparatus is to keep switch 84 open until the apparatus has been lowered to within about 20 feet of the point where perforation is to take place. The switch 84 is then closed, and the

entire apparatus lowered very slowly until firing actually takes place. This procedure will insure that accidental firing will not for any reason take place during the rapid lowering of the apparatus. Instead of having the two relays 89 and 90 in series in the circuit, one relay can be made the enabling relay for the other, as is common in the telephone art. With the circuit as described, it is seen that it is not absolutely necessary to have the radioactive indication and the magnetic indication received simultaneously, if the relays are of the latching type. Thus, if the detector 69 and coil 72 are at different levels, indications therefrom will occur at different times. This will not be disadvantageous as long as the relay is of the latching type.

Although the use of an explosive has been specifically described, it will be appreciated that this is merely a means of obtaining a high gas pressure to drive the bullet into the formation. The use of gas pressure from a tank, the use of a retracted spring which is released, or any of the other expedients commonly known to the art for driving a projectile may be utilized.

The methods described, while most useful for operations in a borehole, may also serve to mark localities under other conditions. Thus, monuments or bench marks are often placed to locate boundary marks and property lines. Such monuments often become covered over with vegetation and sometimes with wind-blown or drifted earth. If a small amount of radioactive material is placed within the monument, it can be found readily by radioactive means. Furthermore, for instance a piece of lumber may be marked with an invisible identifying mark by placing radioactive material thereon either by painting one spot with radioactive solution or by inserting a thin needle with radioactive material contained therein or shooting a bullet into it. This piece of lumber may then be identified in the future, the identifying mark being invisible and not detectable to persons not utilizing radioactive measuring means.

It will be seen that among the advantages obtained by the present invention are those relating to the simultaneous use of more than one physical quantity to determine the point at which perforation is to take place. By the use of two quantities, the accidental obtaining of a false indication is eliminated practically entirely. The two physical quantities mentioned have been selected as being readily usable and readily measurable. However, other physical quantities may be utilized, such as temperature, sound properties, mechanical vibration properties, etc. In each case, markers having pronounced physical properties of the type desired are selected, and are selected to give plural indications. The corresponding instrument responsive to the plural indications is then utilized in determining the point at which perforation is to take place.

In the foregoing, specific mention has been made of a projectile which is driven into the walls of the borehole by explosion or other driving force. After being driven into the walls of the borehole, the projectile and its contents remain intact. However, it will be understood that the bullet may be constructed so that it will shatter upon coming in contact with a formation, and will spread its contents. Thus, the bullet may have within it an explosive charge mixed with radioactive material, which will explode when the bullet comes in contact with the wall of the borehole, and will scatter the radioactive material in the vicinity. In firing, the bullet may

be omitted entirely and a charge of explosive and radioactive material fired against the wall of the borehole. This will spatter the wall of the borehole with the radioactive material, without actually having a single solid projectile embed itself.

Having thus set forth my invention, I claim:

1. A projectile adapted to be fired into and to become lodged in a material so as to permit the subsequent detection thereof comprising a permanently magnetized portion, and a portion containing radioactive material, the magnetized portion serving at least in part as a support and enclosure for the radioactive material, thereby providing a projectile whose presence may be detected both by magnetic and by radioactive means.

2. A projectile adapted to be fired into material to permit subsequent identification thereof, said projectile being of radioactive ray adsorbing character so as to restrict the exit of radioactive rays from the radioactive substance contained therein, further having a portion formed in the said projectile to facilitate the exit of radioactive rays, the said portion having the material and thickness thereof proportioned so as to be substantially more transparent to radioactive rays emitted by the radioactive substance contained therein than the material of the said projectile, the said projectile further comprising a shaped member having a rigid nose tapering continuously down to a point to enable ready penetration of the said material, the said nose being of mechanically resistant character so as to remain intact after it has been fired and has been received by the said material, a radioactive substance permanently contained within the said projectile so as to remain therein after the said projectile has been fired and after the said projectile has been received by the said material, whereby a concentrated source of radioactive rays will be provided within the said material receiving the projectile so as to permit subsequent ready location thereof.

3. A projectile adapted to be fired into material to permit subsequent identification thereof comprising a shaped member having a pointed nose to enable ready penetration of the said material, a cavity within the member, a radioactive material placed within the said cavity permanently, and means to close the cavity to restrict the movement of radioactive material from the said cavity after the projectile has been fired into said material, the material of the projectile being of such nature as to restrict the exit of radioactive rays, further having a portion formed in the rear portion thereof, to facilitate the exit of radioactive rays.

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