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|---|---|
| (51) International Patent Classification:
<i>G01V 5/10</i> (2006.01) | (72) Inventors: HAN, Xiaogang ; 150 W. Warrenville Road, MC 200-1W, Naperville, Illinois 60563 (US). ZETT, Adrian ; 150 W. Warrenville Road, MC 200-1W, Naperville, Illinois 60563 (US). GALVAN AMAYA, Jeanine ; 150 W. Warrenville Road, MC 200-1W, Naperville, Illinois 60563 (US). LANCLOS, Brady ; 150 W. Warrenville Road, MC 200-1W, Naperville, Illinois 60563 (US). |
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| (71) Applicant: BP CORPORATION NORTH AMERICA INC. [US/US]; 501 Westlake Park Boulevard, Houston, Texas 77079 (US). | |

(54) Title: SYSTEMS AND METHODS FOR PULSED NEUTRON LOGGING IN A SUBTERRANEAN WELLBORE

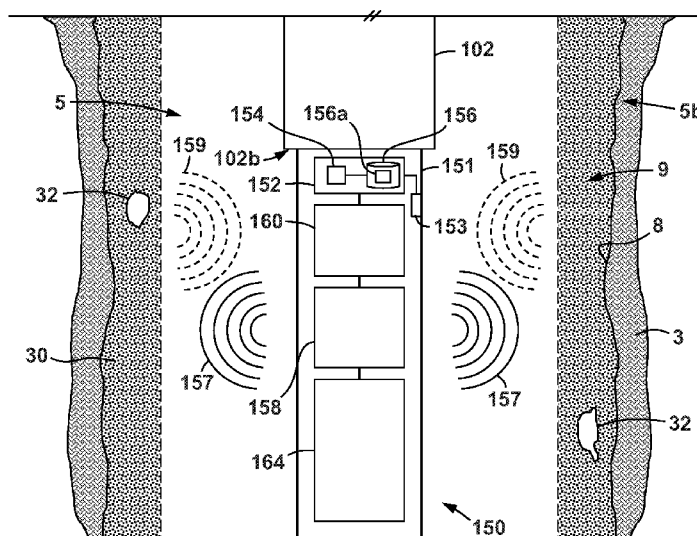


FIG. 4

(57) Abstract: Methods and associated systems are disclosed for performing a logging operation within a subterranean wellbore extending within a subterranean reservoir. In an embodiment, the method includes (a) emitting neutrons into the subterranean wellbore or the subterranean reservoir, and (b) detecting gamma rays emitted from atoms disposed within the subterranean wellbore or the subterranean reservoir. In addition, the method includes (c) determining a first gamma ray count within a first energy window of the gamma rays detected at (b), and (d) determining a second gamma ray count within a second energy window of the gamma rays detected at (b). The second energy window is different than the first energy window. Further, the method includes (e) calculating a ratio of the first gamma ray count to the second gamma ray count.



OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER
INV. G01V5/10
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 524 272 A (PAAP HANS J [US] ET AL) 18 June 1985 (1985-06-18) claim 2 column 1, lines 10-15 column 2, line 32 - column 3, line 30 -----	4,5
Y	US 2004/020646 A1 (FLECKER MICHAEL J [US] ET AL) 5 February 2004 (2004-02-05) paragraphs [0011], [0028] - [0035] -----	1-10
Y	US 2016/003969 A1 (ZHOU TONG [US] ET AL) 7 January 2016 (2016-01-07) paragraph [0025] -----	1-10
A	WO 2015/167433 A1 (HALLIBURTON ENERGY SERVICES INC [US]) 5 November 2015 (2015-11-05) page 16, lines 18-23 -----	1-10



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2019/058850

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4524272	A	18-06-1985	NONE
US 2004020646	A1	05-02-2004	NONE
US 2016003969	A1	07-01-2016	CA 2896051 A1 07-01-2016 GB 2529544 A 24-02-2016 US 2016003969 A1 07-01-2016
WO 2015167433	A1	05-11-2015	EP 3100076 A1 07-12-2016 MX 360670 B 13-11-2018 US 2016238736 A1 18-08-2016 WO 2015167433 A1 05-11-2015

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/058850

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-10

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-10

Method of completing a subterranean wellbore.

2. claims: 11-26

Method of performing a logging operation for a subterranean wellbore extending within a subterranean reservoir, and non-transitory computer readable medium containing instructions to process gamma ray counts in 2 different energy windows.
