

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

To:
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Date of mailing
(day/month/year) **26 March 2019 (26.03.2019)**

Applicant's or agent's file reference 121-79-PCT		FOR FURTHER ACTION See paragraph 2 below	
International application No. PCT/US2018/052367	International filing date (day/month/year) 24 September 2018 (24.09.2018)	Priority date(day/month/year) 29 September 2017 (29.09.2017)	
International Patent Classification (IPC) or both national classification and IPC F02D 41/14(2006.01)i, F02D 41/00(2006.01)i, F02M 31/135(2006.01)i, F02P 5/15(2006.01)i, C01B 3/36(2006.01)i, F02B 39/10(2006.01)i			
Applicant RESEARCH TRIANGLE INSTITUTE			

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43bis. I(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☐ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.
For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/KR International Application Division Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea Facsimile No. +82-42-481-8578	Date of completion of this opinion 26 March 2019 (26.03.2019)	Authorized officer LEE, Chang Ho Telephone No. +82-42-481-8288
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**WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

PCT/US2018/052367

Box No. 1 Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of :

- ☒ the international application in the language in which it was filed
- ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*. I(a))

3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:

- a. ☐ forming part of the international application as filed:
☐ in the form of an Annex C/ST.25 text file.
☐ on paper or in the form of an image file.
- b. ☐ furnished together with the international application under PCT Rule 13*ter*. I(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.
- c. ☐ furnished subsequent to the international filing date for the purposes of international search only:
☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*. I(a)).
☐ on paper or in the form of an image file (Rule 13*ter*. I(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

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Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-38	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	1-35	YES
	Claims	36-38	NO
Industrial applicability (IA)	Claims	1-38	YES
	Claims	NONE	NO

2. Citations and explanations :

Reference is made to the following documents:

D1: US 2009-0282812 A1 (HU, HAORAN) 19 November 2009

D2: US 2004-0103860 A1 (ZUR LOYE et al.) 03 June 2004

D3: US 2016-0245239 A1 (SOUTHWEST RESEARCH INSTITUTE) 25 August 2016

D4: US 2015-0034045 A1 (WISCONSIN ALUMNI RESEARCH FOUNDATION) 05 February 2015

D5: US 2017-0234275 A1 (DELPHI TECHNOLOGIES, INC.) 17 August 2017

I. Novelty and Inventive Step

1. Claims 1-21

1.1 Independent Claim 1

The subject matter of claim 1 differs from prior art documents in a method comprising: increasing a fuel-air equivalence ratio incrementally to generate a fuel-rich feed gas; and while increasing the fuel-air equivalence ratio, adjusting one or more of a throttle, an ignition timing, a load coupled to the engine, a fuel pressure, power to a supercharger acting on the feed gas or part of the feed gas, and power to a preheater acting on the feed gas to maintain a fuel-air equivalence ratio to about 1.6 to 2.4. And it is not obvious to a person skilled in the art by the documents, taken alone or in combination.

Therefore, claim 1 meets the requirements of PCT Article 33(2) and 33(3) with respect to novelty and inventive step.

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1.2 Dependent Claims 2-21

Claims 2-21 are directly or indirectly dependent on claim 1 and therefore meet the requirements of PCT Article 33(2) and 33(3).

2. Claims 22-32

2.1 Independent Claim 22

The subject matter of claim 22 differs from prior art documents in a method for operating an internal combustion engine under fuel-rich conditions, comprising: maintaining a maintenance operating set of conditions after startup of the engine for an exhaust backpressure, an intake manifold pressure, an engine speed, an ignition timing, a fuel gas fuel-air equivalence ratio, and a fuel gas inlet temperature; increasing the fuel gas inlet temperature while maintaining the fuel gas fuel-air equivalence ratio, and monitoring methane and oxygen content of an engine exhaust gas; and adjusting ignition timing in response to the monitored methane and oxygen content. And it is not obvious to a person skilled in the art by the documents, taken alone or in combination.

Therefore, claim 22 meets the requirements of PCT Article 33(2) and 33(3) with respect to novelty and inventive step.

2.2 Dependent Claims 23-32

Claims 23-32 are directly or indirectly dependent on claim 22 and therefore meet the requirements of PCT Article 33(2) and 33(3).

3. Claims 33-35

3.1 Independent Claim 33

Claim 33 comprises all features of either claim 1 or claim 22, and the same reasoning

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applies for claim 33. Therefore, claim 33 meets the requirements of PCT Article 33(2) and 33(3).

3.2 Dependent Claims 34-35

Claims 34-35 are directly or indirectly dependent on claim 33 and therefore meet the requirements of PCT Article 33(2) and 33(3).

4. Claims 36-38

4.1 Independent Claim 36

D1, which is considered to be the closest prior art to the subject matter of claim 36, discloses a gas reformer system comprising: an engine (300) comprising a plurality of combustion chambers (200), conduits (212, 214), an intake valve (204), and an exhaust valve (206); and a gas reformer (320) (see paragraphs [0075], [0077] and figures 2, 10).

This claim differs from D1 in a gas reformer system comprising: an internal combustion engine comprising a throttle, a fuel gas preheater, and a supercharger (hereinafter referred to as feature 36-1); and wherein the internal combustion engine is configured for operating with a fuel gas fuel-air equivalence ratio of between about 1.6 and 2.4 (hereinafter referred to as feature 36-2).

However, the feature 36-1 would be easily conceived from the disclosure of D2 considering that a system comprises: a supercharger (58) mechanically driven by the engine drive system; a heater (51) incorporated into the upper part of the liner; and a throttle (53) used when operating a multi-mode PCCI engine in a spark ignited mode (see paragraphs [0121], [0205] and figures 1a-b). And the feature 36-2 would be easily conceived from the disclosure of D1 considering that a plot (50) shows that increasing the fuel-air equivalence ratio from 1.0 to 1.8 delays the onset of combustion; and if auto-ignition is delayed much more than shown in plot (50) for case (52), auto-ignition will not take place at all (see paragraph [0040] and figure 1). As D1 and D2 are in the same technical field, it is considered that a skilled person would be

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motivated to combine the features of D2 with D1.

Accordingly, this claim would have been obvious over D1 in view of D2. Therefore, claim 36 does not involve an inventive step under PCT Article 33(3).

4.2 Concerning Claim 37

The additional feature of claim 37, characterized in that the internal combustion engine is configured for individually adjusting a fuel gas fuel-air equivalence ratio, a fuel gas inlet temperature, an inlet manifold pressure, an ignition timing, an engine speed, an exhaust manifold pressure, and an exhaust gas temperature in order to operate with a fuel gas fuel-air equivalence ratio of between about 1.6 and 2.4, is not disclosed in D1 or D2. This feature is merely a matter of design option when the general knowledge in the relevant field of the art is used, considering the feature of D1 disclosing that a plot (50) shows that increasing the fuel-air equivalence ratio from 1.0 to 1.8 delays the onset of combustion; and if auto-ignition is delayed much more than shown in plot (50) for case (52), auto-ignition will not take place at all (see paragraph [0040] and figure 1).

Accordingly, this claim would have been obvious over D1 in view of D2. Therefore, claim 37 does not involve an inventive step under PCT Article 33(3).

4.3 Concerning Claim 38

The additional feature of claim 38, characterized in that the internal combustion engine is configured to produce an exhaust gas comprising hydrogen and carbon monoxide, is not disclosed in D1 or D2. This feature would be easily conceived from the disclosure of D1 considering that the engine (300) provides a high proportion of H₂ and CO (see paragraph [0051] and figure 7).

Accordingly, this claim would have been obvious over D1 in view of D2. Therefore, claim 38 does not involve an inventive step under PCT Article 33(3).

II. Industrial Applicability

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Claims 1-38 are industrially applicable under PCT Article 33(4).