July 8, 1958 D. SILVERMAN 2,842,678

SHIELDING IN IRRADIATION WELL LOGGING

Filed Sept. 10, 1953 4 Sheets-Sheet 1

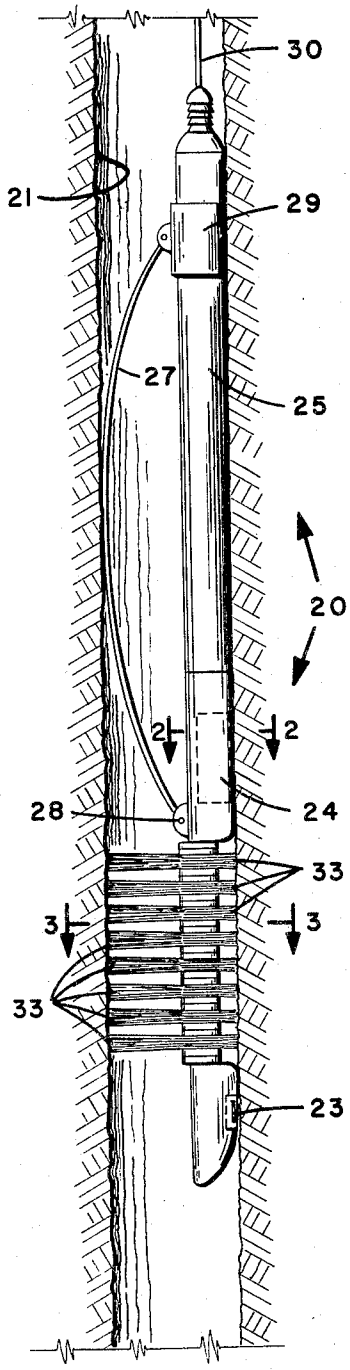


FIG. 1

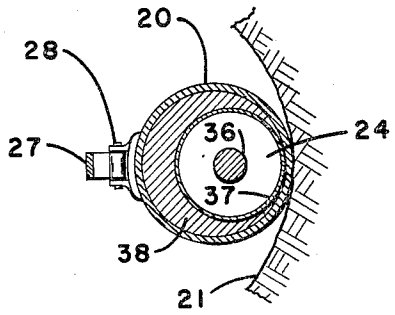


FIG. 2

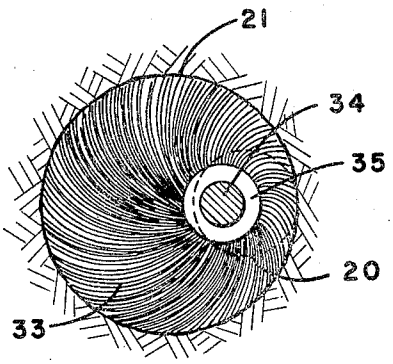


FIG. 3

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July 8, 1958 D. SILVERMAN 2,842,678

SHIELDING IN IRRADIATION WELL LOGGING

Filed Sept. 10, 1953 4 Sheets-Sheet 2

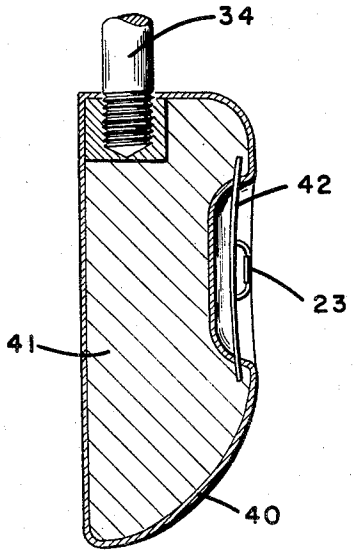


FIG. 4

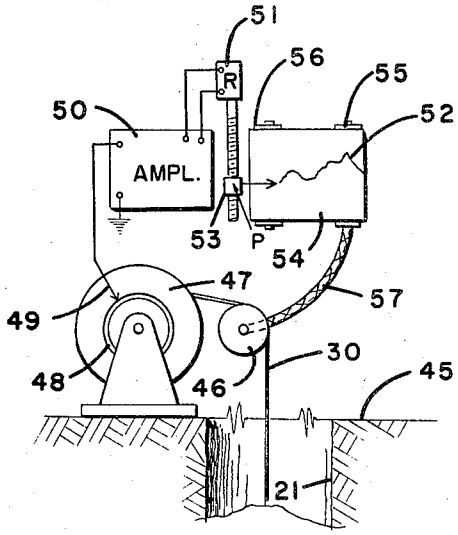


FIG. 5

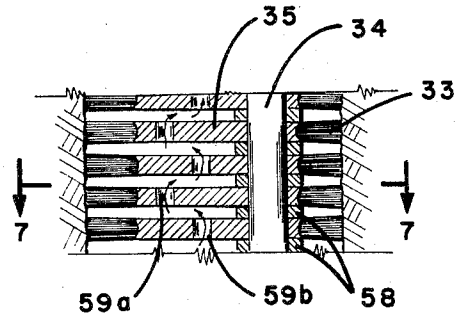


FIG. 6

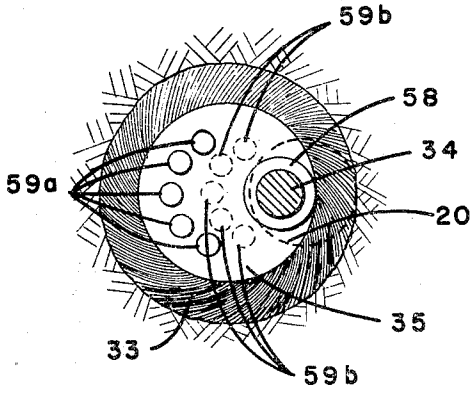


FIG. 7

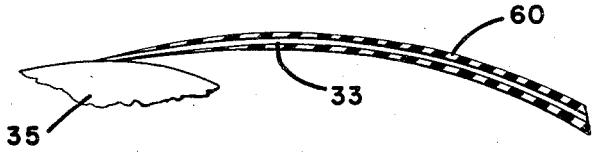


FIG. 8

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July 8, 1958 D. SILVERMAN 2,842,678

SHIELDING IN IRRADIATION WELL LOGGING

Filed Sept. 10, 1953 4 Sheets-Sheet 3

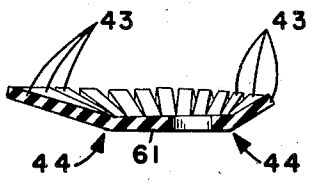


FIG. 11

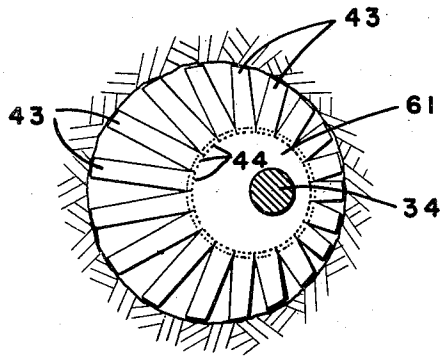


FIG. 10

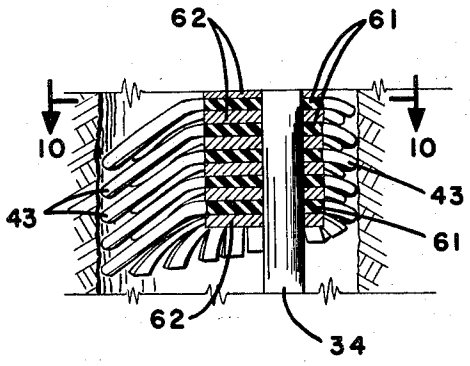


FIG. 9

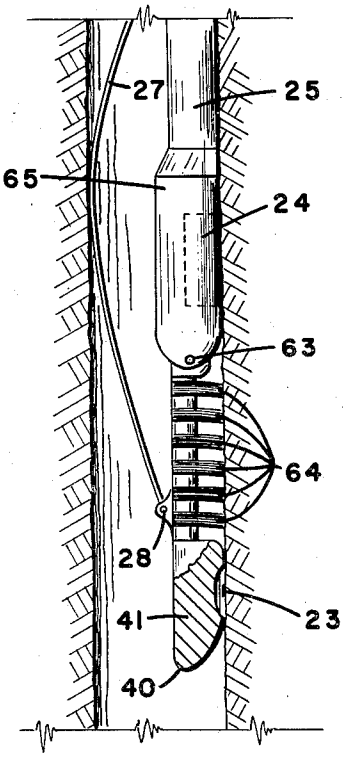


FIG. 12

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July 8, 1958 D. SILVERMAN 2,842,678

SHIELDING IN IRRADIATION WELL LOGGING

Filed Sept. 10, 1953 4 Sheets-Sheet 4

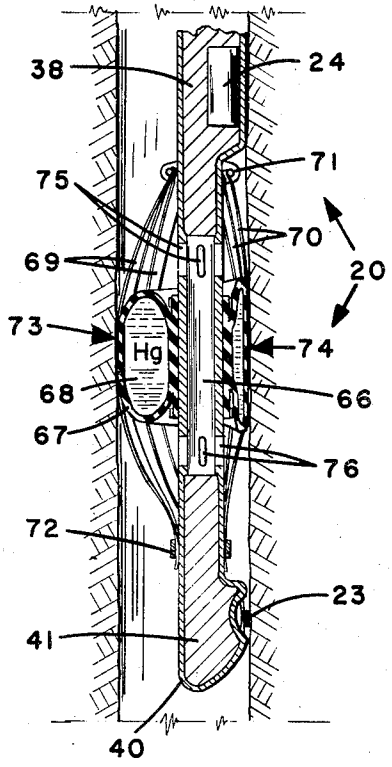


FIG. 13

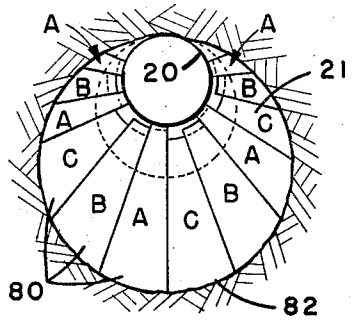


FIG. 15

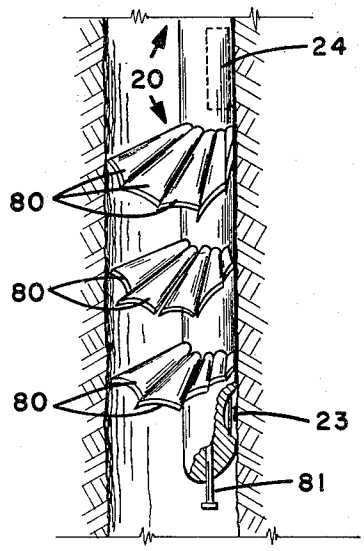


FIG. 14

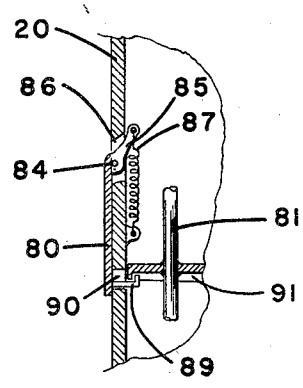


FIG. 16

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United States Patent Office 2,842,678 Patented July 8, 1958

2,842,678

SHIELDING IN IRRADIATION WELL LOGGING

Daniel Silverman, Tulsa, Okla., assignor to Pan American Petroleum Corporation, a corporation of Delaware

Application September 10, 1953, Serial No. 379,414

8 Claims. (Cl. 250—108)

This invention relates to the logging of well formations by irradiating them with a source of penetrating radiations or particles and detecting, at a distance from the source of irradiation, the resulting radiations or particles after travel through a substantialy thickness of the formation. More specifically, the invention is directed to an improved method and apparatus for logging the density of well formations by the absorption and scattering of gamma rays from a concentrated source thereof.

A substantial degree of success has now been attained in logging well-formation densities by the absorption and scattering of gamma rays, and neutron well logging has now been commercially practiced for a number of years. A major difficulty with both types of logging, however, which has only recently been generally recognized for neutron logging, is the variation in detector response due to variations in the bore-hole diameter. This is particularly noticeable in gamma-ray absorption logging where knowledge of or some correction or compensation for bore-hole diameter variations is absolutely essential to prevent misleading errors in determining formation densities. The diameter-variation effect is further accentuated by sensitivity of the logging device to roughness of the bore-hole walls or to abrupt changes in the diameter. Furthermore, gamma-ray absorption logging measurements are also sensitive to the density of the fluids in the well bore, which density has no significance in determining formation density.

It is accordingly a primary object of my invention to provide an improved method and apparatus for reducing or substantially eliminating the effect of bore-hole diameter variations in irradiation well logging. Another object of the invention is to provide a method and apparatus to reduce the adverse effects of bore-hole diameter variations and/or wall roughness on the gamma-ray absorption logging measurements. A further object is to provide a method and apparatus to reduce the influence of varying density of the bore-hole fluids on the log of formation density. A still further object is to provide a method and apparatus substantially eliminating the need for measuring variations in bore-hole diameter to correct for their effect. Other objects, uses, and advantages of the invention will become apparent as the description proceeds.

Briefly stated, the essence of my invention by which the foregoing and other objects are accomplished comprises an arrangement of shielding material around and between the source and the detector of a logging instrument, which arrangement is particularly adapted to prevent the gamma rays traveling along the bore hole from reaching the detector. Specifically, I have found that flexible shielding material, which is placed at an intermediate position between the source and detector and is capable of remaining close to or in contact with the well formations regardless of changes in the well-well-bore diameter, particularly on the side of the instrument which is pressed against these formations, and especially when used in cooperation with certain fixed

shielding at the source and detector, is highly effective to reduce or even substantially eliminate response variacontact between the irradiation source and the formations

Furthermore, with this shielding, the need for tight contact between the irradiation source and the formation and between the detector and the formations is greatly reduced. It is not completely eliminated, however, as any well fluids interposed between the source or the detector and the well wall act as absorbing media in the path of the significant gamma rays which travel chiefly through the formations.

This will be better understood by reference to the accompanying drawings forming a part of this application and illustrating certain embodiments and modifications of my invention. In these drawings:

Figure 1 is a cross-section of a portion of a well bore and an elevation view of an embodiment of the invention in logging position therein;

Figure 2 is an enlarged cross-section of the instrument of Figure 1 along the line 2—2;

Figure 3 is an enlarged cross-section of the well bore and instrument of Figure 1 along the line 3—3;

Figure 4 is an enlarged cross-section view of a preferred mounting for the irradiation source;

Figure 5 is a diagrammatic view of surface recording equipment used with the instrument shown in Figure 1;

Figure 6 is an enlarged cross-section of a well bore and of a modification of the shield members of Figures 1 and 3;

Figure 7 is a cross-section of Figure 6 along the line 7—7;

Figure 8 is a detail view of an individual shielding wire;

Figure 9 is a cross-section view, similar to Figure 6, of a further embodiment of the invention;

Figure 10 is a cross-section of Figure 9 along the line 10—10;

Figure 11 is a cross-section view of one of the flexible shield units of Figure 9;

Figure 12 is a view similar to Figure 1 showing an alternative embodiment of the invention;

Figure 13 is a view similar to Figure 1 but showing, in cross-section, an instrument embodying a further modification of the invention;

Figure 14 is a view similar to Figure 1 of a still further embodiment of the invention;

Figure 15 is a plan view of the shielding elements of Figure 14; and

Figure 16 is a cross-section view of a portion of an instrument body showing the means of mounting and operating the shielding elements of Figures 14 and 15.

Referring now to these drawings in detail and particularly to Figure 1 thereof, a logging instrument **20** is shown in measuring position in a well bore **21**, shown in cross-section, the instrument **20** comprising generally an elongated cylindrical housing. At the lower end of instrument **20** is a gamma-ray source **23** substantially in contact with the wall of well **21**, and at a spacing of the order of fifteen to thirty inches above source **23** is a detector **24**. Source **23** is a capsule or pellet of radioactive material emitting high-energy gamma rays, such as radium, in the amount of about 100 to 500 milligrams, and its equilibrium products, or radioactive cobalt or the like emitting approximately equivalent gamma radiations. Within the upper portion **25** of instrument housing **20** are located the amplifier, power supply, and other equipment necessary to amplify and transmit signals from detector **24** to a recorder at the ground surface.

Instrument **20** is held against one side of the well **21** by an elongated bow spring **27**, the lower end of which is

attached by a pivot 28 just below detector 24 and the upper end of which is attached to a sliding collar 29 partially encircling the upper portion 25 of instrument 20. The instrument is moved through the well bore 21 by the suspending cable 30 containing an insulated conductor by which signals are transmitted to the surface for recording.

In well bores with smooth walls and uniform diameter, the instrument thus far described is well adapted to make density logs by the gamma rays from source 23 which pass through the formations outside of well bore 21 and return to detector 24. It is found, however, that a major portion of the response of detector 24 is to radiation which travels within the well bore 21. This is accentuated particularly if the bore-hole walls are rough, or if poor contact is maintained between the source 23 and/or the detector 24 on the one hand and the wall 21 on the other. In accordance with my invention, the radiation traversing the bore hole is substantially reduced or eliminated by interposing, at an intermediate position between source 23 and detector 24, a plurality of flexible shielding elements 33 capable of substantially attenuating the well-bore radiations. These shielding elements 33 are not only flexible so as to enter the minor wall depressions constituting the wall "roughness," but preferably are also of variable diameter so that, as the well-bore diameter changes, contact between the shielding material 33 and the well wall is maintained. As long as the shielding of elements 33 remains effective, the adverse effects of the source 23 or detector 24 moving away from wall 21 are very markedly reduced.

The exact positioning of the group of elements 33 between the source 23 and detector 24—that is, exactly midway between them, or substantially closer to one than to the other—is not at all critical, being of much less importance than the attribute of flexibility so as to extend nearly completely across the bore hole, or at least to maintain contact with the well wall on a line between the points where the wall is contacted by the source 23 and the detector 24. The term "intermediate position" used herein accordingly means anywhere within a major portion of the space interval between the source and detector.

These elements 33 may be constructed as shown more clearly in Figure 3, as wire brush-like elements extending generally outwardly from a hub 35, but preferably of tangential or spiral form rather than radial, in order to increase the flexibility and ease of adaption to different well diameters. A steel rod 34 extending between the housing for detector 24 and the housing for source 23 supports the hubs 35 of the shielding wires 33. In order to avoid a tendency to cause rotation of instrument 20, the spiral of each element 33 may be oriented in the opposite sense from the spiral of each adjacent element or elements, or the elements 33 may be free to rotate on rod 34.

In conjunction with the attenuation offered by the normal drilling fluids in the well bore, these wire shielding elements 33 are effective to reduce the well-bore radiation to a low level. Still further improvement is noted, however, if the side of detector 24 which is not in contact with the well wall 21 is also shielded. The manner of accomplishing this is shown in Figure 2 in which the detector 24 comprising, for example, an ionization chamber with electrodes 36 and 37, between which is a highly compressed gaseous atmosphere, is eccentrically located within the cylindrical housing 20. Lead shielding 38 fills that portion of housing 20 nearest the center of the well bore, extending around one-half to three-quarters or more of the circumference of detector 24, as well as for some distance above and below the ends of detector 24.

Similarly, as shown in Figure 4, the source 23 is preferably mounted in or on a housing consisting of a steel shell 40 filled with lead 41, the source 23 preferably being mounted on a leaf spring 42, the ends of which are attached to shell 40, with the source capsule 23 facing the well formations. The flexibility of spring 42 maintains source 23 in contact with the well formations and allows it to enter small depressions which the shell is too large to enter. The shielding 41 effectively prevents gamma rays leaving source 23 in a backward direction—that is, away from the formations or toward the center of the well bore—from penetrating any substantial distance.

In Figure 5 is shown surface equipment suitable for recording the indications of detector 24. At ground surface 45 the suspending cable 30 passes over a measuring wheel 46 and is wound on a reel 47. The insulated conductor of cable 30 is brought out to a slip ring 48, contacted by a stationary brush 49, and is thereby connected to an amplifier 50. The signals from detector 24, as amplified by amplifier 50, are applied to a recorder 51 which produces a trace 52 by means of a pen 53 on a moving chart 54 drawn by a take-up roller 55 from a supply roller 56, the take-up roller 55 being coupled by a flexible connection 57 to the depth-measuring wheel 46. As the construction and operation of this equipment may be entirely conventional, no further description of this portion of the apparatus or its operation is believed necessary, other than simply to point out that the deflections of trace 52 are proportional to the variations in response of detector 24, which are inversely related to the formation density.

A modification of the wire-brush shielding elements 33 of Figures 1 and 3 is shown in Figures 6 and 7. Here the mounting hubs 35, shown in cross-section in Figure 6, and to which the wires 33 are attached, are of substantial thickness and of increased diameter, occupying a substantial fraction of the cross-sectional area of the normal well bore. Adjacent hubs 35 are separated by spacers 58 and are provided with openings 59*a* or 59*b*, the two groups of openings being offset from each other on adjacent hubs as indicated by the solid and dotted circles respectively in Figure 7. These openings allow well fluids to pass freely through the shield structure as indicated by the curved arrows of Figure 6 which designate the flow paths during lowering through a well bore.

A detail of a preferred shielding wire construction is shown in Figure 8. In order to increase the shielding effectiveness at the bore-hole wall, particularly for large well diameters when the shielding material is at maximum extension, each individual wire 33 is coated with a flexible absorbing material 60 such as a flexible plastic material impregnated or filled with a heavy gamma-ray absorbing medium such as lead or iron oxide powder. By a spraying or multiple-dipping technique, the thickness of coating 60 may be graduated along the length of wire 33 to make it greatest at the outer end for maximum shielding and least near the point of attachment to hub 35 where maximum flexibility is desired.

An alternative embodiment of a flexible shield structure for use in an intermediate position between the radiation source and detector is shown in Figures 9, 10, and 11. Surrounding the support rod 34 are resilient disks 61, separated by absorbing spacers 62 of lead or steel, the disks 61 having radially projecting flexible fingers 43 of gamma-ray absorbing material such as rubber weighted or compounded with a substantial portion of lead. Preferably the solid disk portion 61 of each shielding unit is formed of tough, flexible rubber or the like to which the less flexible fingers 43 are permanently attached by vulcanizing. As flexing of the fingers 43 occurs chiefly at the base 44 near their point of attachment to the disk 61, less force is required to produce bending in accommodating well-bore irregularities than if the flexibility were distributed along the entire finger length.

It will be understood that the fingers 43 of adjacent units are staggered so as to close off any direct radiation path through the spaces between fingers of any one unit. Well-bore fluids, however, pass easily through these spaces as the logging instrument moves along the bore.

It is preferred that the fingers 43 be inclined upwardly

at a small angle as indicated by Figure 11. Less flexing of fingers 43 occurs and accordingly less pressure is exerted against a well wall 21 during lowering of the logging instrument 20 through a well, while the opposite occurs during raising of the instrument, insuring more positive contact of fingers 43 with the well wall 21.

In Figure 12 is shown an alternative embodiment of the invention in which the source housing 40 is attached through a pivot or hinge connection 63 to the housing of detector 24. The pivot connection 28 of the bow spring 27 is preferably about mid-way between the pivot 63 and the lower end of the housing 40 of source 23. This arrangement permits the source 23 and the detector 24 to maintain contact with the well wall 21 more or less independently of each other, whereas a rigid construction omitting the pivot 63 might at times result in the source 23 or detector 24 being held away from contact with the wall.

Even with this extra degree of freedom of the source and detector, however, in passing abrupt variations in hole diameter or other irregularities of the well wall, there are times when the source 23 and the detector 24 are aligned with each other in such a way that radiations can pass directly through the well fluids along the well wall from the source to the detector without having to penetrate the formations. For the specific purpose of preventing this bypassing, the flexible shielding members 64 are provided which, due to their flexibility, are able at all times to maintain contact with and to penetrate the irregularties of the well wall on the side contacted by the logging instrument.

These shielding members 64 may comprise wire-brush elements similar to those of Figures 1 and 3 except that they extend only partially around the circumference of the well bore. Alternatively, they may comprise small hinged fingers of steel or other high-density absorbing medium or flexible fingers of rubber, as in Figure 9, compounded or weighted with a substantial portion of lead to provide the desired gamma-ray absorption. To the extent that they do not interfere with the action of spring 27, the shielding members 64 may extend around the instrument through any desired angle greater than that shown on the drawing.

Since these shielding members 64 do not prevent passage of radiation up the well bore except close to what is normally the line of contact between the instrument and the bore-hole wall, the upper housing may be enlarged around the detector 24 as indicated at 65 to provide additional shielding thickness on that side of detector 24 away from the borehole wall. This additional shielding 65, like shielding 38 of Figure 2, is effective to prevent reception of most of the gamma rays traveling by paths other than through the well formations.

In Figure 13 is shown an alternative embodiment of the invention which, like that shown in Figure 1, prevents substantially all transmission of gamma radiation along the bore hole between source 23 and detector 24. In this embodiment the housing 40 of source 23 with its shielding material 41 and the housing of detector 24 with its shielding 38 are connected by a hollow tubular member 66, placed somewhat eccentrically with respect to the axis of the source and detector housings, so as to leave a space between the tubing 66 and the well wall in all directions.

Completely surrounding and attached to the central portion of tubular member 66 is a hollow toroidal or "doughnut-shaped" resilient packer or sleeve 67 filled with a heavy gamma-ray absorbing liquid 68 such as mercury. This shape for the rubber or other resilient material of sleeve 67 allows substantial change in its outside diameter without excessive stretching of the material at any point. Further support and protection for the sleeve 67 during running through a well bore is provided by a number of bow springs 69 and 70 substantially surrounding and pivoted to the housing of detector 24 at the pivot ring 71 and slidably engaging the source housing 40 at a retaining ring 72. By providing the springs 70 on the side of the instrument 20 contacting the well wall 21 with less strength or less arch than the springs 69 on the opposite side, the latter springs 69 tend to urge the instrument in a direction to place source 23 and detector 24 in contact with the well wall. Preferably also the sleeve 67 is bonded to the springs 69 and 70 at the center points indicated by the arrows 73 and 74 so that these springs help to expand the sleeve outwardly when the hole diameter increases. Support is also thus given to the sleeve 67 so that rubbing against the well walls does not cause vertical displacement of the sleeve on tubular member 66.

To facilitate running in liquid-filled bore holes, ports 75 and 76 in tubular member 66, located respectively above and below the sleeve 67 allow bore-hole fluids to pass through the tube 66 from one side of sleeve 67 to the other as the instrument passes through a well bore and sleeve 67 maintains contact with the well-bore walls. This arrangement is applicable and often advantageous also in the embodiment of Figures 1 and 3, where the ported tube 66 may be substituted for the solid rod 34.

In Figure 14 is shown a still further embodiment of my invention in which the flexible shielding members intermediate between the source 23 and detector 24 perform the dual function of reducing gamma-ray transmission through the bore-hole fluids and urging the instrument 20 against the well-bore wall. As is shown in this figure, each of these shielding members, typically three in number, comprises a plurality of pivoted, curved plates or petals 80 which together substantially block off the entire cross-section of the well bore regardless of its diameter, within certain limits. The shielding assembly as a whole is thus "flexible" even though each plate is a rigid body. Projecting from the lower end of the instrument 20 is an operating rod 81 by which the shielding elements 80, held retracted during running into a well bore, are released at the bottom of the well and allowed to expand.

The arrangement of these shielding members 80 is better shown in Figure 15. The solid circle 20 represents the outer periphery of the housing of the instrument 20. The dotted circle 21 represents a minimum diameter for the well bore while the solid outline 82 represents the maximum extension of the shielding plates 80, and thus the maximum diameter of well bore in which the shield will be fully effective. The shielding plates 80 lettered A in this figure are those pivoted closest to the instrument 20, and during running into a well bore are folded flat against the outside of the instrument. The plates designated by the letter B form the next layer of plates, and during running into a well are folded downwardly flat against the first layer of plates A. Similarly, the plates lettered C form a third layer, lying flat against plates B when retracted. As indicated in Figure 15, each of the plates fills a segment of the bore hole without appreciable overlapping of other plates at the maximum extension. At lesser extensions, of course, there will be some overlapping of the adjacent plates, but this only adds to their shielding effectiveness.

Typically, the diameter of the instrument 20 may be about three and one-half inches, the thickness of each shielding plate 80 may be about one-quarter inch, the minimum well diameter 21 is about five and one-half inches, and the maximum well diameter 82 is about ten inches. Of course, by utilizing additional layers of such plates 80 a larger maximum diameter than ten inches may be accommodated. Three decks of such plates 80 as indicated in Figure 14 provide a minimum of about three-quarters of an inch of steel as shielding, which is effective to reduce the undesired gamma radiation traversing the bore hole by a large factor.

Figure 16 shows the mounting and actuating means for a typical plate 80 of the embodiment of Figures 14 and 15. The plate 80 is pivoted at the point 84 to the instrument housing wall 20 and is provided with an inwardly

extending arm 85 passing through an opening 86 in the wall 20. A tension spring 87 attached between end of the arm 85 and a fixed point inside housing 20 urges the plate outwardly and up, pivoting it around the point 84. For running into a well, a hook 89 near the lower end of the plate 80 extends through an opening 90 of wall 20 and is engaged by a downwardly open cup 91 attached to the release rod 81. Movement of the rod 81 and cup 91 upwardly relative to wall 20 by bumping against the well-bore bottom thus releases the hook 89 and permits the plate 80 to swing outwardly and up under the force of spring 87. As a practical matter, only the C plates require the hooks 89, as they form the outer layer and hold down the A and B plates by overlapping them.

In the logging of wells using neutrons, some variation in the detector response is noted due to the varying amount and disposition of the hydrogen present in the well-bore liquids, where the well diameter is varying, or the walls are rough. As this is somewhat analogous to the bypassing effect of the bore-hole liquids in gamma-ray absorption logging of formation densities, means such as the flexible shields described herein mounted between the neutron source and detector are effective to displace the bore-hole liquids or to shield the detector against capture gamma rays originating there.

Also, in neutron logging the neutron sources most commonly used also emit substantial quantities of gamma rays, which may pass up the bore hole and be received and recorded along with the gamma rays of neutron capture in the formations, which rays it is desired to observe. The flexible shielding devices disclosed herein are effective in minimizing this source of error and thus improve the accuracy of the neutron log for determining porosity.

While I have thus described my invention in terms of the foregoing specific embodiments and details, it will be apparent that further modifications and combinations of these elements and details can be made and will be apparent to those skilled in the art. The invention, therefore, should not be considered as limited to the exact details described, but its scope is preferably to be ascertained by reference to the appended claims.

I claim:

1. Apparatus for logging wells comprising an elongated housing adapted to be moved through a well bore, a source of penetrating nuclear radiations in said housing, a detector of nuclear radiations in said housing at a fixed spacing from said source, spring means for holding said source and detector and one side of said housing against the wall on one side of a well bore, a substantial thickness of fixed nuclear-radiation shielding at least partially surrounding each of said source and said detector on the side opposite that held against a well wall, flexible nuclear-radiation shielding formed of a plurality of overlapping radiation-absorbing elements at least partially encircling said housing at a position intermediate between said source and said detector, said elements being urged outwardly to extend across a space between said housing and a well wall, the outer periphery of said flexible shielding being movable to maintain contact with a well wall of changing shape, and means for recording an indication of the output of said detector as a function of depth in a well.

2. Apparatus for logging wells comprising an elongated housing adapted to be moved through a well bore, a concentrated source of gamma rays in said housing, a gamma-ray detector in said housing at a fixed spacing from said source, spring means for holding said source and detector and one side of said housing against the wall on one side of a well bore, a substantial thickness of fixed gamma-ray shielding at least partially surrounding each of said source and said detector on the side opposite to that held against a well wall, flexible gamma-ray shielding formed of a plurality of overlapping, gamma-ray-absorbing elements at least partially encircling said housing at a position intermediate between said source and said detector, said elements being urged outwardly to extend across a space between said housing and a well wall, the outer periphery of said flexible shielding being movable to maintain contact with a well wall of changing shape, and means for recording an indication of the output of said detector as a function of depth in a well.

3. Apparatus according to claim 2 in which said gamma-ray-absorbing elements completely surround said housing at a position intermediate between said source and detector and extend substantially entirely across the well bore at said position.

4. Apparatus according to claim 2 in which said gamma-ray-absorbing elements are wires extending outwardly from a mounting hub.

5. Apparatus according to claim 2 in which said flexible gamma-ray shielding comprises a flexible dense-fluid-containing sleeve encircling said housing between said source and detector, said sleeve being urged outwardly to maintain contact with a well wall of changing shape.

6. Apparatus according to claim 2 in which said gamma-ray-absorbing elements comprise a plurality of pivoted plates of gamma-ray-absorbing material, each of said plates substantially blocking off a segment of a well-bore cross section and each of plates pivoting to adapt to different well diameters.

7. Apparatus according to claim 2 in which said gamma-ray-absorbing elements comprise a plurality of resilient, radially projecting fingers containing a gamma-ray-absorbing material.

8. Apparatus according to claim 2 in which said gamma-ray-absorbing elements comprise a plurality of disks of gamma-ray-absorbing material, each of said disks having flexible, gamma-ray-absorbing means projecting outwardly from its rim and adapted to maintain contact with wall of a bore hole.

References Cited in the file of this patent

UNITED STATES PATENTS

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,842,678 July 8, 1958

Daniel Silverman

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

Column 1, line 19, for "substantialy" read -- substantial --; line 20, for "formation" read -- formations --; line 69, strike out "well-"; column 2, line 3, strike out "contact between the irradiation source and the formations" and insert instead -- tions in the detector due to hole-diameter changes. --; line 5, for "formation" read -- formations --.

Signed and sealed this 16th day of September 1958.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents