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[54] **DETERMINING THE LOCATION OF VERTICAL CHANNELS IN A WELLBORE**

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[51] **Int. Cl.** **G01v 5/00**

[58] **Field of Search** ..... 250/43.5 FC, 106 L, 250/106 T, 83.6 W

[56] **References Cited**

UNITED STATES PATENTS

3,251,993	5/1966	Bader et al.	250/106 L X
3,406,284	10/1968	Young	250/106 L X

OTHER PUBLICATIONS

Radioactive Tracer Techniques, by Gore et al., from Journal of Petroleum Technology, Sept., 1956, pp. 12–17.

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[57] **ABSTRACT**

An illustrative embodiment of the invention shows a radioactive tracer technique for distinguishing vertically flowing liquids in formation fractures from flows through passageways in the cement annulus between the steel casing and the borehole wall. Typically, two radiation detectors of different sensitivities respond to a radioactive tracer that has been discharged into the formation at the well depth of interest. If the tracer material moves in a vertical direction with respect to the injection depth, relatively high count rates from both of the detectors indicate that the tracer is flowing vertically through a fracture in the cement. A relatively low count rate in the less sensitive detector, however, indicates that the vertical flow is taking place away from the casing and at some depth within the formation.

9 Claims, 3 Drawing Figures

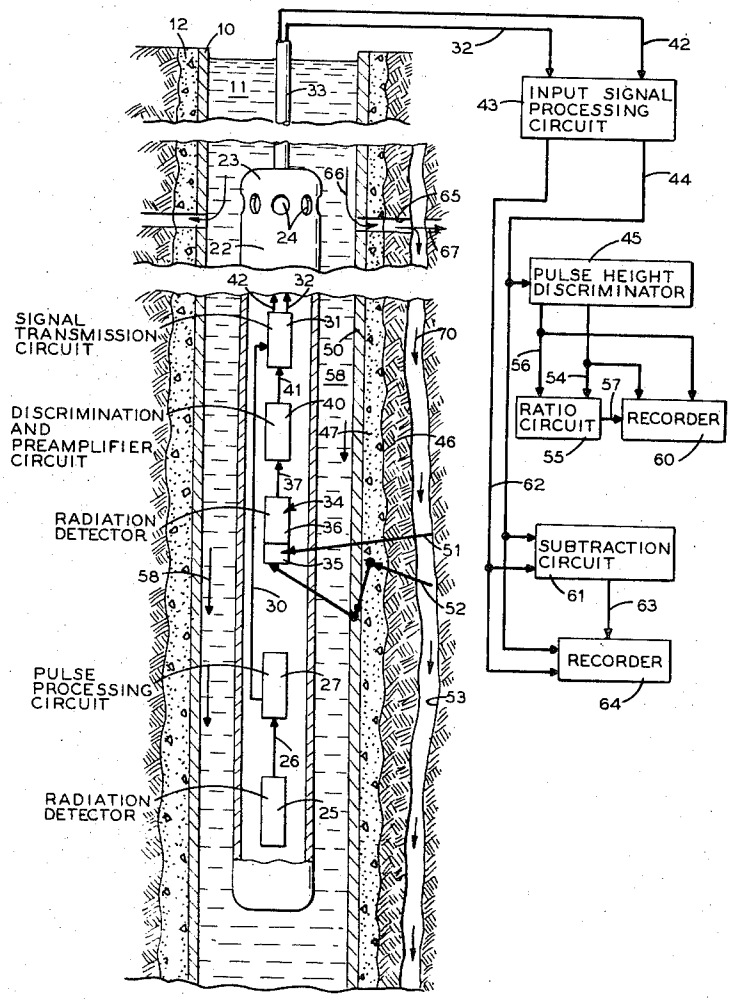
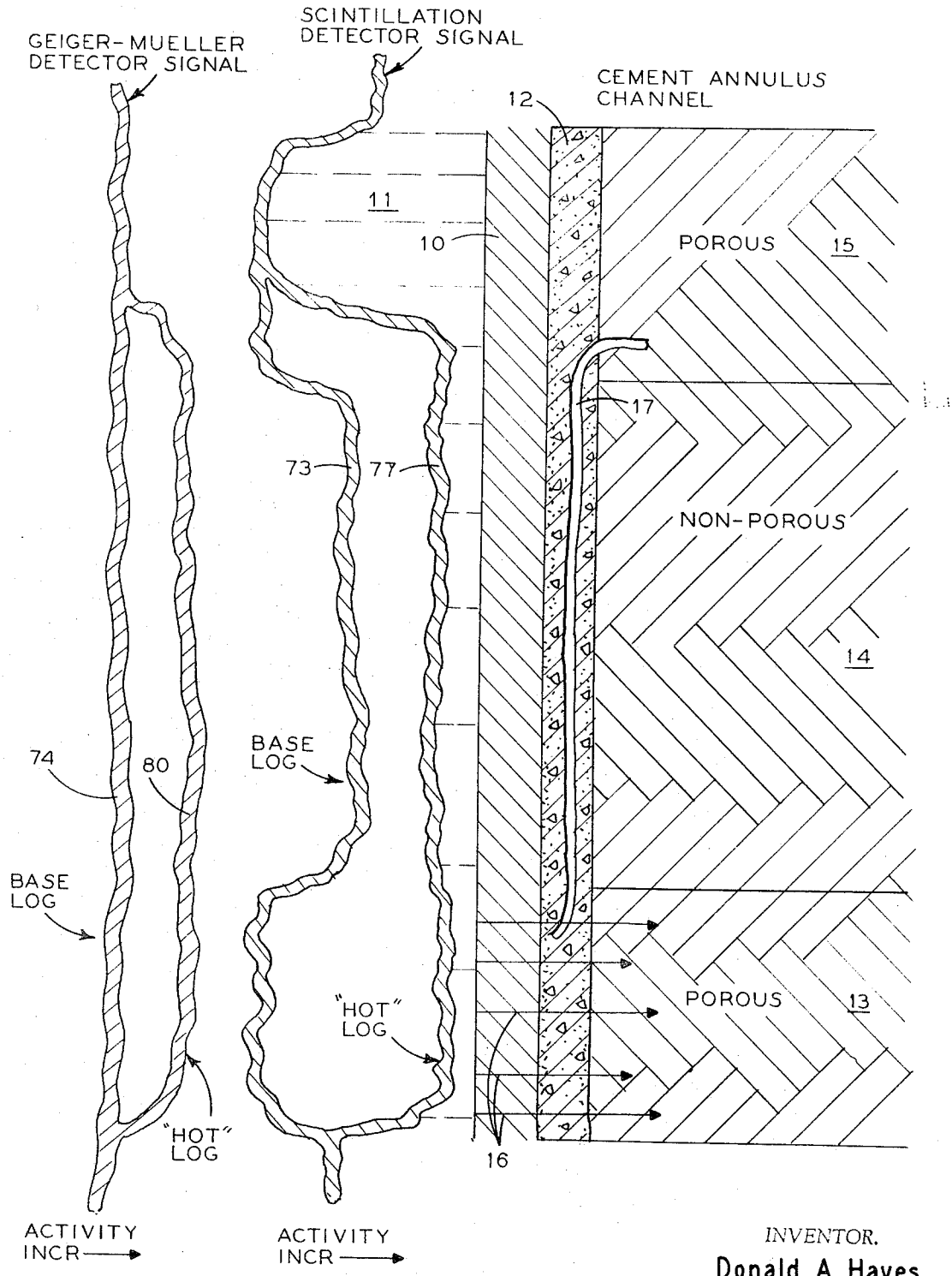


FIG. 1



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FIG. 2

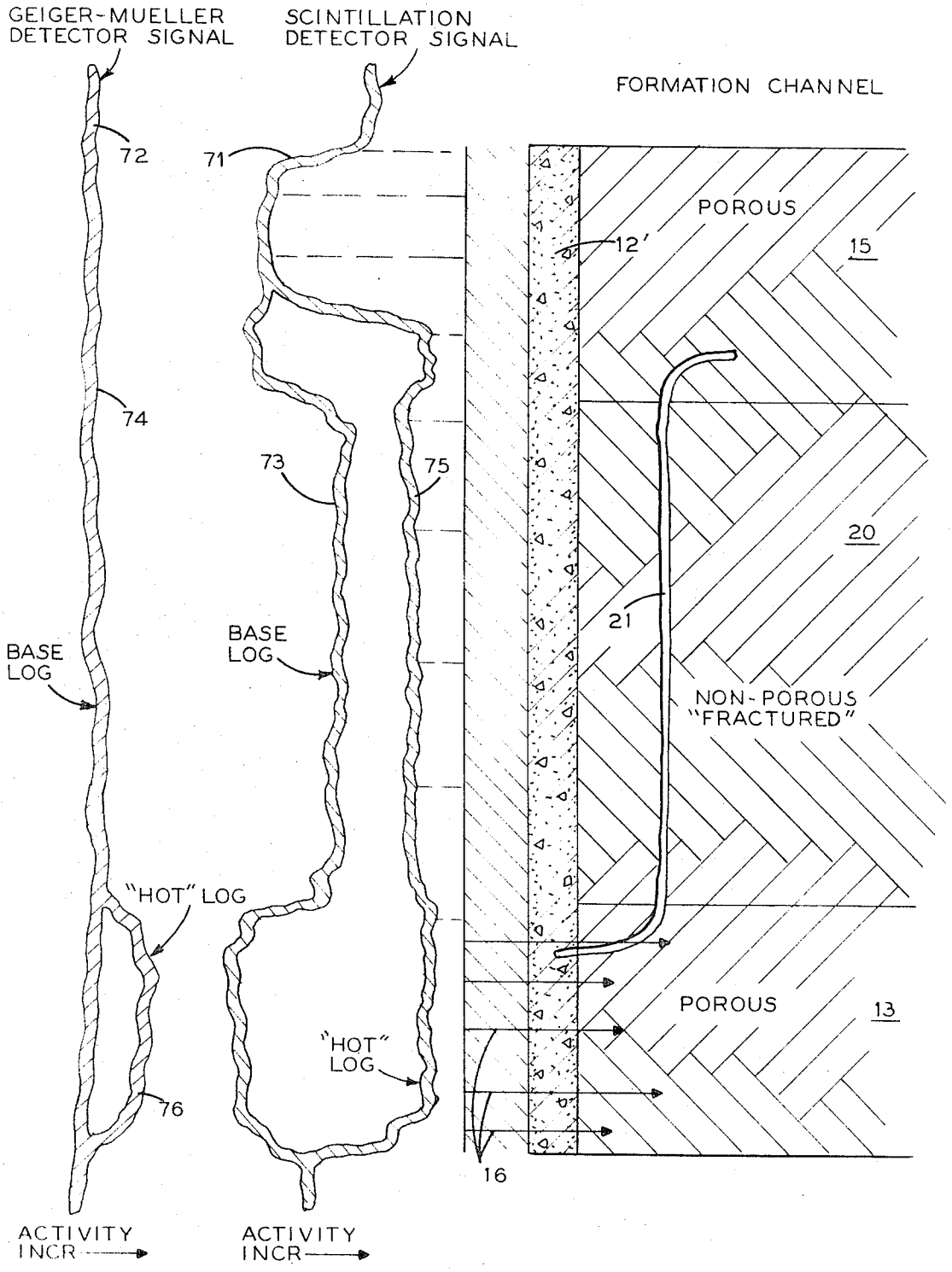
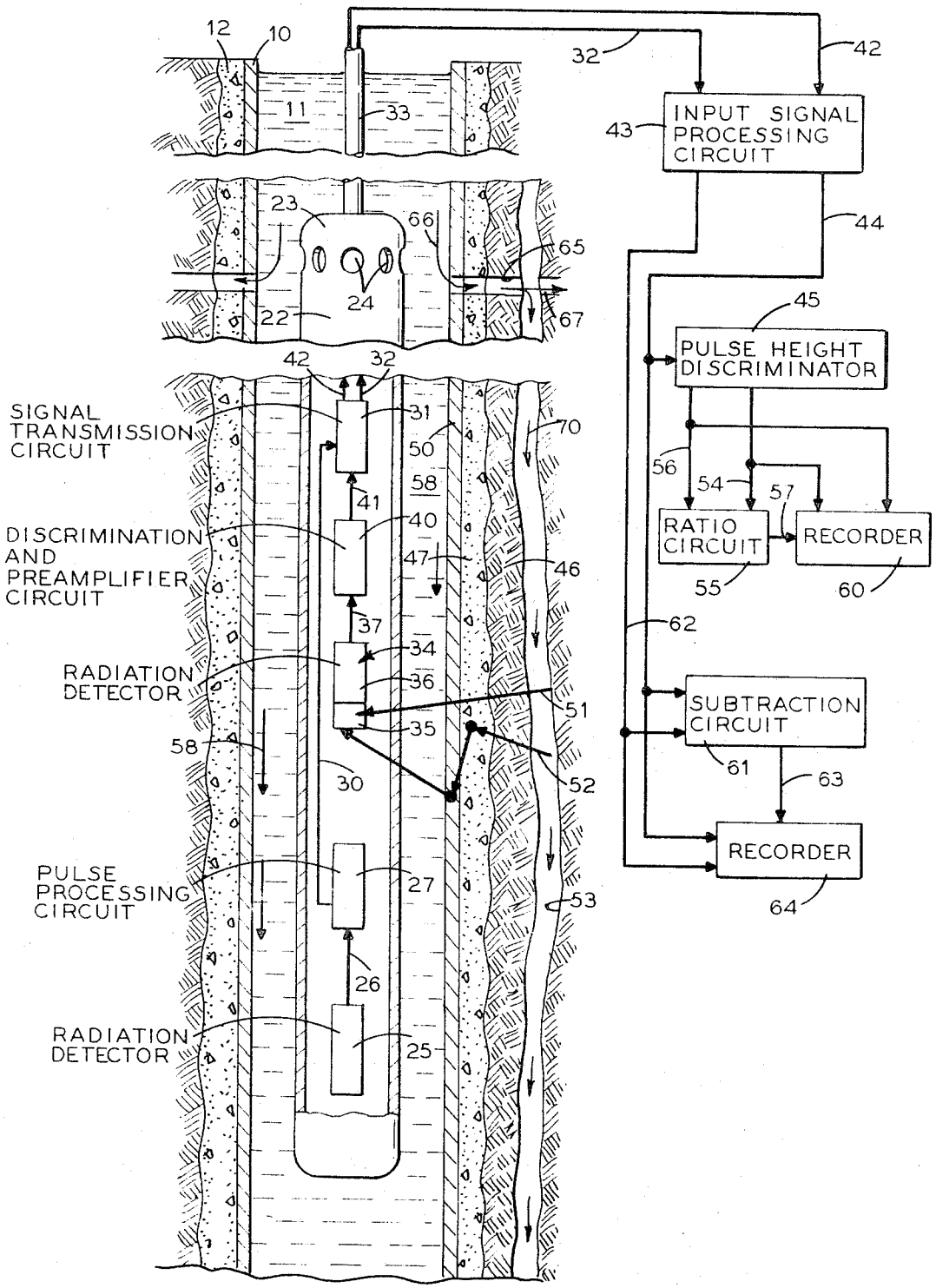

GEIGER-MUELLER DETECTOR SIGNAL
SCINTILLATION DETECTOR SIGNAL
FORMATION CHANNEL
72
71
74
73
75
BASE LOG
BASE LOG
"HOT" LOG
"HOT" LOG
76
16
POROUS
12'
15
20
21
NON-POROUS "FRACTURED"
POROUS
13
ACTIVITY INCR
ACTIVITY INCR

FIG. 3


12
10
11
33
32
42
43
INPUT SIGNAL PROCESSING CIRCUIT
44
23
66
65
24
22
67
45
PULSE HEIGHT DISCRIMINATOR
42
32
SIGNAL TRANSMISSION CIRCUIT
31
50
70
58
41
40
DISCRIMINATION AND PREAMPLIFIER CIRCUIT
47
46
56
54
57
RATIO CIRCUIT
RECORDER
55
60
37
34
RADIATION DETECTOR
36
51
62
SUBTRACTION CIRCUIT
58
35
30
52
61
63
RECORDER
64
PULSE PROCESSING CIRCUIT
27
53
26
RADIATION DETECTOR
25

DETERMINING THE LOCATION OF VERTICAL CHANNELS IN A WELLBORE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to borehole logging techniques and more particularly, to radioactive tracer systems for identifying the location of vertical channeling, and the like.

2. Description of the Prior Art

Producing oil wells frequently are lined with steel casing embedded in an irregular cement annulus. This characteristic structure serves a number of purposes. For example, it prevents the surrounding earth formation from caving into the borehole. If properly set, the casing and cement also prevent vertical fluid communication. For example, a good casing job should enable oil to be produced from a predetermined borehole depth. If the cement annulus is poor and has vertical fractures or channels, attempts to extract oil from the desired production horizon are often frustrated because less viscous or higher pressure liquids at other depths will flow vertically through the channel to the production depth. In this situation, hydrocarbon production will be curtailed, or at least substantially reduced. This condition can lead to the incorrect conclusion that the production horizon in question has been depleted.

Alternatively, if it is assumed that a defective cement annulus is causing a vertical flow condition, and the cause is in fact a vertical fracture in the formation, an expensive and futile attempt to repair sound cement is likely to be undertaken.

Consequently, if vertical channeling through a defective cement annulus can be consistently distinguished from formation channeling, a more reliable basis will be provided for corrective action.

Vertical channeling frequently is identified through radioactive tracer techniques. For example, a quantity of radioactive liquid is discharged into a fluid-filled borehole at the production horizon. The higher pressure in the borehole fluids causes the tracer to flow through the casing perforations and into the formation. If the tracer appears to remain generally in the vicinity of the injection level, it can usually be assumed that there is no channeling. If, however, the radiation emitted from the tracer material is observed to migrate or flow away from the injection level in a vertical direction, it usually is concluded that channeling does exist. This technique fails, however, to distinguish between channeling in the cement annulus and channeling in the formation. Accordingly, a need exists for some reliable system for identifying the approximate location of the vertical channeling condition.

SUMMARY OF THE INVENTION

These and other needs are satisfied to a large extent if the relative degree of tracer radiation energy degradation is observed. For example, Iodine 131 (I^{131}) is a typical tracer logging substance. This isotope emits a 364,000 electron volt (364 kev) gamma ray. If the tracer is flowing through a channel in the cement, few of these 364 kev gamma rays will have the opportunity to interact with or be attenuated by the matter interposed between the channeling fluid and the tracer tool radiation detection apparatus. On the other hand, if the channeling occurs deep within the formation, the probability of high energy gamma ray attenuation and degradation increases. Hence, vertical movement of the tracer coupled with a relative abundance of these higher energy gamma rays indicates that the flow is occurring near the borehole wall, or in the cement annulus.

Considered from another viewpoint, if the "build-up factor" (B_N), which is defined as the ratio of the total number of gamma rays observed at a point to the number of gamma rays with undegraded energies at that point, is close to one, channeling probably is occurring in the cement. If, however, channeling occurs in the formation, the build-up factor should be significantly greater than one.

This phenomenon can be observed with the aid of a number of distinctive tracer logging system configurations. For instance, suitable apparatus for collecting the data in question may include a small pump for discharging a radioactive tracer into the borehole at the depth of interest. A radiation counter that generates signals which are proportional to or reflect the energy of incident radiation also is included in the tool. A circuit, either in the logging tool or on the earth's surface segregates these signals into a low energy channel and a high energy channel. The high energy channel includes the full energy peak region of the radiation which characterizes the tracer isotope that is being observed. The comparison between the high and low energy signals that indicates the apparent depth of the vertical communication channel relative to the borehole can be expressed in many ways. Illustratively, the high energy channel counts during a specific time interval can be subtracted from the corresponding low energy detector counts. A relatively small difference is indicative of channeling in the cement, and a relatively large difference characterizes a formation fracture. Ratio signals that are usually associated with the build-up factor also can be generated within the terms of the invention. In this regard, a high or low ratio signifies a cement channeling condition, depending on the nature of the divisor.

As a further illustration, a logging system of substantially different construction may provide the information that characterizes the invention. In this latter instance, two radiation detectors within the tracer logging tool are vertically spaced. These two detectors, however, each have different respective sensitivities. In accordance with an aspect of the invention, moreover, this sensitivity to the incident radiation is energy dependent. A Geiger-Müller (GM) detector, for example, is relatively insensitive to low energy radiation. In contrast, a scintillation detector is very sensitive not only to low energy radiation, but also to high energy radiation as well.

A scintillation detector, in this regard, comprises a phosphor that produces a brief flash of light in response to an incident gamma ray, the intensity of the light flash being generally proportional to the gamma ray energy that is absorbed by the scintillator material. To complete the scintillation detector, a photomultiplier tube is optically coupled to the scintillator in order to generate an electrical charge pulse output signal that reflects the intensity of the light flash.

Continuing with this illustrative embodiment, the scintillation detector provides a relatively high radiation count rate in spite of the depth at which the channeling occurs. The GM detector, however, responds

largely to those higher energy radiations which have not interacted or have interacted only to a limited extent with the matter interposed between the tracer and the counting tube. In this way, a comparison between the two detector signals will tend to identify in a qualitative manner the location of the vertical flow. For instance, a somewhat lower count from the scintillation detector and a substantially lower count from the GM detector is indicative of vertical crack within the formation. Thus, the relative abundance of lower engery gamma rays and the decreased quantity of undegraded and higher energy radiations registered at the logging tool indicate that a thick mass of matter exists between the tracer and the GM detector.

More specifically, a logging tool containing a radioactive tracer reservoir and ejection pump structure as well as a radiation detector system registers the natural formation radiation background of the formation in question.

A quantity of radioactive tracer material is then introduced into the tool reservoir. The now fully prepared device is lowered through the borehole to the depth of interest. Through pumping or the like, the hydraulic pressure in the borehole is increased until the borehole liquids flow through the casing perforations and into the formation. When this condition has been achieved, with stable flow, a quantity of the tracer material is discharged from the reservoir and flows past the two detectors. The time required for the tracer slug to flow past the fixed distance that separates the detectors provides a measurement of the borehole fluid velocity. This "velocity slug" then is allowed to dissipate within the borehole and formation while the preestablished flow condition is continued. Preferably, the "velocity shot" is taken after the subsequently described logging runs are complete, although the actual procedural sequence is a matter of relatively minor importance.

After a sufficient lapse of time, a second and larger slug of tracer material is discharged into the borehole. The general flow carries at least some of the tracer material through the casing perforations and into the formation. The progress of the tracer through the formation then is observed at regular intervals of 15 to 30 minutes that extend through a period that lasts from 1 to 3 hours. These times depend on the rate of fluid injection into the formation, the higher rates requiring the shorter observation intervals. If, as a consequence of these observations, it appears that the tracer material did not migrate from the perforation depth, it is clear that the formation and the cement are sound and without fractures or channels.

Alternatively, if during these observation intervals the detector signals indicate that the tracer behind the casing is flowing vertically and a good portion of the emitted high energy radiation is not degraded, it can be assumed that only a thin layer of material is interposed between the tracer and the detector. Hence, it can be concluded that the cement is in poor condition. If, however, there is a substantial relative decrease in the high energy radiation, the opposite conclusion can be reached, i.e., that channeling occurs within the formation.

Thus, there is provided in accordance with the invention a reliable technique that provides a qualitative indication of the channeling depth. A more complete appreciation of the invention can be obtained through a study of the following detailed description of a specific embodiment when taken with the drawing, the scope of the invention being pointed out in the claims.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a schematic diagram of a typical cement channeling situation that distinguishes principles of the invention;

FIG. **2** is a schematic diagram of a typical formation channeling situation that further illustrates principles of the invention; and

FIG. **3** is a schematic diagram of a system for practicing the invention in several ways.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

For a more detailed understanding of the invention, attention is invited to FIG. **1** which shows a schematic diagram of a poorly cemented portion of a well. Illustratively, a steel casing **10** is set between the borehole drilling fluid **11** and a porous or fractured cement annulus **12.** The portion of the earth formation under consideration comprises three strata — a porous oil bearing level **13** which is bedded below a different, and relatively non-porous structure **14,** and a topmost formation or porous "thief" zone **15.**

To produce hydrocarbons from the level **13,** the well is "completed" by piercing the casing **10** and cement **12** with horizontal perforations shown illustratively as small arrows **16.** Ordinarily, if the pressure in the borehole fluid **11** is lower than the natural pressure in the production level **13,** oil will flow from the formation through the perforations **16** and into the borehole in order to be pumped or drawn to the earth's surface.

In this connection, however, oil, even at the elevated temperatures that usually exist within an earth formation, ordinarily is more viscous than salt water and other formation fluids. Consequently, if all conditions are equal, salt water will tend to flow more readily into the borehole than the formation oil. Thus, if the thief zone **15** contains salt water at about the same or at a somewhat higher pressure than the production zone **13,** the less viscous liquids in the formation **15** will flow vertically downward through diagrammatic channel **17** in the cement annulus **12** to the perforations **16** at the production level **13.** In this circumstance, if the well at all produces oil, it will do so only in an inefficient and uneconomical manner.

FIG. **2** shows a schematic diagram of the porous oil bearing formation **13** which is separated from the thief zone **15** by the non-porous "fractured" formation **20.** In these circumstances, less viscous or higher pressure fluids of the porous formation **15** flow downward in vertical cracks, fractures or channels **21** in the formation **20** to be extracted through the casing perforations **16.** This vertical fluid communication almost invariably will reduce or block further hydrocarbon production.

Remedial techniques for overcoming the effects of poor cement are often successful, and the prospects for correcting defective cement conditions are usually quite good. Vertical flows caused by fractured formations of the type shown schematically in FIG. **2** present a more difficult situation. The outlook for rectifying a condition of this latter sort is not favorable. Attempts to overcome the problems associated with these formation fractures, moreover, can lead to the entirely opposite effect of destroying the well's production capacity.

A typical device for practicing the invention is shown in FIG. 3. In this connection, a fluid-tight tracer logging tool housing 22 includes an uppermost portion 23 in which a radioactive tracer discharge apparatus (not shown) ejects selected quantities of tracer material through ports 24 on a command signal from the earth's surface. Preferably, a 10 millicurie concentration of I^{131} in a chemical combination with sodium and dissolved in about 15 milliliters of water has been found adequate for the purpose of the invention.

A radiation detector 25 is positioned in the lowermost portion of the housing 22. In accordance with the exemplary embodiment of the invention under consideration, the detector 25 is a GM counting tube that produces an output signal in response to an incident gamma ray. For example, a gamma ray that is emitted from a slug of tracer material penetrates the interposed casing materials and the outer surface of the detector in order to enter the active volume of the detector 25 and ionize some of the fill gas. The ionized gas produces an electrical charge pulse at a detector output which is sent through a conductor 26 to a pulse processing circuit 27 for amplification.

Although only one GM counter is shown in FIG. 3, a bundle of several tubes can be used in order to reduce the time tube 25 is inoperative after each pulse and thereby increase the counting efficiency of the entire system. This detector "dead time" is caused by the time required for the ions that generated the preceeding pulse to recombine and put the tube in a condition to register a new pulse. Grouping several detectors together shortens the collective dead time of the overall array because at least one of the tubes almost always is in a condition to register a "count." All of these detectors would, of course, be coupled to the pulse processing circuit 27.

Amplified signals from the processing circuit 27 are sent through a conductor 30 to a signal transmission circuit 31. The circuit 31 couples the amplified detector pulses to a conductor 32 in an armored cable 33. The cable 33 not only provides a signal transmission path, but also enables a winch system (not shown) to lower and raise the logging tool housing 22 within the well.

A radiation detector which is more sensitive to lower energy gamma rays than the detector 25 also is secured within the housing 22. The detector 34 may include a scintillation phosphor or crystal 35 that is optically coupled to a photomultiplier tube 36. The charge pulse output signal from the photomultiplier tube 36 is generally proportional to the intensity of the incident light stimulus and hence, is related to the radiation energy loss in the crystal 35.

It should be noted, moreover, that the detectors 25 and 34 may be appropriately shielded from any direct background radiation that might originate in the tracer reservoir (not shown) within the tool housing 22.

The photomultiplier tube charge pulses are sent through a conductor 37 to a discriminator and preamplifier circuit 40 to eliminate noise and other spurious signals and to prepare the radiation-related signals for further processing. These signals are transmitted through a conductor 41 to the signal transmission circuit 31 which applies the received signals to a conductor 42 in the armored cable 33 for transmission to the earth's surface.

On the earth's surface, the scintillation detector signals in the conductor 42 are first received in an input signal processing circuit 43. The processing circuit 43 essentially discriminates against noise induced in the conductor 42 during signal transmission through the borehole. The circuit 43 amplifies and regenerates the received pulses that reflect the characteristics of the radiation registered by the downhole detector 34 and apply these signals to a conductor 44.

In accordance with one illustrative embodiment of the invention, these signals from the scintillation detector 34, which are proportional to the energy of the incident radiations, are coupled to a pulse height discriminator circuit 45. The discriminator circuit 45 divides these energy-proportional pulses into two channels of groups — a high energy channel which includes the 364 kev gamma ray that characterizes the I^{131} tracer, and a low energy channel which registers only those gamma rays that are of lesser energy and that indicate attenuation in the formation or in the borehole materials. The discrimination level that distinguishes the high energy channel from the low energy channel can be selected arbitrarily, one criterion being the need to maintain a statistically valid accumulation of detector counts in both channels.

Signals that correspond to the observed high energy gamma radiation are sent from the discriminator 45 through a conductor 54 to a ratio circuit 55. The low energy gamma radiation signals are sent from the pulse height discriminator 45 through a conductor 56 to the ratio circuit 55. The two groups of signals are compared or contrasted in order to determine the apparent depth of a channeling fracture 53 with respect to the borehole by means of the relative abundance of gamma radiations indicated in the two respective channels.

For the purpose of descriptive simplicity, this comparison is illustrated by means of an automatically computed ratio between the high and low energy responsive signals. A ratio, for example of the low energy signals to the high energy signals, when much greater than one, indicates that a substantial amount of high energy gamma ray attenuation has occurred. This rflects that fracture 53 is relatively deep within the formation 46. If, however, the channeling occurs within cement 47, the ratio of high energy gamma radiation and gamma radiation which is degraded in energy should be relatively close to one, as might be expected of a condition which leads to minimal high energy radiation attenuation. The foregoing description of the invention, as it is applied to a specific mathematical technique is for ease of understanding, other arithmetic techniques being clearly within the scope of the invention.

A signal that is related to the ratio of the two detector signals is sent through a conductor 57 to a recorder 60 where, along with signals that correspond to the high and low energy channel activities, a record is made of all of these signals as a function of borehole depth.

In another embodiment of the invention, the depth of the channeling is qualitatively determined by contrasting the GM signal with the gross or total scintillation detector signal that is accumulated during the same period of time. The less sensitive GM detector 25 in essence responds to the higher energy and relatively unattenuated gamma radiation that is emitted from the tracer material. Accordingly, the GM detector 25 will produce a relatively high count rate only when the channeling occurs close to the borehole. The scintilla-

tion detector **34**, however, is sensitive to low energy radiations and hence, produces a total signal output that is substantially less responsive to the depth of the tracer within the cement or the formation.

Thus, a relatively high gamma ray activity signal from the GM detector indicates that the tracer is channeling through the cement **47**. A generally small signal difference between the scintillation detector signal and the signal from the GM detector at the output from a subtraction circuit **61**, however, tends to show that a poor cement condition probably exists.

If the GM detector signal indicates that the high energy gamma ray activity is low, it usually can be concluded that the tracer material is at some depth within the formation. In this latter instance, the difference between the scintillation detector signal and the GM signal at the output of the subtraction circuit **61** should be relatively large. These signal differences, moreover, are sent through a conductor **63** to a recorder **64** in order to make a record of the differences as well as a record of the individual signals as a function of borehole depth.

In operation, the pressure of the borehole fluid **11** is increased through pumping or the like to ensure that there is a liquid flow from the borehole into the formation **46** through casing perforations **65**. The tracer logging tool **22** is lowered into the borehole. The flow velocity within the borehole, as indicated by arrows **66**, is measured along with the measurements required for the practice of the invention after stable or "steady-state" hydrodynamic conditions are attained. Typically, in order to measure the flow velocity in the borehole, the tracer logging tool is positioned with the discharge ports **24** above the casing perforations **65**.

A small quantity of tracer material, perhaps .5cc, is discharged from the ports **24** in order to flow vertically downward as indicated by arrows **58**. The tracer flows past the two vertically spaced detectors **34** and **25**. Because the vertical distance between the detectors is known and the time of peak radioactivity can be registered as it passes each detector, the flow velocity can be determined through simple computation. This velocity data provides some indication of the relative amount of fluid injection at each of the sets of perforations in a well which has "multiple completions."

The radioactive contamination induced in the borehole by the "velocity shot" described above, although small, is allowed to decay through flow dispersion and the passage of a little time. Channeling now may be observed. Tracer material again is ejected from the housing **22**, perhaps on the order of 15 cc, and is carried by the borehole fluid **11** through perforations **65** and into the formation **46** as indicated by arrows **67**. Because in the FIG. **3** illustration channeling occurs in the vertical formation fracture **53**, some of the tracer material will flow down through the crack in the formation **46**. The progress of this vertical tracer movement as indicated by arrows **70** can be observed by drawing the tool housing **22** past the formation in question at regular **15** to **30** minute intervals during a period of 1 ½ to 3 hours. The appropriate observation intervals and periods being selected on the basis of the observed borehole fluid velocity.

In this way, many gamma rays, symbolically designated by arrows **51** and **52**, either pass through the intervening matter and strike the scintillator **35**, or interact through collisions with the structure of the intervening matter before registering with the detector **34**. In the latter instance, the energy of the radiation is diminished or degraded through these interactions and hence, is registered in the low energy channel of the pulse processing system.

As hereinbefore described, the build-up factor, B_N, and hence the apparent depth of channeling, can be observed directly. As an alternative, the build-up factor can be compared with data taken on other formations in which known channeling conditions exist.

For a more complete appreciation of the invention, attention is invited to FIG. **2** which shows an exemplary borehole depth related graph of scintillation detector response **71** and a borehole depth-matched graph of GM detector response **72**. Before any of the radioactive tracer material is ejected from the tool **22** (FIG. **3**), a scintillation detector base log **73** and a GM detector base log **74** are run in the borehole in order to establish the natural background radioactivity of the formation under investigation.

Subsequent to these background observations, some of the radioactive tracer material is ejected from the logging tool to measure the fluid velocity. When the velocity measurement is completed, the tracer material is allowed to disperse and a second slug of tracer material is ejected into the borehole near the casing perforations **16**.

This second slug is afforded an opportunity to flow upwardly through the formation crack **21**. As hereinbefore described, the scintillation detector, which is quite sensitive to lower energy gamma radiation, generates a signal, shown in the composite "hot" log **75**. The log **75** represents a substantial increase in radiation intensity relative to the natural background signal shown in the base log **73**. For illustrative purposes, the hot log **75** is a combination of the cumulative peak radioactive intensities measured during several logging runs through the borehole depth of interest at timed intervals as the tracer material progressed upwardly through the vertical fracture **21**.

In contrast, a "hot" log **76** registered by the GM detector **25** (FIG. **3**) only departs from the natural background radioactivity in the vicinity of the porous formation **13**. This state of affairs reflects a vertically fractured formation **20**. In this situation, the scintillation detector base log **73** and the GM detector base log **74** indicate substantially the same levels of natural radioactive intensity.

Turning now to the poor cement conditions shown in FIG. **1**, the scintillation detector produces a tracer emission gamma radiation log **77** that is generally similar to the scintillation detector log **75** in the fractured formation shown in FIG. **2**. Because the reduced mass between detectors and tracer with poor cement applies a lower degree of attenuation to the gamma radiation emitted from the tracer, a greater abundance of higher energy gamma rays are available to activate the GM detector **25** (FIG. **3**). Consequently, the GM detector registers a much higher radiation level on the log **80** relative to the natural radiation background log **74**.

It should be further noted that the logs **77** and **80** are composed for illustrative purposes from a series of logs acquired through a sequence of timed logging runs.

The background logs, expressed for example, in counts per minute need not be subtracted from the count rates registered in the corresponding hot logs, visual inspection through log overlays, being adequate in

many cases, although fully automatic computation techniques are within the terms of the invention.

Thus, in accordance with features of the invention, a reliable system is provided to distinguish between formation channeling and vertical flow through poor cement. With this improved technique a more rational basis is provided for reaching a decision with respect to the need and advisability for cement repair.

I claim:

1. A method of logging cased well bores for determining whether vertical fluid communication paths exterior of the well bore casing are lying either between said well casing and adjacent earth formations or within said earth formations and comprising the steps of:

displacing radioactive material laterally through the well casing adjacent an interval which may contain a vertical fluid communication path located at an unknown lateral distance from the axis of said well bore;

measuring radioactive radiation along said interval for obtaining at least one radiation measurement indicative of the presence of said radioactive material in either a vertical fluid communication path between said well casing and said earth formations or in a vertical fluid communication path within said earth formation;

measuring radioactive radiation energy along said interval for obtaining at least another radiation measurement selectively indicative of the presence of said radioactive material in a vertical fluid communication path between said well casing and said earth formations; and

comparing said radiation measurements for determining the position of said vertical fluid communication path in relation to said well bore axis.

2. The method of claim 1 further including the step of measuring, before said displacing step, radioactive radiation along said interval for determining the portions of said one radiation measurement and said another radiation measurement respectively resulting from natural background radioactive radiation.

3. The method of claim 1 further including: successively repeating said measuring steps for determining the lateral position of said vertical fluid communication path in relation to said well bore axis at different depths along said interval.

4. A method of logging cased well bores for determining whether vertical fluid communication paths exterior of the well bore casing are lying either between said well casing and adjacent earth formations or within said earth formations and comprising the steps of:

displacing radioactive material laterally through the well casing adjacent an interval which may contain a vertical fluid communication path located at an unknown lateral distance from the axis of said well bore;

measuring the high and low radioactive radiation along said interval for obtaining at least one radiation measurement indicative of the presence of said radioactive material in either a vertical fluid communication path between said well casing and said earth formations or in a vertical fluid communication path within said earth formations;

measuring the high radioactive radiation along said interval for obtaining at least another radiation measurement selectively indicative of the presence of said radioactive material in a vertical fluid communication path between said well casing and said earth formations; and

comparing said radiation measurements for determining the position of said vertical fluid communication path in relation to said well bore axis.

5. The method of claim 4 further including the step of measuring, before said displacing step, radioactive radiations along said interval for determining the portions of said one radiation measurement and said other measurement respectively resulting from natural background radioactive radiation.

6. The method of claim 4 further including: successively repeating said measuring steps for determining the lateral position of said vertical fluid communication path in relation to said well bore axis at different depths along said interval.

7. A method of logging cased well bores for determining whether vertical fluid communication paths exterior of the well bore casing are lying either between said well casing and adjacent earth formations or within said earth formations and comprising the steps of:

displacing radioactive material laterally through the well casing adjacent an interval which may contain a vertical fluid communication path located at an unknown lateral distance from the axis of said well bore;

measuring the radioactive radiation along said interval for obtaining at least one radiation measurement indicative of the presence of said radioactive material in said vertical fluid communication path;

discriminating between the high radioactive radiation and the low radioactive radiation of said measured radioactive radiation for obtaining at least one low radioactive radiation measurement indicative of the presence of said radioactive material in a vertical fluid communication path within said earth formation, and for obtaining at least one high radioactive radiation measurement indicative of the presence of said radioactive material in a vertical fluid communication path between said well casing and said earth formation; and

comparing said high and low radioactive radiation measurements for determining the position of said vertical communication path in relation to said well bore axis.

8. The method of claim 7 further including the step of measuring, before said displacing step, radioactive radiation along said interval for determining the portions of said high radiation measurement and said low radiation measurement respectively resulting from natural background radioactive radiation.

9. The method of claim 7 further including: successively repeating said measuring and discriminating steps for determining the lateral position of said vertical fluid communication path in relation to said well bore axis at different depths along said interval.

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