



(43) International Publication Date
9 January 2014 (09.01.2014)

(51) International Patent Classification:

G01N 29/04 (2006.01) G01N 29/24 (2006.01)
G01N 29/12 (2006.01)

(21) International Application Number:

PCT/US2013/048043

(22) International Filing Date:

27 June 2013 (27.06.2013)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/667,929 3 July 2012 (03.07.2012) US
61/810,756 11 April 2013 (11.04.2013) US

(71) Applicant: EATON CORPORATION [US/US]; Eaton Center, 1000 Eaton Blvd, Cleveland, Ohio 44122 (US).

(72) Inventor: SAUNDERS, Robert Charles; 8209 Petoskey Street, Kalamazoo, Michigan 49009 (US).

(74) Agents: HOLLIS, Brian D. et al.; Remarck Law Group PLC, P.O. Box 210958, Auburn Hills, Michigan 48321 (US).

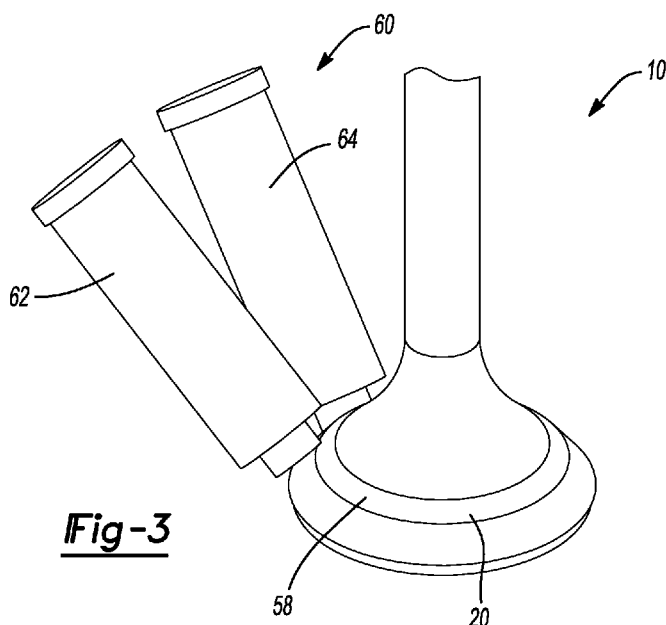
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, 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, 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.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: NON-DESTRUCTIVE TEST OF DETECTING FAULTY WELDS ON AN ENGINE POPPET VALVE



(57) Abstract: A method of detecting a defect in a weld on a valve head of an engine poppet valve is disclosed. A first electromagnetic transducer can be positioned against the valve head in a first location. A second electromagnetic transducer can be positioned against the valve in a second location, distinct from the first location. An electromagnetic wave can be projected from the first electromagnetic transducer. The electromagnetic wave can be projected through the weld. The electromagnetic wave can be received at the second electromagnetic transducer. At least one of the engine poppet valve, the first electromagnetic transducer and the second electromagnetic transducer can be moved while concurrently projecting and receiving the electromagnetic wave. An acoustic resonance of the electromagnetic wave can be recorded and observed. A defect in the weld can be detected based on an acoustic deviation on the recorded acoustic resonance.

NON-DESTRUCTIVE TEST OF DETECTING FAULTY WELDS ON AN ENGINE POPPET VALVE

CROSS-REFERENCE TO RELATED APPLICATIONS

5

[0001] This application claims priority to United States Provisional Application No. 61/667,929 filed on July 3, 2012 and United States Provisional Application No. 61/810,756 filed on April 11, 2013 the content of which are incorporated herein by reference in their entirety.

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FIELD

[0002] The present disclosure relates generally to engine valves and more specifically relates to a method of identifying weld defects on an engine poppet valve.

BACKGROUND

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[0003] The background description provided herein is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventor, to the extent it is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

20

[0004] Engine poppet valves for internal combustion engines can be manufactured in many ways. In the manufacture of engine poppet valves, it is common practice to face the valve with a corrosion, wear, abrasion, and heat resistant alloy to protect the valve face and enhance the useful life of the valve. The term “facing”, or “seat facing” as used herein is intended to encompass the term “hard facing” which is also used in the industry. These terms refer to providing the valve face with a corrosion, wear, abrasion, and/or heat resistant alloy to attain the necessary wear and corrosion resistance required for the given application.

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[0005] In some examples the facing material has been a cobalt based alloy such as Stellite[®] alloy (Stellite is a registered trademark of Deloro Stellite Company, Inc.), or a nickel based alloy like Eatonite[®] (Eatonite is a registered trademark of Eaton Corporation). More recently, Eatonite[®] 6, an iron based alloy, has been used and is rapidly replacing cobalt based alloys. There are other alloys for seat facing,

including, but not limited to, nickel-chromium, or nickel-chromium-cobalt base alloys, or various alloys known in the industry. The facing is usually applied to the valve seating surface by various high temperature techniques, like welding. The seat facing can be applied in a manner that can control metallurgy and microstructure.

5 Typical heat sources for welding include, but are not limited to, oxy-acetylene torch, tungsten inert gas arc (TIG), or plasma arc (transferred or non-transferred), or the like.

[0006] In other engine poppet valve configurations, the valve can include a hollow valve stem having a cannulation. A plug can be inserted into the cannulation. The
10 plug can be formed of metallic material and be joined to the valve head by welds.

SUMMARY

[0007] A method of detecting a defect in a weld on a valve head of an engine poppet valve is disclosed. A first electromagnetic transducer can be positioned
15 against the valve head in a first location. A second electromagnetic transducer can be positioned against the valve in a second location, distinct from the first location. An electromagnetic wave can be projected from the first electromagnetic transducer. The electromagnetic wave can be projected through the weld. The electromagnetic wave can be received at the second electromagnetic transducer. At least one of the
20 engine poppet valve, the first electromagnetic transducer and the second electromagnetic transducer can be moved while concurrently projecting and receiving the electromagnetic wave. An acoustic resonance of the electromagnetic wave can be recorded and observed. A defect in the weld can be detected based on an acoustic deviation on the recorded acoustic resonance.

25 **[0008]** According to additional features the method includes projecting an electromagnetic wave through a valve seat weld on the valve head. Moving at least one of the engine poppet valve, the first electromagnetic transducer and the second electromagnetic transducer can include rotating the engine poppet valve around a longitudinal axis of a valve stem of the engine poppet valve. The defect can
30 comprise at least one of an open bond, porosity in the weld, and lack of fusion of the weld. The valve seat weld can be deposited in a seat facing groove. The valve seat weld can be deposited by one of heat fusing molten material in the seat facing groove, welding a preformed ring within the groove and laser cladding seat facing

material in the seat facing groove. The electromagnetic wave can be projected through a weld joining a valve head and a plug received in a hollow valve stem.

[0009] A method of detecting a defect in a valve seat weld on a valve head of an engine poppet valve is disclosed. A first electromagnetic transducer can be positioned against the valve head in a first location. A second electromagnetic transducer can be positioned against the valve in a second location, distinct from the first location. An electromagnetic wave can be projected from the first electromagnetic transducer. The electromagnetic wave can be projected through the valve seat weld. The electromagnetic wave can be received at the second electromagnetic transducer. At least one of the engine poppet valve, the first electromagnetic transducer and the second electromagnetic transducer can be moved while concurrently projecting and receiving the electromagnetic wave. An acoustic resonance of the electromagnetic wave can be recorded and observed. A defect in the valve seat weld can be detected based on an acoustic deviation on the recorded acoustic resonance.

[0010] According to additional features, the first and second electromagnetic transducers are positioned generally adjacent to each other and against a valve seat face of the valve head. In other examples, the first and second electromagnetic transducers are positioned generally opposed to each other with the first electromagnetic transducer placed generally against a combustion face of the valve head and the second electromagnetic transducer is placed against a valve seat face of the valve head.

[0011] Moving at least one of the engine poppet valve, the first electromagnetic transducer and the second electromagnetic transducer can include rotating the engine poppet valve around a longitudinal axis of a valve stem of the engine poppet valve. The defect can comprise at least one of an open bond, porosity in the weld, and lack of fusion of the weld. The valve seat weld can be deposited in a seat facing groove. The valve seat weld can be deposited by one of heat fusing molten material in the seat facing groove, welding a preformed ring within the groove and laser cladding seat facing material in the seat facing groove. The valve seat weld can be deposited by plasma transferred arc (PTA) welding.

[0012] A method of detecting a defect in a plug weld between a plug and a valve head of an engine poppet valve is disclosed. A first electromagnetic transducer can be positioned against the valve head in a first location. A second electromagnetic

transducer can be positioned against the valve in a second location, distinct from the first location. An electromagnetic wave can be projected from the first electromagnetic transducer. The electromagnetic wave can be projected through the plug weld. The electromagnetic wave can be received at the second
5 electromagnetic transducer. At least one of the engine poppet valve, the first electromagnetic transducer and the second electromagnetic transducer can be moved while concurrently projecting and receiving the electromagnetic wave. An acoustic resonance of the electromagnetic wave can be recorded and observed. A defect in the plug weld can be detected based on an acoustic deviation on the
10 recorded acoustic resonance.

[0013] According to one configuration, the first electromagnetic transducer can be placed on the valve head portion and the second electromagnetic transducer can be placed on the plug. Moving at least one of the engine poppet valve, the first electromagnetic transducer and the second electromagnetic transducer can include
15 rotating the engine poppet valve around a longitudinal axis of a valve stem of the engine poppet valve. The defect can comprise at least one of an open bond, porosity in the weld, and lack of fusion of the weld. The plug can be inserted into a cannulation of a hollow valve stem.

[0014] Further areas of applicability of the present disclosure will become
20 apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The present disclosure will become more fully understood from the
25 detailed description and the accompanying drawings, wherein:

[0016] FIG. 1 is a side perspective view of an engine valve according to one example of the present disclosure;

[0017] FIG. 2 is a side view of the engine valve of FIG. 1 shown with a seat weld according to one example of the present disclosure;

[0018] FIG. 3 is a front perspective view of a first and second electromagnetic
30 transducer initially placed in a first position against the engine valve and proximate to the seat weld according to one example of the present disclosure;

[0019] FIG. 4 is a front perspective view of a first and second electromagnetic transducer initially placed in a second position against the engine valve and proximate to the seat weld according to second example of the present disclosure;

[0020] FIG. 5 is a cross-sectional view of the valve head of FIG. 3 at the seat weld;

[0021] FIG. 6 is a close up cross-sectional view of the valve head at the seat weld shown in FIG. 5;

[0022] FIG. 7 is a close-up cross-sectional view of the valve head at the seat weld shown in FIG. 5 and with a polished surface;

[0023] FIG. 8 is an exemplary plot showing peak amplitude versus degrees of rotation of the valve seat of the valve shown in FIG. 3 wherein the circled areas identify resonance attenuation events and indications of subsurface bonding defects;

[0024] FIG. 9 is a partial cross-sectional view of an engine valve having a plug weld formed at a hollow stem according to additional features of the instant disclosure; and

[0025] FIG. 10 is a cross-sectional view of an engine valve having a plug weld and shown a first and second electromagnetic transducer initially placed in a first position against the engine valve proximate to the plug weld.

DETAILED DESCRIPTION

[0026] With initial reference to FIGS. 1 and 2, an engine poppet valve according to the present disclosure is shown and generally identified at reference 10. The engine poppet valve 10 generally includes a valve stem 12, a fillet 14 and a valve head portion 16. The valve head portion 16 includes a combustion face 18 that faces inwardly into an engine combustion chamber (not shown). A valve seat face 20 (FIG. 2) can be generally identified as a peripheral surface that engages the engine block or a valve seat insert (not shown). The valve head portion 16 can further include a valve head 22 having a predetermined diameter depending on a given application. The fillet 14 is a transition region which tapers concavely inwardly connecting the valve head 22 to the valve stem 12 which extends to a tip 23 having a tip end 24 and a tip chamfer 25. A keeper groove 26 (FIG. 2) can be provided to accommodate a retainer for a valve spring. The engine poppet valve 10 shown in FIGS. 1 and 2 is solid. It will be appreciated from the following discussion that the

teachings herein are also applicable to engine poppet valves that are hollow, or partially solid/hollow.

[0027] With additional reference now to FIG. 2, additional features of the engine poppet valve 10 will be described. The valve head 22 can have a head chamfer 30 that extends from the valve seat face 20. A margin 32 can be formed adjacent the head chamfer 30. In some examples, a stem weld 34 can be used to join the valve stem 12 and the valve head portion 16.

[0028] A seat facing cavity, pocket or groove 56 can be formed into the valve head portion 16. In one example the groove 56 can be formed using a lathe. Other methods may be used. A valve seat weld or seat facing weld 58 can be deposited in the seat facing groove 56. The seat facing weld 58 can be deposited by way of any number of well-known techniques including, but not limited to, heat fusing molten material in the seat facing groove 56, welding a preformed ring within the groove 56, or laser cladding seat facing material therein. One technique is plasma transferred arc (PTA) welding with Eatonite[®] 6 material. A suitable plasma transferred arc welding process is described in U.S. Patent No. 4,104,505, which is assigned to the assignee of the present disclosure, and hereby incorporated by reference. As identified above, a wide variety of seat facing or hard facing alloys may be used with the present invention, including but not limited to, those described in U.S. Patent Nos. 4,075,999 and 4,943,698, both patents being assigned to the assignee of the present disclosure, and hereby incorporated by reference. Subsequent to depositing the seat facing weld 58, the unfinished valve can be re-heated and coined such that the head diameter increases a selected amount to a final or desired valve head diameter. The term “coined” is used herein to include the terms “hot forming”, “forging”, “machining” or “grinding” to work the valve into a final form.

[0029] With additional reference not to FIGS. 3 and 4, an electromagnetic inspection device 60 in the form of a first and second electromagnetic transducer 62 and 64 can be used to detect and image surface and subsurface defects of the seat facing weld 58. While a first and second electromagnetic transducer 62 and 64 are shown, other devices may be used to detect and image surface and subsurface defects of the seat facing weld 58. As used herein the term “defects” can be used to include open bonds, porosity, lack of fusion, and one or more combinations thereof. In the example shown, the first and second electromagnetic transducers 62 and 64

can be used to detect and image surface and subsurface deviations in measured acoustic resonance.

[0030] According to the example shown, the first electromagnetic transducer 62 can be used to transmit acoustic waves, while the second transducer 64 can be used to receive the acoustic waves. The first and second electromagnetic transducers 62 and 64 can be positioned and re-positioned generally circumferentially around and against the valve head 16 at the seat facing weld 58. In general, the first electromagnetic transducer 62 is positioned at a first location and the second electromagnetic transducer is positioned at a second location, distinct from the first location such that one of the electromagnetic transducers 62, 64 can project an electromagnetic wave and the other electromagnetic transducer 62, 64 can receive the electromagnetic wave wherein the electromagnetic wave is transmitted through the seat facing weld 58.

[0031] In one method, the valve 10 or the first and second electromagnetic transducers 62 and 64 (or both) can move and/or rotate while projecting (and receiving) the electromagnetic waves through the valve 10 and more specifically through the seat facing weld 58. In the example shown in FIG. 3, the first and second electromagnetic transducers 62 and 64 are positioned generally adjacent to each other and against the valve seat face 20. In the example shown in FIG. 4, the first and second electromagnetic transducers 62 and 64 are positioned generally opposed to each other with the first electromagnetic transducer 62 placed generally against the combustion face 18 and the second electromagnetic transducer 64 placed against the valve seat face 20.

[0032] In one example, the valve 10 can be rotated around a longitudinal axis of the valve stem while the first and second electromagnetic transducers 62 and 64 remain fixed. The seat facing weld 58 can be detected and imaged such that any acoustic deviations can identify defects such as open bonds, porosity, lack of fusion, and one or more combinations thereof.

[0033] FIGS. 5-7 illustrate various identified defects generally identified at reference 70. Again, the defects may include open bonds, porosity, lack of fusion or combinations thereof. FIG. 8 is an exemplary plot showing peak amplitude versus degrees of rotation of the valve seat face 20 including the seat facing weld 58. Circled areas 80 and 82 identify resonance attenuation events and indications of subsurface bonding defects.

[0034] Turning now to FIG. 9, an engine poppet valve constructed in accordance to another example of the present disclosure is shown and generally identified at reference numeral 110. The engine poppet valve 110 generally includes a hollow valve stem 112 having a cannulation 113. The valve 110 can further include a fillet 114 and a valve head portion 116. The valve head portion 116 includes a combustion face 118 that faces inwardly into an engine combustion chamber (not shown). A valve seat face 120 can be generally identified as a peripheral surface that engages the engine block or a valve seat insert (not shown). The valve head portion 116 can further include a valve head 122 having a predetermined diameter depending on a given application.

[0035] A plug 130 can be inserted into the cannulation 113 of the hollow valve stem 112. The plug 130 can be formed of a metallic material and is joined to the valve head 122 by a plug weld or welds 134. The weld 134 can close the cannulation 113 at the valve seat face 120. The welds 134 can be formed using any welding method and material such as disclosed herein. While the welds 134 are represented as two distinct points in the cross sectional views of FIGS. 9 and 10, the welds 134 can collectively comprise a single and continuous annular weld between a circumference of the plug 130 and an inner diameter that defines the cannulation 113. According to one example, of the present disclosure, the integrity of the welds 134 can be determined by the electromagnetic inspection device 60.

[0036] The first and second electromagnetic transducers 62 and 64 can be positioned and re-positioned generally circumferentially around the valve head 116. In one method, the valve 110 or the first and second electromagnetic transducers 62 and 64 (or both) can move and/or rotate while projecting the electromagnetic waves through the valve 110 and more specifically through the welds 134. The welds 134 can be detected and imaged such that any acoustic deviations can identify defects such as open bonds, porosity, lack of fusion, and one or more combinations thereof. In the example shown in FIG. 10, the first electromagnetic transducer 62 is placed on the valve head portion 116 and the second electromagnetic transducer 64 is placed on the plug 130.

[0037] The foregoing description of the embodiments has been provided for purposes of illustration and description. For example, while the above discussion and illustrations have been focused on determining the integrity of a seat weld and a plug weld of an engine poppet valve, the same methods may be used to detect the

integrity of other welds on an engine poppet valve, such as, but not limited to a stem weld. It is not intended to be exhaustive or to limit the disclosure. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used
5 in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of the disclosure.

CLAIMS

What is claimed is:

1. A method of detecting a defect in a weld on a valve head of an engine poppet valve, the method comprising:
 - positioning a first electromagnetic transducer against the valve head in a first location;
 - positioning a second electromagnetic transducer against the valve head in a second location distinct from the first location;
 - projecting an electromagnetic wave from the first electromagnetic transducer, the electromagnetic wave being projected through the weld;
 - receiving the electromagnetic wave at the second electromagnetic transducer;
 - moving at least one of the engine poppet valve, the first electromagnetic transducer and the second electromagnetic transducer while concurrently projecting and receiving the electromagnetic wave;
 - recording an acoustic resonance of the electromagnetic wave;
 - observing the recorded acoustic resonance; and
 - detecting a defect in the weld based on an acoustic deviation on the recorded acoustic resonance.
2. The method of claim 1 wherein the electromagnetic wave is projected through a valve seat weld on the valve head.
3. The method of claim 1 wherein moving at least one of the engine poppet valve, the first electromagnetic transducer and the second electromagnetic transducer comprises:
 - rotating the engine poppet valve around a longitudinal axis of a valve stem of the engine poppet valve.
4. The method of claim 1 wherein the defect comprises at least one of an open bond, porosity in the weld, and lack of fusion of the weld.

5. The method of claim 2 wherein the valve seat weld is deposited in a seat facing groove.

6. The method of claim 5 wherein the valve seat weld is deposited by one of
5 heat fusing molten material in the seat facing groove, welding a preformed ring within the groove and laser cladding seat facing material in the seat facing groove.

7. The method of claim 1 wherein the electromagnetic wave is projected through a weld joining a valve head and a plug received in a hollow valve stem.

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8. A method of detecting a defect in a valve seat weld on a valve head of an engine poppet valve, the method comprising:

positioning a first electromagnetic transducer against the valve head in a first location;

5 positioning a second electromagnetic transducer against the valve head in a second location distinct from the first location;

projecting an electromagnetic wave from the first electromagnetic transducer, the electromagnetic wave being projected through the valve seat weld;

receiving the electromagnetic wave at the second electromagnetic transducer;

10 moving at least one of the engine poppet valve, the first electromagnetic transducer and the second electromagnetic transducer while concurrently projecting and receiving the electromagnetic wave;

recording an acoustic resonance of the electromagnetic wave;

observing the recorded acoustic resonance; and

15 detecting a defect in the valve seat weld based on an acoustic deviation on the recorded acoustic resonance.

9. The method of claim 8 wherein the first and second electromagnetic transducers are positioned generally adjacent to each other and against a valve seat
20 face of the valve head.

10. The method of claim 8 wherein the first and second electromagnetic transducers are positioned generally opposed to each other with the first electromagnetic transducer placed generally against a combustion face of the valve head and the second electromagnetic transducer is placed against a valve seat face
25 of the valve head.

11. The method of claim 8 wherein moving at least one of the engine poppet valve, the first electromagnetic transducer and the second electromagnetic transducer comprises:

30 rotating the engine poppet valve around a longitudinal axis of a valve stem of the engine poppet valve.

12. The method of claim 8 wherein the defect comprises at least one of an open bond, porosity in the weld, and lack of fusion of the weld.

13. The method of claim 8 wherein the valve seat weld is deposited in a seat facing groove.

5 14. The method of claim 13 wherein the valve seat weld is deposited by one of heat fusing molten material in the seat facing groove, welding a preformed ring within the groove and laser cladding seat facing material in the seat facing groove.

10 15. The method of claim 14 wherein the valve seat weld is deposited by plasma transferred arc (PTA) welding.

16. A method of detecting a defect in a plug weld between a plug and a valve head of an engine poppet valve, the method comprising:

positioning a first electromagnetic transducer against the valve head in a first location;

5 positioning a second electromagnetic transducer against the plug weld in a second location distinct from the first location;

projecting an electromagnetic wave from the first electromagnetic transducer, the electromagnetic wave being projected through the plug weld;

receiving the electromagnetic wave at the second electromagnetic transducer;

10 moving at least one of the engine poppet valve, the first electromagnetic transducer and the second electromagnetic transducer while concurrently projecting and receiving the electromagnetic wave;

recording an acoustic resonance of the electromagnetic wave;

observing the recorded acoustic resonance; and

15 detecting a defect in the plug weld based on an acoustic deviation on the recorded acoustic resonance.

17. The method of claim 16 wherein the first electromagnetic transducer is placed on the valve head and the second electromagnetic transducer is placed on the plug.

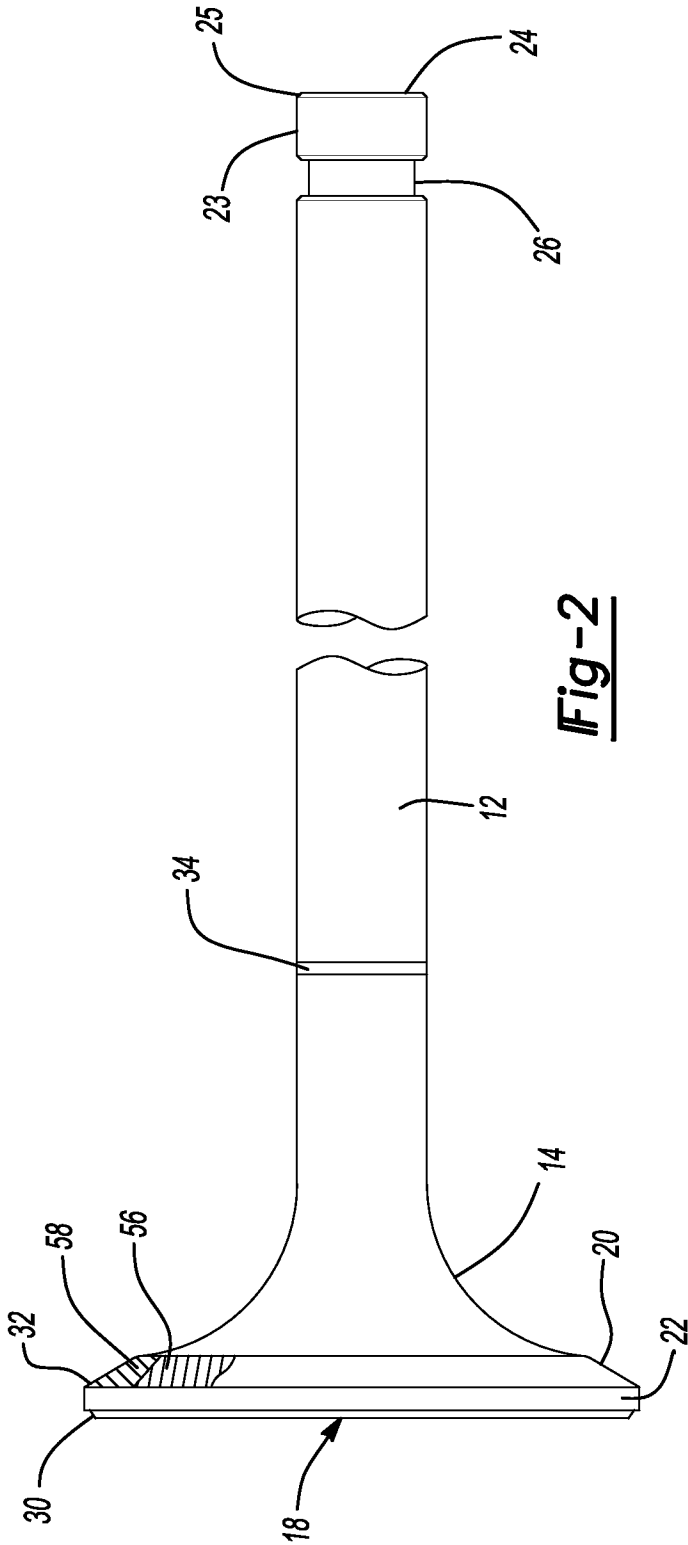
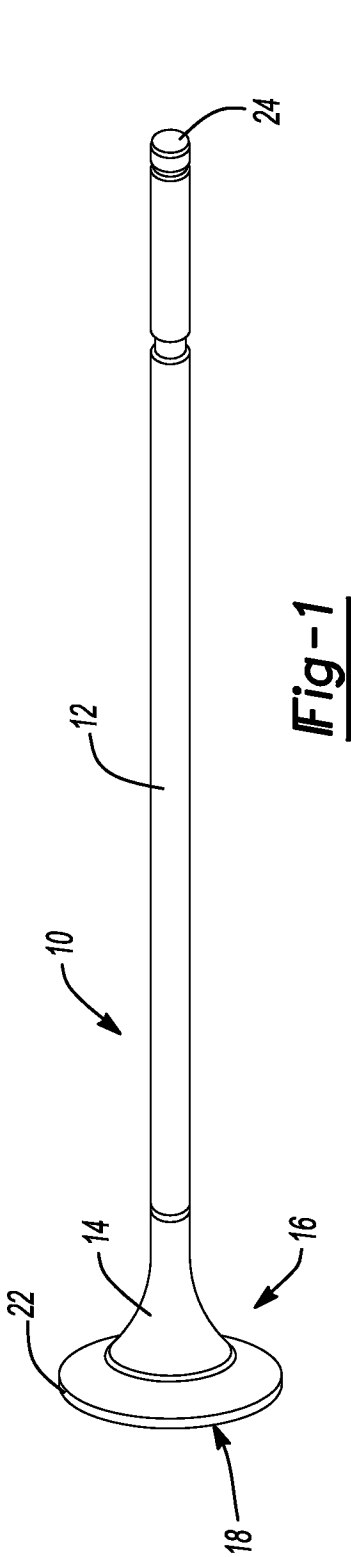
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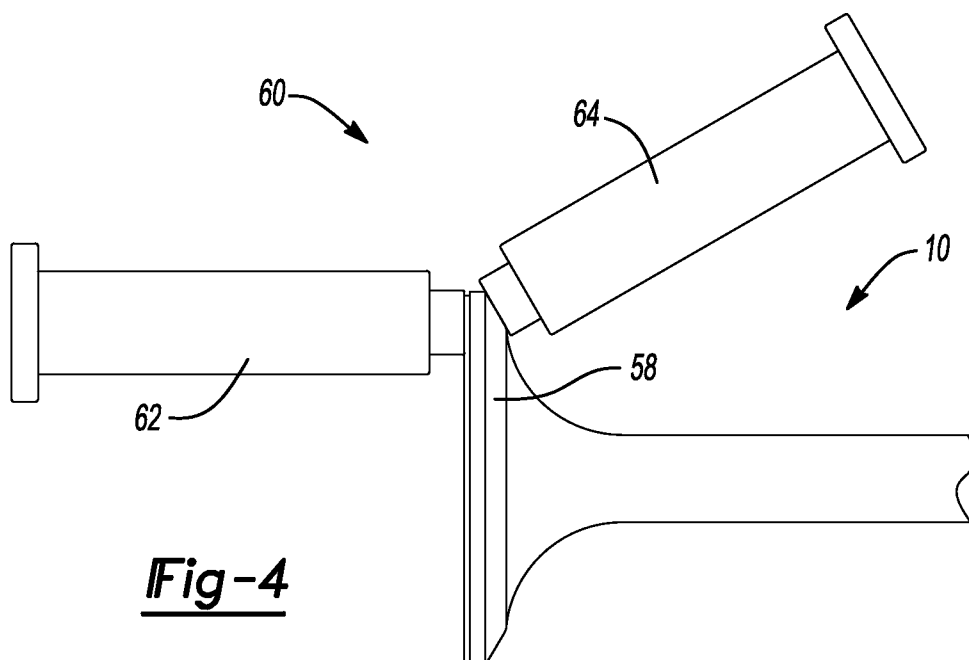
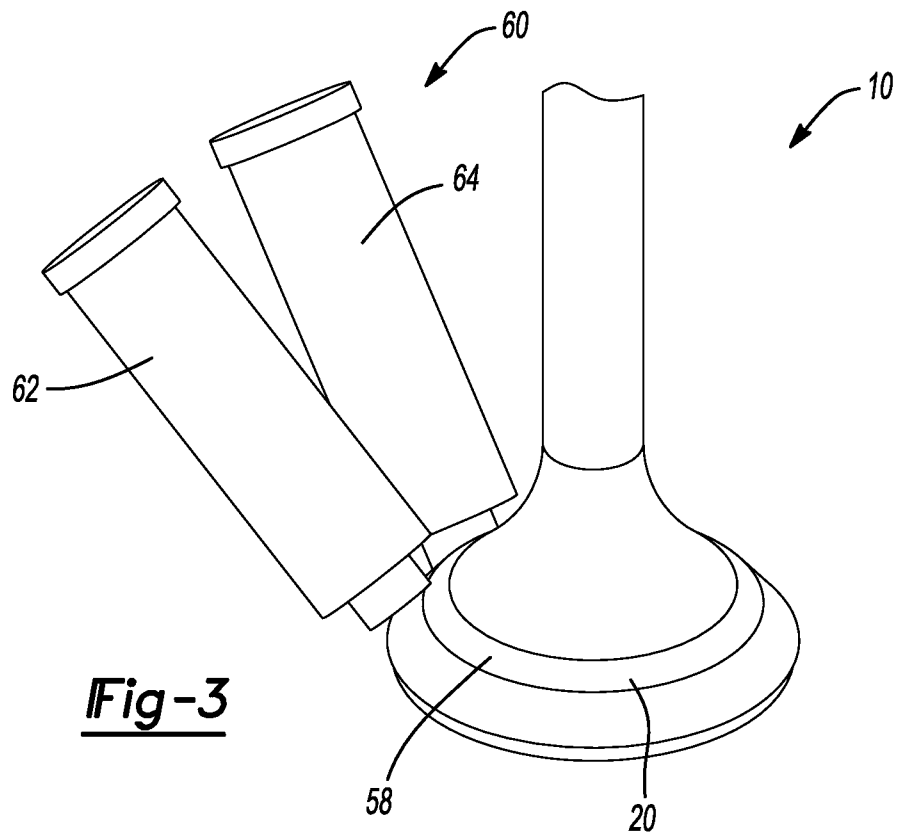
18. The method of claim 16 wherein moving at least one of the engine poppet valve, the first electromagnetic transducer and the second electromagnetic transducer comprises:

rotating the engine poppet valve around a longitudinal axis of a valve stem of
25 the engine poppet valve.

19. The method of claim 16 wherein the defect comprises at least one of an open bond, porosity in the weld, and lack of fusion of the plug weld.

30 20. The method of claim 16 wherein the plug is inserted into a cannulation of a hollow valve stem.





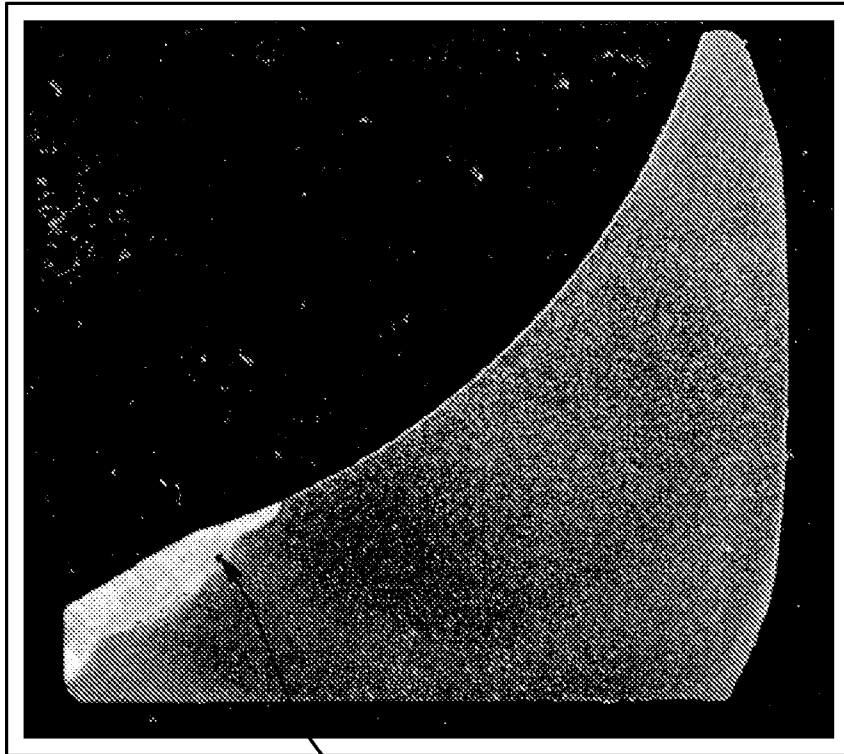


Fig-5

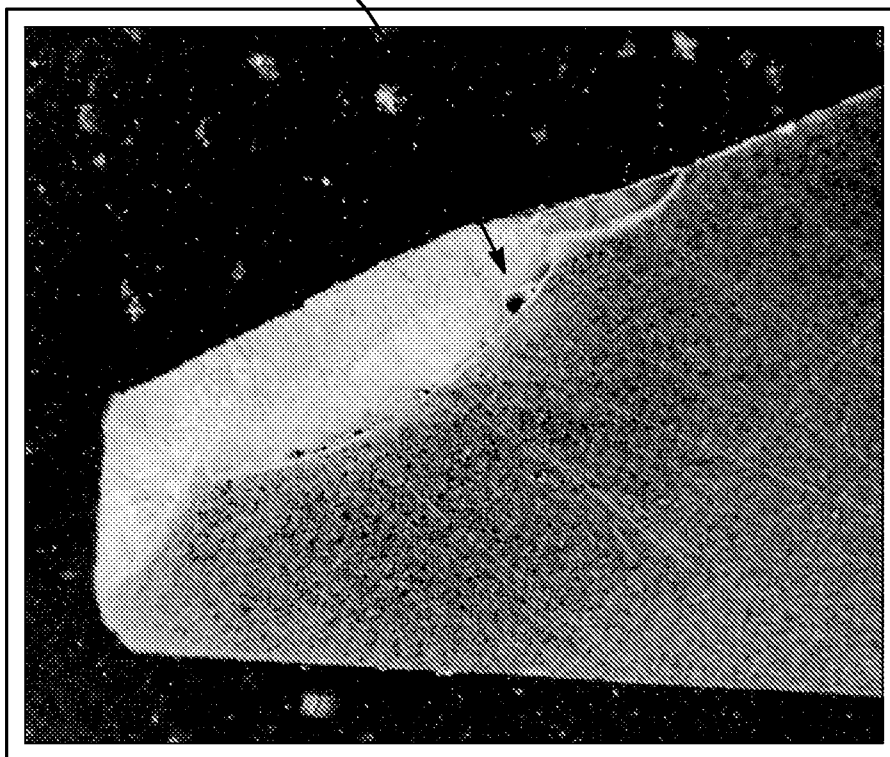


Fig-6

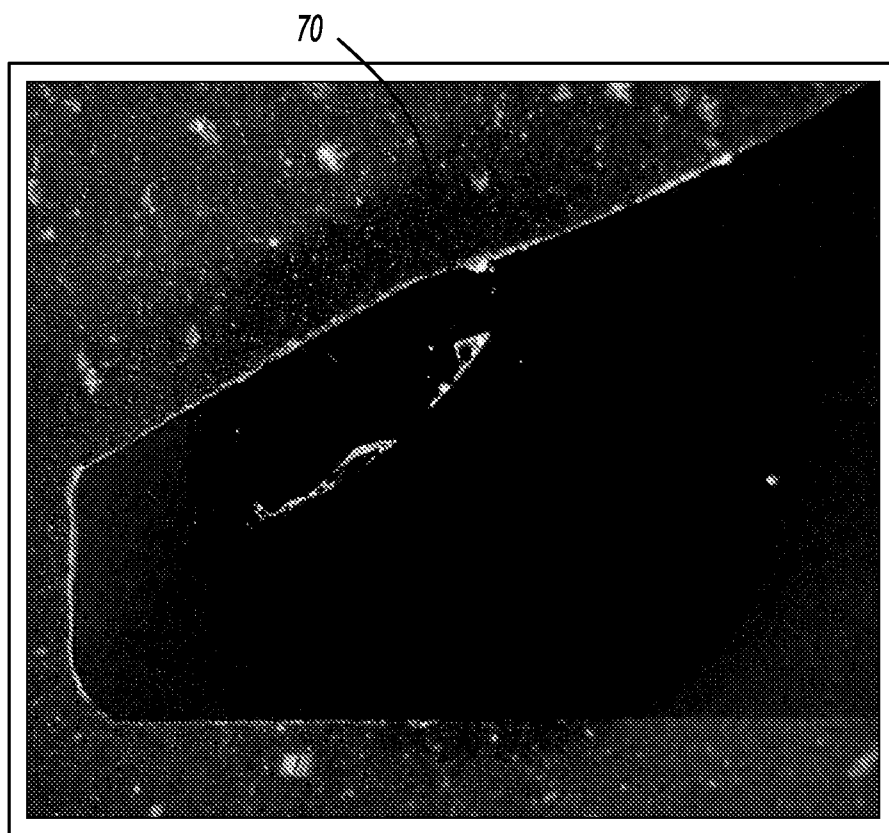


Fig-7

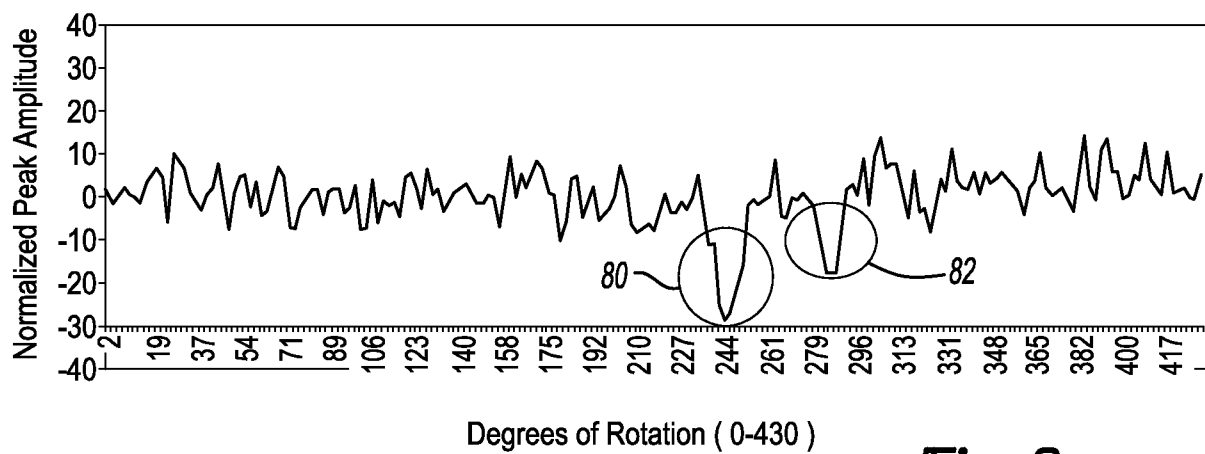
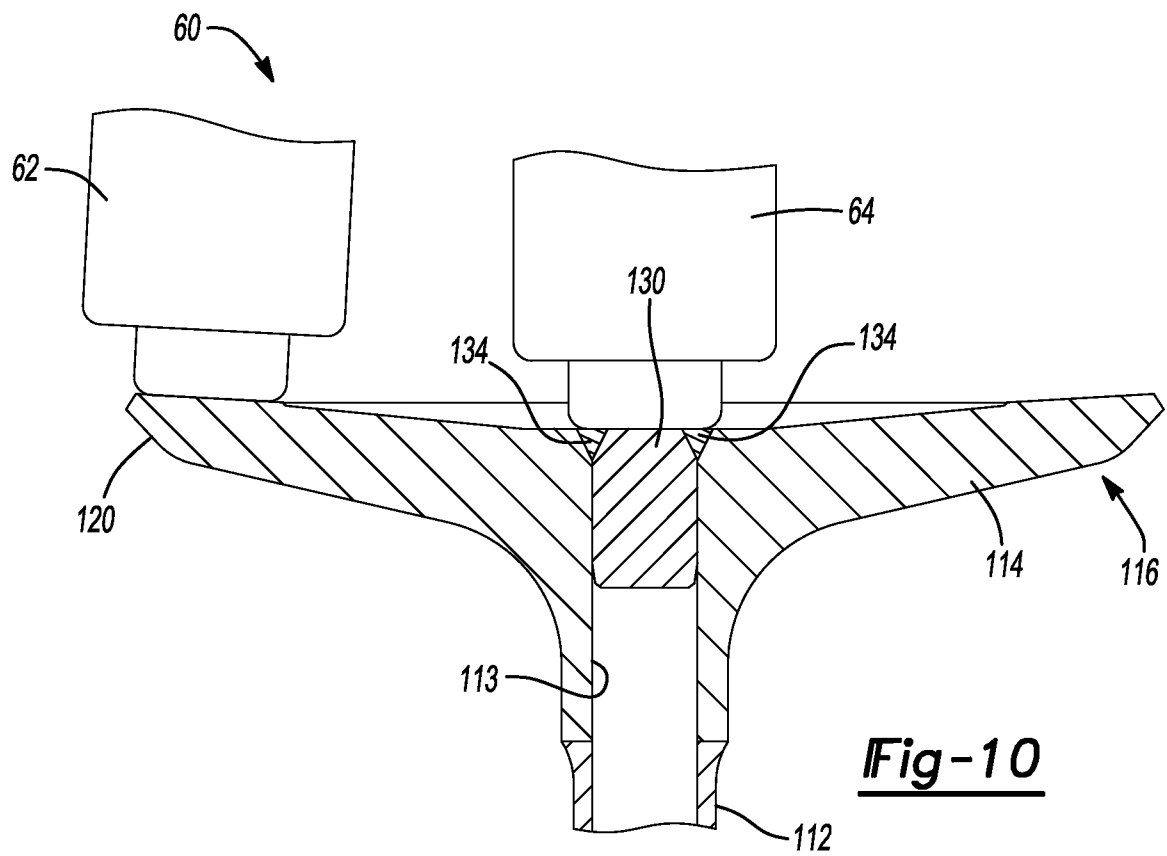
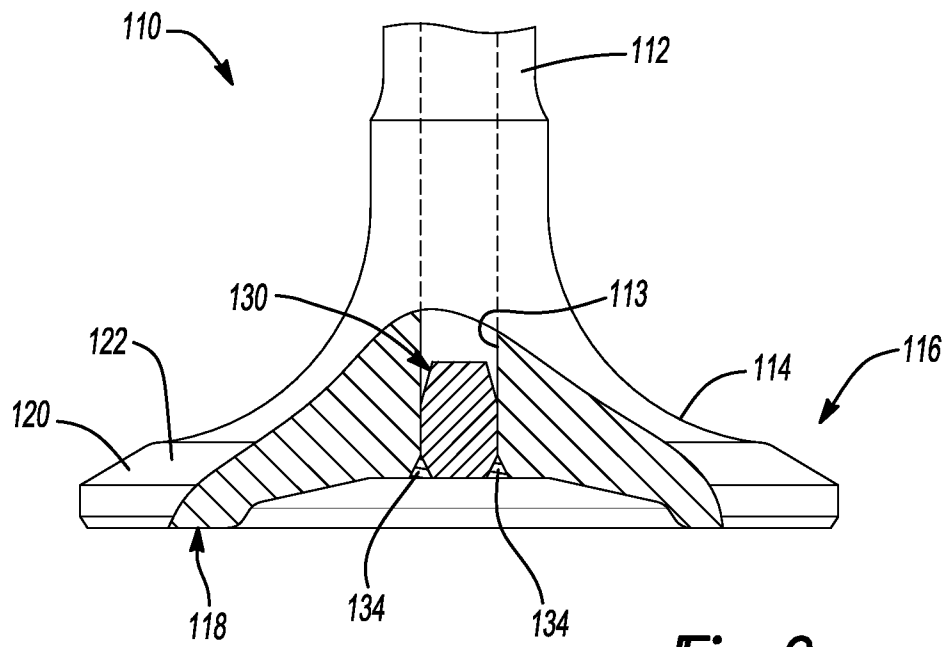


Fig-8



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/048043

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01N29/04 G01N29/12 G01N29/24
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)
G01N F01L

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, WPI Data, INSPEC, COMPENDEX, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 652 389 A (SCHAPS STEPHEN R [US] ET AL) 29 July 1997 (1997-07-29)	1-4, 7-12, 16-19
Y	abstract column 1, lines 5-8 column 4, lines 20-30 column 5, lines 6-44 -----	5,6, 13-15,20
A	US 2 903 886 A (PAUL RENAUT) 15 September 1959 (1959-09-15) column 1, lines 14-22 column 4, lines 35-41 ----- -/-	1-4, 7-12, 16-19



Further documents are listed in the continuation of Box C.



See patent family annex.

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

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Date of the actual completion of the international search

12 September 2013

Date of mailing of the international search report

20/09/2013

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
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Authorized officer

Filipas, Alin

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2013/048043

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2003/205088 A1 (PASSARELLI FRANK [US] PASSARELLI JR FRANK [US]) 6 November 2003 (2003-11-06) abstract paragraphs [0003], [0007], [0008], [0010]; claim 8 -----	1-4, 7-12, 16-19
A	US 4 062 227 A (HEYMAN JOSEPH S) 13 December 1977 (1977-12-13) abstract; claims 1,2 -----	1-4, 7-12, 16-19
A	US 5 631 423 A (RHODES GEORGE W [US]) 20 May 1997 (1997-05-20) abstract column 1, line 64 - column 2, line 13 -----	1-4, 7-12, 16-19
Y	US 4 104 505 A (RAYMENT LARRY W ET AL) 1 August 1978 (1978-08-01) cited in the application the whole document -----	5,6, 13-15,20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2013/048043

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5652389	A	29-07-1997	EP 0809107 A1 26-11-1997 US 5652389 A 29-07-1997
US 2903886	A	15-09-1959	NONE
US 2003205088	A1	06-11-2003	NONE
US 4062227	A	13-12-1977	NONE
US 5631423	A	20-05-1997	NONE
US 4104505	A	01-08-1978	BR 7707145 A 25-07-1978 DE 2748519 A1 03-05-1978 ES 463590 A1 16-07-1978 FR 2369013 A1 26-05-1978 GB 1585206 A 25-02-1981 GB 1585207 A 25-02-1981 IT 1085275 B 28-05-1985 JP S5354134 A 17-05-1978 US 4104505 A 01-08-1978