

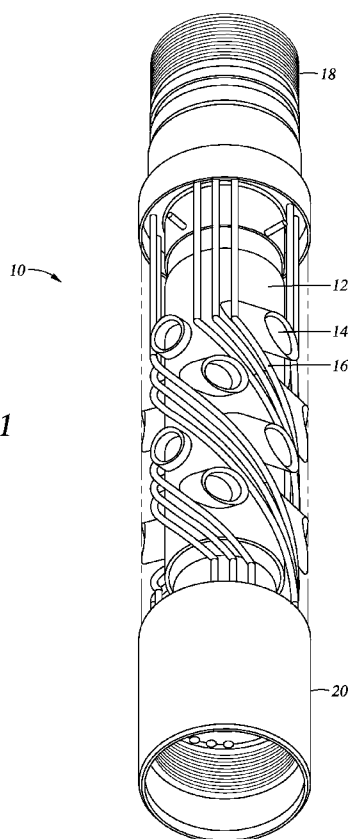


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- (81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, 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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[Continued on next page]

(54) Title: MANUFACTURED PORTED MANDREL AND METHOD FOR MAKING SAME

Fig. 1



(57) Abstract: A ported mandrel additively manufactured with at least two different materials. A unitary ported mandrel includes a mandrel body of a base material; one or more ports including an erosion resistant material; and one or more return pathways. A method for making a unitary ported mandrel for a downhole fracturing operation.



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SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA,
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— *as to the applicant's entitlement to claim the priority of
the earlier application (Rule 4.17(iii))*

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MANUFACTURED PORTED MANDREL AND METHOD FOR MAKING SAME

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Application No. 14/487709 filed on September 16, 2014, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Fracturing operations in the downhole industry for production of fluids and/or sequestration of Carbon Dioxide commonly utilize one or more ported mandrels through which high pressure fracturing fluid and proppant is applied to a formation face that defines a borehole in which the fracturing operations are to take place. The high pressure fluid is employed to induce fractures in the formation beyond the formation face and proppant is employed to maintain these fractures following the removal of pressure on the formation, thereby enhancing permeability of the formation to promote fluid movement there through.

[0003] As the fracturing industry advances, higher pressures, greater rates of fluid flow, and larger proppant volumes are being employed. This is inevitably accompanied by exacerbated erosion of critical parts of the ported mandrels at least. Erosion is a consistent engineering concern in any fluid flow system, but with the higher rates and larger proppant volumes noted, the increased rate of erosion can make the subject activities excessively costly due to accelerated scrap and redress requirements.

[0004] Relatedly, fluid dynamic studies and the ever growing body of information surrounding such studies, suggest that uncommon geometries for ported mandrels could reduce the rate of erosion brought on by these more demanding applications. Some of the possible configurations that could be developed are difficult, or even impossible, to effectively machine thereby rendering their pursuit commercially unattainable.

[0005] In view of the foregoing drawbacks, the art is ever receptive to solutions that can overcome shortcomings of the prior art.

SUMMARY

[0006] A ported mandrel additively manufactured with at least two different materials.

[0007] A unitary ported mandrel includes a mandrel body of a base material; one or more ports including an erosion resistant material; and one or more return pathways.

[0008] A method for making a unitary ported mandrel for a downhole fracturing operation includes determining a layout of ports, return pathways and areas requiring erosion resistance; inputting the foregoing into a computer controller for an additive manufacturing device; and forming the ported mandrel.

[0009] A method for making a unitary ported mandrel for a downhole fracturing operation includes positioning a layer of material according to a programmed configuration of the unitary ported mandrel; positioning another layer of material at least partially in contact with the layer of material; repeating the positioning of a layer and positioning of another layer including positioning layers of erosion resistant material in selected locations until the unitary ported mandrel is complete.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

[0011] Figure 1 is a perspective partially transparent view of a ported mandrel as disclosed herein;

[0012] Figure 2 is a side partially transparent view of the mandrel of Figure 1; and

[0013] Figure 3 is a perspective partially transparent view of an alternate embodiment of a ported mandrel as disclosed herein.

DETAILED DESCRIPTION

[0014] Referring to Figures 1 and 2, a perspective partially transparent view and a side partially transparent view of an additively manufactured ported mandrel 10 are illustrated. The mandrel 10 includes a mandrel body 12, a number of ports 14 and a number of return flow paths 16. Further the mandrel 10 comprises ends 18 and 20 that may be configured as desired to connect with other components of a downhole string (not shown). It will be immediately apparent to one of skill in the art that the mandrel layout is unique. More specifically, the pattern of ports 14 and return flow paths is helical. Further, the ports 14 themselves are provided with a highly erosion resistant material such as carbide. The ports may have a portion thereof coated with erosion resistant material or made of erosion resistant material or the whole port may be made of erosion resistant material. The accomplishment of both of these unique features is supported through the use of additive manufacturing methods. More specifically, additive manufacture is a process whereby individual layers of material are built upon one another until a final product is achieved. This is layer-by-layer or even

molecule-by-molecule. Because of the ability to form the final product from one side and effectively move a computer controlled cross section through the part being produced, otherwise physically difficult or impossible to produce geometries are enabled. In the present invention, a process such as Direct Metal Laser Sintering (DMLS) may be used to create a mandrel as depicted with carbon steel in some places that are not particularly subject to erosion and carbide in areas that are particularly subject to erosion as determined through actual visual examination of used parts or by computer modeling. The material difference allows for cost control and material property control to optimize a particular mandrel for a particular deployment. Importantly, the distinct materials are not distinct parts connected to the other parts of the mandrel. Rather the mandrel body, ports and return pathways including the base material and the erosion resistant materials as disclosed is a unitary ported mandrel. The mandrel is a single formed piece at the end of the additive machining process without any additional components needed to complete the mandrel itself.

[0015] Referring to Figure 3, a more conventional geometry is created using the additive machining method to improve simplicity of protecting areas subject to erosion. Instead of laborious prior art methods of producing matching sets of carbide port inserts, the ports are either made from carbide or coated at appropriate locations during the additive machining process.

[0016] For either embodiment disclosed, the longitudinal ends of the mandrel 10 will be configured for connection (such as, for example only, pin and box threads) with other components of a string to be run downhole for a fracturing operation.

[0017] While the invention has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the claims. Also, in the drawings and the description, there have been disclosed exemplary embodiments of the invention and, although specific terms may have been employed, they are unless otherwise stated used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention therefore not being so limited. Moreover, the use of the terms first, second, etc. do not denote any order or importance, but rather the terms first,

second, etc. are used to distinguish one element from another. Furthermore, the use of the terms a, an, etc. do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced item.

CLAIMS:

What is claimed is:

- 1 A ported mandrel additively manufactured with at least two different materials.
- 2 A unitary ported mandrel comprising:
a mandrel body of a base material;
one or more ports including an erosion resistant material; and
one or more return pathways.
- 3 A unitary ported mandrel as claimed in claim 2 wherein the one or more ports is greater than one and the ports are arranged helically with respect to a longitudinal axis of the mandrel body.
- 4 A unitary ported mandrel as claimed in claim 2 wherein the one or more return pathways are helically arranged with respect to a longitudinal axis of the mandrel body.
- 5 A unitary ported mandrel as claimed in claim 2 wherein the one or more ports are formed entirely of the erosion resistant material.
- 6 A unitary ported mandrel as claimed in claim 2 wherein the one or more ports are coated with the erosion resistant material.
- 7 A unitary ported mandrel as claimed in claim 2 wherein the erosion resistant material is carbide.
- 8 A unitary ported mandrel as claimed in claim 2 wherein the base material is carbon steel.
- 9 A method for making a unitary ported mandrel for a downhole fracturing operation comprising:
determining a layout of ports, return pathways and areas requiring erosion resistance;
inputting the foregoing into a computer controller for an additive manufacturing device; and
forming the ported mandrel.
- 10 A method for making a unitary ported mandrel for a downhole fracturing operation comprising:
positioning a layer of material according to a programmed configuration of the unitary ported mandrel;
positioning another layer of material at least partially in contact with the layer of material;

repeating the positioning of a layer and positioning of another layer including positioning layers of erosion resistant material in selected locations until the unitary ported mandrel is complete.

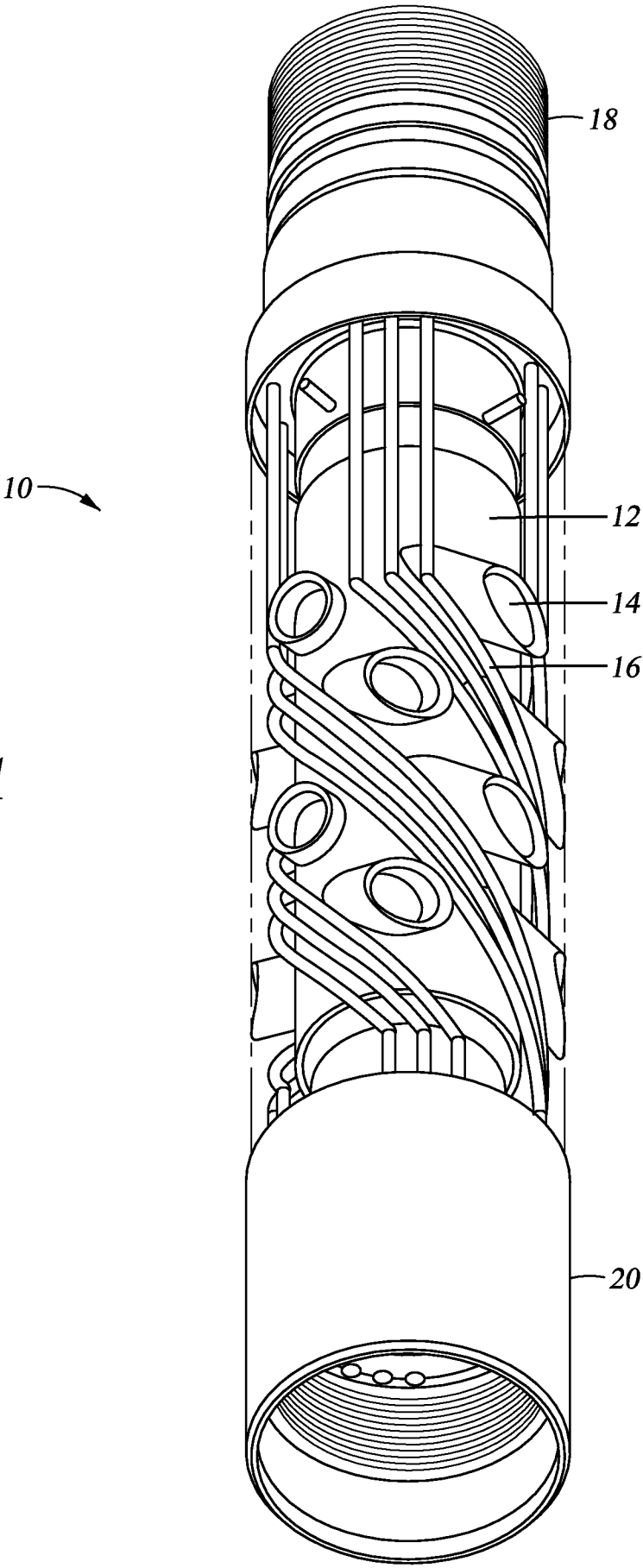


Fig. 1

Fig. 2

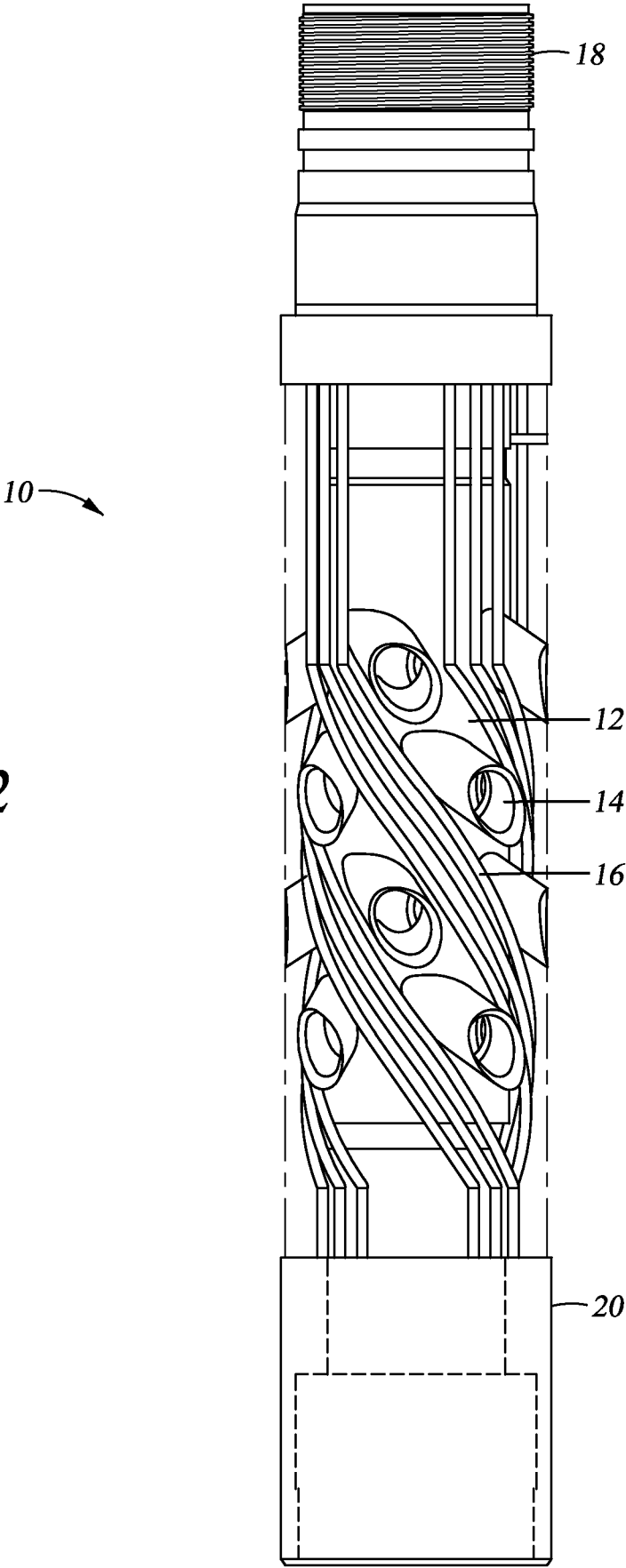
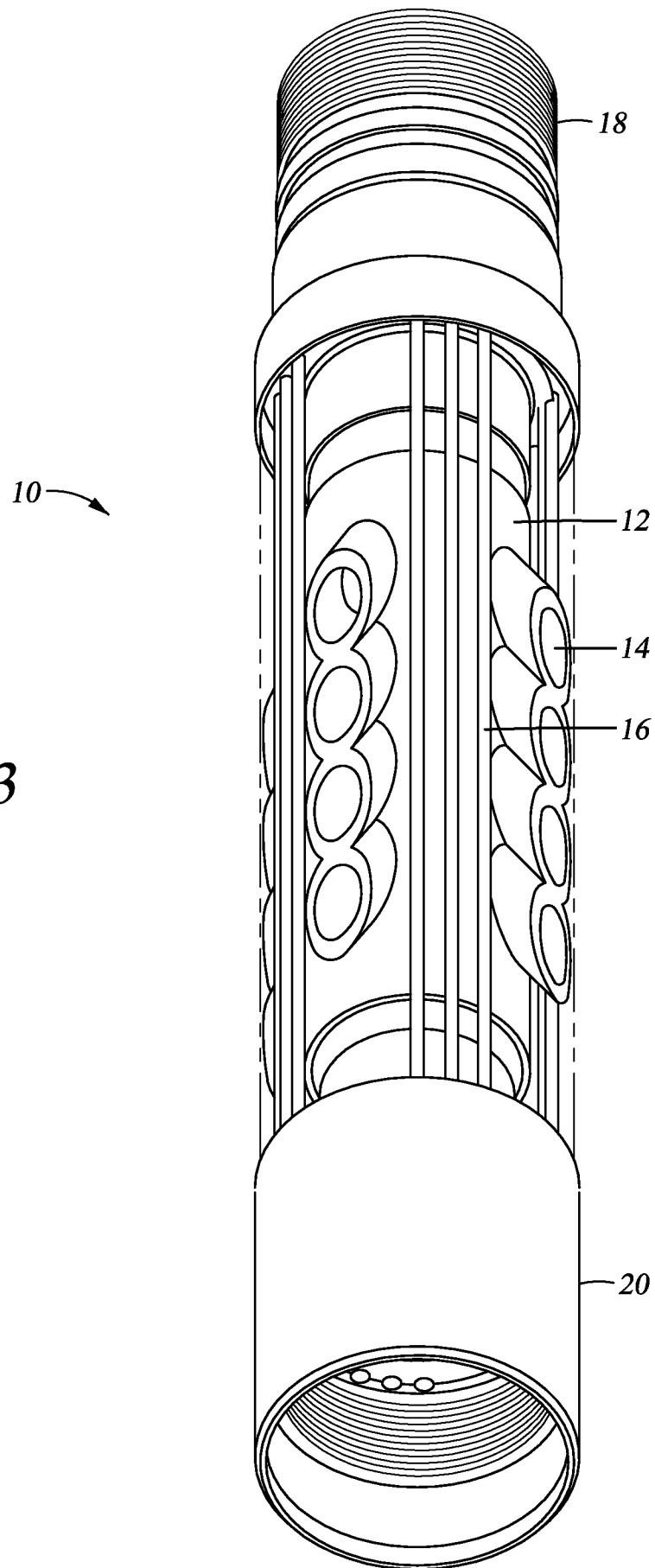


Fig. 3

A. CLASSIFICATION OF SUBJECT MATTER**E21B 23/00(2006.01)i, B23P 15/00(2006.01)i, E21B 43/17(2006.01)i, E21B 43/26(2006.01)i**

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)

E21B 23/00; E21B 23/02; E21B 34/06; G06F 17/50; E21B 43/04; E21B 43/00; E21B 34/10; B23P 15/00; E21B 43/17; E21B 43/26

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords:ported mandrel, material, port, erosion, return pathway

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4782896 A (WITTEN, ERIC B.) 08 November 1988 See column 1, line 65 - column 2, line 5; column 3, line 63 - column 4, line 17; column 5, lines 45-64; and figures 2A-2B, 4.	1-8
Y		9-10
Y	US 2013-0310961 A1 (SCHLUMBERGER TECHNOLOGY CORPORATION) 21 November 2013 See paragraphs [0016]-[0024], [0035]-[0039]; claim 1; and figure 4.	9-10
A	WO 2010-045074 A2 (BAKER HUGHES INCORPORATED et al.) 22 April 2010 See paragraphs [0008], [0016]-[0018]; and figures 1, 4.	1-10
A	US 2009-0242211 A1 (FAGLEY, IV et al.) 01 October 2009 See paragraphs [0047]-[0060]; and figures 3A-3C.	1-10
A	US 2013-0112399 A1 (ROYER et al.) 09 May 2013 See paragraphs [0018]-[0019], [0045]-[0047]; and figures 4A-4C.	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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/049953

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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