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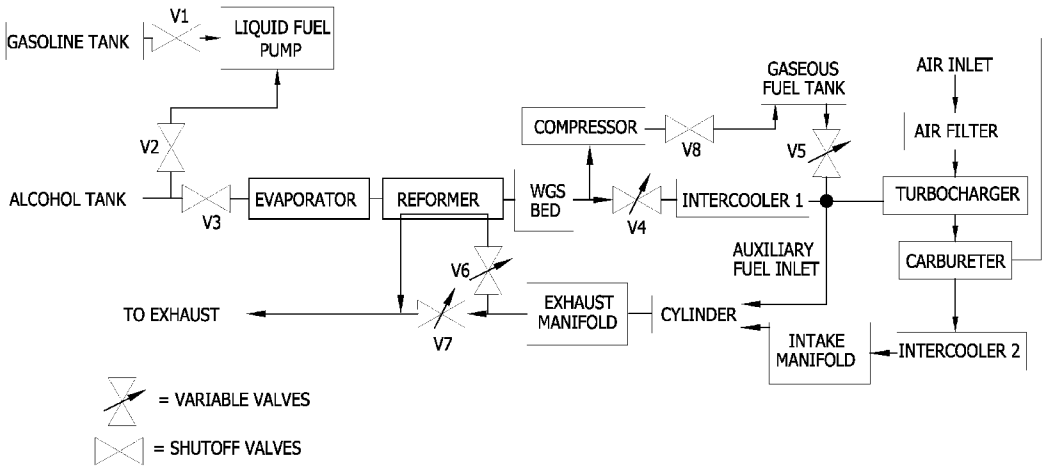
(54) Title: REFORMED ALCOHOL POWER SYSTEMS



(57) Abstract: Improved alcohol reforming processes and reformed alcohol power systems utilizing those processes are disclosed. In preferred embodiments, the alcohol reforming processes utilize a thermally conductive reforming catalyst that allows efficient, low-temperature reforming of an alcohol fuel to produce a reformate gas mixture comprising hydrogen. The present invention makes possible the efficient utilization of alcohol fuels in an internal combustion engine to generate electrical or mechanical power such as in vehicular applications.

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INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
INV. F02M27/02

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)
F02M

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, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2004/035466 A (MONSANTO TECHNOLOGY LLC [US]; MORGENSTERN DAVID A [US]) 29 April 2004 (2004-04-29) page 34, line 15 - page 34, line 27; figures 1,2 page 25, line 23 - page 26, line 35	1-3, 10-33, 35,42-45
X	tables 2,5,6	4,36
X	page 7, line 15 - page 7, line 35	5
X	page 3, line 1 - page 3, line 12	6,8
X	page 9, line 24 - page 9, line 35	7,9
X	page 27, line 23 - page 27, line 27	34
X	table 12	37,38
Y	-----	39-41
Y	US 2003/168023 A1 (ANDERSON KENNETH B [US] ET AL) 11 September 2003 (2003-09-11) paragraph [0023]	39-41
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[X] Further documents are listed in the continuation of Box C.

[X] 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 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.

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Date of the actual completion of the international search	Date of mailing of the international search report
21 February 2008	04/03/2008

Name and mailing address of the ISA/	Authorized officer
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 662 113 A (MCALISTER ROY E [US]) 31 May 2006 (2006-05-31) paragraph [0113] - paragraph [0119]; figures 4,10	1-3
X	WO 95/27845 A (MCALISTER ROY E [US]) 19 October 1995 (1995-10-19) page 17, line 20 - page 18, line 10; figures 4,7,8,10	1-3
X	US 6 155 212 A (MCALISTER ROY E [US]) 5 December 2000 (2000-12-05) column 24, line 30 - column 25, line 30; figures 4,7,8,10	1-3
P,X	EP 1 691 065 A (TOYOTA MOTOR CO LTD [JP]) 16 August 2006 (2006-08-16) Family member WO2005038228 pubblished 2005-04-28 is in Japanese language. paragraph [0016] - paragraph [0034]; figures 1-3	1-3

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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 allsearchable 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 reportcovers 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.:

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: 1-3,10-33,35,42-45

A process for producing mechanical or electrical power from a fuel comprising alcohol, the process comprising:
contacting a feed gas mixture comprising the alcohol fuel with a reforming catalyst in a reforming reaction zone to produce a product reformate gas mixture comprising hydrogen, wherein the reforming catalyst comprises a metal sponge supporting structure and a copper coating at least partially covering the surface of the metal sponge supporting structure;
introducing an intake gas mixture comprising oxygen and the product reformate gas mixture into a combustion chamber of an internal combustion engine and combusting the intake gas mixture to produce an exhaust gas mixture;
discharging an exhaust gas effluent comprising the exhaust gas mixture from the combustion chamber;
utilizing the energy of combustion for the generation of mechanical or electrical power; and
bringing the exhaust gas effluent into thermal contact with the reforming reaction zone to heat the reforming catalyst therein.

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2. claims: 4-9,34,36-41

A process for producing mechanical or electrical power from a fuel comprising ethanol, the process comprising:
contacting a feed gas mixture comprising the ethanol fuel with a reforming catalyst comprising copper in a reforming reaction zone to produce a product reforrnate gas mixture comprising hydrogen, methane and a carbon oxide component selected from the group consisting of carbon monoxide, carbon dioxide and mixtures thereof, wherein the molar ratio of methane to the carbon oxide component in the product reforrnate gas mixture is from about 0.9 to about 1.25 and the rate at which methane is produced in the reformate gas mixture is at least about 50% of the rate of ethanol introduced into the reforming reaction zone on a molar basis; and
introducing an intake gas mixture comprising oxygen and the product reformate gas mixture into a combustion chamber of an internal combustion engine and combusting the intake gas mixture to produce an exhaust gas mixture; and
utilizing the energy of combustion for the generation of mechanical or electrical power.

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3. claims: 46-48

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

A process for producing mechanical or electrical power, the process comprising:
contacting a feed gas mixture comprising an alcohol fuel with a reforming catalyst in a reforming reaction zone to produce a product reformate gas mixture comprising hydrogen;
introducing a prechamber gas mixture comprising oxygen and a first portion of the product reformate gas mixture into a combustion prechamber in fluid communication with a combustion chamber of an internal combustion engine;
introducing an intake gas mixture comprising oxygen and a second portion of the product reformate gas mixture into the combustion chamber;
igniting the prechamber gas mixture in the combustion prechamber to generate a hydrogen-rich flame jet and cause combustion of the intake gas mixture introduced into the combustion chamber, thereby producing an exhaust gas effluent; and
utilizing the energy of combustion for the generation of mechanical or electrical power.

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4. claims: 49-51

A process for producing mechanical or electrical power from a fuel comprising alcohol, the process comprising:
contacting a feed gas mixture comprising the alcohol fuel with a reforming catalyst in a reforming reaction zone to produce a product reforrnate gas mixture comprising hydrogen,
introducing an intake gas mixture comprising oxygen and the product reformate gas mixture into a combustion chamber of an internal combustion engine and combusting the intake gas mixture to produce an exhaust gas mixture;
discharging an exhaust gas effluent comprising the exhaust gas mixture from the combustion chamber;
utilizing the energy of combustion for the generation of mechanical or electrical power; and
recycling and combining at least a portion of the exhaust gas effluent with the intake gas mixture introduced into the combustion chamber of the internal combustion engine.

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5. claims: 52-58

A process for producing mechanical or electrical power in a power system comprising an internal combustion engine utilizing a four-stroke power cycle, the internal combustion engine comprising at least one combustion chamber and an intake valve in fluid communication with the combustion chamber and having an open and closed position, the internal combustion engine being capable of producing a combustion chamber expansion ratio that is greater than the corresponding compression ratio, the process comprising:
introducing an intake gas mixture comprising oxygen and a fuel selected from the group consisting of gasoline, alcohol, reformed alcohol and blends thereof into the combustion chamber of the internal combustion engine;
controlling the length of time the intake valve remains in the open position during the power cycle in response to the type of fuel introduced into the combustion chamber;
combusting the intake gas mixture; and
utilizing the energy of combustion for the generation of mechanical or electrical power.

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6. claims: 59-78

59. A process for reforming an alcohol fuel comprising ethanol, the process comprising:
contacting a feed gas mixture comprising the alcohol fuel with a reforming catalyst in a first reforming reaction zone at a temperature below about 400°C to produce a partially reformed gas mixture comprising hydrogen and methane, wherein the reforming catalyst comprises copper at the surface of a metal supporting structure; and
contacting the partially reformed gas mixture with a reforming catalyst in a second reforming reaction zone at a temperature higher than the temperature maintained in the first reforming reaction zone to reform methane contained in the partially reformed gas mixture and produce a product reformate gas mixture comprising additional hydrogen.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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