

Description

The present invention is concerned with a well logging tool for detecting low energy gamma rays.

In recent years, gamma ray spectroscopy of earth formations in the vicinity of a borehole has been made practical by the development of highly stable scintillation detectors which may be lowered into a borehole. The scintillation detector is responsive to the gamma ray energy spectrum of gamma rays impinging upon the scintillation crystal. At the present time, two commercial well logging services are available for detecting the natural gamma ray spectra produced by uranium, potassium and thorium (or from their radioactive daughters) in earth formations in the vicinity of a borehole.

In the first of these commercially available services, three energy ranges or windows centered about selected gamma ray emission peaks for naturally occurring gamma rays in the decay series of the aforementioned elements are selected. Gamma ray count rates in each of these three energy ranges are transmitted to the surface and processed by a technique called spectrum stripping wherein standard calibration spectra for each of the individual elements (made in standard boreholes) are applied to the measurements of count rates made in the energy ranges chosen to detect each of the three elements sought to be detected. So called "stripping constants" derived from the measurement of the standard spectra in standard boreholes for each of three elements are then applied to the measured spectrum in the unknown earth formations surrounding the borehole. An estimate of the percentage of the particular three elements desired to be detected is made based on the stripping technique.

In a second, slightly more sophisticated, commercially available technique (such as described in U.S. Patent US-A-3,976,878 to Chevalier), five energy ranges or windows are utilized for the measurement of the spectrum of natural gamma rays emitted by the earth formations in the vicinity of a borehole. The five energy range measurements used in this technique are employed in a least squares fitting scheme to determine the elemental concentrations of the three elements, again based on the spectrum of each of the individual elements of the three taken in standard boreholes. The use of the five windows gives an overdetermined set of equations (i.e. 5 equations in 3 unknowns) which are statistically enhanced by the use of the count rate data from the extra two energy windows to distinguish this technique from that described in the foregoing paragraph.

Whilst the above-described techniques are generally satisfactory, there is a problem in using them to detect low energy gamma rays (e.g. $E = 20$ to 200 KEV) because the tool housing absorbs such rays.

U.S. patent specification US-A-3439165 describes a well logging tool comprising pulsed D-T

accelerator housed within a gamma ray detector. The housing includes therewith a mixture of boron-10 and epoxy resin to provide neutron shielding. In such an arrangement, the steel housing tends to absorb low energy gamma rays so that the tool is not suitable for their measurement.

We have now devised a well logging tool which is especially suitable for low energy gamma ray detection.

According to the invention, there is provided a well logging tool sized and adapted for passage through a well borehole for use in detecting naturally occurring gamma rays, said logging tool comprising: at least one pair of threadedly interconnecting tubular members said tubular members when interconnected defining a frusto-conical recess, a tubular composite low atomic number member having at least one end with a complementarily shaped frusto-conical end for tight reception in said recess, a tubular rubber member around said low atomic number member; a wear resistant outer sleeve around said rubber member for protecting said rubber member from abrasion with the borehole; and means disposed within said low atomic number member for detecting gamma rays and separating them into an energy spectrum.

In the tools of the invention, a scintillation type detector is utilized. The gamma ray energy spectrum is detected by the scintillation detector within the tool housing.

The housing is preferably a tubular graphite filament construction, with a tubular aluminum shield.

In order that the invention may be more fully understood, an embodiment thereof will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIGURE 1 illustrates a tool and well bore, in a typical well bore logging operation; and

FIGURE 2 illustrates in longitudinal cross-section part of an embodiment of the present invention.

As illustrated in Figure 1, a borehole traverses earth formations 10 and typically contains a drilling control fluid 11 which produces a hydrostatic pressure within the well bore to control pressures existent in the earth formations. The borehole may be cased, as with a steel casing 12, or be encased or open hole. The logging tool 13 is sized to traverse through the borehole by means of an electrical armored logging cable 14 which is spooled to a conventional winch arrangement (not shown) at the earth's surface. The logging tool contains instrumentation for measuring gamma ray spectral characteristics of the earth formations 10 penetrated by the borehole. Signals from the downhole tool 13 are conducted to the surface on conductors of the cable 14 and supplied to a surface computer 16 which performs signal processing techniques in order to extract the elemental constituents of silicon, calcium, or iron (as well as thorium, uranium, and potassium) present in the earth formations 10 which are then recorded as a function of borehole depth on the

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recorder 17. The well logging cable 14 passes over a sheave wheel 15 which is electrically or mechanically coupled (as indicated by a dotted line 18) to the computer 16 and recorder 17 in order to provide depth information about the downhole tool 13 for the surface recording process. The surface computer 16 may be, for example, a model PDP-11 provided by Digital Equipment Corp. of Cambridge, Mass., U.S.A., and can be programmed in a high level language such as FORTRAN to perform computations and to drive the output displays.

The downhole tool 13 contains near its lower end, a gamma ray detecting system comprising a scintillation crystal and a photomultiplier/amplifier package 18.

Power for the operation of the downhole tool is supplied from a surface power supply 19 via conductors of the cable 14 to a downhole power supply 20 where it is converted to appropriate voltage levels and supplied to the downhole circuitry components of the system as indicated in Figure 1. Gamma ray spectral signals are supplied from the photomultiplier tube to a pulse height analyzer 21 where they are separated into count rates. The pulse height analyzer provides the output signals to a telemetry system 22 where the pulse height gamma ray spectral information is converted to an appropriate digital form for transmission to the surface via conductors of the well logging cable 14. Downhole control circuits 23 provide timing pulses to the pulse height analyzer and telemetry system in order to synchronize the transmission at regular data intervals from the downhole tool to the surface equipment. These synchronization signals are also encoded in the telemetry system 22 and supplied to the surface computer 16.

Thus, naturally occurring gamma rays from the earth-formations 10 are detected by the scintillation crystal/photomultiplier detector system 18 in the downhole tool and are broken down into their energy constituents by the pulse crystal analyzer 21 and telemetered to the surface by the telemetry system 22 on conductors of the armored well logging cable 14. At the surface, the signals are processed in order to extract the elemental constituency of earth formations 10 penetrated by the borehole.

In explanation of the background for the present invention, photoelectric absorption is strongly influenced by the atomic number "Z" of the elements located between the source of radioactivity from the earth formations 10 and the detector 18 in the tool. For a given gamma energy, the absorption (σ) by the elements is proportional to a relationship expressed by the formula $\sigma \sim Z^{4.5}$. Thus if material with atomic numbers greater than or approximately equal to those of the elements being observed, is incorporated or built into the tool housing then such materials will act as filters preventing the gamma ray information derivable from photoelectric absorption affects from reaching the detector 18 within the housing. For example, if the photo-

electric absorption differences to be detected are between silicon ($Z = 14$) and calcium ($Z = 20$) in the formation, then a tool housing made of steel ($Z = 26$) will absorb nearly all of the gammas in the energy range where the formation effects are appreciable. Thus, no significant lithology signal would reach the detector 18. Similarly casing weight ($Z = 26$) measurements are also unduly attenuated by high Z tool cases.

The present invention is intended to minimize the overall photoelectric absorption effect of the tool housing by minimizing the equivalent atomic number of the materials in the tool housing yet maintain temperature, pressure and physical requirements for the tool.

Referring now to Figure 2 in which a low Z toolcase is shown, the housing construction includes threadedly interconnected tubular members 30 and 31. The end of the lower tubular member 30 has a first, outer longitudinally extended recessed section 32 and a second outer, longitudinally extended recessed section 33 which respectively have smaller diameters. The tubular member 30 has an internally threaded portion 34 located midway of the length of the first recessed sections 32. Above the threaded portion 34 is an outwardly tapering wall surface 35. Thus, the member 30 has a terminal end portion with outer diametrically stepped sections and an internal tapered section.

The lower end of the upper tubular member 31 has an outer threaded portion which is arranged to engage with the threaded portion 34 and a radially extended flange 36. When the members 30 and 31 are threadedly interconnected the flange 36 abuts the threaded portion 34. Above the flange 36, the member 31 has an inwardly tapering wall surface 37 which extends upwardly to the end of the member 31. The internal diameter of the member 31 is matched to the internal diameter of the lower member 30.

From the above described construction, it will be appreciated that the members 30 and 31 define a frusto-conically shaped recess between the tapered walls 35 and 37. A complementarily shaped, frusto-conical end of a tubular composite material member 38 is tightly received in the recess between the tapered walls 35 and 37. The procedure for assembling members 30, 31 and 38 is as follows: (1) after it is determined that member 31 fits tightly into member 38, they are bonded together using a high temperature epoxy. (2) the threaded portion of member 31 and the externally tapered section of member 38 are coated with epoxy and threaded into member 30; (3) the epoxy is cured to complete the joint fabrication. Above the frusto-conical end, the member 38 has an internal diameter which is matched to the diameter of member 31 and an outer diameter which is matched to the outer diameter of the second recessed section 33. The tubular composite member 38 is constructed of graphite filaments wound in a cylinder and impregnated with epoxy. A filament structure is

used because this type of composite is capable of higher stresses than other fibre-reinforced materials.

The outer surface of the member 38 and the second recessed section 33 can be enclosed with a thin tubular rubber sleeve 39 which provides a fluid tight seal for the member 38. A thin walled, removable tubular aluminum wear sleeve 40 encloses the rubber sleeve 39 and is sized to be received on the first recessed section 32. The outer diameter of the sleeve 40 conforms to the outer diameter of the member 30, and may incorporate a Teflon (trade mark) anodized outer layer. The aluminum sleeve 40 and the graphite epoxy composite member 38 will transmit low energy gamma energy through 360° of the walls of the housing as contrasted with a single window type of tool.

The selected materials of the housing with low "Z" factors reduce interference by the housing materials with the gamma ray spectrum to be detected and there are no adverse X-ray produced by virtue of the housing materials.

Where it is desired to measure the casing weight or thickness effects, a tubular case made of, for example, titanium can be used, in addition to the above described toolcase, and it will also be effective for use in high pressure operations. Titanium alloys provide a sufficiently low "Z" factor so that gamma ray detection to measure the casing thickness may be made.

Claims

1. A well logging tool sized and adapted for passage through a well borehole for use in detecting naturally occurring gamma rays, said logging tool comprising: at least one pair of threadedly interconnecting tubular members (30, 31), said tubular members when interconnected defining frusto-conical recess, a tubular composite low atomic number member (38) having at least one end with a complementarily shaped frusto-conical end for tight reception in said recess, a tubular rubber member (39) around said low atomic number member; a wear resistant outer sleeve (40) around said rubber member for protecting said rubber member from abrasion with the borehole; and means disposed within said low atomic number member for detecting gamma rays and separating them into an energy spectrum.

2. Apparatus according to claim 1, wherein said recess in said tubular members is defined by upper and lower tubular parts where said upper part defines an inner wall surface (37) and said lower part defines an outer wall surface (35), said lower part having external, stepped diametrical portions respectively for receiving said rubber member and said wear resistant sleeve.

3. Apparatus according to claim 1 or 2, wherein the wear resistant outer sleeve is of aluminum.

4. Apparatus according to any of claims 1 to 3, wherein the tubular composite low atomic number member comprises a filamentary wound graphite or boron member having an epoxy base.

Revendications

1. Outil de diagraphe de puits ayant des dimensions et étant adapté pour passer à travers un trou de sondage, destiné à être utilisé pour détecter les rayons gamma apparaissant naturellement, cet outil de diagraphe comprenant: au moins une paire d'organes tubulaires (30, 31) reliés entre-eux par vissage, lesdits organes tubulaires, lorsqu'ils sont reliés entre-eux, délimitant une cavité tronconique, un élément tubulaire composite (38) de faible nombre atomique ayant au moins une extrémité, avec une extrémité tronconique de forme complémentaire destinée à être reçue étroitement dans ladite cavité, un organe tubulaire en caoutchouc (39) autour dudit élément de faible nombre atomique; un manchon externe (40) résistant autour dudit organe en caoutchouc pour protéger ce dernier de l'abrasion avec le trou; et des moyens disposés à l'intérieur dudit élément de faible nombre atomique pour détecter les rayons gamma et les séparer en un spectre d'énergie.

2. Appareil suivant la revendication 1, dans lequel ladite cavité dans lesdits organes tubulaires est délimitée par des parties tubulaires supérieure et inférieure dans lesquelles ladite partie supérieure délimite une surface (37) de paroi interne, et ladite partie inférieure délimite une surface de paroi externe (35), ladite partie inférieure ayant des portions de diamètres étagés externes respectivement pour recevoir ledit organe en caoutchouc et ledit manchon résistant à l'usure.

3. Appareil suivant l'une des revendications 1 ou 2, dans lequel le manchon externe résistant à l'usure est en aluminium.

4. Appareil suivant l'une quelconque des revendications 1 à 3, dans lequel l'élément composite tubulaire de faible nombre atomique est en un filament de graphite enroulé ou un élément en bore comportant une base époxy.

Patentansprüche

1. Bohrlochvermessungsgerät, das zum Abfahren eines Bohrlochs bemessen und eingerichtet ist und zum Nachweis natürlich vorkommender Gammastrahlen dient, enthaltend: wenigstens ein Paar von durch Gewinde verbundenen rohrförmigen Gliedern (30, 31), die im verbundenen Zustand eine kegelstumpfförmige Ausnehmung bestimmen, ein rohrförmiges Glied (38) aus Verbundmaterial niedriger Ordnungszahl und mit wenigstens einem komplementär geformten kegelstumpfförmigen Ende zur engen Aufnahme in die Ausnehmung; ein rohrförmiges Gummiteil (39) um das Glied niedriger Ordnungszahl; eine verschleißfeste Außenhülse (40) um das Gummiteil zu dessen Schutz gegen Abrieb an dem Bohrloch; und Nachweismittel innerhalb des Gliedes niedriger Ordnungszahl zum Nachweis von Gammastrahlen und deren Aufspaltung in ein Energiespektrum.

2. Gerät nach Anspruch 1, dadurch gekennzeichnet, daß die Ausnehmung in den rohrförmigen Gliedern durch obere und untere rohrförmige

used because this type of composite is capable of higher stresses than other fibre-reinforced materials.

The outer surface of the member 38 and the second recessed section 33 can be enclosed with a thin tubular rubber sleeve 39 which provides a fluid tight seal for the member 38. A thin walled, removable tubular aluminum wear sleeve 40 encloses the rubber sleeve 39 and is sized to be received on the first recessed section 32. The outer diameter of the sleeve 40 conforms to the outer diameter of the member 30, and may incorporate a Teflon (trade mark) anodized outer layer. The aluminum sleeve 40 and the graphite epoxy composite member 38 will transmit low energy gamma energy through 360° of the walls of the housing as contrasted with a single window type of tool.

The selected materials of the housing with low "Z" factors reduce interference by the housing materials with the gamma ray spectrum to be detected and there are no adverse X-ray produced by virtue of the housing materials.

Where it is desired to measure the casing weight or thickness effects, a tubular case made of, for example, titanium can be used, in addition to the above described toolcase, and it will also be effective for use in high pressure operations. Titanium alloys provide a sufficiently low "Z" factor so that gamma ray detection to measure the casing thickness may be made.

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2. Apparatus according to claim 1, wherein said recess in said tubular members is defined by upper and lower tubular parts where said upper part defines an inner wall surface (37) and said lower part defines an outer wall surface (35), said lower part having external, stepped diametrical portions respectively for receiving said rubber member and said wear resistant sleeve.

3. Apparatus according to claim 1 or 2, wherein the wear resistant outer sleeve is of aluminum.

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2. Gerät nach Anspruch 1, dadurch gekennzeichnet, daß die Ausnehmung in den rohrförmigen Gliedern durch obere und untere rohrförmige



Teile bestimmt ist, wobei der obere Teil eine innere Wandfläche (37) und der untere Teil eine äußere Wandfläche (35) bestimmt und der untere Teil äußere Teile mit abgestuften Durchmessern zur Aufnahme des Gummiteils und der verschleißfesten Hülse aufweist.

3. Gerät nach Anspruch 1 oder 2, dadurch

gekennzeichnet, daß die verschleißfeste Außenhülse aus Aluminium ist.

4. Gerät nach einem der Ansprüche 1 bis 3, dadurch gekennzeichnet, daß das rohrförmige Glied aus Verbundmaterial niedriger Ordnungszahl ein faserförmiges, gewickeltes Teil aus Graphit oder Bor mit einer Epoxidbasis aufweist.

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