

(19) World Intellectual Property  
Organization  
International Bureau



(43) International Publication Date  
2 December 2004 (02.12.2004)

PCT

(10) International Publication Number  
**WO 2004/104560 A3**

(51) International Patent Classification<sup>7</sup>: **G01V 3/32**

(21) International Application Number:  
PCT/US2004/016014

(22) International Filing Date: 21 May 2004 (21.05.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
10/442,585 21 May 2003 (21.05.2003) US

(71) Applicant (for all designated States except US): **BAKER HUGHES INCORPORATED** [US/US]; 3900 Essex Lane, Suite 1200, Houston, TX 77027 (US).

(72) Inventors: **KRUSPE, Thomas**; Halber Weg 5, 29342 Wienhausen (DE). **KIESEL, Christian**; Alte Stockener

Str. 20, 30419 Hannover (DE). **THERN, Holger**; Langensalzastr. 21, 30169 Hannover (DE). **SURHOLT, Iris**; Rehbdish 20, 30167 Hannover (DE).

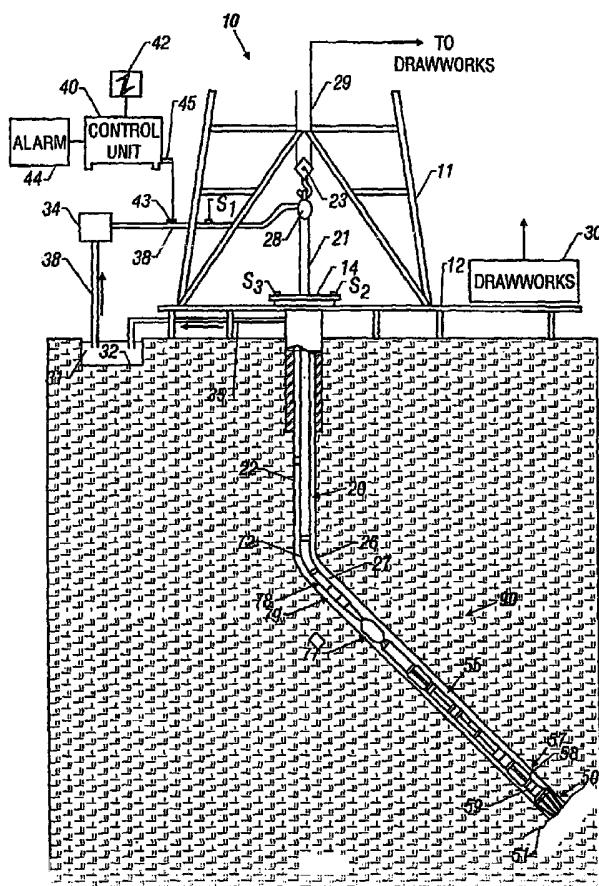
(74) Agents: **RIDDLE, Albert, J.** et al.; Baker Hughes Incorporated, 3900 Essex Lane, Suite 1200, Houston, TX 77027 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH,

[Continued on next page]

(54) Title: FORMATION-BASED INTERPRETATION OF NMR DATA FOR CARBONATE RESERVOIRS



(57) Abstract: An apparatus and method for determining a parameter of interest of a formation composed of carbonate rock. A nuclear magnetic resonance (NMR) sensor assembly produces a pulsed RF field designed for obtaining measurements indicative of the parameter of interest of the formation. A downhole processor processes the measurements for obtaining BVI and BVM using a cutoff time based on classification of the carbonate. Further processing is done to estimate the permeability of the carbonate.



GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

(88) Date of publication of the international search report:  
24 March 2005

*For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

**Published:**

— with international search report

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US2004/016014

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 G01V3/32

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)  
IPC 7 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 practical, search terms used)

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages                  | Relevant to claim No. |
|------------|-----------------------------------------------------------------------------------------------------|-----------------------|
| X          | US 6 088 656 A (RAMAMOORTHY RAGHU ET AL)<br>11 July 2000 (2000-07-11)                               | 1,5-8                 |
| Y          | column 2, line 31 - line 44<br>column 6, line 16 - line 40                                          | 2-4,9-17              |
| X          | US 5 680 043 A (HURLIMANN MARTIN D ET AL)<br>21 October 1997 (1997-10-21)                           | 1                     |
| Y          | column 9, line 15 - line 26                                                                         | 2-4,9-17              |
| O,X        | US 2002/153888 A1 (KRUSPE THOMAS ET AL)<br>24 October 2002 (2002-10-24)<br>cited in the application | 18-28                 |
| A          | paragraphs '0021!, '0029!, '0030!                                                                   | 1-17                  |
| P,X        | US 2003/231017 A1 (KRUSPE THOMAS ET AL)<br>18 December 2003 (2003-12-18)<br>the whole document      | 1-27                  |
|            | -----<br>-/-                                                                                        |                       |

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in 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 document 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

1 November 2004

Date of mailing of the international search report

01/12/2004

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Thomas, J

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US2004/016014

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages                                 | Relevant to claim No. |
|------------|--------------------------------------------------------------------------------------------------------------------|-----------------------|
| X          | WO 03/016953 A (BAKER HUGHES INC)<br>27 February 2003 (2003-02-27)<br>abstract                                     | 18                    |
| Y          | US 6 559 639 B2 (MINH CHANH CAO ET AL)<br>6 May 2003 (2003-05-06)<br>paragraphs '0016!, '0017!, '0071! -<br>'0073! | 12,14,15              |

## INTERNATIONAL SEARCH REPORT

International Application No

PCT/US2004/016014

| Patent document<br>cited in search report |    | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
|-------------------------------------------|----|---------------------|----------------------------|---------------------|
| US 6088656                                | A  | 11-07-2000          | GB 2346230 A ,B            | 02-08-2000          |
| US 5680043                                | A  | 21-10-1997          | CA 2172439 A1              | 24-09-1996          |
|                                           |    |                     | GB 2299171 A ,B            | 25-09-1996          |
|                                           |    |                     | NO 961119 A                | 24-09-1996          |
| US 2002153888                             | A1 | 24-10-2002          | US 6446736 B1              | 10-09-2002          |
|                                           |    |                     | US 6247542 B1              | 19-06-2001          |
|                                           |    |                     | CA 2457672 A1              | 27-02-2003          |
|                                           |    |                     | EP 1425613 A1              | 09-06-2004          |
|                                           |    |                     | WO 03016953 A1             | 27-02-2003          |
|                                           |    |                     | US 2003231017 A1           | 18-12-2003          |
|                                           |    |                     | US 2004196038 A1           | 07-10-2004          |
|                                           |    |                     | US 2002153136 A1           | 24-10-2002          |
|                                           |    |                     | US 2002108784 A1           | 15-08-2002          |
|                                           |    |                     | US 2004089475 A1           | 13-05-2004          |
|                                           |    |                     | AU 2889299 A               | 20-09-1999          |
|                                           |    |                     | AU 759201 B2               | 10-04-2003          |
|                                           |    |                     | AU 3066399 A               | 20-09-1999          |
|                                           |    |                     | CA 2322884 A1              | 10-09-1999          |
|                                           |    |                     | EP 1064452 A1              | 03-01-2001          |
|                                           |    |                     | GB 2354543 A ,B            | 28-03-2001          |
|                                           |    |                     | GB 2374102 A ,B            | 09-10-2002          |
|                                           |    |                     | GB 2375365 A ,B            | 13-11-2002          |
|                                           |    |                     | NO 20004426 A              | 01-11-2000          |
|                                           |    |                     | NO 20004427 A              | 01-11-2000          |
|                                           |    |                     | WO 9945236 A1              | 10-09-1999          |
|                                           |    |                     | WO 9945234 A1              | 10-09-1999          |
| US 2003231017                             | A1 | 18-12-2003          | US 2002153888 A1           | 24-10-2002          |
|                                           |    |                     | US 6446736 B1              | 10-09-2002          |
|                                           |    |                     | US 6247542 B1              | 19-06-2001          |
|                                           |    |                     | CA 2457672 A1              | 27-02-2003          |
|                                           |    |                     | EP 1425613 A1              | 09-06-2004          |
|                                           |    |                     | WO 03016953 A1             | 27-02-2003          |
|                                           |    |                     | US 2004196038 A1           | 07-10-2004          |
|                                           |    |                     | US 2002153136 A1           | 24-10-2002          |
|                                           |    |                     | US 2002108784 A1           | 15-08-2002          |
|                                           |    |                     | US 2004089475 A1           | 13-05-2004          |
| WO 03016953                               | A  | 27-02-2003          | US 2002153888 A1           | 24-10-2002          |
|                                           |    |                     | CA 2457672 A1              | 27-02-2003          |
|                                           |    |                     | EP 1425613 A1              | 09-06-2004          |
|                                           |    |                     | WO 03016953 A1             | 27-02-2003          |
|                                           |    |                     | US 2003231017 A1           | 18-12-2003          |
|                                           |    |                     | US 2004196038 A1           | 07-10-2004          |
| US 6559639                                | B2 | 16-01-2003          | US 2003011366 A1           | 16-01-2003          |
|                                           |    |                     | AU 741420 B2               | 29-11-2001          |
|                                           |    |                     | CA 2283996 A1              | 02-04-2000          |
|                                           |    |                     | CN 1255633 A               | 07-06-2000          |
|                                           |    |                     | GB 2343256 A ,B            | 03-05-2000          |
|                                           |    |                     | IT MI992039 A1             | 30-03-2001          |
|                                           |    |                     | NL 1013149 C2              | 30-05-2000          |
|                                           |    |                     | NL 1013149 A1              | 04-04-2000          |
|                                           |    |                     | NO 994790 A                | 03-04-2000          |
|                                           |    |                     | AU 5015099 A               | 06-04-2000          |
|                                           |    |                     | EG 22126 A                 | 30-08-2002          |

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US2004/016014

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
|-------------------------------------------|---------------------|----------------------------|---------------------|
| US 6559639                                | B2                  | ID 24554 A                 | 27-07-2000          |