IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, and ETHANOL BOOSTING SYSTEMS, LLC, Plaintiffs, v. FORD MOTOR COMPANY, Defendant.	C.A. No. 19-cv-196-CFC-SRF **JURY TRIAL DEMANDED**

JOINT CLAIM CONSTRUCTION CHART

Pursuant to Paragraph 15 of the Court's Scheduling Order (D.I. 17), Plaintiffs Ethanol Boosting Systems, LLC and the Massachusetts Institute of Technology and Defendant Ford Motor Company (collectively, "the Parties") jointly provide this Joint Claim Construction Chart (1) identifying for the Court the 7 terms and phrases that Ford has identified for construction and (2) setting forth each party's proposed constructions with citations only to intrinsic evidence.

As set forth in its invalidity contentions, and as identified in the initial exchange of claim terms for construction, Ford also believes that a number of claim terms at issue in the patent are indefinite. However, it is the parties' understanding that the Court prefers to address indefiniteness issues separately from claim

construction. To the extent the Court would prefer to address indefiniteness issues at claim construction, the parties can supplement this document.

The Parties also attach a separate text-searchable PDF of each of the patents in issue, as well as U.S. Patent Application No. 10/991,774—to which each claims priority. Below is a key for such materials:

Exhibit	Document Description
1.	U.S. Patent Application No. 10/991,774, dated November 18, 2004[1]
2.	U.S. Patent No. 8,069,839 B2 (Cohn, et al.), dated December 6, 2011
3.	U.S. Patent No. 9,255,519 B2 (Cohn, et al.), dated February 9, 2016
4.	U.S. Patent No. 9,810,166 B2 (Cohn, et al.), dated November 7, 2017
5.	U.S. Patent No. 10,138,826 B2 (Cohn, et al.), dated November 27, 2018
6.	Excerpts of the File History for U.S. Patent Application No. 10/991,774 ('033 File History)
7.	Excerpts of the File History for U.S. Patent No. 9,810,166 B2 ('166 File History)

I. Agreed Claim Constructions

The parties have stipulated to the following constructions for the following claim terms and respectfully request that the Court include these constructions in its claim construction order:

Term	Construction
"port injection" / "port fuel injection"	"injection of fuel into an intake port or intake manifold"

[1] Because each of the asserted patents shares a common specification with that included in U.S. Patent Application No. 10/991,774, for the Court's convenience the parties cite to this document in lieu of the individual specifications.

['839 (Claim 1), '166 (Claims 1, 19)] / ['839 (Claim 7), '166 (Claims 1, 7, 10-12, 19, 22-23), '826 (Claims 1, 12, 21, 31)]	
"direct injection" / "direct fuel injection" ['839 (Claims 1, 8), '166 (Claims 1, 5, 16, 18, 19, 21-22, 26-28, 30), '826 (Claims 1, 12)] / ['166 (Claims 1, 19)]	"direct injection of fuel into a cylinder"[2]
"first fueling system that directly injects fuel" / "first fueling system" / "first fueling system that uses direct injection" ['519 (Claims 1, 13)] / ['519 (Claims 1-3, 5, 10-11, 13-14, 16-18, 21, 24-25, 27-30), '826 (Claims 2-4, 13-21, 23-26, 29-33)] / ['826 (Claims 1, 12)]	Plain and ordinary meaning[3]
"second fueling system that injects fuel into a region outside of the cylinder" / "second fueling system" / "second fueling system using port fuel injection" ['519 (Claim 1)] / ['826 (Claims 1, 12, 21, 23, 24, 30, 31)] / ['826 (Claims 21, 31)]	Plain and ordinary meaning

[2] The parties agree that, by agreeing to this construction of the phrases "direct injection" and "direct fuel injection," Ford has not waived its argument that the type of fuel required to be used in direct injection is a fuel that contains an anti-knock agent that is not gasoline, and that is different from the fuel used for port injection/in the second fueling system.

[3] The parties agree that, by agreeing to this construction of the phrases "first fueling system that directly injects fuel," "first fueling system," and "first fueling system that uses direct injection," Ford has not waived its argument that each requires a fuel that contains an anti-knock agent that is not gasoline, and that is different from the fuel used for port injection/in the second fueling system.

"employs spark retard so as to reduce the amount of fuel that is introduced into the cylinder by the first fueling system" ['519 (Claim 1)]	"uses spark retard so as to reduce the amount of fuel that is introduced into the cylinder by direct injection"
"spark retard is employed [to/so] as to reduce the amount of fuel that is provided by the first fueling system to zero" ['519 (Claims 2, 16)]	"spark retard is used so as to reduce to zero the amount of fuel that is provided by direct injection"
"input" ['519 (Claim 13-14)]	"information, including one or more signals"

The parties further state that, to narrow the issues in dispute, Plaintiffs have agreed not to assert Claims 29 and 30 of U.S. Patent No. 10,138,826.

II. Disputed Claim Constructions

The following terms/phrases remain in dispute:

1. **"torque"** ['839 (Claims 1-2, 7-8), '519 (Claims 1, 3-4, 6, 10-11, 15, 18-20, 22, 26, 29), '166 (Claims 1-4, 7-8, 10, 14-16, 19-21, 23, 26-28), '826 (Claim 1-8, 10-15, 20-24, 29-33)]

Plaintiffs' Construction:	**Ford's Construction:**
Plain and ordinary (no construction needed). Alternatively, if construed, "measure of a turning or rotating force on an object."	"Torque is the measure of a turning or rotational force on an object. Torque is calculated by multiplying force and distance. It is a vector quantity, meaning it has both a direction and a magnitude."
Intrinsic Support: • Ex. 1 (Orig. Appl.) at *passim.*	**Intrinsic Support:** • Ex. 2 ('839 Patent) at 5:42-6:27; Claims 1, 2, 7, 8, 13, 15, 16, 19,

• Ex. 2 ('839 Patent) at Claims 1-2, 7-8. • Ex. 3 ('519 Patent) at Claims 1, 3-4, 6, 10-11, 15, 18-20, 22, 26, 29. • Ex. 4 ('166 Patent) at Claims 1-4, 7-8, 10, 14-16, 19-21, 23, 26-28. • Ex. 5 ('826 Patent) at Claim 1-8, 10-15, 20-24, 29-33.	and 20. • Ex. 3 ('519 Patent) at 5:61-6:45; Claims 1, 3, 4, 6, 7, 10, 11, 15, 18, 19, 20, 22, 26, and 29. • Ex. 4 ('166 Patent) at 6:4-55; Claims 1, 2, 3, 4, 6, 7, 8, 9, 10, 14, 15, 16, 19, 20, 21, 23, 26, 27, 28, and 29. • Ex. 5 ('826 Patent) at 6:6-57; Claims 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 21, 22, 23, 24, 25, 28, 29, 30, 31, 32, and 33.

2. **"torque range"** ['519 (Claims 19, 20, 22), '166 (Claims 1, 10, 14-16, 20, 28, 29), '826 (Claims 1-15, 20-25, 28-33)] / **"range of torque"** ['519 (Claims 1, 4), '166 (Claims 7-8, 19)]

Plaintiffs' Construction:	**Ford's Construction:**
Plain and ordinary (no construction needed). Alternatively, if construed, "range of torque values from one value of torque to another value of torque."	"a range of torque values from one specific value of torque to another specific value of torque"
Intrinsic Support: • Ex. 1 (Orig. Appl.) at 8:21-24, 9:3-10. • Ex. 3 ('519 Patent) at Claim 20. • Ex. 4 ('166 Patent) at Claim 8; *see also* Ex. 4 ('166 Patent) at Claims 9, 10, 20, 29. • Ex. 5 ('826 Patent) at Claim 1; *see also* Ex. 5 ('826 Patent) at Claims 12, 22-25, 30, 31.	**Intrinsic Support:** • Ex. 3 ('519 Patent) at 5:61-6:62; Claims 1, 3, 4, 6, 7, 10, 11, 15, 18, 19, 20, 22, 26, and 29. • Ex. 4 ('166 Patent) at 6:4-7:5; Claims 1, 2, 3, 4, 6, 7, 8, 9, 10, 14, 15, 16, 19, 20, 21, 23, 26, 27, 28, and 29. • Ex. 5 ('826 Patent) at 6:6-7:7; Claims 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 21, 22, 23, 24, 25, 28, 29, 30, 31, 32, and 33.

3. **"above a selected torque value the ratio of fuel that is directly injected to fuel that is port injected increases"** ['839 (Claim 1)]

Plaintiffs' Construction:	**Ford's Construction:**
Plain and ordinary (no construction needed).	"Above a selected torque value the ratio of fuel that is directly injected to fuel that is port injected is always increasing"
Intrinsic Support: • Ex. 1 (Orig. Appl.) at 4:17-26, 9:13-14, 5:25-26, 6:5-7, 10:16-20, 12:8-9. • Ex. 2 ('839 Patent) at Claims 1-6. • *See also* Ex. 6 ('033 File History) at EBS00000018-28, at -21, -26; and EBS00000091-103, at -94, -100.	**Intrinsic Support:** • Ex. 2 ('839 Patent) at Abstract; 1:29-32, 54-62; 3:2-12; 5:27-38; 5:42-6:27; Claims 1, 2, 3, 4, 5, 6, 7, 8, 15, 16, 17, 18, 19, 20; and Fig. 2. • Ex. 6 ('033 Patent Pros. History) at EBS00000034-38; and EBS00000054-103.

4. **"fuel that is directly injected"** ['839 (Claim 1)] / **"directly injected fuel"** ['839 (Claims 2-5)] / **"fuel provided by direct injection"** ['166 (Claims 5, 16, 27, 28)] / **"fueling that is provided by the first fueling system"** ['826 (Claims 3-8)] / **"fueling from the first fueling system"** ['166 (Claim 10)] / **"fuel provided by the first fueling system"** ['826 (Claims 13-15)] / **"fuel is provided by a first fueling system"** ['826 (Claim 31)]

Plaintiffs' Construction:	**Ford's Construction:**
Plain and ordinary (no construction needed). Alternatively, if construed, "fuel is provided by a first fueling system using direct injection" ['826 (Claim 31)] should be construed to mean "fuel is directly injected into a cylinder" and the remainder should be construed to mean	"a fuel that contains an anti-knock agent that is not gasoline, and that is different from the fuel used for port injection/in the second fueling system"

"fuel that is directly injected into a cylinder."	
Intrinsic Support: • Ex. 1 (Orig. Appl.) at 5:25-26, 6:5-7, 3:5-8, 12:8-9; *see also* Ex. 1 (Orig. Appl.) at 3:8-11, 5:1-2, 10:16-20, FIG. 3. • Ex. 2 ('839 Patent) at Claims 1, 8-11, 15. • *See also* Ex. 6 ('033 File History) at EBS00000018-28, at -21, -26; and EBS00000091-103, at -97-99. • *See also* Ex. 7 ('166 File History) at EBS00001959-75, at -1964, -1971-72.	**Intrinsic Support:** • Ex. 2 ('839 Patent) at Title; Abstract; 1:14-17, 42-62; 1:66-2:40; 2:61-6:67; Claims 1, 2, 3, 4, 5, 9, 10, 11, 15, 16, 17, 18, 19, 20; Figs. 1, 2, 3, 4, and 5. • Ex. 4 ('166 Patent) at Title; Abstract; 1:35-38, 1:65-2:19; 2:23-67; 3:21-7:25; Claims 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 23, 27, 28, 29, 30; Figs. 1, 2, 3, 4, and 5. • Ex. 5 ('826 Patent) at Title; Abstract; 1:38-41, 2:1-22; 2:26-3:3; 3:24-7:37; Claims 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33; Figs. 1, 2, 3, 4, and 5. • Ex. 6 ('033 Patent Pros. History) at EBS00000034-38; and EBS00000054-103. • Ex. 7 ('166 Patent Pros. History) at EBS-00001998-2033.

5. **"highest loads"** ['839 (Claim 6)]

Plaintiffs' Construction:	**Ford's Construction:**
Plain and ordinary (no construction needed). Alternatively, if construed, "engine's highest torques at a given engine speed."	"Highest torques"

Intrinsic Support: • Ex. 1 (Orig. Appl.) at 8:22-25; *see also* Ex. 1 (Orig. Appl.) at 8:6-9:11. • Ex. 2 ('839 Patent) at Claims 1, 6, 18. • *See also* Ex. 7 ('166 File History) at EBS00002038-45, at -2044-45.	**Intrinsic Support:** • Ex. 2 ('839 Patent) at 1:56-62; Claims 6 and 18.

6. **"decreases with decreasing torque"** ['519 (Claim 1)]

Plaintiffs' Construction:	**Ford's Construction:**
Plain and ordinary (no construction needed).	"always decreasing with decreasing torque"
Intrinsic Support: • Ex. 1 (Orig. Appl.) at 3:2-5, 9:12-14; *see also* Ex. 1 (Orig. Appl.) at 3:18-25, 4:21-27, 8:6-9:11. • Ex. 3 ('519 Patent) at Claims 1-3, 5-6, 9-11. • *See also* Ex. 6 ('033 File History) at EBS00000018-28, at -21, -26; and EBS00000091-103, at -97-100.	**Intrinsic Support:** • Ex. 3 ('519 Patent) at Abstract; 1:47-50; 2:5-14; 3:21-31; 5:46-57; 5:61-6:45; Claims 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31; Fig. 2; • Ex. 6 ('033 Patent Pros. History) at EBS00000034-38; and EBS00000054-103.

7. **"closed loop control that utilizes a sensor that detects knock"** ['519 (Claim 1)] / **"input from the knock sensor is utilized in a closed loop control system that controls"** ['519 (Claim 14)] / **"where closed loop control with a knock detector is used"** ['519 (Claim 18)]

Plaintiffs' Construction:	**Ford's Construction:**
Plain and ordinary (no construction needed). Alternatively, if construed, "closed loop control that utilizes a sensor that detects knock" (Claim 1) should be construed to	"a microprocessor that uses a direct feedback input signal from a knock sensor" / "a direct feedback input signal from the knock sensor is used by a microprocessor to control" / "a direct

mean "a feedback system that uses a sensor that detects knock." If construed, "input from the knock sensor is utilized in a closed loop control system that controls" (Claim 14) should be construed to mean "input from the knock sensor is used by a feedback system that controls." If construed, "where closed loop control with a knock detector is used" (Claim 18) should be construed to mean "where a feedback system with a knock sensor is used."	feedback input signal from the knock detector is used by a microprocessor"
Intrinsic Support: • Ex. 1 (Orig. Appl.) at 3:18-25, 4:21-27, 9:26-28, FIG 1 & 5. • Ex. 3 ('519 Patent) at Claims 1, 2, 5, 10, 13, 14, 18, 19, 24, 25, 27, 29. • *See also* Ex. 6 ('033 File History) at EBS00000091-103, at -99-100. • *See also* Ex. 7 ('166 File History) at EBS00002038-45, at -44-45.	**Intrinsic Support:** • Ex. 3 ('519 Patent) at 2:35-45; 3:13-31; Claims 1, 13, 14, 18, 19, 24, 25, 29; Figs 1 and 5.

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EXHIBIT 1

JOINT

APPLICATION

FOR

UNITED STATES LETTERS PATENT

TO THE ASSISTANT COMMISSIONER FOR PATENTS:

BE IT KNOWN, that we,

Daniel R. Cohn, Chestnut Hill, Massachusetts

Leslie Bromberg, Sharon, Massachusetts

John B. Heywood, Newton, Massachusetts

have invented certain new and useful improvements in **Fuel Management System for Variable Ethanol Octane Enhancement of Gasoline Engines** of which the following is a specification:

Attorney Docket No.: 0492611-0598
Express Mail No. EV196632874US
Date of Filing: November 18, 2004
Customer Number: 24280

Fuel Management System for Variable Ethanol Octane Enhancement of Gasoline Engines

Background of the Invention

This invention relates to spark ignition gasoline engines utilizing an antiknock agent which is a liquid fuel with a higher octane number than gasoline such as ethanol to improve engine efficiency.

It is known that the efficiency of spark ignition (SI) gasoline engines can be increased by high compression ratio operation and particularly by engine downsizing. The engine downsizing is made possible by the use of substantial pressure boosting from either turbocharging or supercharging. Such pressure boosting makes it possible to obtain the same performance in a significantly smaller engine. See, J. Stokes, *et al.*, "A Gasoline Engine Concept For Improved Fuel Economy – The Lean-Boost System," SAE Paper 2001-01-2902. The use of these techniques to increase engine efficiency, however, is limited by the onset of engine knock. Knock is the undesired detonation of fuel and can severely damage an engine. If knock can be prevented, then high compression ratio operation and high pressure boosting can be used to increase engine efficiency by up to twenty-five percent.

Octane number represents the resistance of a fuel to knocking but the use of higher octane gasoline only modestly alleviates the tendency to knock. For example, the difference between regular and premium gasoline is typically six octane numbers. That is significantly less than is needed to realize fully the efficiency benefits of high compression ratio or turbocharged operation. There is thus a need for a practical means for achieving a much higher level of octane enhancement so that engines can be operated much more efficiently.

It is known to replace a portion of gasoline with small amounts of ethanol added at the refinery. Ethanol has a blending octane number (ON) of 110 (versus 95 for premium gasoline) (see J.B. Heywood, "Internal Combustion Engine Fundamentals," McGraw Hill, 1988, p. 477) and is also attractive because it is a renewable energy, biomass-derived fuel, but the small amounts of ethanol that have heretofore been added to gasoline have had a relatively small impact on engine performance. Ethanol is much more expensive than gasoline and the amount of ethanol that is readily available is much smaller than that of gasoline because of the relatively limited amount of biomass that is available for its production. An object of the present invention

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is to minimize the amount of ethanol or other antiknock agent that is used to achieve a given level of engine efficiency increase. By restricting the use of ethanol to the relatively small fraction of time in an operating cycle when it is needed to prevent knock in a higher load regime and by minimizing its use at these times, the amount of ethanol that is required can be limited to a relatively small fraction of the fuel used by the spark ignition gasoline engine.

Summary of the Invention

In one aspect, the invention is a fuel management system for efficient operation of a spark ignition gasoline engine including a source of an antiknock agent such as ethanol. An injector directly injects the ethanol into a cylinder of the engine and a fuel management system controls injection of the antiknock agent into the cylinder to control knock with minimum use of the antiknock agent. A preferred antiknock agent is ethanol. Ethanol has a high heat of vaporization so that there is substantial cooling of the air-fuel charge to the cylinder when it is injected directly into the engine. This cooling effect reduces the octane requirement of the engine by a considerable amount in addition to the improvement in knock resistance from the relatively high octane number of ethanol. Methanol, tertiary butyl alcohol, MTBE, ETBE, and TAME may also be used. Wherever ethanol is used herein it is to be understood that other antiknock agents are contemplated.

The fuel management system uses a fuel management control system that may use a microprocessor that operates in an open loop fashion on a predetermined correlation between octane number enhancement and fraction of fuel provided by the antiknock agent. To conserve the ethanol, it is preferred that it be added only during portions of a drive cycle requiring knock resistance and that its use be minimized during these times. Alternatively, the gasoline engine may include a knock sensor that provides a feedback signal to a fuel management microprocessor system to minimize the amount of the ethanol added to prevent knock in a closed loop fashion.

In one embodiment the injectors stratify the ethanol to provide non-uniform deposition within a cylinder. For example, the ethanol may be injected proximate to the cylinder walls and swirl can create a ring of ethanol near the walls.

In another embodiment of this aspect of the invention, the system includes a measure of the amount of the antiknock agent such as ethanol in the source containing the antiknock agent to control turbocharging, supercharging or spark retard when the amount of ethanol is low.

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The direct injection of ethanol provides substantially a 13°C drop in temperature for every ten percent of fuel energy provided by ethanol. An instantaneous octane enhancement of at least 4 octane numbers may be obtained for every 20 percent of the engine's energy coming from the ethanol.

Brief Description of the Drawing

Fig. 1 is a block diagram of one embodiment of the invention disclosed herein.

Fig. 2 is a graph of the drop in temperature within a cylinder as a function of the fraction of energy provided by ethanol.

Fig. 3 is a schematic illustration of the stratification of cooler ethanol charge using direct injection and swirl motion for achieving thermal stratification.

Fig. 4 is a schematic illustration showing ethanol stratified in an inlet manifold.

Fig. 5 is a block diagram of an embodiment of the invention in which the fuel management microprocessor is used to control a turbocharger and spark retard based upon the amount of ethanol in a fuel tank.

Description of the Preferred Embodiment

With reference first to **Fig. 1**, a spark ignition gasoline engine **10** includes a knock sensor **12** and a fuel management microprocessor system **14**. The fuel management microprocessor system **14** controls the direct injection of an antiknock agent such as ethanol from an ethanol tank **16**. The fuel management microprocessor system **14** also controls the delivery of gasoline from a gasoline tank **18** into engine manifold **20**. A turbocharger **22** is provided to improve the torque and power density of the engine **10**. The amount of ethanol injection is dictated either by a predetermined correlation between octane number enhancement and fraction of fuel that is provided by ethanol in an open loop system or by a closed loop control system that uses a signal from the knock sensor **12** as an input to the fuel management microprocessor **14**. In both situations, the fuel management processor **14** will minimize the amount of ethanol added to a cylinder while still preventing knock. It is also contemplated that the fuel management microprocessor system **14** could provide a combination of open and closed loop control.

As show in **Fig. 1** it is preferred that ethanol be directly injected into the engine **10**. Direct injection substantially increases the benefits of ethanol addition and decreases the required

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amount of ethanol. Recent advances in fuel injector and electronic control technology allows fuel injection directly into a spark ignition engine rather than into the manifold **20**. Because ethanol has a high heat of vaporization there will be substantial cooling when it is directly injected into the engine **10**. This cooling effect further increases knock resistance by a considerable amount. In the embodiment of **Fig. 1** port fuel injection of the gasoline in which the gasoline is injected into the manifold rather than directly injected into the cylinder is preferred because it is advantageous in obtaining good air/fuel mixing and combustion stability that are difficult to obtain with direct injection.

Ethanol has a heat of vaporization of 840kJ/kg, while the heat of vaporization of gasoline is about 350kJ/kg. The attractiveness of ethanol increases when compared with gasoline on an energy basis, since the lower heating value of ethanol is 26.9MJ/kg while for gasoline it is about 44MJ/kg. Thus, the heat of vaporization per Joule of combustion energy is 0.031 for ethanol and 0.008 for gasoline. That is, for equal amounts of energy the required heat of vaporization of ethanol is about four times higher than that of gasoline. The ratio of the heat of vaporization per unit air required for stoichiometric combustion is about 94 kJ/kg of air for ethanol and 24 kJ/kg of air for gasoline, or a factor of four smaller. Thus, the net effect of cooling the air charge is about four times lower for gasoline than for ethanol (for stoichiometric mixtures wherein the amount of air contains oxygen that is just sufficient to combust all of the fuel).

In the case of ethanol direct injection according to one aspect of the invention, the charge is directly cooled. The amount of cooling due to direct injection of ethanol is shown in **Fig. 2**. It is assumed that the air/fuel mixture is stoichiometric without exhaust gas recirculation (EGR), and that gasoline makes up the rest of the fuel. It is further assumed that only the ethanol contributes to charge cooling. Gasoline is vaporized in the inlet manifold and does not contribute to cylinder charge cooling. The direct ethanol injection provides about 13°C of cooling for each 10% of the fuel energy provided by ethanol. It is also possible to use direct injection of gasoline as well as direct injection of ethanol. However, under certain conditions there can be combustion stability issues.

The temperature decrement because of the vaporization energy of the ethanol decreases with lean operation and with EGR, as the thermal capacity of the cylinder charge increases. If

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the engine operates at twice the stoichiometric air/fuel ratio, the numbers indicated in **Fig. 2** decrease by about a factor of 2 (the contribution of the ethanol itself and the gasoline is relatively modest). Similarly, for a 20% EGR rate, the cooling effect of the ethanol decreases by about 25%.

The octane enhancement effect can be estimated from the data in **Fig. 2**. Direct injection of gasoline results in approximately a five octane number decrease in the octane number required by the engine, as discussed by Stokes, *et al.* Thus the contribution is about five octane numbers per 30K drop in charge temperature. As ethanol can decrease the charge temperature by about 120K, then the decrease in octane number required by the engine due to the drop in temperature, for 100% ethanol, is twenty octane numbers. Thus, when 100% of the fuel is provided by ethanol, the octane number enhancement is approximately thirty-five octane numbers with a twenty octane number enhancement coming from direct injection cooling and a fifteen octane number enhancement coming from the octane number of ethanol. From the above considerations, it can be projected that even if the octane enhancement from direct cooling is significantly lower, a total octane number enhancement of at least 4 octane numbers should be achievable for every 20% of the total fuel energy that is provided by ethanol.

Alternatively the ethanol and gasoline can be mixed together and then port injected through a single injector per cylinder, thereby decreasing the number of injectors that would be used. However, the air charge cooling benefit from ethanol would be lost.

Alternatively the ethanol and gasoline can be mixed together and then port fuel injected using a single injector per cylinder, thereby decreasing the number of injectors that would be used. However, the substantial air charge cooling benefit from ethanol would be lost. The volume of fuel between the mixing point and the port fuel injector should be minimized in order to meet the demanding dynamic octane-enhancement requirements of the engine.

Relatively precise determinations of the actual amount of octane enhancement from given amounts of direct ethanol injection can be obtained from laboratory and vehicle tests in addition to detailed calculations. These correlations can be used by the fuel management microprocessor system **14**.

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An additional benefit of using ethanol for octane enhancement is the ability to use it in a mixture with water. Such a mixture can eliminate the need for the costly and energy consuming water removal step in producing pure ethanol that must be employed when ethanol is added to gasoline at a refinery. Moreover, the water provides an additional cooling (due to vaporization) that further increases engine knock resistance. In contrast the present use of ethanol as an additive to gasoline at the refinery requires that the water be removed from the ethanol.

Since unlike gasoline, ethanol is not a good lubricant and the ethanol fuel injector can stick and not open, it is desirable to add a lubricant to the ethanol. The lubricant will also denature the ethanol and make it unattractive for human consumption.

Further decreases in the required ethanol for a given amount of octane enhancement can be achieved with stratification (non-uniform deposition) of the ethanol addition. Direct injection can be used to place the ethanol near the walls of the cylinder where the need for knock reduction is greatest. The direct injection may be used in combination with swirl. This stratification of the ethanol in the engine further reduces the amount of ethanol needed to obtain a given amount of octane enhancement. Because only the ethanol is directly injected and because it is stratified both by the injection process and by thermal centrifugation, the ignition stability issues associated with gasoline direct injection (GDI) can be avoided.

It is preferred that ethanol be added to those regions that make up the end-gas and are prone to auto-ignition. These regions are near the walls of the cylinder. Since the end-gas contains on the order of 25% of the fuel, substantial decrements in the required amounts of ethanol can be achieved by stratifying the ethanol.

In the case of the engine **10** having substantial organized motion (such as swirl), the cooling will result in forces that thermally stratify the discharge (centrifugal separation of the regions at different density due to different temperatures). The effect of ethanol addition is to increase gas density since the temperature is decreased. With swirl the ethanol mixture will automatically move to the zone where the end-gas is, and thus increase the anti-knock effectiveness of the injected ethanol. The swirl motion is not affected much by the compression stroke and thus survives better than tumble-like motion that drives turbulence towards top-dead-center (TDC) and then dissipates. It should be pointed out that relatively modest swirls result in

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large separating (centrifugal) forces. A 3m/s swirl motion in a 5cm radius cylinder generates accelerations of about 200m/s^2, or about 20g's.

Fig. 3 illustrates ethanol direct injection and swirl motion for achieving thermal stratification. Ethanol is predominantly on an outside region which is the end-gas region. **Fig. 4** illustrates a possible stratification of the ethanol in an inlet manifold with swirl motion and thermal centrifugation maintaining stratification in the cylinder. In this case of port injection of ethanol, however, the advantage of substantial charge cooling may be lost.

With reference again to **Fig. 2**, the effect of ethanol addition all the way up to 100% ethanol injection is shown. At the point that the engine is 100% direct ethanol injected, there may be issues of engine stability when operating with only stratified ethanol injection that need to be addressed. In the case of stratified operation it may also be advantageous to stratify the injection of gasoline in order to provide a relatively uniform equivalence ratio across the cylinder (and therefore lower concentrations of gasoline in the regions where the ethanol is injected). This situation can be achieved, as indicated in **Fig. 4**, by placing fuel in the region of the inlet manifold that is void of ethanol.

The ethanol used in the invention can either be contained in a separate tank from the gasoline or may be separated from a gasoline/ethanol mixture stored in one tank.

The instantaneous ethanol injection requirement and total ethanol consumption over a drive cycle can be estimated from information about the drive cycle and the increase in torque (and thus increase in compression ratio, engine power density, and capability for downsizing) that is desired. A plot of the amount of operating time spent at various values of torque and engine speed in FTP and US06 drive cycles can be used. It is necessary to enhance the octane number at each point in the drive cycle where the torque is greater than permitted for knock free operation with gasoline alone. The amount of octane enhancement that is required is determined by the torque level.

A rough illustrative calculation shows that only a small amount of ethanol might be needed over the drive cycle. Assume that it is desired to increase the maximum torque level by a factor of two relative to what is possible without direct injection ethanol octane enhancement.

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Information about the operating time for the combined FTP and US06 cycles shows that approximately only 10 percent of the time is spent at torque levels above 0.5 maximum torque and less than 1 percent of the time is spent above 0.9 maximum torque. Conservatively assuming that 100 % ethanol addition is needed at maximum torque and that the energy fraction of ethanol addition that is required to prevent knock decreases linearly to zero at 50 percent of maximum torque, the energy fraction provided by ethanol is about 30 percent. During a drive cycle about 20 percent of the total fuel energy is consumed at greater than 50 percent of maximum torque since during the 10 percent of the time that the engine is operated in this regime, the amount of fuel consumed is about twice that which is consumed below 50 percent of maximum torque. The amount of ethanol energy consumed during the drive cycle is thus roughly around 6 percent (30 percent x 0.2) of the total fuel energy.

In this case then, although 100% ethanol addition was needed at the highest value of torque, only 6% addition was needed averaged over the drive cycle. The ethanol is much more effectively used by varying the level of addition according to the needs of the drive cycle. Because of the lower heat of combustion of ethanol, the required amount of ethanol would be about 9% of the weight of the gasoline fuel or about 9% of the volume (since the densities of ethanol and gasoline are comparable). A separate tank with a capacity of about 1.8 gallons would then be required in automobiles with twenty gallon gasoline tanks. The stored ethanol content would be about 9% of that of gasoline by weight, a number not too different from present-day reformulated gasoline. Stratification of the ethanol addition could reduce this amount by more than a factor of two. An on-line ethanol distillation system might alternatively be employed but would entail elimination or reduction of the increase torque and power available from turbocharging.

Because of the relatively small amount of ethanol and present lack of an ethanol fueling infrastructure, it is important that the ethanol vehicle be operable if there is no ethanol on the vehicle. The engine system can be designed such that although the torque and power benefits would be lower when ethanol is not available, the vehicle could still be operable by reducing or eliminating turbocharging capability and/or by increasing spark retard so as to avoid knock. As shown in **Fig. 5**, the fuel management microprocessor system **14** uses ethanol fuel level in the ethanol tank **16** as an input to control the turbocharger **22** (or supercharger or spark retard, not

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shown). As an example, with on-demand ethanol octane enhancement, a 4-cylinder engine can produce in the range of 280 horsepower with appropriate turbocharging or supercharging but could also be drivable with an engine power of 140 horsepower without the use of ethanol according to the invention.

The impact of a small amount of ethanol upon fuel efficiency through use in a higher efficiency engine can greatly increase the energy value of the ethanol. For example, gasoline consumption could be reduced by 20% due to higher efficiency engine operation from use of a high compression ratio, strongly turbocharged operation and substantial engine downsizing. The energy value of the ethanol, including its value in direct replacement of gasoline (5% of the energy of the gasoline), is thus roughly equal to 25% of the gasoline that would have been used in a less efficient engine without any ethanol. The 5% gasoline equivalent energy value of ethanol has thus been leveraged up to a 25% gasoline equivalent value. Thus, ethanol can cost roughly up to five times that of gasoline on an energy basis and still be economically attractive. The use of ethanol as disclosed herein can be a much greater value use than in other ethanol applications.

Although the above discussion has featured ethanol as an exemplary anti-knock agent, the same approach can be applied to other high octane fuel and fuel additives with high vaporization energies such as methanol (with higher vaporization energy per unit fuel), and other anti-knock agents such as tertiary butyl alcohol, or ethers such as methyl tertiary butyl ether (MTBE), ethyl tertiary butyl ether (ETBE), or tertiary amyl methyl ether (TAME).

It is recognized that modifications and variations of the invention disclosed herein will be apparent to those of ordinary skill in the art and it is intended that all such modifications and variations be included within the scope of the appended claims.

What is claimed is:

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1. Fuel management system for efficient operation of a spark ignition gasoline engine comprising:

a gasoline engine;

a source of an anti-knock agent;

an injector for direct injection of the anti-knock agent into a cylinder of the engine; and

a fuel management control system for controlling injection of the anti-knock agent into the cylinder to control knock.

2. The system of claim 1 wherein the injectors stratify the anti-knock agent to provide non-uniform deposition within a cylinder.

3. The system of claim 2 wherein the anti-knock agent is deposited near the walls of the cylinder.

4. The system of claim 2 wherein the stratification is obtained through direct injection and charge swirl.

5. The system of claim 1 wherein the anti-knock agent is selected from the group consisting of ethanol, methanol, tertiary butyl alcohol, MTBE, ETBE and TAME.

6. The system of claim 1 wherein the fuel management system includes a microprocessor that operates in an open loop fashion on a predetermined correlation between octane number enhancement and fraction of fuel provided by the anti-knock agent.

7. The system of claim 1 wherein the gasoline engine includes a knock sensor providing a feedback signal to a fuel management microprocessor to minimize the amount of the anti-knock agent added to prevent knock in a closed loop fashion.

8. The system of claim 1 wherein the anti-knock agent is ethanol.

9. The system of claim 8 wherein the ethanol is mixed with water.

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10. The system of claim 8 wherein the ethanol is mixed with a lubricant.

11. The system of claim 1 wherein the engine has substantial organized motion such as swirl.

12. The system of claim 1 wherein the system includes a measure of the amount of anti-knock agent in the source to control turbocharging, supercharging or spark retard when the amount of anti-knock agent is low.

13. The system of claim 1 wherein the anti-knock agent is added only during portions of a drive cycle requiring knock resistance.

14. The system of claim 1 wherein gasoline is port injected into the engine.

15. The system of claim 1 wherein the gasoline is directly injected into the cylinder.

16. The system of claim 8 wherein the direct injection of ethanol provides substantially a 13°C drop in temperature for every 10% of fuel energy provided by the ethanol.

17. The system of claim 1 wherein the fuel management system substantially minimizes the amount of anti-knock agent used over a drive cycle.

18. The system of claim 8 wherein an octane enhancement of at least 4 octane numbers is obtained when 20% of the fuel energy in a cylinder comes from ethanol.

19. The system of claim 1 wherein turbocharging or supercharging are reduced or eliminated and/or spark retard is increased when the anti-knock agent is not available.

20. The system of claim 8 wherein ethanol is injected proximate to a cylinder wall and swirl creates a ring of ethanol.

21. Fuel management system for efficient operation of a spark ignition engine comprising:

a gasoline engine;

a source of anti-knock agent;

a means for port fuel injection of the anti-knock agent; and

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a fuel management control system for controlling injection of the anti-knock agent into the cylinder to control knock.

22. The system of claim 21 wherein the ethanol and gasoline are mixed together and then port injected.

23. The system of claim 21 wherein the port injection is stratified.

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Abstract of the Disclosure

Fuel management system for efficient operation of a spark ignition gasoline engine. Injectors inject an anti-knock agent such as ethanol directly into a cylinder of the engine. A fuel management microprocessor system controls injection of the anti-knock agent so as to control knock and minimize that amount of the anti-knock agent that is used in a drive cycle. It is preferred that the anti-knock agent is ethanol. The use of ethanol can be further minimized by injection in a non-uniform manner within a cylinder. The ethanol injection suppresses knock so that higher compression ratio and/or engine downsizing from increased turbocharging or supercharging can be used to increase the efficiency of the engine.

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Customer Number: 24280

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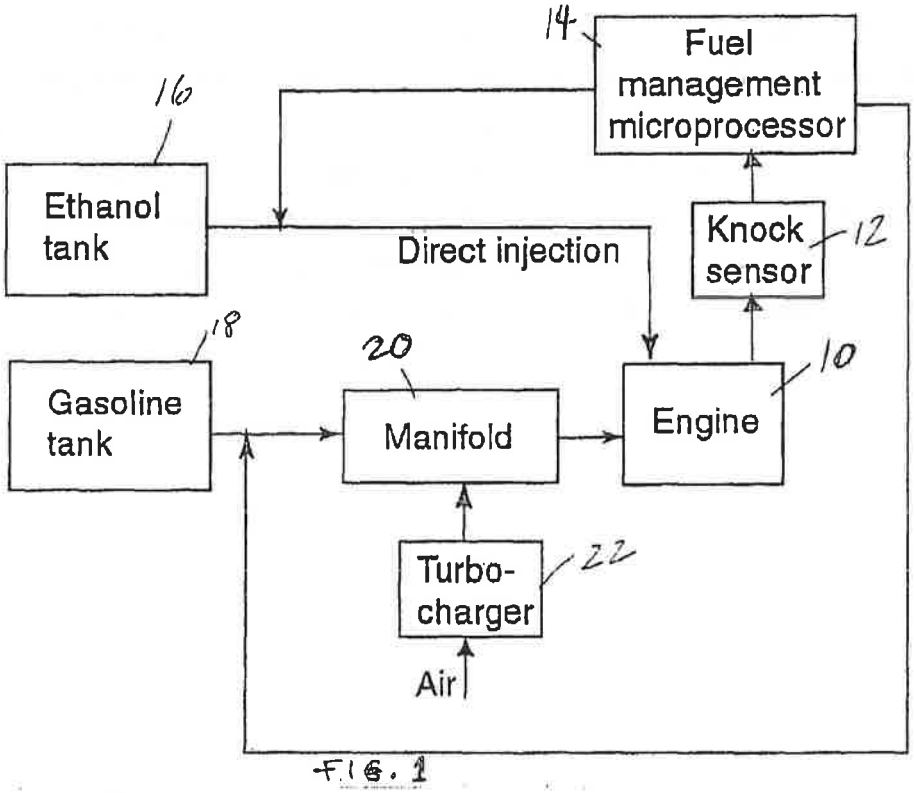
14
Fuel management microprocessor
16
Ethanol tank
Direct injection
Knock sensor
12
18
Gasoline tank
20
Manifold
Engine
10
Turbo-charger
22
Air

FIG. 1

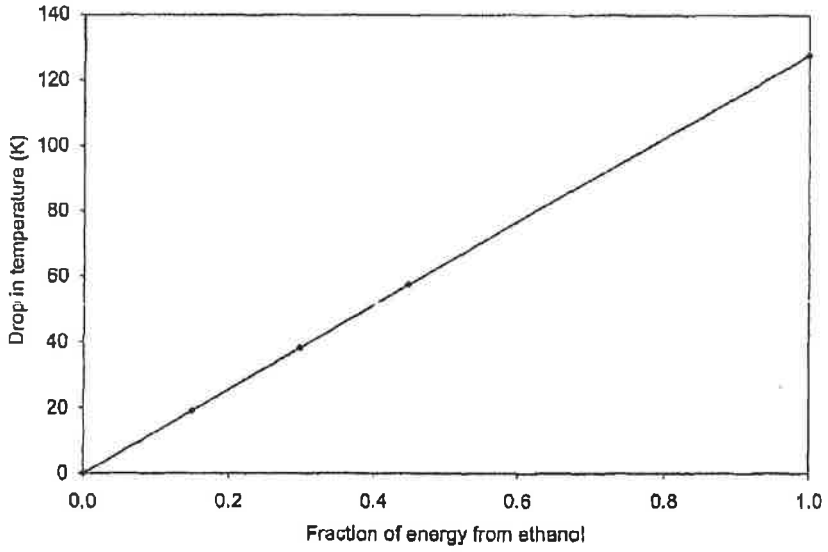
140
120
100
80
60
40
20
0
Drop in temperature (K)
0.0
0.2
0.4
0.6
0.8
1.0
Fraction of energy from ethanol

FIG. 2

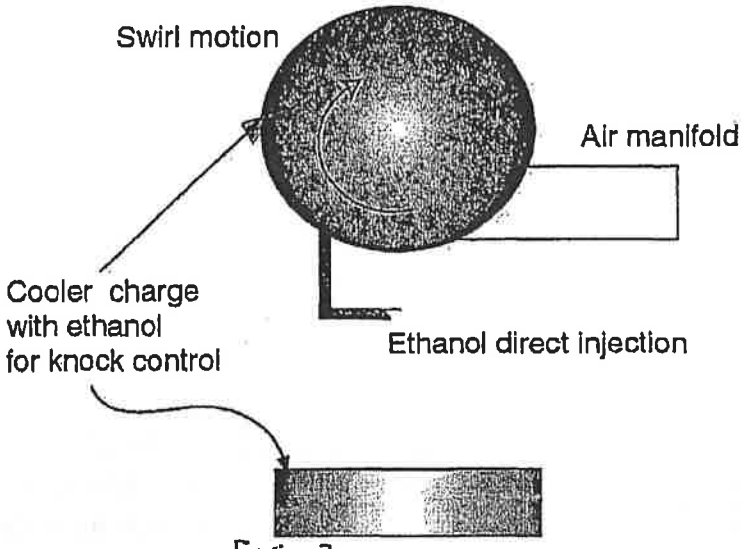
Swirl motion
Air manifold
Cooler charge with ethanol for knock control
Ethanol direct injection

FIG. 3

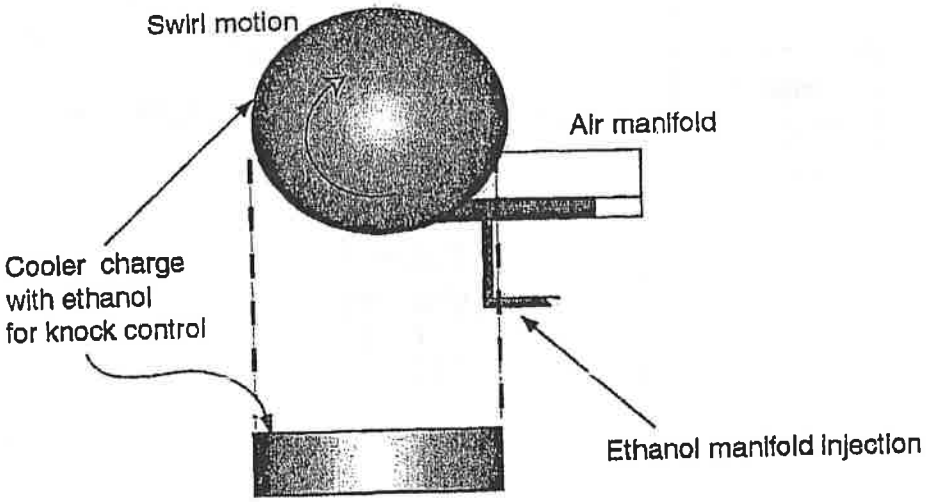
Swirl motion
Air manifold
Cooler charge with ethanol for knock control
Ethanol manifold injection

FIG. 4

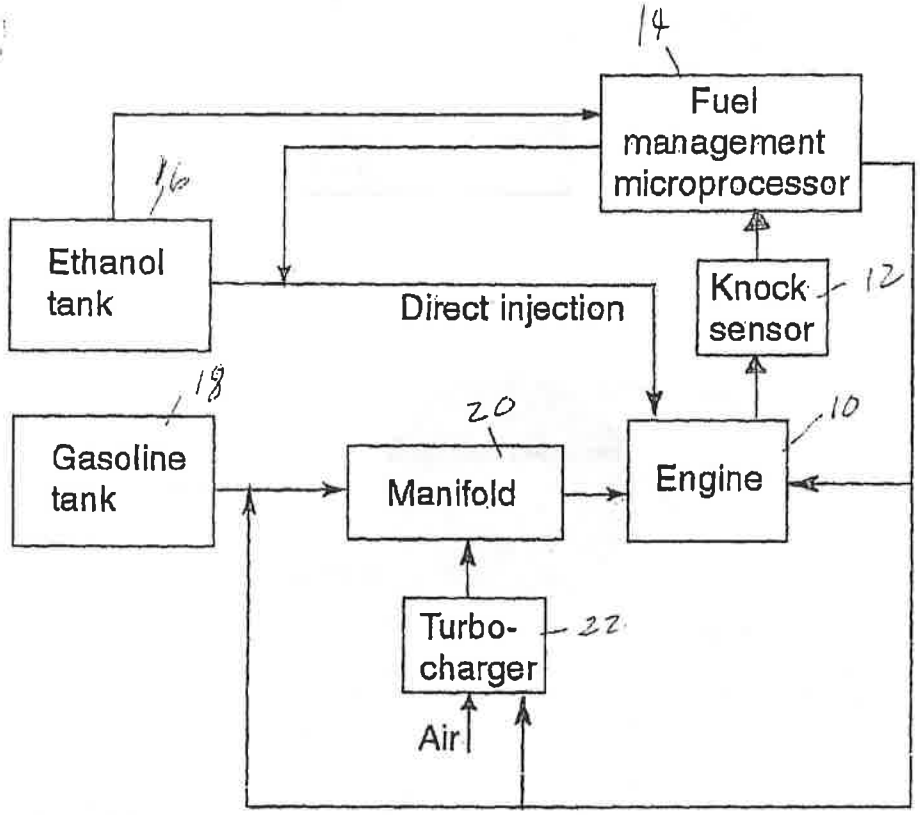
14
Fuel management microprocessor
16
Ethanol tank
Direct injection
Knock sensor
12
18
Gasoline tank
20
Manifold
Engine
10
Turbo-charger
22
Air

FIG. 5

EXHIBIT 2

US008069839B2

(12) **United States Patent**
Cohn et al.

(10) **Patent No.: US 8,069,839 B2**
(45) **Date of Patent: Dec. 6, 2011**

(54) **FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES**

(75) Inventors: **Daniel R. Cohn**, Cambridge, MA (US); **Leslie Bromberg**, Sharon, MA (US); **John B. Heywood**, Newtonville, MA (US)

(73) Assignee: **Massachusetts Institute of Technology**, Cambridge, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/117,448**

(22) Filed: **May 27, 2011**

(65) **Prior Publication Data**

US 2011/0226210 A1 Sep. 22, 2011

Related U.S. Application Data

(63) Continuation of application No. 12/815,842, filed on Jun. 15, 2010, now Pat. No. 7,971,572, and a continuation of application No. 12/329,729, filed on Dec. 8, 2008, now Pat. No. 7,762,233, and a continuation of application No. 11/840,719, filed on Aug. 17, 2007, now Pat. No. 7,740,004, and a continuation of application No. 10/991,774, filed on Nov. 18, 2004, now Pat. No. 7,314,033.

(51) **Int. Cl.**
F02B 7/00 (2006.01)

(52) **U.S. Cl.** ..... **123/431**; 123/198 A; 123/575

(58) **Field of Classification Search** ..... 123/295, 123/299, 300, 525, 27 GE, 198 A, 575, 1 A, 123/559.1, 527
See application file for complete search history.

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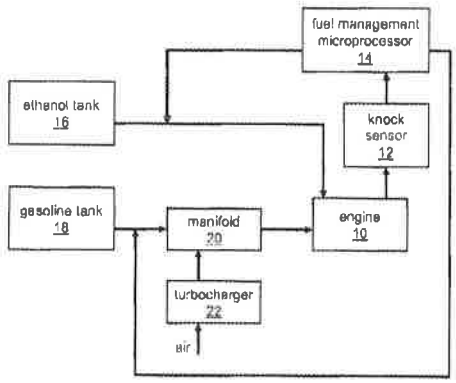
Primary Examiner — Hai Huynh
(74) *Attorney, Agent, or Firm* — Sam Pasternack; MIT's Technology Licensing Office

(57) **ABSTRACT**

Fuel management system for efficient operation of a spark ignition gasoline engine. Injectors inject an anti-knock agent such as ethanol directly into a cylinder of the engine. A fuel management microprocessor system controls injection of the anti-knock agent so as to control knock and minimize that amount of the anti-knock agent that is used in a drive cycle. It is preferred that the anti-knock agent is ethanol. The use of ethanol can be further minimized by injection in a non-uniform manner within a cylinder. The ethanol injection suppresses knock so that higher compression ratio and/or engine downsizing from increased turbocharging or supercharging can be used to increase the efficiency of the engine.

20 Claims, 3 Drawing Sheets



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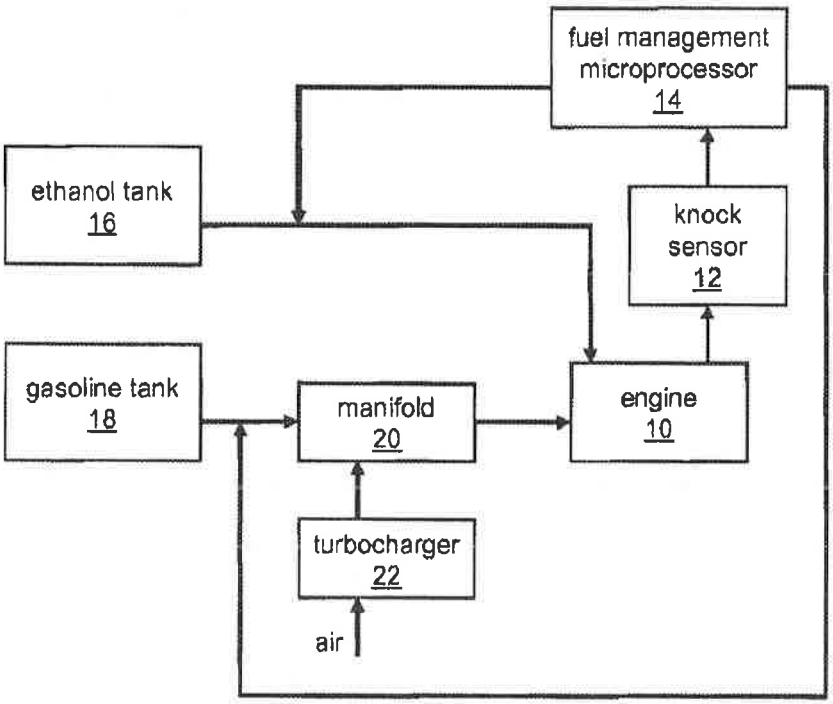
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ethanol tank 16
knock sensor 12
gasoline tank 18
manifold 20
engine 10
turbocharger 22
air

FIG. 1

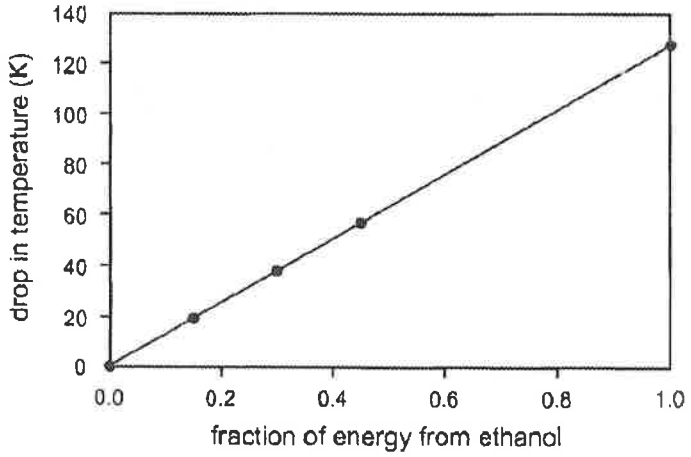
drop in temperature (K)
140
120
100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
fraction of energy from ethanol

FIG. 2

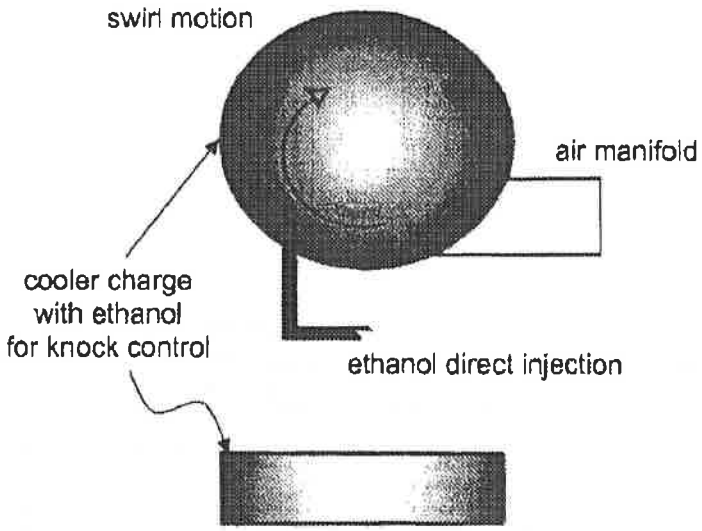
swirl motion
air manifold
cooler charge
with ethanol
for knock control
ethanol direct injection

FIG. 3

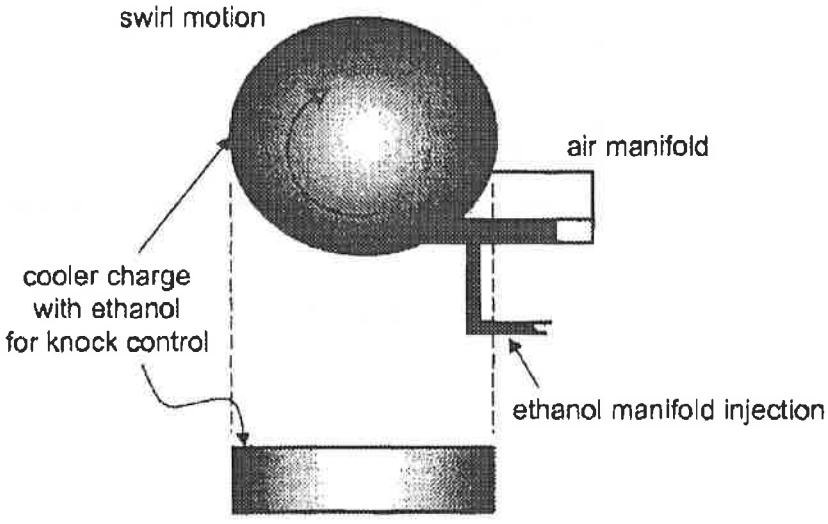
swirl motion
air manifold
cooler charge
with ethanol
for knock control
ethanol manifold injection

FIG. 4

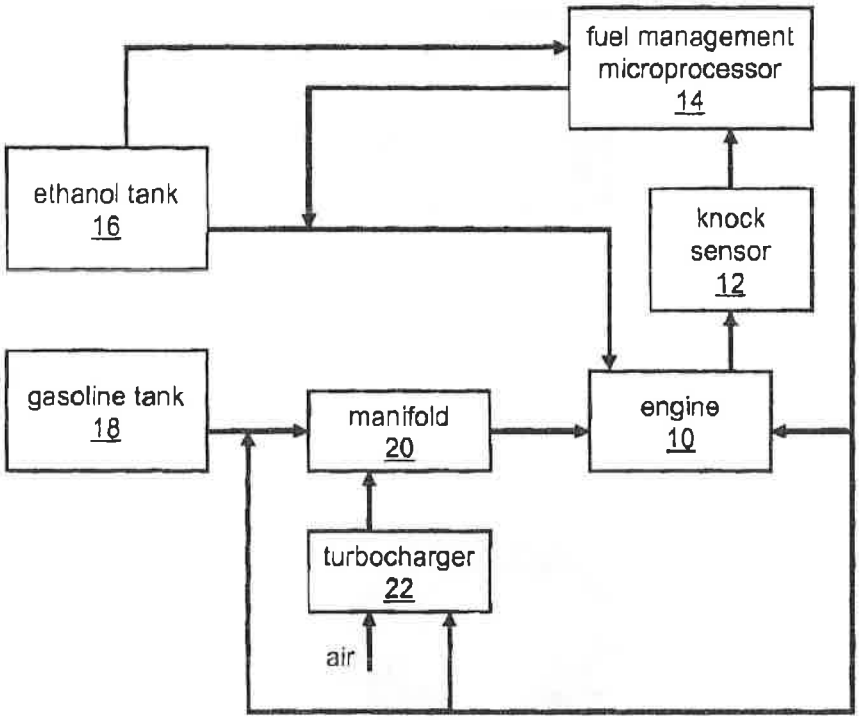
fuel management microprocessor 14
ethanol tank 16
knock sensor 12
gasoline tank 18
manifold 20
engine 10
turbocharger 22
air

FIG. 5

FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES

This application is a continuation of U.S. patent application Ser. No. 12/815,842 filed Jun. 15, 2010 which is a continuation of U.S. patent application Ser. No. 12/329,729 filed on Dec. 8, 2008 which is a continuation of U.S. patent application Ser. No. 11/840,719 filed on Aug. 17, 2007, which is a continuation of U.S. patent application Ser. No. 10/991,774, which is now issued as U.S. Pat. No. 7,314,033.

BACKGROUND

This invention relates to spark ignition gasoline engines utilizing an antiknock agent which is a liquid fuel with a higher octane number than gasoline such as ethanol to improve engine efficiency.

It is known that the efficiency of spark ignition (SI) gasoline engines can be increased by high compression ratio operation and particularly by engine downsizing. The engine downsizing is made possible by the use of substantial pressure boosting from either turbocharging or supercharging. Such pressure boosting makes it possible to obtain the same performance in a significantly smaller engine. See, J. Stokes, et al., "A Gasoline Engine Concept For Improved Fuel Economy The Lean-Boost System," SAE Paper 2001-01-2902. The use of these techniques to increase engine efficiency, however, is limited by the onset of engine knock. Knock is the undesired detonation of fuel and can severely damage an engine. If knock can be prevented, then high compression ratio operation and high pressure boosting can be used to increase engine efficiency by up to twenty-five percent.

Octane number represents the resistance of a fuel to knocking but the use of higher octane gasoline only modestly alleviates the tendency to knock. For example, the difference between regular and premium gasoline is typically six octane numbers. That is significantly less than is needed to realize fully the efficiency benefits of high compression ratio or turbocharged operation. There is thus a need for a practical means for achieving a much higher level of octane enhancement so that engines can be operated much more efficiently.

It is known to replace a portion of gasoline with small amounts of ethanol added at the refinery. Ethanol has a blending octane number (ON) of 110 (versus 95 for premium gasoline) (see J. B. Heywood, "Internal Combustion Engine Fundamentals," McGraw Hill, 1988, p. 477) and is also attractive because it is a renewable energy, biomass-derived fuel, but the small amounts of ethanol that have heretofore been added to gasoline have had a relatively small impact on engine performance. Ethanol is much more expensive than gasoline and the amount of ethanol that is readily available is much smaller than that of gasoline because of the relatively limited amount of biomass that is available for its production. An object of the present invention is to minimize the amount of ethanol or other antiknock agent that is used to achieve a given level of engine efficiency increase. By restricting the use of ethanol to the relatively small fraction of time in an operating cycle when it is needed to prevent knock in a higher load regime and by minimizing its use at these times, the amount of ethanol that is required can be limited to a relatively small fraction of the fuel used by the spark ignition gasoline engine.

SUMMARY

In one aspect, the invention is a fuel management system for efficient operation of a spark ignition gasoline engine including a source of an antiknock agent such as ethanol. An injector directly injects the ethanol into a cylinder of the engine and a fuel management system controls injection of the antiknock agent into the cylinder to control knock with minimum use of the antiknock agent. A preferred antiknock agent is ethanol. Ethanol has a high heat of vaporization so that there is substantial cooling of the air-fuel charge to the cylinder when it is injected directly into the engine. This cooling effect reduces the octane requirement of the engine by a considerable amount in addition to the improvement in knock resistance from the relatively high octane number of ethanol. Methanol, tertiary butyl alcohol, MTBE, ETBE, and TAME may also be used. Wherever ethanol is used herein it is to be understood that other antiknock agents are contemplated.

The fuel management system uses a fuel management control system that may use a microprocessor that operates in an open loop fashion on a predetermined correlation between octane number enhancement and fraction of fuel provided by the antiknock agent. To conserve the ethanol, it is preferred that it be added only during portions of a drive cycle requiring knock resistance and that its use be minimized during these times. Alternatively, the gasoline engine may include a knock sensor that provides a feedback signal to a fuel management microprocessor system to minimize the amount of the ethanol added to prevent knock in a closed loop fashion.

In one embodiment the injectors stratify ethanol to provide non-uniform deposition within a cylinder. For example, the ethanol may be injected proximate to the cylinder walls and swirl can create a ring of ethanol near the walls.

In another embodiment of this aspect of the invention, the system includes a measure of the amount of the antiknock agent such as ethanol in the source containing the antiknock agent to control turbocharging, supercharging or spark retard when the amount of ethanol is low.

The direct injection of ethanol provides substantially a 13° C. drop in temperature for every ten percent of fuel energy provided by ethanol. An instantaneous octane enhancement of at least 4 octane numbers may be obtained for every 20 percent of the engine's energy coming from the ethanol.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of one embodiment of the invention disclosed herein.

FIG. **2** is a graph of the drop in temperature within a cylinder as a function of the fraction of energy provided by ethanol.

FIG. **3** is a schematic illustration of the stratification of cooler ethanol charge using direct injection and swirl motion for achieving thermal stratification.

FIG. **4** is a schematic illustration showing ethanol stratified in an inlet manifold.

FIG. **5** is a block diagram of an embodiment of the invention in which the fuel management microprocessor is used to control a turbocharger and spark retard based upon the amount of ethanol in a fuel tank.

DETAILED DESCRIPTION

With reference first to FIG. **1**, a spark ignition gasoline engine **10** includes a knock sensor **12** and a fuel management microprocessor system **14**. The fuel management microprocessor system **14** controls the direct injection of an antiknock agent such as ethanol from an ethanol tank **16**. The fuel management microprocessor system **14** also controls the delivery of gasoline from a gasoline tank **18** into engine

manifold **20**. A turbocharger **22** is provided to improve the torque and power density of the engine **10**. The amount of ethanol injection is dictated either by a predetermined correlation between octane number enhancement and fraction of fuel that is provided by ethanol in an open loop system or by a closed loop control system that uses a signal from the knock sensor **12** as an input to the fuel management microprocessor **14**. In both situations, the fuel management processor **14** will minimize the amount of ethanol added to a cylinder while still preventing knock. It is also contemplated that the fuel management microprocessor system **14** could provide a combination of open and closed loop control.

As show in FIG. **1** it is preferred that ethanol be directly injected into the engine **10**. Direct injection substantially increases the benefits of ethanol addition and decreases the required amount of ethanol. Recent advances in fuel injector and electronic control technology allows fuel injection directly into a spark ignition engine rather than into the manifold **20**. Because ethanol has a high heat of vaporization there will be substantial cooling when it is directly injected into the engine **10**. This cooling effect further increases knock resistance by a considerable amount. In the embodiment of FIG. **1** port fuel injection of the gasoline in which the gasoline is injected into the manifold rather than directly injected into the cylinder is preferred because it is advantageous in obtaining good air/fuel mixing and combustion stability that are difficult to obtain with direct injection.

Ethanol has a heat of vaporization of 840 kJ/kg, while the heat of vaporization of gasoline is about 350 kJ/kg. The attractiveness of ethanol increases when compared with gasoline on an energy basis, since the lower heating value of ethanol is 26.9 MJ/kg while for gasoline it is about 44 MJ/kg. Thus, the heat of vaporization per Joule of combustion energy is 0.031 for ethanol and 0.008 for gasoline. That is, for equal amounts of energy the required heat of vaporization of ethanol is about four times higher than that of gasoline. The ratio of the heat of vaporization per unit air required for stoichiometric combustion is about 94 kJ/kg of air for ethanol and 24 kJ/kg of air for gasoline, or a factor of four smaller. Thus, the net effect of cooling the air charge is about four times lower for gasoline than for ethanol (for stoichiometric mixtures wherein the amount of air contains oxygen that is just sufficient to combust all of the fuel).

In the case of ethanol direct injection according to one aspect of the invention, the charge is directly cooled. The amount of cooling due to direct injection of ethanol is shown in FIG. **2**. It is assumed that the air/fuel mixture is stoichiometric without exhaust gas recirculation (EGR), and that gasoline makes up the rest of the fuel. It is further assumed that only the ethanol contributes to charge cooling. Gasoline is vaporized in the inlet manifold and does not contribute to cylinder charge cooling. The direct ethanol injection provides about 13° C. of cooling for each 10% of the fuel energy provided by ethanol. It is also possible to use direct injection of gasoline as well as direct injection of ethanol. However, under certain conditions there can be combustion stability issues.

The temperature decrement because of the vaporization energy of the ethanol decreases with lean operation and with EGR, as the thermal capacity of the cylinder charge increases. If the engine operates at twice the stoichiometric air/fuel ratio, the numbers indicated in FIG. **2** decrease by about a factor of 2 (the contribution of the ethanol itself and the gasoline is relatively modest). Similarly, for a 20% EGR rate, the cooling effect of the ethanol decreases by about 25%.

The octane enhancement effect can be estimated from the data in FIG. **2**. Direct injection of gasoline results in approximately a five octane number decrease in the octane number required by the engine, as discussed by Stokes, et al. Thus the contribution is about five octane numbers per 30K drop in charge temperature. As ethanol can decrease the charge temperature by about 120K, then the decrease in octane number required by the engine due to the drop in temperature, for 100% ethanol, is twenty octane numbers. Thus, when 100% of the fuel is provided by ethanol, the octane number enhancement is approximately thirty-five octane numbers with a twenty octane number enhancement coming from direct injection cooling and a fifteen octane number enhancement coming from the octane number of ethanol. From the above considerations, it can be projected that even if the octane enhancement from direct cooling is significantly lower, a total octane number enhancement of at least 4 octane numbers should be achievable for every 20% of the total fuel energy that is provided by ethanol.

Alternatively the ethanol and gasoline can be mixed together and then port injected through a single injector per, cylinder, thereby decreasing the number of injectors that would be used. However, the air charge cooling benefit from ethanol would be lost.

Alternatively the ethanol and gasoline can be mixed together and then port fuel injected using a single injector per cylinder, thereby decreasing the number of injectors that would be used. However, the substantial air charge cooling benefit from ethanol would be lost. The volume of fuel between the mixing point and the port fuel injector should be minimized in order to meet the demanding dynamic octane-enhancement requirements of the engine.

Relatively precise determinations of the actual amount of octane enhancement from given amounts of direct ethanol injection can be obtained from laboratory and vehicle tests in addition to detailed calculations. These correlations can be used by the fuel management microprocessor system **14**.

An additional benefit of using ethanol for octane enhancement is the ability to use it in a mixture with water. Such a mixture can eliminate the need for the costly and energy consuming water removal step in producing pure ethanol that must be employed when ethanol is added to gasoline at a refinery. Moreover, the water provides an additional cooling (due to vaporization) that further increases engine knock resistance. In contrast the present use of ethanol as an additive to gasoline at the refinery requires that the water be removed from the ethanol.

Since unlike gasoline, ethanol is not a good lubricant and the ethanol fuel injector can stick and not open, it is desirable to add a lubricant to the ethanol. The lubricant will also denature the ethanol and make it unattractive for human consumption.

Further decreases in the required ethanol for a given amount of octane enhancement can be achieved with stratification (non-uniform deposition) of the ethanol addition. Direct injection can be used to place the ethanol near the walls of the cylinder where the need for knock reduction is greatest. The direct injection may be used in combination with swirl. This stratification of the ethanol in the engine further reduces the amount of ethanol needed to obtain a given amount of octane enhancement. Because only the ethanol is directly injected and because it is stratified both by the injection process and by thermal centrifugation, the ignition stability issues associated with gasoline direct injection (GDI) can be avoided.

It is preferred that ethanol be added to those regions that make up the end-gas and are prone to auto-ignition. These regions are near the walls of the cylinder. Since the end-gas

contains on the order of 25% of the fuel, substantial decrements in the required amounts of ethanol can be achieved by stratifying the ethanol.

In the case of the engine **10** having substantial organized motion (such as swirl), the cooling result in forces that thermally stratify the discharge (centrifugal separation of the regions at different density due to different temperatures). The effect of ethanol addition is to increase gas density since the temperature is decreased. With swirl the ethanol mixture will automatically move to the zone where the end-gas is, and thus increase the anti-knock effectiveness of the injected ethanol. The swirl motion is not affected much by the compression stroke and thus survives better than tumble-like motion that drives turbulence towards top-dead-center (TDC) and then dissipates. It should be pointed out that relatively modest swirls result in large separating (centrifugal) forces. A 3 m/s swirl motion in a 5 cm radius cylinder generates accelerations of about 200 m/s^2, or about 20 g's.

FIG. **3** illustrates ethanol direct injection and swirl motion for achieving thermal stratification. Ethanol is predominantly on an outside region which is the end-gas region. FIG. **4** illustrates a possible stratification of the ethanol in an inlet manifold with swirl motion and thermal centrifugation maintaining stratification in the cylinder. In this case of port injection of ethanol, however, the advantage of substantial charge cooling may be lost.

With reference again to FIG. **2**, the effect of ethanol addition all the way up to 100% ethanol injection is shown. At the point that the engine is 100% direct ethanol injected, there may be issues of engine stability when operating with only stratified ethanol injection that need to be addressed. In the case of stratified operation it may also be advantageous to stratify the injection of gasoline in order to provide a relatively uniform equivalence ratio across the cylinder (and therefore lower concentrations of gasoline in the regions where the ethanol is injected). This situation can be achieved, as indicated in FIG. **4**, by placing fuel in the region of the inlet manifold that is void of ethanol.

The ethanol used in the invention can either be contained in a separate tank from the gasoline or may be separated from a gasoline/ethanol mixture stored in one tank.

The instantaneous ethanol injection requirement and total ethanol consumption over a drive cycle can be estimated from information about the drive cycle and the increase in torque (and thus increase in compression ratio, engine power density, and capability for downsizing) that is desired. A plot of the amount of operating time spent at various values of torque and engine speed in FTP and US06 drive cycles can be used. It is necessary to enhance the octane number at each point in the drive cycle where the torque is greater than permitted for knock free operation with gasoline alone. The amount of octane enhancement that is required is determined by the torque level.

A rough illustrative calculation shows that only a small amount of ethanol might be needed over the drive cycle. Assume that it is desired to increase the maximum torque level by a factor of two relative to what is possible without direct injection ethanol octane enhancement. Information about the operating time for the combined FTP and US06 cycles shows that approximately only 10 percent of the time is spent at torque levels above 0.5 maximum torque and less than 1 percent of the time is spent above 0.9 maximum torque. Conservatively assuming that 100% ethanol addition is needed at maximum torque and that the energy fraction of ethanol addition that is required to prevent knock decreases linearly to zero at 50 percent of maximum torque, the energy fraction provided by ethanol is about 30 percent. During a drive cycle about 20 percent of the total fuel energy is consumed at greater than 50 percent of maximum torque since during the 10 percent of the time that the engine is operated in this regime, the amount of fuel consumed is about twice that which is consumed below 50 percent of maximum torque. The amount of ethanol energy consumed during the drive cycle is thus roughly around 6 percent (30 percent×0.2) of the total fuel energy.

In this case then, although 100% ethanol addition was needed at the highest value of torque, only 6% addition was needed averaged over the drive cycle. The ethanol is much more effectively used by varying the level of addition according to the needs of the drive cycle.

Because of the lower heat of combustion of ethanol, the required amount of ethanol would be about 9% of the weight of the gasoline fuel or about 9% of the volume (since the densities of ethanol and gasoline are comparable). A separate tank with a capacity of about 1.8 gallons would then be required in automobiles with twenty gallon gasoline tanks. The stored ethanol content would be about 9% of that of gasoline by weight, a number not too different from present-day reformulated gasoline. Stratification of the ethanol addition could reduce this amount by more than a factor of two. An on-line ethanol distillation system might alternatively be employed but would entail elimination or reduction of the increase torque and power available from turbocharging.

Because of the relatively small amount of ethanol and present lack of an ethanol fueling infrastructure, it is important that the ethanol vehicle be operable if there is no ethanol on the vehicle. The engine system can be designed such that although the torque and power benefits would be lower when ethanol is not available, the vehicle could still be operable by reducing or eliminating turbocharging capability and/or by increasing spark retard so as to avoid knock. As shown in FIG. **5**, the fuel management microprocessor system **14** uses ethanol fuel level in the ethanol tank **16** as an input to control the turbocharger **22** (or supercharger or spark retard, not shown). As an example, with on-demand ethanol octane enhancement, a 4-cylinder engine can produce in the range of 280 horsepower with appropriate turbocharging or supercharging but could also be drivable with an engine power of 140 horsepower without the use of ethanol according to the invention.

The impact of a small amount of ethanol upon fuel efficiency through use in a higher efficiency engine can greatly increase the energy value of the ethanol. For example, gasoline consumption could be reduced by 20% due to higher efficiency engine operation from use of a high compression ratio, strongly turbocharged operation and substantial engine downsizing. The energy value of the ethanol, including its value in direct replacement of gasoline (5% of the energy of the gasoline), is thus roughly equal to 25% of the gasoline that would have been used in a less efficient engine without any ethanol. The 5% gasoline equivalent energy value of ethanol has thus been leveraged up to a 25% gasoline equivalent value. Thus, ethanol can cost roughly up to five times that of gasoline on an energy basis and still be economically attractive. The use of ethanol as disclosed herein can be a much greater value use than in other ethanol applications.

Although the above discussion has featured ethanol as an exemplary anti-knock agent, the same approach can be applied to other high octane fuel and fuel additives with high vaporization energies such as methanol (with higher vaporization energy per unit fuel), and other anti-knock agents such as tertiary butyl alcohol, or ethers such as methyl tertiary butyl ether (MTBE), ethyl tertiary butyl ether (ETBE), or tertiary amyl methyl ether (TAME).

It is recognized that modifications and variations of the invention disclosed herein will be apparent to those of ordinary skill in the art and it is intended that all such modifications and variations be included within the scope of the appended claims.

What is claimed is:

1. A spark ignition engine that is fueled both by direct injection and by port injection wherein above a selected torque value the ratio of fuel that is directly injected to fuel that is port injected increases; and wherein the engine is operated at a substantially stoichiometric fuel/air ratio.

2. The spark ignition engine of claim 1 where the ratio of directly injected fuel to port injected fuel increases with increasing torque.

3. The spark ignition engine of claim 2 where the ratio of directly injected fuel to port injected fuel is determined by a signal from a knock detector.

4. The spark ignition engine of claim 3 further including a microprocessor that controls the ratio of the directly injected fuel to the port injected fuel based on the signal from the knock detector.

5. The spark ignition engine of claim 2 where open loop control is used to determine the ratio of the directly injected fuel to the port injected fuel.

6. The spark ignition engine of claim 1 where the engine operates at a substantially stoichiometric fuel/air ratio at the highest loads.

7. The spark ignition engine of claim 1 where the engine operates at some value of torque with port fuel injection alone.

8. The spark ignition engine of claim 1 where the engine operates at some value of torque with direct injection alone.

9. The spark ignition engine of claim 1 where the engine is fueled with ethanol.

10. The spark ignition engine of claim 1 where the engine is fueled with methanol.

11. The spark ignition engine of claim 1 where the engine is fueled with a gasoline-alcohol mixture.

12. The spark ignition engine of claim 1 where the directly injected fuel is injected so as to have a higher concentration in the end gas region.

13. The spark ignition engine of claim 12 where the knock free torque of the engine is higher than for a uniform distribution of directly injected fuel.

14. The spark ignition engine of claim 11 where the directly injected fuel is concentrated on the periphery of the cylinder.

15. A spark ignition engine which is fueled with port injection of fuel and is also fueled with direct injection of fuel and where above a certain value of torque the ratio of fuel that is directly injected to fuel that is port injected increases and where the engine is operated with a substantially stoichiometric fuel/air ratio

and where the engine is fueled with gasoline and ethanol and where the ethanol is directly injected such the octane enhancement from evaporative cooling of the ethanol is greater than the octane enhancement from the intrinsic octane of the ethanol.

16. The spark ignition engine of claim 15 where the ratio of directly injected fuel to port injected fuel increases with increasing torque.

17. The spark ignition engine of claim 15 where a signal from a knock sensor determines the ratio of directly injected fuel to port injected fuel.

18. The spark ignition engine of claim 15 where the engine is operated at a substantially stoichiometric fuel/air ratio at the highest loads.

19. The spark ignition engine of claim 15 where at some level of torque the engine is fueled only with port injection.

20. The spark ignition engine of claim 15 where at some level of torque the engine is fueled only with direct injection.

* * * * *

EXHIBIT 3

US009255519B2

(12) **United States Patent**
Cohn et al.

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(45) **Date of Patent: *Feb. 9, 2016**

(54) **FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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See application file for complete search history.

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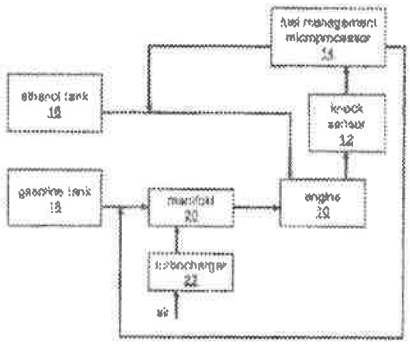
(57) **ABSTRACT**

Fuel management system for efficient operation of a spark ignition gasoline engine. Injectors inject an anti-knock agent such as ethanol directly into a cylinder of the engine. A fuel management microprocessor system controls injection of the anti-knock agent so as to control knock and minimize that amount of the anti-knock agent that is used in a drive cycle. It is preferred that the anti-knock agent is ethanol. The use of ethanol can be further minimized by injection in a non-uniform manner within a cylinder. The ethanol injection suppresses knock so that higher compression ratio and/or engine downsizing from increased turbocharging or supercharging can be used to increase the efficiency or the engine.

31 Claims, 3 Drawing Sheets



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continuation of application No. 13/629,836, filed on Sep. 28, 2012, now Pat. No. 8,522,746, and a continuation of application No. 13/368,382, filed on Feb. 8, 2012, now Pat. No. 8,302,580, and a continuation of application No. 13/282,787, filed on Oct. 27, 2011, now Pat. No. 8,146,568, and a continuation of application No. 13/117,448, filed on May 27, 2011, now Pat. No. 8,069,839, and a continuation of application No. 12/815,842, filed on Jun. 15, 2010, now Pat. No. 7,971,572, and a continuation of application No. 12/329,729, filed on Dec. 8, 2008, now Pat. No. 7,762,233, and a continuation of application No. 11/840,719, filed on Aug. 17, 2007, now Pat. No. 7,740,004, and a continuation of application No. 10/991,774, filed on Nov. 18, 2004, now Pat. No. 7,314,033.

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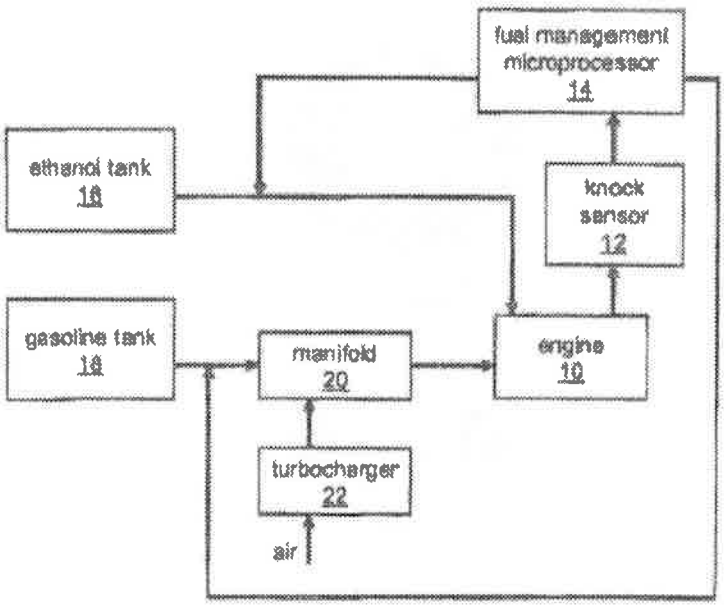
fuel management microprocessor 14
ethanol tank 16
knock sensor 12
gasoline tank 18
manifold 20
engine 10
turbocharger 22
air

FIG. 1

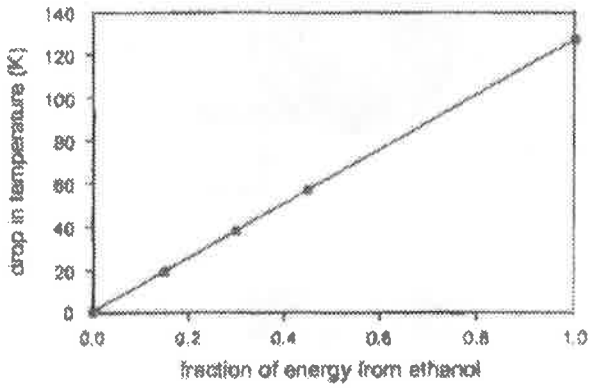
drop in temperature (K)
140
120
100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
fraction of energy from ethanol

FIG. 2

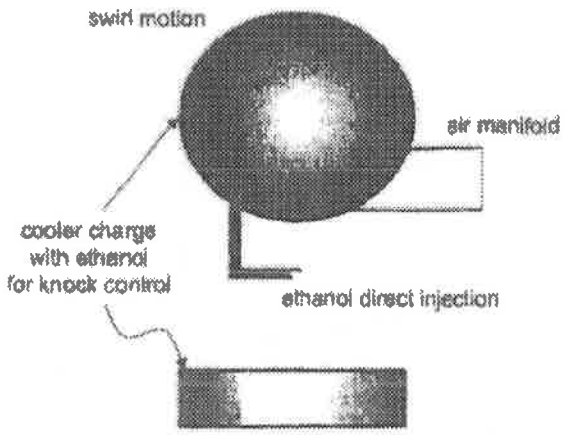
swirl motion
air manifold
cooler charge
with ethanol
for knock control
ethanol direct injection

FIG. 3

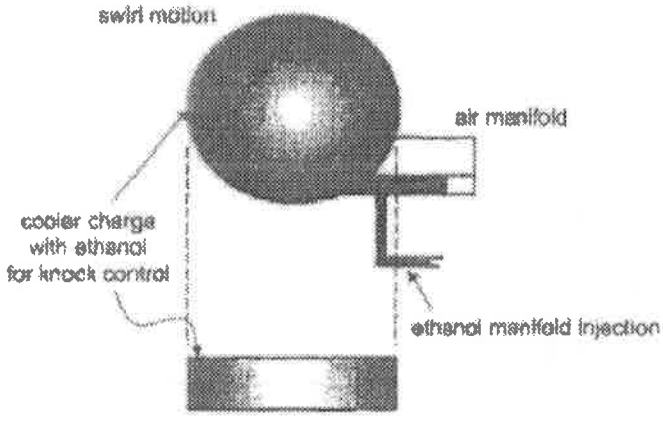
swirl motion
air manifold
cooler charge
with ethanol
for knock control
ethanol manifold injection

FIG. 4

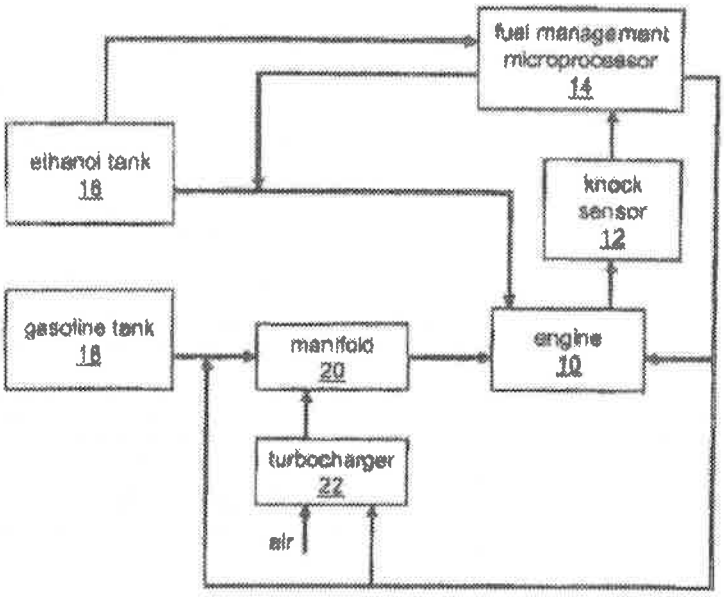
fuel management microprocessor 14
ethanol tank 16
knock sensor 12
gasoline tank 18
manifold 20
engine 10
turbocharger 22
air

FIG. 5

FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES

This application is a continuation of U.S. patent application Ser. No. 14/249,806 filed on Apr. 10, 2014, which is a continuation of U.S. patent application Ser. No. 13/956,498 filed on Aug. 1, 2013, which is now issued as U.S. Pat. No. 8,733,321, which is a continuation of U.S. patent application Ser. No. 13/629,836 filed on Sep. 28, 2012 which is now issued as U.S. Pat. No. 8,522,746, which is a continuation of U.S. patent application Ser. No. 13/368,382 filed on Feb. 8, 2012, which is now issued as U.S. Pat. No. 8,302,580, which is a continuation of U.S. patent application Ser. No. 13/282,787 filed Oct. 27, 2011, which is now issued as U.S. Pat. No. 8,146,568, which is a continuation of U.S. patent application Ser. No. 13/117,448 filed May 27, 2011, which is now issued as U.S. Pat. No. 8,069,839, which is a continuation of U.S. patent application Ser. No. 12/815,842, filed Jun. 15, 2010, which is now issued as U.S. Pat. No. 7,971,572, which is a continuation of U.S. patent application Ser. No. 12/329,729 filed on Dec. 8, 2008, which is now issued as U.S. Pat. No. 7,762,233, which is a continuation of U.S. patent application Ser. No. 11,840,719 filed on Aug. 17, 2007, which is now issued as U.S. Pat. No. 7,740,004, which is a continuation of U.S. patent application Ser. No. 10/991,774, which is now issued as U.S. Pat. No. 7,314,033.

BACKGROUND

This invention relates to spark ignition gasoline engines utilizing an antiknock agent which is a liquid fuel with a higher octane number than gasoline such as ethanol to improve engine efficiency.

It is known that the efficiency of spark ignition (SI) gasoline engines can be increased by high compression ratio operation and particularly by engine downsizing. The engine downsizing is made possible by the use of substantial pressure boosting from either turbocharging or supercharging. Such pressure boosting makes it possible to obtain the same performance in a significantly smaller engine. See, J. Stokes, et al., "A Gasoline Engine Concept For Improved Fuel Economy The Lean-Boost System," SAE Paper 2001-01-2902. The use of these techniques to increase engine efficiency, however, is limited by the onset of engine knock. Knock is the undesired detonation of fuel and can severely damage an engine. If knock can be prevented, then high compression ratio operation and high pressure boosting can be used to increase engine efficiency by up to twenty-five percent.

Octane number represents the resistance of a fuel to knocking but the use of higher octane gasoline only modestly alleviates the tendency to knock. For example, the difference between regular and premium gasoline is typically six octane numbers. That is significantly less than is needed to realize fully the efficiency benefits of high compression ratio or turbocharged operation. There is thus a need for a practical means for achieving a much higher level of octane enhancement so that engines can be operated much more efficiently.

It is known to replace a portion of gasoline with small amount of ethanol added at the refinery. Ethanol has a blending octane number (ON) of 110 (versus 95 for premium gasoline) (see J. B. Heywood, "Internal Combustion Engine Fundamentals," McGraw Hill, 1988, p. 477) and is also attractive because it is a renewable energy, biomass-derived fuel, but the small amounts of ethanol that have heretofore been added to gasoline have had a relatively small impact on engine performance. Ethanol is much more expensive than gasoline and the amount of ethanol that is readily available is much smaller than that of gasoline because of the relatively limited amount of biomass that is available for its production. An object of the present invention is to minimize the amount of ethanol or other antiknock agent that is used to achieve a given level of engine efficiency increase. By restricting the use of ethanol to the relatively small fraction of time in an operating cycle when it is needed to prevent knock in a higher load regime and by minimizing its use at these times, the amount of ethanol that is required can be limited to a relatively small fraction of the fuel used by the spark ignition gasoline engine.

SUMMARY

In one aspect, the invention is a fuel management system for efficient operation of a spark ignition gasoline engine including a source of an antiknock agent such as ethanol. An injector directly injects the ethanol into a cylinder of the engine and a fuel management system controls injection of the antiknock agent into the cylinder to control knock with minimum use of the antiknock agent. A preferred antiknock agent is ethanol. Ethanol has a high heat of vaporization so that there is substantial cooling of the air-fuel charge to the cylinder when it is injected directly into the engine. This cooling effect reduces the octane requirement of the engine by a considerable amount in addition to the improvement in knock resistance from the relatively high octane number of ethanol. Methanol, tertiary butyl alcohol, MTBE, ETBE, and TAME may also be used. Wherever ethanol is used herein it is to be understood that other antiknock agents are contemplated.

The fuel management system uses a fuel management control system that may use a microprocessor that operates in an open loop fashion on a predetermined correlation between octane number enhancement and fraction of fuel provided by the antiknock agent. To conserve the ethanol, it is preferred that it be added only during portions of a drive cycle requiring knock resistance and that its use be minimized during these times. Alternatively, the gasoline engine may include a knock sensor that provides a feedback signal to a fuel management microprocessor system to minimize the amount of the ethanol added to prevent knock in a closed loop fashion.

In one embodiment the injectors stratify the ethanol to provide non-uniform deposition within a cylinder. For example, the ethanol may be injected proximate to the cylinder walls and swirl can create a ring of ethanol near the walls.

In another embodiment of this aspect of the invention, the system includes a measure of the amount of the antiknock agent such as ethanol in the source containing the antiknock agent to control turbocharging, supercharging or spark retard when the amount of ethanol is low.

The direct injection of ethanol provides substantially a 13° C. drop in temperature for every ten percent of fuel energy provided by ethanol. An instantaneous octane enhancement of at least 4 octane numbers may be obtained for every 20 percent of the engine's energy coming form the ethanol.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of one embodiment of the invention disclosed herein.

FIG. **2** is a graph of the drop in temperature within a cylinder as a function of the fraction of energy provided by ethanol.

FIG. **3** is a schematic illustration of the stratification of cooler ethanol charge using direct injection and swirl motion for achieving thermal stratification.

FIG. **4** is a schematic illustration showing ethanol stratified in an inlet manifold.

FIG. **5** is a block diagram of an embodiment of the invention in which the fuel management microprocessor is used to control a turbocharger and spark retard based upon the amount of ethanol in a fuel tank.

DETAILED DESCRIPTION

With reference first to FIG. **1**, a spark ignition gasoline engine **10** includes a knock sensor **12** and a fuel management microprocessor system **14**. The fuel management microprocessor system **14** controls the direct injection of an antiknock agent such as ethanol from an ethanol tank **16**. The fuel management microprocessor system **14** also controls the delivery of gasoline from a gasoline tank **18** into engine manifold **20**. A turbocharger **22** is provided to improve the torque and power density of the engine **10**. The amount of ethanol injection is dictated either by a predetermined correlation between octane number enhancement and fraction of fuel that is provided by ethanol in an open loop system or by a closed loop control system that uses a signal from the knock sensor **12** as an input to the fuel management microprocessor **14**. In both situations, the fuel management processor **14** will minimize the amount of ethanol added to a cylinder while still preventing knock. It is also contemplated that the fuel management microprocessor system **14** could provide a combination of open and closed loop control.

As show in FIG. **1** it is preferred that ethanol be directly injected into the engine **10**. Direct injection substantially increases the benefits of ethanol addition and decreases the required amount of ethanol. Recent advances in fuel injector and electronic control technology allows fuel injection directly into a spark ignition engine rather than into the manifold **20**. Because ethanol has a high heat of vaporization there will be substantial cooling when it is directly injected into the engine **10**. This cooling effect further increases knock resistance by a considerable amount. In the embodiment of FIG. **1** port fuel injection of the gasoline in which the gasoline is injected into the manifold rather than directly injected into the cylinder is preferred because it is advantageous in obtaining good air/fuel mixing and combustion stability that are difficult to obtain with direct injection.

Ethanol has a heat of vaporization of 840 kJ/kg, while the heat of vaporization of gasoline is about 350 kJ/kg. The attractiveness of ethanol increases when compared with gasoline on an energy basis, since the lower heating value of ethanol is 26.9 MJ/kg while for gasoline it is about 44 MJ/kg. Thus, the heat of vaporization per Joule of combustion energy is 0.031 for ethanol and 0.008 for gasoline. That is, for equal amounts of energy the required heat of vaporization of ethanol is about four times higher than that of gasoline. The ratio of the heat of vaporization per unit air required for stoichiometric combustion is about 94 kJ/kg of air for ethanol and 24 kJ/kg of air for gasoline, or a factor of four smaller. Thus, the net effect of cooling the air charge is about four times lower for gasoline than for ethanol (for stoichiometric mixtures wherein the amount of air contains oxygen that is just sufficient to combust all of the fuel).

In the case of ethanol direct injection according to one aspect of the invention, the charge is directly cooled. The amount of cooling due to direct injection of ethanol is shown in FIG. **2**. It is assumed that the air/fuel mixture is stoichiometric without exhaust gas recirculation (EGR), and that gasoline makes up the rest of the fuel. It is further assumed that only the ethanol contributes to charge cooling. Gasoline is vaporized in the inlet manifold and does not contribute to cylinder charge cooling. The direct ethanol injection provides about 13° C. of cooling for each 10% of the fuel energy provided by ethanol. (It is also possible to use direct injection of gasoline as well as direct injection of ethanol. However, under certain conditions there can be combustion stability issues.

The temperature decrement because of the vaporization energy of the ethanol decreases with lean operation and with EGR, as the thermal capacity of the cylinder charge increases. If the engine operates at twice the stoichiometric air/fuel ratio, the numbers indicated in FIG. **2** decrease by about a factor of 2 (the contribution of the ethanol itself and the gasoline is relatively modest). Similarly, for a 20% EGR rate, the cooling effect of the ethanol decreases by about 25%.

The octane enhancement effect can be estimated from the data in FIG. **2**. Direct injection of gasoline results in approximately a five octane number decrease in the octane number required by the engine, as discussed by Stokes, et al. Thus the contribution is about five octane numbers per 30 K drop in charge temperature. As ethanol can decrease the charge temperature by about 120 K, then the decrease in octane number required by the engine due to the drop in temperature, for 100% ethanol, is twenty octane numbers. Thus, when 100% of the fuel is provided by ethanol, the octane number enhancement is approximately thirty-five octane numbers with a twenty octane number enhancement coming from direct injection cooling and a fifteen octane number enhancement coming from the octane number of ethanol. From the above considerations, it can be projected that even if the octane enhancement from direct cooling is significantly lower, a total octane number enhancement of at least 4 octane numbers should be achievable for every 20% of the total fuel energy that is provided by ethanol.

Alternatively the ethanol and gasoline can be mixed together and then port injected through a single injector per cylinder, thereby decreasing the number of injectors that would be used. However, the air charge cooling benefit from ethanol would be lost.

Alternatively the ethanol and gasoline can be mixed together and then port fuel injected using a single injector per cylinder, thereby decreasing the number of injectors that would be used. However, the substantial air charge cooling benefit from ethanol would be lost. The volume of fuel between the mixing point and the port fuel injector should be minimized in order to meet the demanding dynamic octane-enhancement requirements of the engine.

Relatively precise determinations of the actual amount of octane enhancement from given amounts of direct ethanol injection can be obtained from laboratory and vehicle tests in addition to detailed calculations. These correlations can be used by the fuel management microprocessor system **14**.

An additional benefit of using ethanol for octane enhancement is the ability to use it in a mixture with water. Such a mixture can eliminate the need for the costly and energy consuming water removal step in producing pure ethanol that must be employed when ethanol is added to gasoline at a refinery. Moreover, the water provides an additional cooling (due to vaporization) that further increases engine knock resistance. In contrast the present use of ethanol as an additive to gasoline at the refinery requires that the water be removed from the ethanol.

Since unlike gasoline, ethanol is not a good lubricant and the ethanol fuel injector can stick and not open, it is desirable

to add a lubricant to the ethanol. The lubricant will also denature the ethanol and make it unattractive for human consumption.

Further decreases in the required ethanol for a given amount of octane enhancement can be achieved with stratification (non-uniform deposition) of the ethanol addition. Direct injection can be used to place the ethanol near the walls of the cylinder where the need for knock reduction is greatest. The direct injection may be used in combination with swirl. This stratification of the ethanol in the engine further reduces the amount of ethanol needed to obtain a given amount of octane enhancement. Because only the ethanol is directly injected and because it is stratified both by the injection process and by thermal centrifugation, the ignition stability issues associated with gasoline direct injection (GDI) can be avoided.

It is preferred that ethanol be added to those regions that make up the end-gas and are prone to auto-ignition. These regions are near the walls of the cylinder. Since the end-gas contains on the order of 25% of the fuel, substantial decrements in the required amounts of ethanol can be achieved by stratifying the ethanol.

In the case of the engine **10** having substantial organized motion (such as swirl), the cooling will result in forces that thermally stratify the discharge (centrifugal separation of the regions at different density due to different temperatures). The effect of ethanol addition is to increase gas density since the temperature is decreased. With swirl the ethanol mixture will automatically move to the zone where the end-gas is, and thus increase the anti-knock effectiveness of the injected ethanol. The swirl motion is not affected much by the compression stroke and thus survives better than tumble-like motion that drives turbulence towards top-dead-center (TDC) and then dissipates. It should be pointed out that relatively modest swirls result in large separating (centrifugal) forces. A 3 m/s swirl motion in a 5 cm radius cylinder generates accelerations of about 200 m/s^2, or about 20 g's.

FIG. **3** illustrates ethanol direct injection and swirl motion for achieving thermal stratification. Ethanol is predominantly on an outside region which is the end-gas region. FIG. **4** illustrates a possible stratification of the ethanol in an inlet manifold with swirl motion and thermal centrifugation maintaining stratification in the cylinder. In this case of port injection of ethanol, however, the advantage of substantial charge cooling may be lost.

With reference again to FIG. **2**, the effect of ethanol addition all the way up to 100% ethanol injection is shown. At the point that the engine is 100% direct ethanol injected, there may be issues of engine stability when operating with only stratified ethanol injection that need to be addressed. In the case of stratified operation it may also be advantageous to stratify the injection of gasoline in order to provide a relatively uniform equivalence ratio across the cylinder (and therefore lower concentrations of gasoline in the regions where the ethanol is injected). This situation can be achieved, as indicated in FIG. **4**, by placing fuel in the region of the inlet manifold that is void of ethanol.

The ethanol used in the invention can either be contained in a separate tank from the gasoline or may be separated from a gasoline/ethanol mixture stored in one tank.

The instantaneous ethanol injection requirement and total ethanol consumption over a drive cycle can be estimated from information about the drive cycle and the increase in torque (and thus increase in compression ratio engine power density, and capability for downsizing) that is desired. A plot of the amount of operating time spent at various values of torque and engine speed in FTP and US06 drive cycles can be used. It is necessary to enhance the octane number at each point in the drive cycle where the torque is greater than permitted for knock free operation with gasoline alone. The amount of octane enhancement that is required is determined by the torque level.

A rough illustrative calculation shows that only a small amount of ethanol might be needed over the drive cycle. Assume that it is desired to increase the maximum torque level by a factor of two relative to what is possible without direct injection ethanol octane enhancement. Information about the operating time for the combined FTP and US06 cycles shows that approximately only 10 percent of the time is spent at torque levels above 0.5 maximum torque and less than 1 percent of the time is spent above 0.9 maximum torque. Conservatively assuming that 100% ethanol addition is needed at maximum torque and that the energy fraction of ethanol addition that is required to prevent knock decreases linearly to zero at 50 percent of maximum torque, the energy fraction provided by ethanol is about 30 percent. During a drive cycle about 20 percent of the total fuel energy is consumed at greater than 50 percent of maximum torque since during the 10 percent of the time that the engine is operated in this regime, the amount of fuel consumed is about twice that which is consumed below 50 percent of maximum torque. The amount of ethanol energy consumed during the drive cycle is thus roughly around 6 percent (30 percent×0.2) of the total fuel energy.

In this case then, although 100% ethanol addition was needed at the highest value of torque, only 6% addition was needed averaged over the drive cycle. The ethanol is much more effectively used by varying the level of addition according to the needs of the drive cycle.

Because of the lower heat of combustion of ethanol, the required amount of ethanol would be about 9% of the weight of the gasoline fuel or about 9% of the volume (since the densities of ethanol and gasoline are comparable). A separate tank with a capacity of about 1.8 gallons would then be required in automobiles with twenty gallon gasoline tanks. The stored ethanol content would be about 9% of that of gasoline by weight, a number not too different from present-day reformulated gasoline. Stratification of the ethanol addition could reduce this amount by more than a factor of two. An on-line ethanol distillation system might alternatively be employed but would entail elimination or reduction of the increase torque and power available from turbocharging.

Because of the relatively small amount of ethanol and present lack of an ethanol fueling infrastructure, it is important that the ethanol vehicle be operable if there is no ethanol on the vehicle. The engine system can be designed such that although the torque and power benefits would be lower when ethanol is not available, the vehicle could still be operable by reducing or eliminating turbocharging capability and/or by increasing spark retard so as to avoid knock. As shown in FIG. **5**, the fuel management microprocessor system **14** uses ethanol fuel level in the ethanol tank **16** as an input to control the turbocharger **22** (or supercharger or spark retard, not shown). As an example, with on-demand ethanol octane enhancement, a 4-cylinder engine can produce in the range of 280 horsepower with appropriate turbocharging or supercharging but could also be drivable with an engine power of 140 horsepower without the use of ethanol according to the invention.

The impact of a small amount of ethanol upon fuel efficiency through use in a higher efficiency engine can greatly increase the energy value of the ethanol. For example, gasoline consumption could be reduced by 20% due to higher efficiency engine operation from use of a high compression ratio, strongly turbocharged operation and substantial engine

downsizing. The energy value of the ethanol, including its value in direct replacement of gasoline (5% of the energy of the gasoline), is thus roughly equal to 25% of the gasoline that would have been used in a less efficient engine without any ethanol. The 5% gasoline equivalent energy value of ethanol has thus been leveraged up to a 25% gasoline equivalent value. Thus, ethanol can cost roughly up to five times that of gasoline on an energy basis and still be economically attractive. The use of ethanol as disclosed herein can be a much greater value use than in other ethanol applications.

Although the above discussion has featured ethanol as an exemplary anti-knock agent, the same approach can be applied to other high octane fuel and fuel additives with high vaporization energies such as methanol (with higher vaporization energy per unit fuel), and other anti-knock agents such as tertiary butyl alcohol, or ethers such as methyl tertiary butyl ether (MTBE), ethyl tertiary butyl ether (ETBE), or tertiary amyl methyl ether (TAME).

It is recognized that modifications and variations of the invention disclosed herein will be apparent to those of ordinary skill in the art and it is intended that all such modifications and variations be included within the scope of the appended claims.

The invention claimed is:

1. A fuel management system for a turbocharged or supercharged spark ignition engine where the fuel management system controls fueling from a first fueling system that directly injects fuel into at least one cylinder as a liquid and increases knock suppression by vaporization cooling and from a second fueling system that injects fuel into a region outside of the cylinder;

and where there is a range of torque where both fueling systems are used at the same value of torque;

and where the fraction of fuel in the cylinder that is introduced by the first fueling system decreases with decreasing torque and the fuel management system controls the change in the fraction of fuel introduced by the first fueling system using closed loop control that utilizes a sensor that detects knock;

and where the fuel management system also employs spark retard so as to reduce the amount of fuel that is introduced into the cylinder by the first fueling system.

2. The fuel management system of claim 1 where the spark retard is employed to as to reduce the amount of fuel that is provided by the first fueling system to zero.

3. The fuel management system of claim 1 where when the torque is increased the increase in the fraction of fuel that is introduced by the first fueling system is minimized while still preventing knock.

4. The fuel management system of claim 1 where without employing the spark retard there is a range of torque in which only the second fueling system is used.

5. The fuel management system of claim 1 where the fuel management system employs the spark retard in response to sensed information and both the sensed information and information about knock are used to control the fuel that is introduced by the first fueling system.

6. The fuel management system of claim 1 where the maximum torque that the engine provides occurs when both the first and second fueling systems are used at the same value of torque.

7. The fuel management system of claim 1 where the only the first fueling system is used at the maximum torque that the engine provides.

8. The fuel management system of claim 1 where only the first fueling system is used when the highest knock resistance is required.

9. The fuel management system of claim 1 where both the first and second fueling system are used when the highest knock resistance is required.

10. The fuel management system of claim 1 where as the torque is increased the increase in the fraction of fuel in the cylinder that is provided by the first fueling system is substantially equal to that needed to prevent knock.

11. The fuel management system of claims 1 or 3 where the fuel management system minimizes the increase in the fraction of fuel in the cylinder that is provided by the first fueling system as torque is increased.

12. The fuel management system of claim 1 where the second fueling system uses port fuel injection.

13. A fuel management system for a spark ignition engine that controls fueling from a first fueling system that directly injects fuel into at least one cylinder as a liquid and increases knock suppression by vaporization cooling and from a second fueling system that provides fuel to the cylinder using port fuel injection;

and where the fuel management system uses information from a sensed parameter to control spark retard so as to decrease the amount of fuel that would otherwise be provided by the first fueling system;

and where the fuel management system uses input that includes input from the sensed parameter and input from knock sensor.

14. The fuel management system of claim 13 where input from the knock sensor is utilized in a closed loop control system that controls the fraction of fuel that is introduced into the first fueling system.

15. The fuel management system of claim 13 where both the first and second fueling systems are used at the same value of torque.

16. The fuel management system of claim 13 where spark retard is employed so as to reduce the use of the first fueling system to zero.

17. The fuel management system of claim 13 where the engine is turbocharged or supercharged and the level of turbocharging or supercharging is reduced so as to decrease the amount of fuel from the first fueling system.

18. The fuel management system of claim 13 where closed loop control with a knock detector is used to increase the relative amount of fuel from the first fueling system as torque is increased.

19. A fuel management system for a turbocharged or supercharged spark ignition engine where the fuel management system controls fueling from a first fueling system that directly injects fuel into at least one cylinder as a liquid and increases knock suppression by vaporization cooling and from a second fueling system that introduces fuel into the cylinder by port fuel injection:

and where during a driving cycle there is a first torque range where both fueling systems are used at the same torque and where the fraction of fuel in the cylinder that is introduced by the first fueling system is increased so as to prevent knock as torque increases;

and where the fuel management system matches the fraction of fuel that is provided by first fueling system with the amount needed to prevent knock at a given value of torque; and

where the fuel management system uses closed loop control that employs a knock detector.

20. The fuel management system of claim 19 where there is a second torque range where only the second fueling system is used and the highest value of torque in the second torque range is lower than at least one value of torque in the first torque range.

21. The fuel management system of claim 19 where the fuel management system minimizes the amount of fuel from the first fueling system while still preventing knock.

22. The fuel management system of claim 19 where the maximum knock resistance required by the engine is in the first torque range.

23. The fuel management system of claim 19 where for the maximum knock resistance required by the engine only the first fueling system is used.

24. A fuel management system for a spark ignition engine that controls fueling from a first fueling system that introduces fuel into at least one cylinder as a liquid and increases knock resistance by vaporization cooling and from a second fueling system;

and where the knock resistance of fuel introduced by the first fueling system is greater than the knock resistance of fuel introduced by the second fueling system;

and where the fuel management system uses information from a sensed parameter to control spark retard so as to decrease the amount of fuel that would otherwise be provided by the first fueling system;

and where the fuel management system uses input that includes input from the sensed parameter and input from knock sensor.

25. The fuel management system of claim 24 where input from the knock sensor is utilized in a closed loop control system that controls the fraction of fuel that is introduced into the first fueling system.

26. The fuel management system of claim 24 where both the first and second fueling systems are used at the same value of torque.

27. The fuel management system of claim 24 where spark retard is employed so as to reduce the use of the first fueling system to zero.

28. The fuel management system of claim 24 where turbocharging or supercharging is used and the level of turbocharging or supercharging is reduced so as to decrease the amount of fuel from the first fueling system.

29. The fuel management system of claim 24 where closed loop control with a knock detector is used to increase the relative amount of fuel firm the first fueling system as torque is increased.

30. The fuel management system of claim 24 where the first fueling system uses direct injection.

31. The fuel management system of claim 24 where the second fueling system uses port fuel injection.

* * * * *

EXHIBIT 4

US009810166B2

(12) **United States Patent**
Cohn et al.

(10) **Patent No.: US 9,810,166 B2**
(45) **Date of Patent: *Nov. 7, 2017**

(54) **FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES**

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(Continued)

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CPC ***F02D 41/0025*** (2013.01); ***F02B 47/04*** (2013.01); ***F02D 35/027*** (2013.01);
(Continued)

(58) **Field of Classification Search**
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(Continued)

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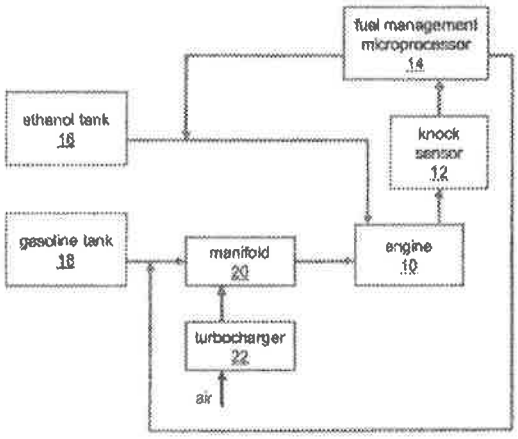
(57) **ABSTRACT**

Fuel management system for efficient operation of a spark ignition gasoline engine. Injectors inject an anti-knock agent such as ethanol directly into a cylinder of the engine. A fuel management microprocessor system controls injection of the anti-knock agent so as to control knock and minimize that amount of the anti-knock agent that is used in a drive cycle. It is preferred that the anti-knock agent is ethanol. The use of ethanol can be further minimized by injection in a non-uniform manner within a cylinder. The ethanol injection suppresses knock so that higher compression ratio and/or engine downsizing from increased turbocharging or supercharging can be used to increase the efficiency or the engine.

30 Claims, 3 Drawing Sheets



Related U.S. Application Data

No. 14/478,069, filed on Sep. 5, 2014, now Pat. No. 9,255,519, and a continuation of application No. 14/249,806, filed on Apr. 10, 2014, now Pat. No. 8,857,410, and a continuation of application No. 13/956,498, filed on Aug. 1, 2013, now Pat. No. 8,733,321, and a continuation of application No. 13/629,836, filed on Sep. 28, 2012, now Pat. No. 8,522,746, and a continuation of application No. 13/368,382, filed on Feb. 8, 2012, now Pat. No. 8,302,580, and a continuation of application No. 13/282,787, filed on Oct. 27, 2011, now Pat. No. 8,146,568, and a continuation of application No. 13/117,448, filed on May 27, 2011, now Pat. No. 8,069,839, and a continuation of application No. 12/815,842, filed on Jun. 15, 2010, now Pat. No. 7,971,572, and a continuation of application No. 12/329,729, filed on Dec. 8, 2008, now Pat. No. 7,762,233, and a continuation of application No. 11/840,719, filed on Aug. 17, 2007, now Pat. No. 7,740,004, and a continuation of application No. 10/991,774, filed on Nov. 18, 2004, now Pat. No. 7,314,033.

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CPC ***F02D 41/3094*** (2013.01); ***F02M 25/14*** (2013.01); ***F02P 5/045*** (2013.01); *F02D 2041/389* (2013.01); *F02D 2200/1002* (2013.01)

(58) **Field of Classification Search**

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See application file for complete search history.

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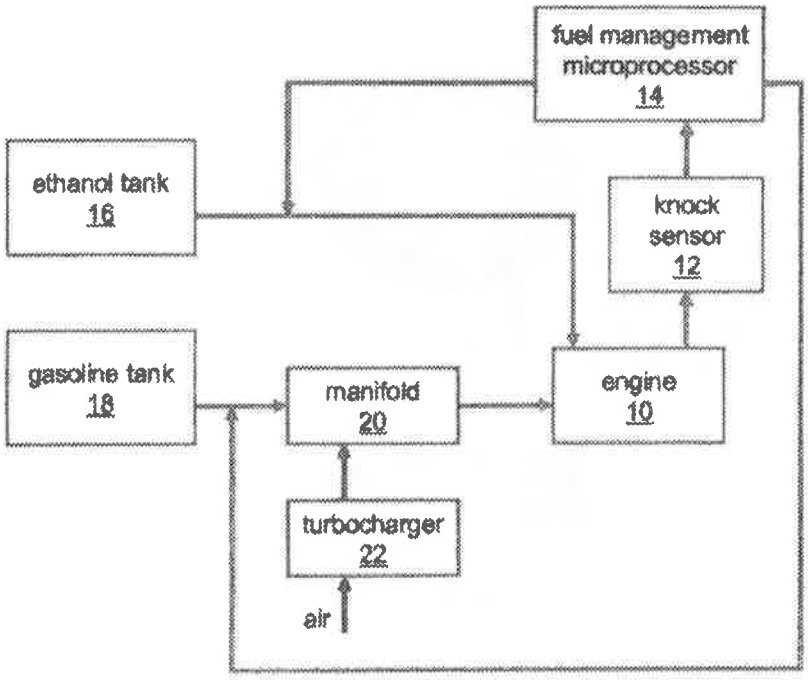
fuel management microprocessor 14
ethanol tank 16
knock sensor 12
gasoline tank 18
manifold 20
engine 10
turbocharger 22
air

FIG. 1

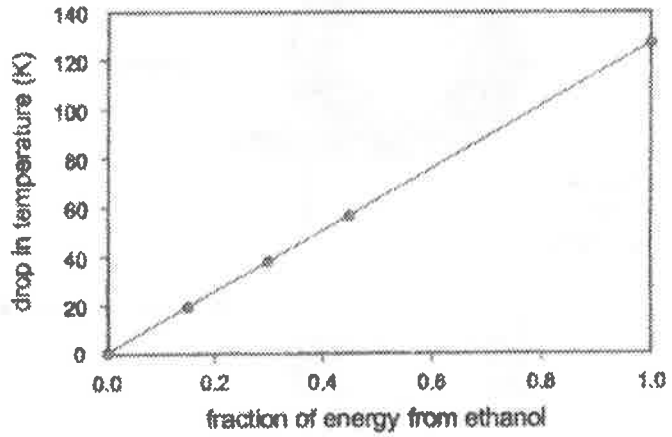
drop in temperature (K)
140
120
100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
fraction of energy from ethanol

FIG. 2

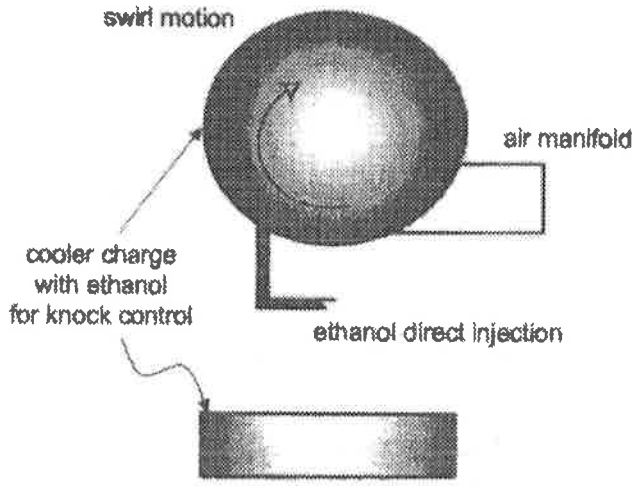
swirl motion
air manifold
cooler charge
with ethanol
for knock control
ethanol direct injection

FIG. 3

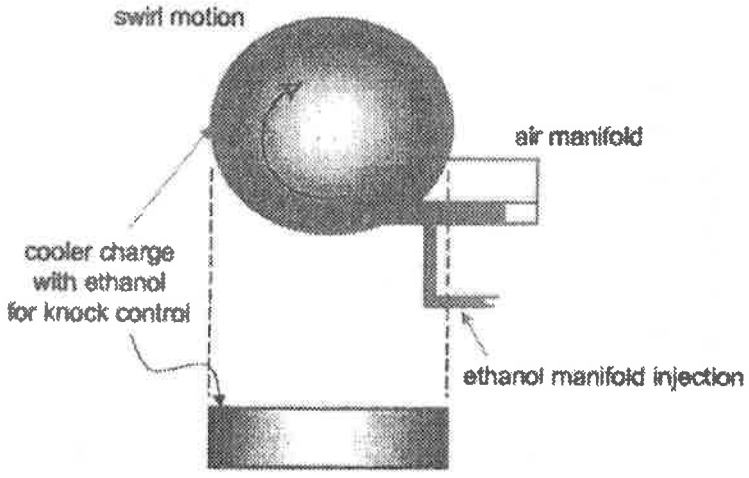
swirl motion
air manifold
cooler charge
with ethanol
for knock control
ethanol manifold injection

FIG. 4

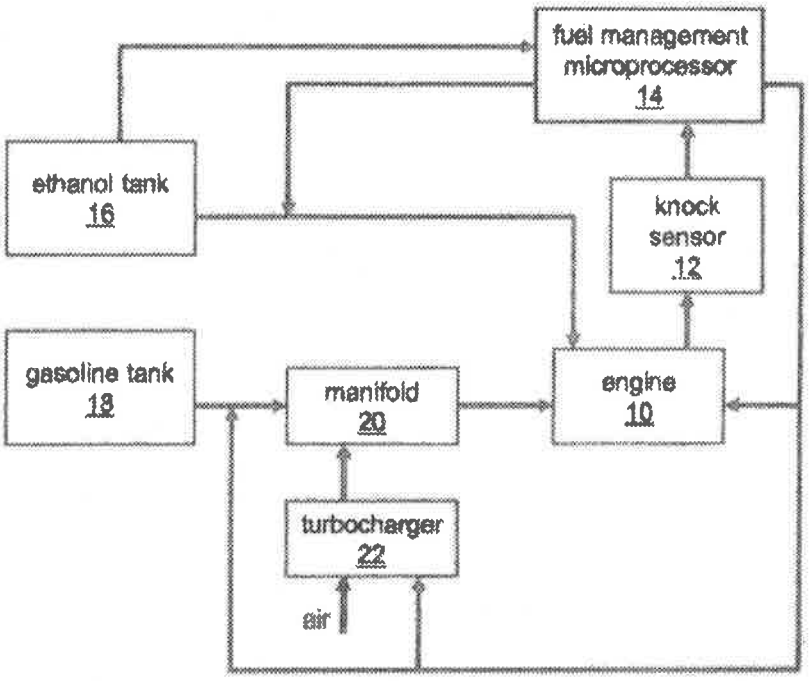
fuel management microprocessor 14
ethanol tank 16
knock sensor 12
gasoline tank 18
manifold 20
engine 10
turbocharger 22
air

FIG. 5

FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES

This application is a continuation of U.S. patent application Ser. No. 14/982,086 filed on Dec. 29, 2015, which is a continuation of U.S. patent application Ser. No. 14/478,069 filed on Sep. 5, 2014, which is a continuation of U.S. patent application Ser. No. 14/249,806 filed on Apr. 10, 2014, which is now issued as U.S. Pat. No. 8,857,410, which is a continuation of U.S. patent application Ser. No. 13/956,498 filed on Aug. 1, 2013, which is now issued as U.S. Pat. No. 8,733,321, which is a continuation of U.S. patent application Ser. No. 13/629,836 filed on Sep. 28, 2012, which is now issued as U.S. Pat. No. 8,522,746, which is a continuation of U.S. patent application Ser. No. 13/368,382 filed on Feb. 8, 2012, which is now issued as U.S. Pat. No. 8,302,580, which is a continuation of U.S. patent application Ser. No. 13/282,787 filed Oct. 27, 2011, which is now issued as U.S. Pat. No. 8,146,568, which is a continuation of U.S. patent application Ser. No. 13/117,448 filed May 27, 2011, which is now issued as U.S. Pat. No. 8,069,839, which is a continuation of U.S. patent application Ser. No. 12/815,842, filed Jun. 15, 2010, which is now issued as U.S. Pat. No. 7,971,572, which is a continuation of U.S. patent application Ser. No. 12/329,729 filed on Dec. 8, 2008, which is now issued as U.S. Pat. No. 7,762,233, which is a continuation of U.S. patent application Ser. No. 11/840,719 filed on Aug. 17, 2007, which is now issued as U.S. Pat. No. 7,740,004, which is a continuation of U.S. patent application Ser. No. 10/991,774, which is now issued as U.S. Pat. No. 7,314,033.

BACKGROUND

This invention relates to spark ignition gasoline engines utilizing an antiknock agent which is a liquid fuel with a higher octane number than gasoline such as ethanol to improve engine efficiency.

It is known that the efficiency of spark ignition (SI) gasoline engines can be increased by high compression ratio operation and particularly by engine downsizing. The engine downsizing is made possible by the use of substantial pressure boosting from either turbocharging or supercharging. Such pressure boosting makes it possible to obtain the same performance in a significantly smaller engine. See, J. Stokes, et al., "A Gasoline Engine Concept For Improved Fuel Economy The Lean-Boost System," SAE Paper 2001-01-2902. The use of these techniques to increase engine efficiency, however, is limited by the onset of engine knock. Knock is the undesired detonation of fuel and can severely damage an engine. If knock can be prevented, then high compression ratio operation and high pressure boosting can be used to increase engine efficiency by up to twenty-five percent.

Octane number represents the resistance of a fuel to knocking but the use of higher octane gasoline only modestly alleviates the tendency to knock. For example, the difference between regular and premium gasoline is typically six octane numbers. That is significantly less than is needed to realize fully the efficiency benefits of high compression ratio or turbocharged operation. There is thus a need for a practical means for achieving a much higher level of octane enhancement so that engines can be operated much more efficiently.

It is known to replace a portion of gasoline with small amounts of ethanol added at the refinery. Ethanol has a blending octane number (ON) of 110 (versus 95 for premium gasoline) (see J. B. Heywood, "Internal Combustion Engine Fundamentals," McGraw Hill, 1988, p. 477) and is also attractive because it is a renewable energy, biomass-derived fuel, but the small amounts of ethanol that have heretofore been added to gasoline have had a relatively small impact on engine performance. Ethanol is much more expensive than gasoline and the amount of ethanol that is readily available is much smaller than that of gasoline because of the relatively limited amount of biomass that is available for its production. An object of the present invention is to minimize the amount of ethanol or other antiknock agent that is used to achieve a given level of engine efficiency increase. By restricting the use of ethanol to the relatively small fraction of time in an operating cycle when it is needed to prevent knock in a higher load regime and by minimizing its use at these times, the amount of ethanol that is required can be limited to a relatively small fraction of the fuel used by the spark ignition gasoline engine.

SUMMARY

In one aspect, the invention is a fuel management system for efficient operation of a spark ignition gasoline engine including a source of an antiknock agent such as ethanol. An injector directly injects the ethanol into a cylinder of the engine and a fuel management system controls injection of the antiknock agent into the cylinder to control knock with minimum use of the antiknock agent. A preferred antiknock agent is ethanol. Ethanol has a high heat of vaporization so that there is substantial cooling of the air-fuel charge to the cylinder when it is injected directly into the engine. This cooling effect reduces the octane requirement of the engine by a considerable amount in addition to the improvement in knock resistance from the relatively high octane number of ethanol. Methanol, tertiary butyl alcohol, MTBE, ETBE, and TAME may also be used. Wherever ethanol is used herein it is to be understood that other antiknock agents are contemplated.

The fuel management system uses a fuel management control system that may use a microprocessor that operates in an open loop fashion on a predetermined correlation between octane number enhancement and fraction of fuel provided by the antiknock agent. To conserve the ethanol, it is preferred that it be added only during portions of a drive cycle requiring knock resistance and that its use be minimized during these times. Alternatively, the gasoline engine may include a knock sensor that provides a feedback signal to a fuel management microprocessor system to minimize the amount of the ethanol added to prevent knock in a closed loop fashion.

In one embodiment the injectors stratify the ethanol to provide non-uniform deposition within a cylinder. For example, the ethanol may be injected proximate to the cylinder walls and swirl can create a ring of ethanol near the walls.

In another embodiment of this aspect of the invention, the system includes a measure of the amount of the antiknock agent such as ethanol in the source containing the antiknock agent to control turbocharging, supercharging or spark retard when the amount of ethanol is low.

The direct injection of ethanol provides substantially a 13° C. drop in temperature for every ten percent of fuel energy provided by ethanol. An instantaneous octane enhancement of at least 4 octane numbers may be obtained for every 20 percent of the engine's energy coming from the ethanol.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of one embodiment of the invention disclosed herein.

FIG. **2** is a graph of the drop in temperature within a cylinder as a function of the fraction of energy provided by ethanol.

FIG. **3** is a schematic illustration of the stratification of cooler ethanol charge using direct injection and swirl motion for achieving thermal stratification.

FIG. **4** is a schematic illustration showing ethanol stratified in an inlet manifold.

FIG. **5** is a block diagram of an embodiment of the invention in which the fuel management microprocessor is used to control a turbocharger and spark retard based upon the amount of ethanol in a fuel tank.

DETAILED DESCRIPTION

With reference first to FIG. **1**, a spark ignition gasoline engine **10** includes a knock sensor **12** and a fuel management microprocessor system **14**. The fuel management microprocessor system **14** controls the direct injection of an anti-knock agent such as ethanol from an ethanol tank **16**. The fuel management microprocessor system **14** also controls the delivery of gasoline from a gasoline tank **18** into engine manifold **20**. A turbocharger **22** is provided to improve the torque and power density of the engine **10**. The amount of ethanol injection is dictated either by a predetermined correlation between octane number enhancement and fraction of fuel that is provided by ethanol in an open loop system or by a closed loop control system that uses a signal from the knock sensor **12** as an input to the fuel management **125** microprocessor **14**. In both situations, the fuel management processor **14** will minimize the amount of ethanol added to a cylinder while still preventing knock. It is also contemplated that the fuel management microprocessor system **14** could provide a combination of open and closed loop control.

As show in FIG. **1** it is preferred that ethanol be directly injected into the engine **10**. Direct injection substantially increases the benefits of ethanol addition and decreases the required amount of ethanol. Recent advances in fuel injector and electronic control technology allows fuel injection directly into a spark ignition engine rather than into the manifold **20**. Because ethanol has a high heat of vaporization there will be substantial cooling when it is directly injected into **135** the engine **10**. This cooling effect further increases knock resistance by a considerable amount. In the embodiment of FIG. **1** port fuel injection of the gasoline in which the gasoline is injected into the manifold rather than directly injected into the cylinder is preferred because it is advantageous in obtaining good air/fuel mixing and combustion stability that are difficult to obtain with direct injection.

Ethanol has a heat of vaporization of 840 kJ/kg, while the heat of vaporization of gasoline is about 350 kJ/kg. The attractiveness of ethanol increases when compared with gasoline on an energy basis, since the lower heating value of ethanol is 26.9 MJ/kg while for gasoline it is about 44 MJ/kg. Thus, the heat of vaporization per Joule of combustion energy is 0.031 for ethanol and 0.008 for gasoline. That is, for equal amounts of energy the required heat of vaporization of ethanol is about four times higher than that of gasoline. The ratio of the heat of vaporization per unit air required for stoichiometric combustion is about 94 kJ/kg of air for ethanol and 24 kJ/kg of air for gasoline, or a factor of four smaller. Thus, the net effect of cooling the air charge is about four times lower for gasoline than for ethanol (for stoichiometric mixtures wherein the amount of air contains oxygen that is just sufficient to combust all of the fuel).

In the case of ethanol direct injection according to one aspect of the invention, the charge is directly cooled. The amount of cooling due to direct injection of ethanol is shown in FIG. **2**. It is assumed that the air/fuel mixture is stoichiometric without exhaust gas recirculation (EGR), and that gasoline makes up the rest of the fuel. It is further assumed that only the ethanol contributes to charge cooling. Gasoline is vaporized in the inlet manifold and does not contribute to cylinder charge cooling. The direct ethanol injection provides about 13° C. of cooling for each 10% of the fuel energy provided by ethanol. (It is also possible to use direct injection of gasoline as well as direct injection of ethanol. However, under certain conditions there can be combustion stability issues.

The temperature decrement because of the vaporization energy of the ethanol decreases with lean operation and with EGR, as the thermal capacity of the cylinder charge increases. If the engine operates at twice the stoichiometric air/fuel ratio, the numbers indicated in FIG. **2** decrease by about a factor of 2 (the contribution of the ethanol itself and the gasoline is relatively modest). Similarly, for a 20% EGR rate, the cooling effect of the ethanol decreases by about 25%.

The octane enhancement effect can be estimated from the data in FIG. **2**. Direct injection of gasoline results in approximately a five octane number decrease in the octane number required by the engine, as discussed by Stokes, et al. Thus the contribution is about five octane numbers per 30K drop in charge temperature. As ethanol can decrease the charge temperature by about 120K, then the decrease in octane number required by the engine due to the drop in temperature, for 100% ethanol, is twenty octane numbers. Thus, when 100% of the fuel is provided by ethanol, the octane number enhancement is approximately thirty-five octane numbers with a twenty octane number enhancement coming from direct injection cooling and a fifteen octane number enhancement coming from the octane number of ethanol. From the above considerations, it can be projected that even if the octane enhancement from direct cooling is significantly lower, a total octane number enhancement of at least 4 octane numbers should be achievable for every 20% of the total fuel energy that is provided by ethanol.

Alternatively the ethanol and gasoline can be mixed together and then port injected through a single injector per cylinder, thereby decreasing the number of injectors that would be used. However, the air charge cooling benefit from ethanol would be lost.

Alternatively the ethanol and gasoline can be mixed together and then port fuel injected using a single injector per cylinder, thereby decreasing the number of injectors that would be used. However, the substantial air charge cooling benefit from ethanol would be lost. The volume of fuel between the mixing point and the port fuel injector should be minimized in order to meet the demanding dynamic octane-enhancement requirements of the engine.

Relatively precise determinations of the actual amount of octane enhancement from given amounts of direct ethanol injection can be obtained from laboratory and vehicle tests in addition to detailed calculations. These correlations can be used by the fuel management microprocessor system **14**.

An additional benefit of using ethanol for octane enhancement is the ability to use it in a mixture with water. Such a mixture can eliminate the need for the costly and energy consuming water removal step in producing pure ethanol

that must be employed when ethanol is added to gasoline at a refinery. Moreover, the water provides an additional cooling (due to vaporization) that further increases engine knock resistance. In contrast the present use of ethanol as an additive to gasoline at the refinery requires that the water be removed from the ethanol.

Since unlike gasoline, ethanol is not a good lubricant and the ethanol fuel injector can stick and not open, it is desirable to add a lubricant to the ethanol. The lubricant will also denature the ethanol and make it unattractive for human consumption.

Further decreases in the required ethanol for a given amount of octane enhancement can be achieved with stratification (non-uniform deposition) of the ethanol addition. Direct injection can be used to place the ethanol near the walls of the cylinder where the need for knock reduction is greatest. The direct injection may be used in combination with swirl. This stratification of the ethanol in the engine further reduces the amount of ethanol needed to obtain a given amount of octane enhancement. Because only the ethanol is directly injected and because it is stratified both by the injection process and by thermal centrifugation, the ignition stability issues associated with gasoline direct injection (GDI) can be avoided.

It is preferred that ethanol be added to those regions that make up the end-gas and are prone to auto-ignition. These regions are near the walls of the cylinder. Since the end-gas contains on the order of 25% of the fuel, substantial decrements in the required amounts of ethanol can be achieved by stratifying the ethanol.

In the case of the engine **10** having substantial organized motion (such as swirl), the cooling will result in forces that thermally stratify the discharge (centrifugal separation of the regions at different density due to different temperatures). The effect of ethanol addition is to increase gas density since the temperature is decreased. With swirl the ethanol mixture will automatically move to the zone where the end-gas is, and thus increase the anti-knock effectiveness of the injected ethanol. The swirl motion is not affected much by the compression stroke and thus survives better than tumble-like motion that drives turbulence towards top-dead-center (TDC) and then dissipates. It should be pointed out that relatively modest swirls result in large separating (centrifugal) forces. A 3 m/s swirl motion in a 5 cm radius cylinder generates accelerations of about 200 m/s^2, or about 20 g's.

FIG. **3** illustrates ethanol direct injection and swirl motion for achieving thermal stratification. Ethanol is predominantly on an outside region which is the end-gas region. FIG. **4** illustrates a possible stratification of the ethanol in an inlet manifold with swirl motion and thermal centrifugation maintaining stratification in the cylinder. In this case of port injection of ethanol, however, the advantage of substantial charge cooling may be lost.

With reference again to FIG. **2**, the effect of ethanol addition all the way up to 100% ethanol injection is shown. At the point that the engine is 100% direct ethanol injected, there may be issues of engine stability when operating with only stratified ethanol injection that need to be addressed. In the case of stratified operation it may also be advantageous to stratify the injection of gasoline in order to provide a relatively uniform equivalence ratio across the cylinder (and therefore lower concentrations of gasoline in the regions where the ethanol is injected). This situation can be achieved, as indicated in FIG. **4**, by placing fuel in the region of the inlet manifold that is void of ethanol.

The ethanol used in the invention can either be contained in a separate tank from the gasoline or may be separated from a gasoline/ethanol mixture stored in one tank.

The instantaneous ethanol injection requirement and total ethanol consumption over a drive cycle can be estimated from information about the drive cycle and the increase in torque (and thus increase in compression ratio, engine power density, and capability for downsizing) that is desired. A plot of the amount of operating time spent at various values of torque and engine speed in FTP and US06 drive cycles can be used. It is necessary to enhance the octane number at each point in the drive cycle where the torque is greater than permitted for knock free operation with gasoline alone. The amount of octane enhancement that is required is determined by the torque level.

A rough illustrative calculation shows that only a small amount of ethanol might be needed over the drive cycle. Assume that it is desired to increase the maximum torque level by a factor of two relative to what is possible without direct injection ethanol octane enhancement. Information about the operating time for the combined FTP and US06 cycles shows that approximately only 10 percent of the time is spent at torque levels above 0.5 maximum torque and less than 1 percent of the time is spent above 0.9 maximum torque. Conservatively assuming that 100% ethanol addition is needed at maximum torque and that the energy fraction of ethanol addition that is required to prevent knock decreases linearly to zero at 50 percent of maximum torque, the energy fraction provided by ethanol is about 30 percent. During a drive cycle about 20 percent of the total fuel energy is consumed at greater than 50 percent of maximum torque since during the 10 percent of the time that the engine is operated in this regime, the amount of fuel consumed is about twice that which is consumed below 50 percent of maximum torque. The amount of ethanol energy consumed during the drive cycle is thus roughly around 6 percent (30 percent×0.2) of the total fuel energy.

In this case then, although 100% ethanol addition was needed at the highest value of torque, only 6% addition was needed averaged over the drive cycle. The ethanol is much more effectively used by varying the level of addition according to the needs of the drive cycle.

Because of the lower heat of combustion of ethanol, the required amount of ethanol would be about 9% of the weight of the gasoline fuel or about 9% of the volume (since the densities of ethanol and gasoline are comparable). A separate tank with a capacity of about 1.8 gallons would then be required in automobiles with twenty gallon gasoline tanks. The stored ethanol content would be about 9% of that of gasoline by weight, a number not too different from present-day reformulated gasoline. Stratification of the ethanol addition could reduce this amount by more than a factor of two. An on-line ethanol distillation system might alternatively be employed but would entail elimination or reduction of the increase torque and power available from turbocharging.

Because of the relatively small amount of ethanol and present lack of an ethanol fueling infrastructure, it is important that the ethanol vehicle be operable if there is no ethanol on the vehicle. The engine system can be designed such that although the torque and power benefits would be lower when ethanol is not available, the vehicle could still be operable by reducing or eliminating turbocharging capability and/or by increasing spark retard so as to avoid knock. As shown in FIG. **5**, the fuel management microprocessor system **14** uses ethanol fuel level in the **295** ethanol tank **16** as an input to control the turbocharger **22** (or supercharger or spark retard, not shown). As an example, with on-demand

ethanol octane enhancement, a 4-cylinder engine can produce in the range of 280 horsepower with appropriate turbocharging or supercharging but could also be drivable with an engine power of 140 horsepower without the use of ethanol according to the invention.

The impact of a small amount of ethanol upon fuel efficiency through use in a higher efficiency engine can greatly increase the energy value of the ethanol. For example, gasoline consumption could be reduced by 20% due to higher efficiency engine operation from use of a high compression ratio, strongly turbocharged operation and substantial engine downsizing. The energy value of the ethanol, including its value in direct replacement of gasoline (5% of the energy of the gasoline), is thus roughly equal to 25% of the gasoline that would have been used in a less efficient engine without any ethanol. The 5% gasoline equivalent energy value of ethanol has thus been leveraged up to a 25% gasoline equivalent value. Thus, ethanol can cost roughly up to five times that of gasoline on an energy basis and still be economically attractive. The use of ethanol as disclosed herein can be a much greater value use than in other ethanol applications.

Although the above discussion has featured ethanol as an exemplary anti-knock agent, the same approach can be applied to other high octane fuel and fuel additives with high vaporization energies such as methanol (with higher vaporization energy per unit fuel), and other anti-knock agents such as tertiary butyl alcohol, or ethers such as methyl tertiary butyl ether (MTBE), ethyl tertiary butyl ether (ETBE), or tertiary amyl methyl ether (TAME).

It is recognized that modifications and variations of the invention disclosed herein will be apparent to those of ordinary skill in the art and it is intended that all such modifications and variations be included within the scope of the appended claims.

The invention claimed is:

1. A fuel management system for a spark ignition engine which utilizes port fuel injection and also utilizes direct fuel injection;

and where there is a first torque range where direct injection and port injection are both used at the same value of torque throughout the first torque range

and where in at least part of the first torque range as torque is increased the amount of fuel that is directly injected is changed so as to obtain knock-free operation and the amount of directly injected fuel used to provide knock-free operation is minimized.

2. The fuel management system of claim 1 where as torque is increased the fraction of fuel that is directly injected is increased to the value that prevents knock.

3. The fuel management system of claim 1 where active control using a knock detector is used to change the amount of fuel that is directly injected as torque is increased.

4. The fuel management system of claim 1 or 2 where open loop control using a lookup table is also used to change the amount of fuel that is directly injected as torque is increased.

5. The fuel management system of claim 4 where a predetermined correlation between knock resistance and fraction of fuel provided by direct injection is employed.

6. The fuel management system of claim 1 where if torque is increased beyond the highest value of torque in the first range of torque, direct injection alone would be required for knock-free operation.

7. The fuel management system of claim 1 where only port fuel injection is used in a second range of torque.

8. The fuel management system of claim 7 where as the torque increases beyond the highest value of torque in the second range of torque, the engine operates in the first range of torque.

9. The fuel management system of claim 7 where as the torque increased beyond the highest value in the second range of torque, the engine operates in the first range of torque;

and where if the torque were to be increased beyond the highest value in the first range of torque, direct injection alone would be required for knock-free operation.

10. The fuel management system of claim 7 where the highest torque in the second torque range is the highest torque at which knock-free operation can be obtained with port fuel injection alone.

11. The fuel management system of claim 7 where when spark retard is employed to enable operation with port fuel injection alone where it would not otherwise be used and where the spark retard is controlled by sensed information.

12. The fuel management system of claim 7 where spark retard is employed so that port fuel injection alone can be used where it would not otherwise be used.

13. The fuel management system of claim 1 where spark retard is used to reduce the fraction of fuel that is provided by direct injection.

14. The fuel management system of claim 1 where the amount of directly injected fuel is minimized throughout the first torque range.

15. The fuel management system of claim 1 where the amount of directly injected fuel is minimized from zero torque to the highest torque in the first torque range.

16. The fuel management system of claim 1 where there is third torque range where the highest torque is the highest torque in the first torque range of the operation and where within the third torque range as torque is increased the fraction of fuel provided by direct injection is changed to the value needed to prevent knock.

17. The fuel management system of claim 9 or 16 where the engine is turbocharged.

18. The fuel management system of claim 16 where the amount of direct injection is minimized.

19. A fuel management system for a turbocharged spark ignition engine which utilizes port fuel injection and also utilizes direct fuel injection;

and where there is a first range of torque throughout which direct injection and port injection are used at the same value of torque;

and wherein as torque is increased the fraction of fuel that is directly injected is increased to a value that prevents knock;

and where there is a second range of torque where only port fuel injection is used;

and where when torque exceeds the highest torque in the second range of torque the engine operates in the first range of torque.

20. The fuel management system of claim 19 where the second torque range starts at zero torque.

21. The fuel management system of claim 19 or 20 where the highest value of torque in the second region of torque is the highest value of torque at which direct injection is not needed to prevent knock.

22. A spark ignition engine where port fuel injection and direct injection are used and the fraction of fuel provided by direct injection is increased so as to prevent knock that would otherwise occur; and where spark retard is employed to enable reduction of the amount of direct injection that would otherwise be employed.

23. The spark ignition engine of claim 22 where the engine is operated with port fuel injection alone at values of torque where port fuel injection alone would not otherwise be employed.

24. The spark ignition engine of claim 22 or 23 where the spark retard is controlled by detection of knock and by information from another sensed parameter.

25. The spark ignition engine of claim 22 or 23 where without the application of the spark retard the engine is operated with direct injection alone.

26. The spark ignition engine of claim 22 or 23 where without the application of the spark retard the engine is operated with both port fuel injection and direct injection at the same value of torque.

27. The spark ignition engine of claim 22 where without the employment of the spark retard the fraction of fuel provided by direct injection increases with increasing torque.

28. The spark ignition engine of claim 22 where there is a first torque range throughout which port fuel injection and direct injection are used at the same torque and wherein the fraction of fuel provided by direct injection increases with increasing torque in such a way as to enable knock-free operation and where there is a second torque range where only port fuel injection is used and where when the torque exceeds the highest torque in this range, the engine operates in the first torque range.

29. The spark ignition engine of claim 28 where the engine operates in the second torque range between zero torque and the highest torque in the second torque range.

30. The spark ignition engine of claim 22 where spark retard is used to reduce the amount of direct injection to zero from what it would otherwise have been.

* * * * *

EXHIBIT 5

US010138826B2

(12) **United States Patent**
Cohn et al.

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(45) **Date of Patent: *Nov. 27, 2018**

(54) **FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES**

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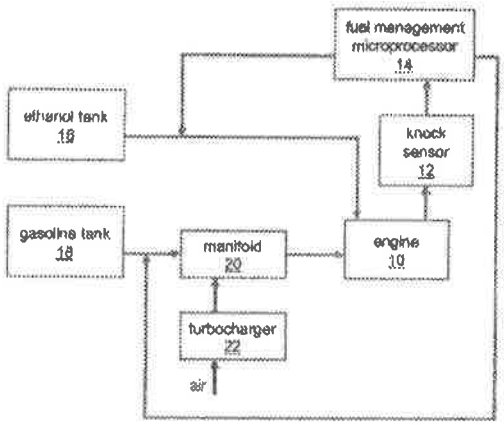
(57) **ABSTRACT**

Fuel management system for efficient operation of a spark ignition gasoline engine. Injectors inject an anti-knock agent such as ethanol directly into a cylinder of the engine. A fuel management microprocessor system controls injection of the anti-knock agent so as to control knock and minimize that amount of the anti-knock agent that is used in a drive cycle. It is preferred that the anti-knock agent is ethanol. The use of ethanol can be further minimized by injection in a non-uniform manner within a cylinder. The ethanol injection suppresses knock so that higher compression ratio and/or engine downsizing from increased turbocharging or supercharging can be used to increase the efficiency or the engine.

33 Claims, 3 Drawing Sheets



Related U.S. Application Data

continuation of application No. 14/982,086, filed on Dec. 29, 2015, now Pat. No. 9,695,784, and a continuation of application No. 14/478,069, filed on Sep. 5, 2014, now Pat. No. 9,255,519, and a continuation of application No. 14/249,806, filed on Apr. 10, 2014, now Pat. No. 8,857,410, and a continuation of application No. 13/956,498, filed on Aug. 1, 2013, now Pat. No. 8,733,321, and a continuation of application No. 13/629,836, filed on Sep. 28, 2012, now Pat. No. 8,522,746, and a continuation of application No. 13/368,382, filed on Feb. 8, 2012, now Pat. No. 8,302,580, and a continuation of application No. 13/282,787, filed on Oct. 27, 2011, now Pat. No. 8,146,568, and a continuation of application No. 13/117,448, filed on May 27, 2011, now Pat. No. 8,069,839, and a continuation of application No. 12/815,842, filed on Jun. 15, 2010, now Pat. No. 7,971,572, and a continuation of application No. 12/329,729, filed on Dec. 8, 2008, now Pat. No. 7,762,233, and a continuation of application No. 11/840,719, filed on Aug. 17, 2007, now Pat. No. 7,740,004, and a continuation of application No. 10/991,774, filed on Nov. 18, 2004, now Pat. No. 7,314,033.

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See application file for complete search history.

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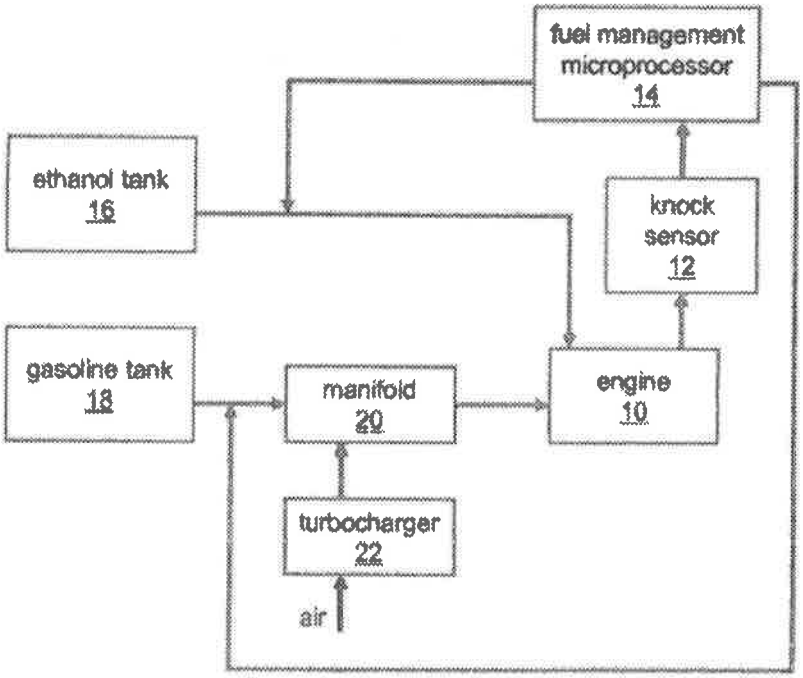
fuel management microprocessor 14
ethanol tank 16
knock sensor 12
gasoline tank 18
manifold 20
engine 10
turbocharger 22
air

FIG. 1

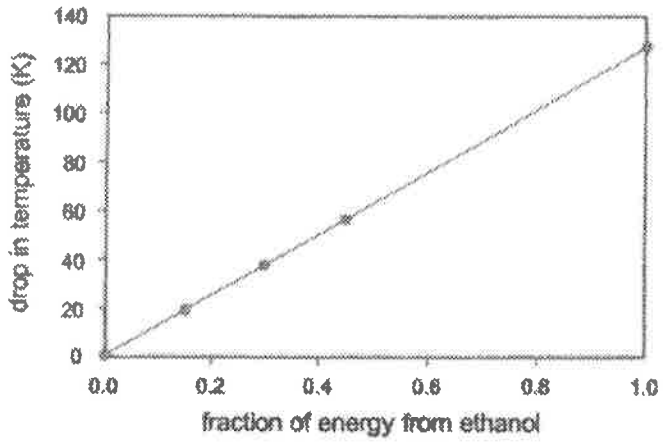
drop in temperature (K)
140
120
100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
fraction of energy from ethanol

FIG. 2

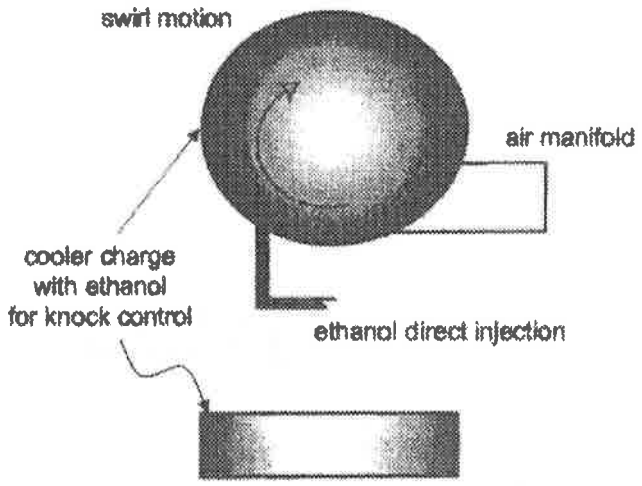
swirl motion
air manifold
cooler charge
with ethanol
for knock control
ethanol direct injection

FIG. 3

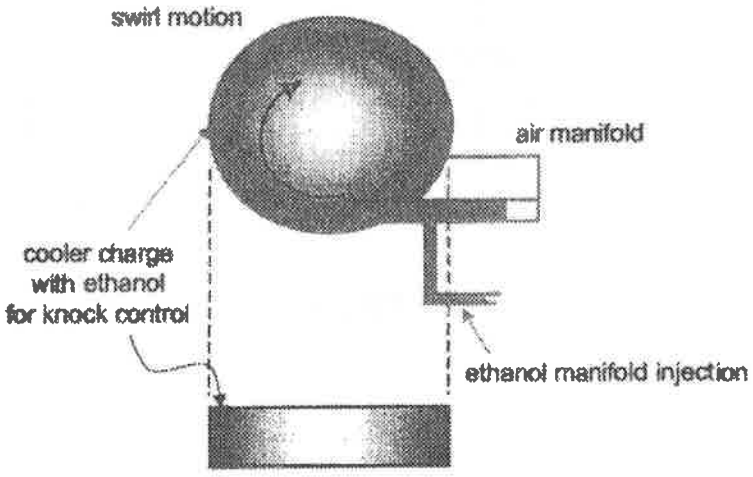
swirl motion
air manifold
cooler charge
with ethanol
for knock control
ethanol manifold injection

FIG. 4

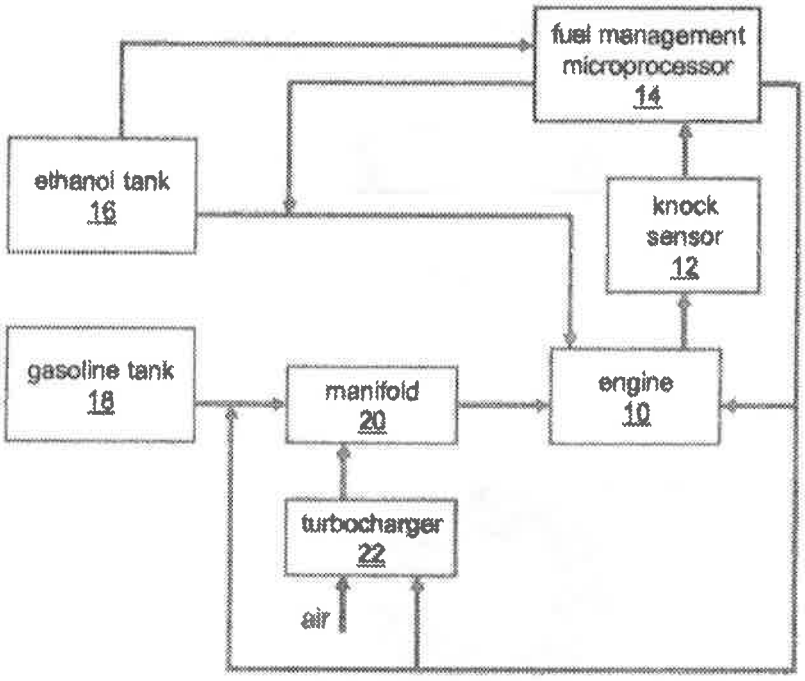
fuel management microprocessor 14
ethanol tank 16
knock sensor 12
gasoline tank 18
manifold 20
engine 10
turbocharger 22
air

FIG. 5

FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES

This application is a continuation of U.S. patent application Ser. No. 15/463,425 filed on Mar. 20, 2017, which is a continuation of U.S. patent application Ser. No. 14/982,086 filed on Dec. 29, 2015, which is a continuation of U.S. patent application Ser. No. 14/478,069 filed on Sep. 5, 2014, which is a continuation of U.S. patent application Ser. No. 14/249,806 filed on Apr. 10, 2014, which is now issued as U.S. Pat. No. 8,857,410, which is a continuation of U.S. patent application Ser. No. 13/956,498 filed on Aug. 1, 2013, which is now issued as U.S. Pat. No. 8,733,321, which is a continuation of U.S. patent application Ser. No. 13/629,836 filed on Sep. 28, 2012, which is now issued as U.S. Pat. No. 8,522,746, which is a continuation of U.S. patent application Ser. No. 13/368,382 filed on Feb. 8, 2012, which is now issued as U.S. Pat. No. 8,302,580, which is a continuation of U.S. patent application Ser. No. 13/282,787 filed Oct. 27, 2011, which is now issued as U.S. Pat. No. 8,146,568, which is a continuation of U.S. patent application Ser. No. 13/117,448 filed May 27, 2011, which is now issued as U.S. Pat. No. 8,069,839, which is a continuation of U.S. patent application Ser. No. 12/815,842, filed Jun. 15, 2010, which is now issued as U.S. Pat. No. 7,971,572, which is a continuation of U.S. patent application Ser. No. 12/329,729 filed on Dec. 8, 2008, which is now issued as U.S. Pat. No. 7,762,233, which is a continuation of U.S. patent application Ser. No. 11/840,719 filed on Aug. 17, 2007, which is now issued as U.S. Pat. No. 7,740,004, which is a continuation of U.S. patent application Ser. No. 10/991,774, which is now issued as U.S. Pat. No. 7,314,033.

BACKGROUND

This invention relates to spark ignition gasoline engines utilizing an antiknock agent which is a liquid fuel with a higher octane number than gasoline such as ethanol to improve engine efficiency.

It is known that the efficiency of spark ignition (SI) gasoline engines can be increased by high compression ratio operation and particularly by engine downsizing. The engine downsizing is made possible by the use of substantial pressure boosting from either turbocharging or supercharging. Such pressure boosting makes it possible to obtain the same performance in a significantly smaller engine. See, J. Stokes, et al., "A Gasoline Engine Concept For Improved Fuel Economy The Lean-Boost System," SAE Paper 2001-01-2902. The use of these techniques to increase engine efficiency, however, is limited by the onset of engine knock. Knock is the undesired detonation of fuel and can severely damage an engine. If knock can be prevented, then high compression ratio operation and high pressure boosting can be used to increase engine efficiency by up to twenty-five percent.

Octane number represents the resistance of a fuel to knocking but the use of higher octane gasoline only modestly alleviates the tendency to knock. For example, the difference between regular and premium gasoline is typically six octane numbers. That is significantly less than is needed to realize fully the efficiency benefits of high compression ratio or turbocharged operation. There is thus a need for a practical means for achieving a much higher level of octane enhancement so that engines can be operated much more efficiently.

It is known to replace a portion of gasoline with small amounts of ethanol added at the refinery. Ethanol has a blending octane number (ON) of 110 (versus 95 for premium gasoline) (see J. B. Heywood, "Internal Combustion Engine Fundamentals," McGraw Hill, 1988, p. 477) and is also attractive because it is a renewable energy, biomass-derived fuel, but the small amounts of ethanol that have heretofore been added to gasoline have had a relatively small impact on engine performance. Ethanol is much more expensive than gasoline and the amount of ethanol that is readily available is much smaller than that of gasoline because of the relatively limited amount of biomass that is available for its production. An object of the present invention is to minimize the amount of ethanol or other antiknock agent that is used to achieve a given level of engine efficiency increase. By restricting the use of ethanol to the relatively small fraction of time in an operating cycle when it is needed to prevent knock in a higher load regime and by minimizing its use at these times, the amount of ethanol that is required can be limited to a relatively small fraction of the fuel used by the spark ignition gasoline engine.

SUMMARY

In one aspect, the invention is a fuel management system for efficient operation of a spark ignition gasoline engine including a source of an antiknock agent such as ethanol. An injector directly injects the ethanol into a cylinder of the engine and a fuel management system controls injection of the antiknock agent into the cylinder to control knock with minimum use of the antiknock agent. A preferred antiknock agent is ethanol. Ethanol has a high heat of vaporization so that there is substantial cooling of the air-fuel charge to the cylinder when it is injected directly into the engine. This cooling effect reduces the octane requirement of the engine by a considerable amount in addition to the improvement in knock resistance from the relatively high octane number of ethanol. Methanol, tertiary butyl alcohol, MTBE, ETBE, and TAME may also be used. Wherever ethanol is used herein it is to be understood that other antiknock agents are contemplated.

The fuel management system uses a fuel management control system that may use a microprocessor that operates in an open loop fashion on a predetermined correlation between octane number enhancement and fraction of fuel provided by the antiknock agent. To conserve the ethanol, it is preferred that it be added only during portions of a drive cycle requiring knock resistance and that its use be minimized during these times. Alternatively, the gasoline engine may include a knock sensor that provides a feedback signal to a fuel management microprocessor system to minimize the amount of the ethanol added to prevent knock in a closed loop fashion.

In one embodiment the injectors stratify the ethanol to provide non-uniform deposition within a cylinder. For example, the ethanol may be injected proximate to the cylinder walls and swirl can create a ring of ethanol near the walls.

In another embodiment of this aspect of the invention, the system includes a measure of the amount of the antiknock agent such as ethanol in the source containing the antiknock agent to control turbocharging, supercharging or spark retard when the amount of ethanol is low.

The direct injection of ethanol provides substantially a 13° C. drop in temperature for every ten percent of fuel energy provided by ethanol. An instantaneous octane

enhancement of at least 4 octane numbers may be obtained for every 20 percent of the engine's energy coming from the ethanol.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of one embodiment of the invention disclosed herein.

FIG. **2** is a graph of the drop in temperature within a cylinder as a function of the fraction of energy provided by ethanol.

FIG. **3** is a schematic illustration of the stratification of cooler ethanol charge using direct injection and swirl motion for achieving thermal stratification.

FIG. **4** is a schematic illustration showing ethanol stratified in an inlet manifold.

FIG. **5** is a block diagram of an embodiment of the invention in which the fuel management microprocessor is used to control a turbocharger and spark retard based upon the amount of ethanol in a fuel tank.

DETAILED DESCRIPTION

With reference first to FIG. **1**, a spark ignition gasoline engine **10** includes a knock sensor **12** and a fuel management microprocessor system **14**. The fuel management microprocessor system **14** controls the direct injection of an anti-knock agent such as ethanol from an ethanol tank **16**. The fuel management microprocessor system **14** also controls the delivery of gasoline from a gasoline tank **18** into engine manifold **20**. A turbocharger **22** is provided to improve the torque and power density of the engine **10**. The amount of ethanol injection is dictated either by a predetermined correlation between octane number enhancement and fraction of fuel that is provided by ethanol in an open loop system or by a closed loop control system that uses a signal from the knock sensor **12** as an input to the fuel management microprocessor **14**. In both situations, the fuel management processor **14** will minimize the amount of ethanol added to a cylinder while still preventing knock. It is also contemplated that the fuel management microprocessor system **14** could provide a combination of open and closed loop control.

As show in FIG. **1** it is preferred that ethanol be directly injected into the engine **10**. Direct injection substantially increases the benefits of ethanol addition and decreases the required amount of ethanol. Recent advances in fuel injector and electronic control technology allows fuel injection directly into a spark ignition engine rather than into the manifold **20**. Because ethanol has a high heat of vaporization there will be substantial cooling when it is directly injected into the engine **10**. This cooling effect further increases knock resistance by a considerable amount. In the embodiment of FIG. **1** port fuel injection of the gasoline in which the gasoline is injected into the manifold rather than directly injected into the cylinder is preferred because it is advantageous in obtaining good air/fuel mixing and combustion stability that are difficult to obtain with direct injection.

Ethanol has a heat of vaporization of 840 kJ/kg, while the heat of vaporization of gasoline is about 350 kJ/kg. The attractiveness of ethanol increases when compared with gasoline on an energy basis, since the lower heating value of ethanol is 26.9 MJ/kg while for gasoline it is about 44 MJ/kg. Thus, the heat of vaporization per Joule of combustion energy is 0.031 for ethanol and 0.008 for gasoline. That is, for equal amounts of energy the required heat of vaporization of ethanol is about four times higher than that of gasoline. The ratio of the heat of vaporization per unit air required for stoichiometric combustion is about 94 kJ/kg of air for ethanol and 24 kJ/kg of air for gasoline, or a factor of four smaller. Thus, the net effect of cooling the air charge is about four times lower for gasoline than for ethanol (for stoichiometric mixtures wherein the amount of air contains oxygen that is just sufficient to combust all of the fuel).

In the case of ethanol direct injection according to one aspect of the invention, the charge is directly cooled. The amount of cooling due to direct injection of ethanol is shown in FIG. **2**. It is assumed that the air/fuel mixture is stoichiometric without exhaust gas recirculation (EGR), and that gasoline makes up the rest of the fuel. It is further assumed that only the ethanol contributes to charge cooling. Gasoline is vaporized in the inlet manifold and does not contribute to cylinder charge cooling. The direct ethanol injection provides about 13° C. of cooling for each 10% of the fuel energy provided by ethanol. (It is also possible to use direct injection of gasoline as well as direct injection of ethanol. However, under certain conditions there can be combustion stability issues.

The temperature decrement because of the vaporization energy of the ethanol decreases with lean operation and with EGR, as the thermal capacity of the cylinder charge increases. If the engine operates at twice the stoichiometric air/fuel ratio, the numbers indicated in FIG. **2** decrease by about a factor of 2 (the contribution of the ethanol itself and the gasoline is relatively modest). Similarly, for a 20% EGR rate, the cooling effect of the ethanol decreases by about 25%.

The octane enhancement effect can be estimated from the data in FIG. **2**. Direct injection of gasoline results in approximately a five octane number decrease in the octane number required by the engine, as discussed by Stokes, et al. Thus the contribution is about five octane numbers per 30K drop in charge temperature. As ethanol can decrease the charge temperature by about 120K, then the decrease in octane number required by the engine due to the drop in temperature, for 100% ethanol, is twenty octane numbers. Thus, when 100% of the fuel is provided by ethanol, the octane number enhancement is approximately thirty-five octane numbers with a twenty octane number enhancement coming from direct injection cooling and a fifteen octane number enhancement coming from the octane number of ethanol. From the above considerations, it can be projected that even if the octane enhancement from direct cooling is significantly lower, a total octane number enhancement of at least 4 octane numbers should be achievable for every 20% of the total fuel energy that is provided by ethanol.

Alternatively the ethanol and gasoline can be mixed together and then port injected through a single injector per cylinder, thereby decreasing the number of injectors that would be used. However, the air charge cooling benefit from ethanol would be lost.

Alternatively the ethanol and gasoline can be mixed together and then port fuel injected using a single injector per cylinder, thereby decreasing the number of injectors that would be used. However, the substantial air charge cooling benefit from ethanol would be lost. The volume of fuel between the mixing point and the port fuel injector should be minimized in order to meet the demanding dynamic octane-enhancement requirements of the engine.

Relatively precise determinations of the actual amount of octane enhancement from given amounts of direct ethanol injection can be obtained from laboratory and vehicle tests in addition to detailed calculations. These correlations can be used by the fuel management microprocessor system **14**.

An additional benefit of using ethanol for octane enhancement is the ability to use it in a mixture with water. Such a mixture can eliminate the need for the costly and energy consuming water removal step in producing pure ethanol that must be employed when ethanol is added to gasoline at a refinery. Moreover, the water provides an additional cooling (due to vaporization) that further increases engine knock resistance. In contrast the present use of ethanol as an additive to gasoline at the refinery requires that the water be removed from the ethanol.

Since unlike gasoline, ethanol is not a good lubricant and the ethanol fuel injector can stick and not open, it is desirable to add a lubricant to the ethanol. The lubricant will also denature the ethanol and make it unattractive for human consumption.

Further decreases in the required ethanol for a given amount of octane enhancement can be achieved with stratification (non-uniform deposition) of the ethanol addition. Direct injection can be used to place the ethanol near the walls of the cylinder where the need for knock reduction is greatest. The direct injection may be used in combination with swirl. This stratification of the ethanol in the engine further reduces the amount of ethanol needed to obtain a given amount of octane enhancement. Because only the ethanol is directly injected and because it is stratified both by the injection process and by thermal centrifugation, the ignition stability issues associated with gasoline direct injection (GDI) can be avoided.

It is preferred that ethanol be added to those regions that make up the end-gas and are prone to auto-ignition. These regions are near the walls of the cylinder. Since the end-gas contains on the order of 25% of the fuel, substantial decrements in the required amounts of ethanol can be achieved by stratifying the ethanol.

In the case of the engine **10** having substantial organized motion (such as swirl), the cooling will result in forces that thermally stratify the discharge (centrifugal separation of the regions at different density due to different temperatures). The effect of ethanol addition is to increase gas density since the temperature is decreased. With swirl the ethanol mixture will automatically move to the zone where the end-gas is, and thus increase the anti-knock effectiveness of the injected ethanol. The swirl motion is not affected much by the compression stroke and thus survives better than tumble-like motion that drives turbulence towards top-dead-center (TDC) and then dissipates. It should be pointed out that relatively modest swirls result in large separating (centrifugal) forces. A 3 m/s swirl motion in a 5 cm radius cylinder generates accelerations of about 200 m/s^2, or about 20 g's.

FIG. **3** illustrates ethanol direct injection and swirl motion for achieving thermal stratification. Ethanol is predominantly on an outside region which is the end-gas region. FIG. **4** illustrates a possible stratification of the ethanol in an inlet manifold with swirl motion and thermal centrifugation maintaining stratification in the cylinder. In this case of port injection of ethanol, however, the advantage of substantial charge cooling may be lost.

With reference again to FIG. **2**, the effect of ethanol addition all the way up to 100% ethanol injection is shown. At the point that the engine is 100% direct ethanol injected, there may be issues of engine stability when operating with only stratified ethanol injection that need to be addressed. In the case of stratified operation it may also be advantageous to stratify the injection of gasoline in order to provide a relatively uniform equivalence ratio across the cylinder (and therefore lower concentrations of gasoline in the regions where the ethanol is injected). This situation can be achieved, as indicated in FIG. **4**, by placing fuel in the region of the inlet manifold that is void of ethanol.

The ethanol used in the invention can either be contained in a separate tank from the gasoline or may be separated from a gasoline/ethanol mixture stored in one tank.

The instantaneous ethanol injection requirement and total ethanol consumption over a drive cycle can be estimated from information about the drive cycle and the increase in torque (and thus increase in compression ratio, engine power density, and capability for downsizing) that is desired. A plot of the amount of operating time spent at various values of torque and engine speed in FTP and US06 drive cycles can be used. It is necessary to enhance the octane number at each point in the drive cycle where the torque is greater than permitted for knock free operation with gasoline alone. The amount of octane enhancement that is required is determined by the torque level.

A rough illustrative calculation shows that only a small amount of ethanol might be needed over the drive cycle. Assume that it is desired to increase the maximum torque level by a factor of two relative to what is possible without direct injection ethanol octane enhancement. Information about the operating time for the combined FTP and US06 cycles shows that approximately only 10 percent of the time is spent at torque levels above 0.5 maximum torque and less than 1 percent of the time is spent above 0.9 maximum torque. Conservatively assuming that 100% ethanol addition is needed at maximum torque and that the energy fraction of ethanol addition that is required to prevent knock decreases linearly to zero at 50 percent of maximum torque, the energy fraction provided by ethanol is about 30 percent. During a drive cycle about 20 percent of the total fuel energy is consumed at greater than 50 percent of maximum torque since during the 10 percent of the time that the engine is operated in this regime, the amount of fuel consumed is about twice that which is consumed below 50 percent of maximum torque. The amount of ethanol energy consumed during the drive cycle is thus roughly around 6 percent (30 percent×0.2) of the total fuel energy.

In this case then, although 100% ethanol addition was needed at the highest value of torque, only 6% addition was needed averaged over the drive cycle. The ethanol is much more effectively used by varying the level of addition according to the needs of the drive cycle.

Because of the lower heat of combustion of ethanol, the required amount of ethanol would be about 9% of the weight of the gasoline fuel or about 9% of the volume (since the densities of ethanol and gasoline are comparable). A separate tank with a capacity of about 1.8 gallons would then be required in automobiles with twenty gallon gasoline tanks. The stored ethanol content would be about 9% of that of gasoline by weight, a number not too different from present-day reformulated gasoline. Stratification of the ethanol addition could reduce this amount by more than a factor of two. An on-line ethanol distillation system might alternatively be employed but would entail elimination or reduction of the increase torque and power available from turbocharging.

Because of the relatively small amount of ethanol and present lack of an ethanol fueling infrastructure, it is important that the ethanol vehicle be operable if there is no ethanol on the vehicle. The engine system can be designed such that although the torque and power benefits would be lower when ethanol is not available, the vehicle could still be operable by reducing or eliminating turbocharging capability and/or by increasing spark retard so as to avoid knock. As shown in FIG. **5**, the fuel management microprocessor system **14** uses ethanol fuel level in the ethanol tank **16** as

an input to control the turbocharger 22 (or supercharger or spark retard, not shown). As an example, with on-demand ethanol octane enhancement, a 4-cylinder engine can produce in the range of 280 horsepower with appropriate turbocharging or supercharging but could also be drivable with an engine power of 140 horsepower without the use of ethanol 300 according to the invention.

The impact of a small amount of ethanol upon fuel efficiency through use in a higher efficiency engine can greatly increase the energy value of the ethanol. For example, gasoline consumption could be reduced by 20% due to higher efficiency engine operation from use of a high compression ratio, strongly turbocharged operation and substantial engine downsizing. The energy value of the ethanol, including its value in direct replacement of gasoline (5% of the energy of the gasoline), is thus roughly equal to 25% of the gasoline that would have been used in a less efficient engine without any ethanol. The 5% gasoline equivalent energy value of ethanol has thus been leveraged up to a 25% gasoline equivalent value. Thus, ethanol can cost roughly up to five times that of gasoline on an energy basis and still be economically attractive. The use of ethanol as disclosed herein can be a much greater value use than in other ethanol applications.

Although the above discussion has featured ethanol as an exemplary anti-knock agent, the same approach can be applied to other high octane fuel and fuel additives with high vaporization energies such as methanol (with higher vaporization energy per unit fuel), and other anti-knock agents such as tertiary butyl alcohol, or ethers such as methyl tertiary butyl ether (MTBE), ethyl tertiary butyl ether (ETBE), or tertiary amyl methyl ether (TAME).

It is recognized that modifications and variations of the invention disclosed herein will be apparent to those of ordinary skill in the art and it is intended that all such modifications and variations be included within the scope of the appended claims.

The invention claimed is:

1. A fuel management system for a spark ignition engine that has a first fueling system that uses direct injection and also has a second fueling system that uses port fuel injection:

and where the fueling is such that there is a first torque range where both the first and second fueling system are used throughout the range;

and where the fraction of fueling provided by the first fueling system is higher at the highest value of torque in the first torque range than in the lowest value of torque in the first torque range;

and where there is a second torque range where only the second fueling system is used;

where when the torque is higher than the highest value of torque in the second torque range the engine is operated in the first torque range;

and where the second torque range extends from zero torque to the highest torque in the second torque range.

2. The fuel management system of claim 1 where the fraction of fueling that is provided by the first fueling system in the first torque range increases with increasing torque.

3. The fuel management system of claim 1 where the fraction of fueling that is provided by the first fueling system in the first torque range increases with increasing torque in such a way that knock is prevented.

4. The fuel management system of claim 1 where the fraction of fueling that is provided by the first fueling system in the first torque range increases with increasing torque such that it is substantially equal to the fraction needed to prevent knock.

5. The fuel management system of claim 1 where in at least part of the first torque range closed loop control using a knock detector is used to increase the fraction of fueling that is provided by the first fueling system in the first torque range with increasing torque such that it is substantially equal to the fraction needed to prevent knock.

6. The fuel management system of claim 1 where in at least part of the first torque range closed loop control using a knock detector is used to increase the fraction of fueling that is provided by the first fueling system in the first torque range with increasing torque such that it is substantially equal to the fraction needed to prevent knock and where open loop control using a look up table is also employed.

7. The fuel management system of claim 1 where throughout the entire first torque range closed loop control using a knock detector is used to increase the fraction of fueling that is provided by the first fueling system in the first torque range with increasing torque such that it is substantially equal to the fraction needed to prevent knock.

8. The fuel management system of claim 1 where throughout the entire first torque range closed loop control using a knock detector is used to increase the fraction of fueling that is provided by the first fueling system in the first torque range with increasing torque such that it is substantially equal to the fraction needed to prevent knock and where open loop control using a look up table is also employed.

9. The fuel management system of claim 1 where if torque were increased beyond the highest torque in the second torque range fueling by the first fueling system alone would be needed to prevent knock.

10. The fuel management system of claim 1 where fueling from the first fueling system throughout the first torque range is minimized.

11. The fuel management system of claim 1 the highest torque in the second torque range is the highest torque at which the engine can be operated without the need for fueling from the first fueling system to prevent knock.

12. A fuel management system for a spark ignition engine that has a first fueling system that uses direct injection and also has a second fueling system that uses port fuel injection:

and where the fueling is such that there is a first torque range where both the first and second fueling system are used throughout the range;

and where there is a second torque range where only the second fueling system is used;

where when the torque is higher than the highest value of torque in the second torque range the engine is operated in the first torque range;

and where the second torque range extends from zero torque to the highest torque in the second torque range.

13. The fuel management system of claim 12 where the fraction of fuel provided by the first fueling system increases with increasing torque in at least part of the first torque range.

14. The fuel management system of claim 12 where the fraction of fuel provided by the first fueling system increases with increasing torque in at least part of the first torque range;

and where spark retard is used to reduce the fraction of fuel that is provided by the first fueling system.

15. The fuel management system of claim 12 where the fraction of fuel provided by the first fueling system increases with increasing torque in at least part of the first torque range;

and where spark retard is used to reduce the fraction of fuel provided by the first fueling system to zero.

16. The fuel management system of claim 12 where spark retard is used to reduce the fraction of fuel that is provided by the first fueling system.

17. The fuel management system of claim 12 where spark retard is used to reduce the fraction of fuel that is provided by the first fueling system;

and where the fuel management system uses information from a knock detector and a sensed parameter.

18. The fuel management system of claim 12 where spark retard is used to reduce the fraction of fuel that is provided by the first fueling system to zero.

19. The fuel management system of claim 12 where spark retard is used to reduce the fraction of fuel that is provided by the first fueling system to zero;

and where the fuel management system uses information from a knock detector and a sensed parameter.

20. The fuel management system of claim 12 where the fraction of fuel provided by the first fueling system in the first torque range increases with increasing torque;

and where spark retard is used to reduce the fraction of fuel that would otherwise be used.

21. A fuel management system for a spark ignition engine where a fuel is provided by a first fueling system using direct injection and by a second fueling system using port fuel injection;

and where there is a torque range throughout which both fueling systems are used;

and wherein as torque decreases the fraction of fueling provided by the first fueling system decreases;

and where there is second torque range where only the second fueling system is used.

22. The fuel management system of claim 21 where when the torque is higher than the highest torque in the second torque range the engine is operated in the first torque range.

23. The fuel management system of claim 22 where when the torque is higher than the highest torque in the second torque range the engine is operated in the first torque range;

and where the second fueling system is used from zero torque to the highest torque in the first torque range;

and where the highest torque in the first torque range is the highest torque at which the engine is operated with the use of both the first and second fueling systems;

and where in at least part of the first torque as torque is increased, the fraction of fuel that is provided by the first fueling system is such that it is substantially equal to that needed to prevent knock as torque is increased.

24. The fuel management system of claim 22 where when the torque is higher than the highest torque in the second torque range the engine is operated in the first torque range;

and where the second fueling system is used from zero torque to the highest torque in the first torque range;

and where the highest torque in the first torque range is the highest torque at which the engine is operated with the use of both the first and second fueling systems;

and where throughout the first torque range as torque is increased, the fraction of fuel that is provided by the first fueling system is such that it is substantially equal to that needed to prevent knock as torque is increased.

25. The fuel management system of claim 22 where when the torque is higher than the highest torque in the second torque range the engine is operated in the first torque range;

and where the second fueling system is used from zero torque to the highest torque in the first torque range;

and where the highest torque in the first torque range is the highest torque at which the engine is operated with the use of both the first and second fueling systems;

and where throughout the first torque range as torque is increased, the fraction of fuel that is provided by the first fueling system is such that it is substantially equal to that needed to prevent knock as torque is increased;

and where the highest torque in the first torque range is the highest torque at which the engine can be operated without the necessity of operating with use of the first fueling system alone.

26. The fuel management system of claim 22 where spark retard is employed so as to reduce the fraction of fuel that is provided by first fueling system.

27. The fuel management system of claim 22 where spark retard is employed so as to enable operation with the second fueling system alone where it would not otherwise be employed.

28. The fuel management system of claim 21 where when the torque is higher than the highest torque in the second torque range the engine is operated in the first torque range;

and where the second torque range extends from zero torque to the highest torque in the first torque range.

29. The fuel management system of claim 21 where when the torque is higher than the highest torque in the second torque range the engine is operated in the first torque range;

and where the second torque range extends from zero torque to the highest torque in the first torque range;

and where in at least part of the first torque range as torque is increased, the fraction of fuel that is provided by the first fueling system is such that it is substantially equal to that needed to prevent knock as torque is increased.

30. The fuel management system of claim 29 where when the torque is higher than the highest torque in the second torque range the engine is operated in the first torque range;

and where the second fueling system is used from zero torque to the highest torque in the first torque range;

and where throughout the first torque range as torque is increased, the fraction of fuel that is provided by the first fueling system is such that it is substantially equal to that needed to prevent knock as torque is increased.

31. A fuel management system for a spark ignition engine where a fuel is provided by a first fueling system using direct injection and by a second fueling system using port fuel injection;

and where there is a first torque range through which both fueling systems are used; and

wherein as torque decreases the fraction of fueling provided by the first fueling system decreases;

and where there is second torque range where only the second fueling system is used;

and where the second torque range extends from zero torque to the lowest torque in the first torque range;

and where spark retard is employed so as to reduce the fraction of fuel is provided by the first fueling system.

32. The fuel management system of claim 31 where in at least part of the first torque range the fraction of fuel that is provided by the first fueling system is substantially equal to that needed to prevent knock;

and where the fueling management system uses a knock sensor to control the fraction of fuel that is provided by the first fueling system;

and where spark retard is used to reduce the fraction of fuel provided by the first fueling system to zero.

33. The fuel management system of claim 31 where throughout the first torque range the fraction of fuel that is provided by the first fueling system is substantially equal to that needed to prevent knock;

and where the fueling management system uses a knock sensor and also open loop control using a lookup table to control the fraction of fuel that is provided by the first fueling system;

and where spark retard is used to reduce the fraction of fuel provided by the first fueling system to zero;

and where the fuel management system uses information from a knock detector and from a sensed parameter in the control of spark retard;

and where the highest torque in the second torque range is the highest torque at which the engine can be operation with the second fueling system alone without producing knock.

* * * * *

EXHIBIT 6

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

24280 7590 08/16/2007

CHOATE, HALL & STEWART LLP
TWO INTERNATIONAL PLACE
BOSTON, MA 02110

EXAMINER	
ALI, HYDER	
ART UNIT	PAPER NUMBER
3747	

DATE MAILED: 08/16/2007

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/991,774	11/18/2004	Daniel R. Cohn	0492611-0598	8282

TITLE OF INVENTION: FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEHMENT OF GASOLINE ENGINES

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	$700	$300	$0	$1000	11/16/2007

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PTOL-85 (Rev. 08/07) Approved for use through 08/31/2007.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address, and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

24280 7590 08/16/2007

CHOATE, HALL & STEWART LLP
TWO INTERNATIONAL PLACE
BOSTON, MA 02110

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)

(Signature)

(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/991,774	11/18/2004	Daniel R. Cohn	0492611-0598	8282

TITLE OF INVENTION: FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEHMENT OF GASOLINE ENGINES

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	$700	$300	$0	$1000	11/16/2007

EXAMINER	ART UNIT	CLASS-SUBCLASS
ALI, HYDER	3747	123-19800A

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____

2 _____

3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

☐ Issue Fee

☐ Publication Fee (No small entity discount permitted)

☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

☐ A check is enclosed.

☐ Payment by credit card. Form PTO-2038 is attached.

☐ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/991,774	11/18/2004	Daniel R. Cohn	0492611-0598	8282

24280 7590 08/16/2007

CHOATE, HALL & STEWART LLP
TWO INTERNATIONAL PLACE
BOSTON, MA 02110

EXAMINER	
ALI, HYDER	
ART UNIT	PAPER NUMBER
3747	

DATE MAILED: 08/16/2007

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 25 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 25 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

PTOL-85 (Rev. 08/07) Approved for use through 08/31/2007

ED

Notice of Allowability	Application No. 10/991,774	Applicant(s) COHN ET AL.	
	Examiner HYDER ALI	Art Unit 3747	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *Arguments/Remarks filed on 07/27/2007*.

2. ☒ The allowed claim(s) is/are *57-60*.

3. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☐ All b) ☐ Some* c) ☐ None of the:
      1. ☐ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

4. ☒ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☒ Examiner's Amendment/Comment
8. ☐ Examiner's Statement of Reasons for Allowance
9. ☐ Other _____.

Hyder Ali

EXAMINER'S AMENDMENT

An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

The application has been amended as follows:

Oath/Declaration Objection

Oath/Declaration is objected to because the oath/declaration duty to disclose statement is improper.

The oath or declaration is defective. A new oath or declaration in compliance with 37 CFR 1.67(a) identifying this application by application number and filing date is required. See MPEP §§ 602.01 and 602.02.

The oath or declaration is defective because:

It does not state that the person making the oath or declaration acknowledges the duty to disclose to the Office all information known to the person to be material to patentability as defined in 37 CFR 1.56.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to HYDER ALI whose telephone number is (571) 272-4836. The examiner can normally be reached on M-F (8:30-5:00).

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Stephen Kirk Cronin can be reached on (571) 272-4536. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

Hyder Ali.

ha

STEPHEN K. CRONIN
SUPERVISORY PATENT EXAMINER

EAST Search History

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	3	turbocharger and spark adj ignition adj engine and port adj fuel adj injection and gasoline and knock and ethanol and vehicle and energy adj fraction	US-PGPUB	OR	OFF	2007/08/13 13:28
L2	1	turbocharger and spark adj ignition adj engine and port adj fuel adj injection and gasoline and knock and ethanol and vehicle and energy adj fraction	USPAT	OR	OFF	2007/08/13 13:27

Application Number	Application/Control No.	Applicant(s)/Patent under Reexamination	
	10/991,774	COHN ET AL.	

Document Code - DISQ	Internal Document – DO NOT MAIL

TERMINAL DISCLAIMER	☒ APPROVED	☐ DISAPPROVED
Date Filed : 07/27/07	This patent is subject to a Terminal Disclaimer	REASONS:

Approved/Disapproved by:

☐ Sharon Greene
Paralegal Specialist
Technology Center 3700

☐ Patricia Martin
Paralegal Specialist
Technology Center 3700

☒ Jan Hurley
Paralegal Specialist
Technology Center 3700

☐ Andre Robinson
Paralegal Specialist
Technology Center 3700

U.S. Patent and Trademark Office

ATTORNEY DOCKET NO. 0492611-0598

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Cohn, *et al.*
Serial No.: 10/991,774 **Examiner:** ALI, HYDER

Filed: November 18, 2004 **Art Unit:** 1714

For: FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES

RESPONSE TO OFFICE ACTION

In response to the office action mailed May 25, 2007 please consider the following remarks:

REMARKS

Reexamination and reconsideration of the rejections are hereby requested.

Claims 57-60 are pending in this application. Claims 57 and 58 stand rejected on the ground of non-statutory obviousness-type double patentee. Claim 59 and 60 stand allowed.

Included herewith is a terminal disclaimer with respect to co-pending and co-owned application serial number 11/100,026 (now US Patent No. 7,225,787) It is submitted that this terminal disclaimer overcomes the obviousness-type double patenting rejection.

It is submitted that this application is in condition for allowance and early favorable action is requested.

Respectfully submitted,
CHOATE, HALL & STEWART LLP

/SamPasternack/
Sam Pasternack

Date: July 27, 2007

Patent Department
CHOATE, HALL & STEWART, LLP
Two International Place
Boston, MA 02110
Tel: (617) 248-5000
Fax: (617) 248-4000

4235440v1

PTO/SB/25 (04-07)
Approved for use through 09/30/2007. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

TERMINAL DISCLAIMER TO OBVIATE A PROVISIONAL DOUBLE PATENTING REJECTION OVER A PENDING "REFERENCE" APPLICATION	Docket Number (Optional)

In re Application of: FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES

Application No.: 10/991,774

Filed: November 18, 2004

For: Daniel R. Cohn

The owner*, Massachuets Institute of Technology, of 100 percent interest in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of any patent granted on pending **reference** Application Number 11/100,026, filed on 04-06-2005, as such term is defined in 35 U.S.C. 154 and 173, and as the term of any patent granted on said **reference** application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending **reference** application. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and any patent granted on the **reference** application are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of any patent granted on the instant application that would extend to the expiration date of the full statutory term as defined in 35 U.S.C. 154 and 173 of any patent granted on said **reference** application, "as the term of any patent granted on said **reference** application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending **reference** application," in the event that any such patent granted on the pending **reference** application expires for failure to pay a maintenance fee, is held unenforceable, is found invalid by a court of competent jurisdiction, is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321, has all claims canceled by a reexamination certificate, is reissued, or is in any manner terminated prior to the expiration of its full statutory term as shortened by any terminal disclaimer filed prior to its grant.

Check either box 1 or 2 below, if appropriate.

1. ☐ For submissions on behalf of a business/organization (e.g., corporation, partnership, university, government agency, etc.), the undersigned is empowered to act on behalf of the business/organization.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

2. ☑ The undersigned is an attorney or agent of record. Reg. No. 29576

/SamPasternack/ — Signature
07/27/2007 — Date

Sam Pasternack — Typed or printed name

617-248-5143 — Telephone Number

☑ Terminal disclaimer fee under 37 CFR 1.20(d) is included.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

*Statement under 37 CFR 3.73(b) is required if terminal disclaimer is signed by the assignee (owner). Form PTO/SB/96 may be used for making this statement. See MPEP § 324.

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/991,774	11/18/2004	Daniel R. Cohn	0492611-0598	8282

24280 7590 05/25/2007
CHOATE, HALL & STEWART LLP
TWO INTERNATIONAL PLACE
BOSTON, MA 02110

EXAMINER	
ALI, HYDER	
ART UNIT	**PAPER NUMBER**
3747	

MAIL DATE	DELIVERY MODE
05/25/2007	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No.	Applicant(s)	
	10/991,774	COHN ET AL.	
	Examiner	Art Unit	
	HYDER ALI	3747	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *09 March 2007*.

2a)☐ This action is **FINAL.** 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *57-60* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☒ Claim(s) *59 and 60* is/are allowed.

6)☒ Claim(s) *57 and 58* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *18 November 2004* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☒ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

Inventorship

This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

Oath/Declaration Objection

Oath/Declaration is objected to because the oath/declaration duty to disclose statement is improper.

The oath or declaration is defective. A new oath or declaration in compliance with 37 CFR 1.67(a) identifying this application by application number and filing date is required. See MPEP §§ 602.01 and 602.02.

> The oath or declaration is defective because:
> It does not state that the person making the oath or declaration acknowledges the duty to disclose to the Office all information known to the person to be material to patentability as defined in 37 CFR 1.56.

Double Patenting

The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent

and to prevent possible harassment by multiple assignees. A nonstatutory obviousness-type double patenting rejection is appropriate where the conflicting claims are not identical, but at least one examined application claim is not patentably distinct from the reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference claim(s). See, e.g., *In re Berg*, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); and *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on a nonstatutory double patenting ground provided the conflicting application or patent either is shown to be commonly owned with this application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement.

Effective January 1, 1994, a registered attorney or agent of record may sign a terminal disclaimer. A terminal disclaimer signed by the assignee must fully comply with 37 CFR 3.73(b).

Claims 57 and 58 are provisionally rejected on the ground of nonstatutory obviousness-type double patenting as being unpatentable over claims 77-85 of copending Application No. 11/100026. Although the conflicting claims are not identical, they are not patentably distinct from each other because they have the same structure and scope.

This is a provisional obviousness-type double patenting rejection because the conflicting claims have not in fact been patented.

Allowable Subject Matter

Claims 59 and 60 are allowed.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to HYDER ALI whose telephone number is (571) 272-4836. The examiner can normally be reached on M-F (8:30-5:00).

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Stephen Kirk Cronin can be reached on (571) 272-4536. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

Hyder Ali

ha

Tony M. Argenbright
Primary Examiner
Art Unit 3747

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/991,774	11/18/2004	Daniel R. Cohn	0492611-0598	8282

24280 7590 12/19/2006
CHOATE, HALL & STEWART LLP
TWO INTERNATIONAL PLACE
BOSTON, MA 02110

EXAMINER	
ALI, HYDER	
ART UNIT	**PAPER NUMBER**
3747	
MAIL DATE	**DELIVERY MODE**
12/19/2006	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

Advisory Action Before the Filing of an Appeal Brief	Application No. 10/991,774	Applicant(s) COHN ET AL.	
	Examiner HYDER ALI	Art Unit 3747	

--The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

THE REPLY FILED 30 November 2006 FAILS TO PLACE THIS APPLICATION IN CONDITION FOR ALLOWANCE.

1. ☒ The reply was filed after a final rejection, but prior to or on the same day as filing a Notice of Appeal. To avoid abandonment of this application, applicant must timely file one of the following replies: (1) an amendment, affidavit, or other evidence, which places the application in condition for allowance; (2) a Notice of Appeal (with appeal fee) in compliance with 37 CFR 41.31; or (3) a Request for Continued Examination (RCE) in compliance with 37 CFR 1.114. The reply must be filed within one of the following time periods:
   a) ☐ The period for reply expires _____ months from the mailing date of the final rejection.
   b) ☒ The period for reply expires on: (1) the mailing date of this Advisory Action, or (2) the date set forth in the final rejection, whichever is later. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of the final rejection.
   Examiner Note: If box 1 is checked, check either box (a) or (b). ONLY CHECK BOX (b) WHEN THE FIRST REPLY WAS FILED WITHIN TWO MONTHS OF THE FINAL REJECTION. See MPEP 706.07(f).

Extensions of time may be obtained under 37 CFR 1.136(a). The date on which the petition under 37 CFR 1.136(a) and the appropriate extension fee have been filed is the date for purposes of determining the period of extension and the corresponding amount of the fee. The appropriate extension fee under 37 CFR 1.17(a) is calculated from: (1) the expiration date of the shortened statutory period for reply originally set in the final Office action; or (2) as set forth in (b) above, if checked. Any reply received by the Office later than three months after the mailing date of the final rejection, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

NOTICE OF APPEAL

2. ☐ The Notice of Appeal was filed on _____. A brief in compliance with 37 CFR 41.37 must be filed within two months of the date of filing the Notice of Appeal (37 CFR 41.37(a)), or any extension thereof (37 CFR 41.37(e)), to avoid dismissal of the appeal. Since a Notice of Appeal has been filed, any reply must be filed within the time period set forth in 37 CFR 41.37(a).

AMENDMENTS

3. ☒ The proposed amendment(s) filed after a final rejection, but prior to the date of filing a brief, will not be entered because
   (a) ☒ They raise new issues that would require further consideration and/or search (see NOTE below);
   (b) ☐ They raise the issue of new matter (see NOTE below);
   (c) ☐ They are not deemed to place the application in better form for appeal by materially reducing or simplifying the issues for appeal; and/or
   (d) ☐ They present additional claims without canceling a corresponding number of finally rejected claims.
   NOTE: *Claims 57-60 constitute new issue.* (See 37 CFR 1.116 and 41.33(a)).
4. ☐ The amendments are not in compliance with 37 CFR 1.121. See attached Notice of Non-Compliant Amendment (PTOL-324).
5. ☐ Applicant's reply has overcome the following rejection(s): _____.
6. ☐ Newly proposed or amended claim(s) _____ would be allowable if submitted in a separate, timely filed amendment canceling the non-allowable claim(s).
7. ☒ For purposes of appeal, the proposed amendment(s): a) ☒ will not be entered, or b) ☐ will be entered and an explanation of how the new or amended claims would be rejected is provided below or appended.
   The status of the claim(s) is (or will be) as follows:
   Claim(s) allowed: _____.
   Claim(s) objected to: _____.
   Claim(s) rejected: *1-16,18-20 and 24-56*.
   Claim(s) withdrawn from consideration: _____.

AFFIDAVIT OR OTHER EVIDENCE

8. ☐ The affidavit or other evidence filed after a final action, but before or on the date of filing a Notice of Appeal will not be entered because applicant failed to provide a showing of good and sufficient reasons why the affidavit or other evidence is necessary and was not earlier presented. See 37 CFR 1.116(e).
9. ☐ The affidavit or other evidence filed after the date of filing a Notice of Appeal, but prior to the date of filing a brief, will not be entered because the affidavit or other evidence failed to overcome all rejections under appeal and/or appellant fails to provide a showing a good and sufficient reasons why it is necessary and was not earlier presented. See 37 CFR 41.33(d)(1).
10. ☐ The affidavit or other evidence is entered. An explanation of the status of the claims after entry is below or attached.

REQUEST FOR RECONSIDERATION/OTHER

11. ☐ The request for reconsideration has been considered but does NOT place the application in condition for allowance because: _____.
12. ☐ Note the attached Information Disclosure Statement(s). (PTO/SB/08) Paper No(s). _____
13. ☒ Other: PTO-413 (Interview Summary).

Hyder Ali

STEPHEN K. CRONIN
SUPERVISORY PATENT EXAMINER

Interview Summary	Application No.	Applicant(s)	
	10/991,774	COHN ET AL.	
	Examiner	Art Unit	
	HYDER ALI	3747	

All participants (applicant, applicant's representative, PTO personnel):

(1) *HYDER ALI*.

(2) *Sam Pasternack*.

(3) *Dr. Daniel Cohn*.

(4)_____.

Date of Interview: *27 November 2006*.

Type: a)☒ Telephonic b)☐ Video Conference
c)☐ Personal [copy given to: 1)☐ applicant 2)☐ applicant's representative]

Exhibit shown or demonstration conducted: d)☐ Yes e)☒ No.
If Yes, brief description: _____.

Claim(s) discussed: *Proposed amendments claims 57-60*.

Identification of prior art discussed: *Art of record Jessel (US 4,541,383) and Watanabe et al (US 6,513,505)*.

Agreement with respect to the claims f)☐ was reached. g)☒ was not reached. h)☐ N/A.

Substance of Interview including description of the general nature of what was agreed to if an agreement was reached, or any other comments: *Examiner Ali indicated that there could be 35 USC 112, 2nd paragraph issues raised by the proposed amendments claims 57-60*.

(A fuller description, if necessary, and a copy of the amendments which the examiner agreed would render the claims allowable, if available, must be attached. Also, where no copy of the amendments that would render the claims allowable is available, a summary thereof must be attached.)

THE FORMAL WRITTEN REPLY TO THE LAST OFFICE ACTION MUST INCLUDE THE SUBSTANCE OF THE INTERVIEW. (See MPEP Section 713.04). If a reply to the last Office action has already been filed, APPLICANT IS GIVEN A NON-EXTENDABLE PERIOD OF THE LONGER OF ONE MONTH OR THIRTY DAYS FROM THIS INTERVIEW DATE, OR THE MAILING DATE OF THIS INTERVIEW SUMMARY FORM, WHICHEVER IS LATER, TO FILE A STATEMENT OF THE SUBSTANCE OF THE INTERVIEW. See Summary of Record of Interview requirements on reverse side or on attached sheet.

Hyder Ali

Examiner Note: You must sign this form unless it is an Attachment to a signed Office action.

Examiner's signature, If required

Summary of Record of Interview Requirements

Manual of Patent Examining Procedure (MPEP), Section 713.04, Substance of Interview Must be Made of Record
A complete written statement as to the substance of any face-to-face, video conference, or telephone interview with regard to an application must be made of record in the application whether or not an agreement with the examiner was reached at the interview.

Title 37 Code of Federal Regulations (CFR) § 1.133 Interviews
Paragraph (b)
In every instance where reconsideration is requested in view of an interview with an examiner, a complete written statement of the reasons presented at the interview as warranting favorable action must be filed by the applicant. An interview does not remove the necessity for reply to Office action as specified in §§ 1.111, 1.135. (35 U.S.C. 132)

37 CFR §1.2 Business to be transacted in writing.
All business with the Patent or Trademark Office should be transacted in writing. The personal attendance of applicants or their attorneys or agents at the Patent and Trademark Office is unnecessary. The action of the Patent and Trademark Office will be based exclusively on the written record in the Office. No attention will be paid to any alleged oral promise, stipulation, or understanding in relation to which there is disagreement or doubt.

The action of the Patent and Trademark Office cannot be based exclusively on the written record in the Office if that record is itself incomplete through the failure to record the substance of interviews.

It is the responsibility of the applicant or the attorney or agent to make the substance of an interview of record in the application file, unless the examiner indicates he or she will do so. It is the examiner's responsibility to see that such a record is made and to correct material inaccuracies which bear directly on the question of patentability.

Examiners must complete an Interview Summary Form for each interview held where a matter of substance has been discussed during the interview by checking the appropriate boxes and filling in the blanks. Discussions regarding only procedural matters, directed solely to restriction requirements for which interview recordation is otherwise provided for in Section 812.01 of the Manual of Patent Examining Procedure, or pointing out typographical errors or unreadable script in Office actions or the like, are excluded from the interview recordation procedures below. Where the substance of an interview is completely recorded in an Examiners Amendment, no separate Interview Summary Record is required.

The Interview Summary Form shall be given an appropriate Paper No., placed in the right hand portion of the file, and listed on the "Contents" section of the file wrapper. In a personal interview, a duplicate of the Form is given to the applicant (or attorney or agent) at the conclusion of the interview. In the case of a telephone or video-conference interview, the copy is mailed to the applicant's correspondence address either with or prior to the next official communication. If additional correspondence from the examiner is not likely before an allowance or if other circumstances dictate, the Form should be mailed promptly after the interview rather than with the next official communication.

The Form provides for recordation of the following information:
- Application Number (Series Code and Serial Number)
- Name of applicant
- Name of examiner
- Date of interview
- Type of interview (telephonic, video-conference, or personal)
- Name of participant(s) (applicant, attorney or agent, examiner, other PTO personnel, etc.)
- An indication whether or not an exhibit was shown or a demonstration conducted
- An identification of the specific prior art discussed
- An indication whether an agreement was reached and if so, a description of the general nature of the agreement (may be by attachment of a copy of amendments or claims agreed as being allowable). Note: Agreement as to allowability is tentative and does not restrict further action by the examiner to the contrary.
- The signature of the examiner who conducted the interview (if Form is not an attachment to a signed Office action)

It is desirable that the examiner orally remind the applicant of his or her obligation to record the substance of the interview of each case. It should be noted, however, that the Interview Summary Form will not normally be considered a complete and proper recordation of the interview unless it includes, or is supplemented by the applicant or the examiner to include, all of the applicable items required below concerning the substance of the interview.

A complete and proper recordation of the substance of any interview should include at least the following applicable items:
1) A brief description of the nature of any exhibit shown or any demonstration conducted,
2) an identification of the claims discussed,
3) an identification of the specific prior art discussed,
4) an identification of the principal proposed amendments of a substantive nature discussed, unless these are already described on the Interview Summary Form completed by the Examiner,
5) a brief identification of the general thrust of the principal arguments presented to the examiner,
   (The identification of arguments need not be lengthy or elaborate. A verbatim or highly detailed description of the arguments is not required. The identification of the arguments is sufficient if the general nature or thrust of the principal arguments made to the examiner can be understood in the context of the application file. Of course, the applicant may desire to emphasize and fully describe those arguments which he or she feels were or might be persuasive to the examiner.)
6) a general indication of any other pertinent matters discussed, and
7) if appropriate, the general results or outcome of the interview unless already described in the Interview Summary Form completed by the examiner.

Examiners are expected to carefully review the applicant's record of the substance of an interview. If the record is not complete and accurate, the examiner will give the applicant an extendable one month time period to correct the record.

Examiner to Check for Accuracy

If the claims are allowable for other reasons of record, the examiner should send a letter setting forth the examiner's version of the statement attributed to him or her. If the record is complete and accurate, the examiner should place the indication, "Interview Record OK" on the paper recording the substance of the interview along with the date and the examiner's initials.

RECEIVED
CENTRAL FAX CENTER
NOV 3 0 2006

Attorney Docket No: 0492611-0598

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Cohn, et al.	Examiner:	Hyder Ali
Serial No.:	10/991,774	Art Unit:	3747
Filing Date:	November 18, 2004		
Title:	FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES		

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Certificate of Facsimile Transmission

I certify that this correspondence is being transmitted via facsimile to (mail stop if applicable) Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, via facsimile no. 571-273-8300

November 30, 2006 _____ _____
Date Signature

Elizabeth Burke
Typed or Printed Name of person signing certificate

AMENDMENT AFTER FINAL ACTION

In response to the Office Action mailed September 27, 2006 finally rejecting the pending claims, it is requested that this amendment be entered and the application allowed:

Amendments to the Claims are reflected in the listing of claims that begins on page 2 of this paper.

Remarks begin on page 7 of this paper.

Do not enter
HA
12/12/06

4149358v1

Index of Claims

Application/Control No.	Applicant(s)/Patent under Reexamination
10/991,774	COHN ET AL.
Examiner	**Art Unit**
HYDER ALI	3747

✓	Rejected	–	(Through numeral) Cancelled	N	Non-Elected	A	Appeal
=	Allowed	+	Restricted	I	Interference	O	Objected

Claim		Date									
Final	Original	4/18/06	9/11/06	12/11/06							
	1	✓	✓	✓							
	2	–	–	✓							
	3			✓							
	4			✓							
	5			✓							
	6			✓							
	7			✓							
	8			✓							
	9			✓							
	10			✓							
	11			✓							
	12			✓							
	13			✓							
	14			✓							
	15		✓	✓							
	16		✓	✓							
	17		✓	✓							
	18		✓	✓							
	19	✓	✓	✓							
	20	✓	✓	✓							
	21		✓	✓							
	22		✓	✓							
	23		✓	✓							
	24	✓	✓	✓							
	25			✓							
	26			✓							
	27			✓							
	28			✓							
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Search Notes	Application/Control No.	Applicant(s)/Patent under Reexamination
	10/991,774	COHN ET AL.
	Examiner	Art Unit
	HYDER ALI	3747

SEARCHED			
Class	Subclass	Date	Examiner
123	1A	4/17/2006	HA
123	198A	4/17/2006	HA
123	525	4/17/2006	HA
123	25A	4/17/2006	HA
123	25J	4/17/2006	HA
123	435	9/19/06	HA
123	575	9/19/06	HA
123	406.29	9/19/06	HA
123	406.47	9/19/06	HA
UPDATED		9/19/06	HA
UPDATED		12/12/06	HA

INTERFERENCE SEARCHED			
Class	Subclass	Date	Examiner

SEARCH NOTES (INCLUDING SEARCH STRATEGY)		
	DATE	EXMR
SEARCHED EAST SEE EAST SEARCH PRINT OUT.	4/17/2006	HA

U.S. Patent and Trademark Office

Part of Paper No. 20060414

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

Bib Data Sheet

CONFIRMATION NO. 8282

SERIAL NUMBER	FILING DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/991,774	11/18/2004 RULE	123	3747	0492611-0598

APPLICANTS

Daniel R. Cohn, Chestnut Hill, MA;

Leslie Bromberg, Sharon, MA;
John B. Heywood, Newton, MA;

** CONTINUING DATA ********** NONE

** FOREIGN APPLICATIONS ********** NONE

IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** SMALL ENTITY **
** 03/01/2005

Foreign Priority claimed	STATE OR COUNTRY	SHEETS DRAWING	TOTAL CLAIMS	INDEPENDENT CLAIMS
35 USC 119 (a-d) conditions met / Verified and Acknowledged (Examiner's Signature / Initials)	MA	3	56	2

ADDRESS
24280
CHOATE, HALL & STEWART LLP
TWO INTERNATIONAL PLACE
BOSTON , MA
02110

TITLE
Fuel management system for variable ethanol octane enhancement of gasoline engines

FILING FEE RECEIVED	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:	
1312		☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other ☐ Credit

PATENT APPLICATION FEE DETERMINATION RECORD
Effective October 1, 2004

Application or Docket Number: 10991774

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)
TOTAL CLAIMS	23	
FOR	NUMBER FILED	NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	23 minus 20=	* 3
INDEPENDENT CLAIMS	2 minus 3 =	*
MULTIPLE DEPENDENT CLAIM PRESENT		☐

* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY TYPE ☐	RATE	FEE	OR	OTHER THAN SMALL ENTITY	RATE	FEE
	BASIC FEE	395.00	OR		BASIC FEE	790.00
	X$ 9=	27	OR		X$18=	
	X44=		OR		X88=	
	+150=		OR		+300=	
	TOTAL	422	OR		TOTAL	

CLAIMS AS AMENDED - PART II

AMENDMENT A (Column 1) (Column 2) (Column 3)

	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA
Total	* 53	Minus	** 23	* 33
Independent	* 2	Minus	*** 9	* 0
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

SMALL ENTITY	RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY	RATE	ADDITIONAL FEE
	X$ 9=	85	OR		X$18=	
	X44=		OR		X88=	
	+150=		OR		+300=	
	TOTAL ADDIT. FEE	85	OR		TOTAL ADDIT. FEE	

1 21

7-10-06

AMENDMENT B (Column 1) (Column 2) (Column 3)

	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA
Total	* 52	Minus	** 53	* —
Independent	* 3	Minus	*** 5	* —
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

	RATE	ADDITIONAL FEE	OR		RATE	ADDITIONAL FEE
	X$ 9=		OR		X$18=	
	X44=		OR		X88=	
	+150=		OR		+300=	
	TOTAL ADDIT. FEE		OR		TOTAL ADDIT. FEE	

11-30-06

AMENDMENT C (Column 1) (Column 2) (Column 3)

	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA
Total	* 4	Minus	**	*
Independent	* 4	Minus	***	*
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

	RATE	ADDITIONAL FEE	OR		RATE	ADDITIONAL FEE
	X$ 9=		OR		X$18=	
	X44=		OR		X88=	
	+150=		OR		+300=	
	TOTAL ADDIT. FEE		OR		TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

FORM PTO-875 (Rev. 10/04) — Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE

Index of Claims

Application No.	Applicant(s)
10991774	
Examiner	**Art Unit**

√	Rejected	–	(Through numeral) Cancelled	N	Non-Elected	A	Appeal
=	Allowed	+	Restricted	I	Interference	O	Objected

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CHOATE

CHOATE HALL & STEWART LLP

Fax

Recipient	Company	Fax	Phone
Commissioner for Patents	USPTO	571-273-8300	571-272-2600

From	Sam Pasternack	Number of Pages	9 (including fax cover sheet)
Date	November 30, 2006	Client Number	0492611-0598
Phone	617-248-5000	Operator	Elizabeth Burke
		Time Sent	

Comments

Applicant: Cohn, et al.
Examiner: Hyder Ali
Serial No.: 10/991,774
Art Unit: 3747
Filing Date: November 18, 2004
Title: **FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES**

Transmitted herewith for filing in the above-referenced application, please find the following documents:

1) Amendment After Final Action (8 pages); and
2) This Transmittal (1 page).

Applicants believe no fees are due at this time. However, Please charge any additional fees or credit any overpayments to our Deposit Account No. 03-1721.

Kindly acknowledge receipt of the attached documents by return facsimile transmission.

Thank you for your kind attention to this request.

Respectfully Submitted,

Sam Pasternack
Reg. No. 29,576

Return by Inter-office Mail Hold for pick-up

Two International Place | Boston MA 02110 | t 617-248-5000 | f 617-248-4000 | choate.com

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Attorney Docket No: 0492611-0598

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Cohn, et al.	Examiner:	Hyder Ali
Serial No.:	10/991,774	Art Unit:	3747
Filing Date:	November 18, 2004		

Title: **FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES**

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Certificate of Facsimile Transmission

I certify that this correspondence is being transmitted via facsimile to (mail stop if applicable) Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, via facsimile no. 571-273-8300

November 30, 2006 — Date

Signature

Elizabeth Burks

Typed or Printed Name of person signing certificate

AMENDMENT AFTER FINAL ACTION

In response to the Office Action mailed September 27, 2006 finally rejecting the pending claims, it is requested that this amendment be entered and the application allowed:

Amendments to the Claims are reflected in the listing of claims that begins on page 2 of this paper.

Remarks begin on page 7 of this paper.

4149358v1

Amendment to the Claims

Claims 1-56 cancelled.

Claim 57. (New) A turbocharged, spark ignition engine which uses port fuel injection of gasoline from a first source in addition to direct fuel injection of liquid denatured ethanol from a second source comprising:

a spark ignition engine;

a turbocharger;

means for port fuel injection of gasoline from the first source;

means for direct fuel injection of liquid denatured ethanol from the second source;

wherein during part of engine operating time, the engine is powered both by gasoline that is port fuel injected and ethanol that is directly injected; and

wherein during part of the operating time the instantaneous ethanol energy fraction is at least 20%; and

wherein the ethanol is directly injected in an amount such that the evaporative cooling of the fuel/air charge by the directly injected ethanol combined with the higher octane number of the ethanol enhances the octane number by at least 20 octane numbers; and

a fuel management system including a microprocessor which increases the ethanol energy fraction with increasing torque so that it is sufficient to prevent knock; and

wherein the fuel management system uses closed loop control with information from a knock detector to vary the ethanol energy fraction when the instantaneous ethanol fraction is at least 20%; and

wherein the fuel management system minimizes the ethanol use by using information from the knock detector; and

wherein the turbocharged direct injection spark ignition engine is operated at a substantially stoichiometric air/fuel ratio; and

wherein the fuel management microprocessor uses information about the ethanol level in the second source to control the turbocharger; and

wherein the turbocharging is eliminated or reduced when there is no ethanol in the second source; and

wherein a vehicle with this spark ignition engine can be operated on port fuel injected gasoline alone without knock.

Claim 58. (New) A turbocharged, spark ignition engine which uses port fuel injection of gasoline from a first source in addition to direct fuel injection of liquid denatured ethanol from a second source comprising:

a spark ignition engine;

a turbocharger;

means for port fuel injection of gasoline from the first source;

means for direct fuel injection of liquid denatured ethanol from the second source;

wherein during part of the engine operating time, the engine is powered both by gasoline that is port fuel injected and ethanol that is directly injected; and

wherein during part of the operating time the instantaneous ethanol energy fraction is at least 20%; and

wherein the ethanol is directly injected in such an amount that the evaporative cooling of the fuel/air charge by the directly injected ethanol combined with the higher octane number of the ethanol enhances the octane number by at least 20 octane numbers; and

a fuel management system including a microprocessor which increases the ethanol energy fraction with increasing torque so that it is sufficient to prevent knock; and

wherein the fuel management system uses the combination of open loop control using a look up table and closed loop control using a knock detector to vary the ethanol energy fraction; and

wherein the fuel management system minimizes the ethanol use by using information from the knock detector; and

wherein the turbocharged direct injection spark ignition engine is operated at a substantially stoichiometric air/fuel ratio; and

wherein the fuel management microprocessor uses information about the level of ethanol in the second source to control the turbocharger; and

and further wherein the turbocharging is eliminated or reduced when there is no ethanol in the second source; and

wherein a vehicle using this engine can be operated on port fueled gasoline alone without knock; and

further wherein liquid ethanol is directly injected in an amount such that the turbocharged spark ignition engine is operated without knock at a horsepower level which is at least twice the horsepower level without knock as is the case when it is when operated with port fuel injected gasoline alone.

Claim 59. (New) A turbocharged, spark ignition engine which uses port fuel injection of gasoline from a first source in addition to direct fuel injection of liquid denatured ethanol from a second source comprising:

a spark ignition engine;

a turbocharger;

means for port fuel injection of gasoline from the first source;

means for direct injection of liquid denatured ethanol from the second source;

wherein during part of the engine operating time, the engine is powered both by gasoline that is port fuel injected and ethanol that is directly injected; and

wherein during part of the operating time the instantaneous ethanol energy fraction is at least 20%; and

wherein the ethanol is directly injected in an amount such that the evaporative cooling of the fuel/air charge by the directly injected ethanol combined with the higher octane number of the ethanol enhances the octane number by at least 20 octane numbers; and

a fuel management system including a microprocessor which increases the ethanol energy fraction with increasing torque so that it is sufficient to prevent knock; and

wherein the fuel management system uses the combination of open loop control using a look up table and closed loop control using a knock detector to vary the ethanol energy fraction; and

wherein the fuel management system minimizes ethanol use by using information from the knock detector; and

wherein the turbocharged direct injection spark ignition engine is operated at a substantially stoichiometric air/fuel ratio; and

wherein the fuel management system microprocessor uses information about the level of ethanol in the second source to control the turbocharger;

and further wherein the turbocharging is eliminated or reduced when there is no ethanol in the second source; and

wherein a vehicle using this engine can be operated on port fueled gasoline alone without knock; and

wherein the fuel management microprocessor uses information about the level of the ethanol in the second source to control spark retard; and

where the spark retard is increased when there is no ethanol in the second source; and

further wherein liquid ethanol is directly injected in an amount such that the turbocharged spark ignition engine is operated without knock at a horsepower level which is at least twice the horsepower level without knock than is the case when it is when operated with port fuel injected gasoline alone.

Claim 60. (New) A turbocharged spark ignition engine which uses port fuel injection of gasoline from a first source in addition to direct injection of liquid denatured ethanol from a second source comprising:

a spark ignition engine;

a turbocharger;

means for port fuel injection of gasoline from the first source;

means for direct injection of liquid denatured ethanol from the second source;

wherein during part of the engine operating time, the engine is powered by a fuel that consists of both gasoline that is port fuel injected and ethanol that is directly injected; and

wherein under some operating conditions the instantaneous ethanol energy fraction is at least 20%; and

wherein the ethanol is directly injected in an amount such that the evaporative cooling of the fuel/air charge by the directly injected ethanol combined with the higher octane number of the ethanol enhances the octane number by at least 20 octane numbers; and

a fuel management system including a microprocessor which increases the ethanol energy fraction with increasing torque so that it is sufficient to prevent knock; and

wherein the fuel management system uses a combination of open loop control with a look up table and closed loop control using a knock sensor to control the ethanol energy fraction; and

wherein the open loop control uses a predetermined correlation between a required octane enhancement and the fraction of the fuel provided by ethanol;

wherein the fuel management system minimizes the ethanol use by using information from the knock sensor; and

wherein the turbocharged direct injection spark ignition engine is operated at a substantially stoichiometric air /fuel ratio;

wherein the fuel management microprocessor uses information about the level of ethanol in the second source to control the turbocharger;

and further wherein the turbocharging is eliminated or reduced when there is no ethanol in the second source; and

wherein a vehicle using this spark ignition engine can be operated on port fueled gasoline alone without knock; and

wherein the fuel management microprocessor uses information about the level of the ethanol in the second source to control spark retard; and

wherein the spark retard is increased when there is no ethanol in the second source; and

wherein the fuel management system includes a measure of the ethanol in the second source to control turbocharging when the amount of ethanol is low; and

wherein the fuel management system includes a measure of the ethanol in the second source to control spark retard when the amount of ethanol is low;

further wherein liquid ethanol is directly injected in an amount such that the turbocharged spark ignition engine operates without knock at a horsepower level which is at least twice the horsepower level without knock which is the case when operated with port fuel injected gasoline alone; and

wherein the engine can be operated on the denatured ethanol alone; and

wherein the ethanol fraction needed to prevent knock is reduced by concentrating the ethanol in regions that make up the end -gas and are prone to auto-ignition;

wherein the ethanol is injected so as to place the ethanol near the walls of the engine cylinder; and

wherein swirl is used to create a ring of ethanol near the walls of the cylinder; and

wherein the ethanol is mixed with a lubricant.

Remarks

It is requested that the foregoing Amendment be entered and considered.

The undersigned attorney and one of the inventors, Dr. Daniel Cohn, wish to thank examiner Ali for according them a telephone interview of sufficient length to discuss this application and a related application. The undersigned also wishes to thank examiner Cronin for a short telephone interview to address a potential 35 USC §112, 2nd paragraph issue. It is submitted that the foregoing Amendments place this application into condition for allowance.

During the interview with examiner Ali, applicants discussed Claims 57-60 forming this Amendment in relation to the cited prior art. The applicants pointed out that many of the limitations in the newly presented claims distinguish over the prior art. For example, applicants pointed out that the claims now require "means for port fuel injection of gasoline from the first source" and "means for direct fuel injection of liquid denatured alcohol from the second source." The applicants pointed out that none of the prior art references, alone or in combination, teach or suggest the combination of port fuel injection of gasoline along with direct fuel injection of liquid denatured ethanol. Other limitations that distinguish these claims from the prior art were also mentioned.

After examiner Ali asked questions concerning the teachings in the prior art, he indicated that these claims distinguish over the references. At this point, examiner Ali indicated that there could be 35 USC §112, 2nd paragraph issues raised by the claims. Examiner Ali suggested that we discuss any potential 112, 2nd paragraph, issues with his supervisor, Mr. Cronin.

During a telephone interview with Mr. Cronin, Applicant agreed that the preamble was not as clear as it could be. The undersigned suggested changing the beginning of the preamble to recite "a turbocharged spark ignition engine." The undersigned proposed making the first limitation consistent with the preamble by reciting a spark ignition engine. Examiner Cronin stated that those changes would eliminate the 35 USC §112, 2nd paragraph issues.

In response to the telephone interviews, pending Claims 1-56 have been cancelled herein and replaced with new claims 57-60. Based on the telephone interviews with examiners Ali and Cronin, it is submitted that these claims are in condition for allowance and early favorable action is requested.

Respectfully submitted,
CHOATE, HALL & STEWART LLP

Sam Pasternack
Registration No. 29,576

Patent Department
CHOATE, HALL & STEWART, LLP
Two International Place
Boston, MA 02110
Tel: (617) 248-5000
Fax: (617) 248-4000

Dated: November 30, 2006

4149358v1

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/991,774	11/18/2004	Daniel R. Cohn	0492611-0598	8282

24280 7590 09/27/2006

CHOATE, HALL & STEWART LLP
TWO INTERNATIONAL PLACE
BOSTON, MA 02110

EXAMINER	
ALI, HYDER	

ART UNIT	PAPER NUMBER
3747	

DATE MAILED: 09/27/2006

Please find below and/or attached an Office communication concerning this application or proceeding.

PTO-90C (Rev. 10/03)

Office Action Summary	Application No.	Applicant(s)	
	10/991,774	COHN ET AL.	
	Examiner	Art Unit	
	HYDER ALI	3747	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *10 July 2006*.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-16,18-20 and 24-56* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-16,18-20 and 24-56* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *18 November 2004* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date *7/10/06*.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

Inventorship

This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

Claim Objections

The subject matter of independent claim 30 such as "engine torque is above a selected fraction of maximum torque" must be shown or cancelled.

The subject matter of claim 2, such as "the injectors deposit the anti-knock agent to provide non-uniform deposition within a cylinder" must be shown or cancelled.

The subject matter of claim 3, such as "the anti-knock agent is deposited near the walls of the cylinder" must be shown or cancelled.

The subject matter of claim 9, such as "ethanol is mixed with water" must be shown or cancelled.

The subject matter of claim 10, such as "ethanol is mixed with a lubricant" must be shown or cancelled.

The subject matter of claim 11, such as "the engine has substantial organized motion such as swirl" **should read** "the engine has substantial organized motion".

The subject matter of claim 15, such as "the gasoline is directly injected into the cylinder" must be shown or cancelled.

The subject matter of dependent claims 12,19,45,50,55,56 such as "turbocharging and /or supercharging" is not clear because independent claims 1 and 30 are not a turbocharged and/or supercharged engine.

The subject matter of claim 20, such as "swirl creates a ring of ethanol" must be shown or cancelled.

The subject matter of claim 53,54, such as "torque and/or horsepower" must be shown or cancelled.

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

1. Claims 1-3,5,7,8,12-16,18,19,24-36,38-40,45-56 are rejected under 35 U.S.C. 103(a) as being unpatentable over Watanabe et al (US 6,513,505) in view of Jessel (US 4,541,383).

Watanabe et al discloses fuel management system for operation of a spark ignition gasoline engine comprising: a gasoline engine; a source of a liquid fuel anti-knock agent

9; an injector 2 for direct injection of the liquid fuel anti-knock agent into a cylinder of the engine for vaporization in the cylinder to provide charge cooling; and a fuel management control system 30 including a microprocessor for controlling injection of the liquid fuel anti-knock agent into the cylinder; wherein the fuel management control system microprocessor substantially minimizes (**See Fig. 4 for the control of the duty ratio D of the control valve 15when D=D0 which is maximum 100% alcohol; when D=D1 which is smaller than 100% alcohol; when D=D2 which is also smaller than 100% alcohol. See Fig. 5 for a routine for calculating the duty ratio D of the control valve 15. This routine is executed every predetermined time by interruption. Col. 5, lines 45-66 and col. 6, lines 1-27**) the amount of anti-knock agent used over a drive cycle.

Assuming it is not inherent in the **Watanabe et al** patent that injecting anti-knock agent into the engine is for controlling engine knock during heavy load and/or during low rpm and/or when engine torque is above a selected fraction of maximum torque to control knock.

Also assuming control of the duty ratio D in the **Watanabe et al** patent is not for minimizing anti-knock agent.

Jessel discloses operating engines by injecting small, but effective, quantities of anti-knock agent into the engine in response both to detected knock and engine load conditions. When knock is detected, such small quantities of anti-knock agent are injected at rates and for time periods dependent upon the engine load condition, as measured by a quantity representative of mass airflow to the engine. **See col. 1, lines**

12-18. Jessel discloses a system for modulating or regulating the amount of anti-knock additive in relation to actual engine load condition causing engine knock. **See col. 2, lines 27-30. Jessel** discloses alcohol injector 48; controller 32; manifold pressure sensor 37; knock detector 30. Jessel also discloses a fuel management control system for controlling injection of the liquid ethanol into the cylinder when engine torque is above a selected fraction of maximum torque to control knock.

It would have been obvious to a person having an ordinary skill in the art to modify **Watanabe et al** by employing operating engines by injecting small, but effective, quantities of anti-knock agent into the engine in response both to detected knock and engine load conditions as taught by **Jessel.** Motivation to do so would have been to minimize anti-knock agent during the drive cycle while preventing engine knocking.

With regard to claim 2, Watanabe et al discloses the injectors will deposit the anti-knock agent to provide non-uniform deposition within cylinders.

With regard to claim 3, Watanabe et al discloses the anti-knock agent is deposited near the walls of the cylinders.

With regard to claim 5, Watanabe et al discloses anti-knock agent is alcohol.

With regard to claim 7, Jessel discloses wherein the gasoline engine includes a knock sensor 30 providing a feedback signal to a fuel management microprocessor to minimize the amount of the anti-knock agent added to prevent knock in a closed loop fashion.

With regard to claim 8, Watanabe et al discloses anti-knock agent is alcohol such as ethanol.

With regard to claims 12,19,45,50,55,56 wherein turbocharging or supercharging are reduced or eliminated and/or spark retard is increased when the anti-knock agent is not available **(inherently and necessary present in Watanabe et al patent and/or Jessel patent and/or obvious matter of design choice and/or turbocharging or supercharging should be cancelled because independents claims 1,30 are not turbocharged and/or supercharged engine).**

With regard to claim 13, Jessel discloses the high octane fuel is added only during portions of a drive cycle requiring knock resistance.

With regard to claim 14, Jessel discloses wherein gasoline is port injected into the engine.

With regard to claim 15, Watanabe et al discloses wherein the gasoline is directly injected into the cylinder.

With regard to claims 16 and 47, wherein the direct injection of ethanol provides substantially a 13 degrees Celsius drop in temperature for every 10% of fuel energy provided by the ethanol (optional design choice if it is not inherently and necessary present in Watanabe et al patent).

With regard to claim 48, Jessel discloses wherein the fuel management system substantially minimizes the amount of anti-knock agent used over a drive cycle.

With regard to claims 18 and 49, wherein an octane enhancement of at least 4 octane numbers is obtained when 20% of the fuel energy in a cylinder comes from ethanol (optional design choice if it is not inherently and necessary present in Jessel patent and/or Watanabe et al patent).

With regard to claims 24,51, Watanabe et al and Jessel both discloses wherein the engine is operated with substantially a stoichiometric air/fuel ratio.

With regard to claim 25, Jessel discloses wherein the alcohol such as ethanol is added only during portions of the drive cycle requiring knock resistance and its use is minimized during those times.

With regard to claims 26,52, Watanabe et al discloses wherein the ethanol is separated from a gasoline/alcohol (ethanol) mixture.

With regard to claim 27, wherein torque of the engine at which knock occurs can be increased by at least a factor of two by the direct injection of ethanol (optional design choice if it is not inherently and necessary present in Watanabe et al patent).

With regard to claim 28, wherein horsepower of a given size engine can be at least doubled by using alcohol (ethanol) octane enhancement (optional design choice if it is not inherently and necessary present in Watanabe et al patent).

With regard to claim 29, wherein gasoline consumption is reduced by at least 20% due to higher efficiency engine operation (optional design choice if it is not inherently and necessary present in Watanabe et al patent).

With regard to claim 30, **as discussed above**, Jessel discloses injecting ethanol into the engine when engine torque is above a selected fraction of maximum torque to control knock and Watanabe et al discloses direct injection of the ethanol into the cylinder of an engine.

With regard to claim 31, Jessel discloses wherein torque levels at which the ethanol is directly injected are those where knock would occur absent the ethanol injection.

With regard to claim 32, combining the teaching of Watanabe et al and Jessel discloses wherein the fraction of total fuel provided by the directly injected ethanol increases with increasing torque.

With regard to claim 33, Jessel discloses wherein gasoline is port fuel injected.

With regard to claim 34, both Watanabe et al and Jessel discloses wherein up to and including substantially 100% of the fuel can be **(intended use and/or functional language)** provided by the ethanol.

With regard to claim 35, both Watanabe et al and Jessel discloses wherein octane number is enhanced with increasing torque.

With regard to claim 36, wherein an octane enhancement of more than 20 octane numbers is achieved (optional design choice if it is not disclose by Watanabe et al patent and/or Jessel patent).

With regard to claim 38, Jessel wherein the gasoline engine includes a knock sensor 30 providing a feedback signal to a fuel management microprocessor to minimize the amount of the anti-knock agent added to prevent knock in a closed loop fashion.

With regard to claim 39, Watanabe et al discloses wherein the injectors 2 provide non-uniform deposition of the ethanol within a cylinder.

With regard to claim 40, Watanabe et al discloses wherein the ethanol is deposited near the walls of the cylinder.

With regard to claim 46, Watanabe et al discloses wherein the gasoline is directly injected into the cylinder.

With regard to claim 53, Watanabe et al discloses wherein the engine can be operated with only gasoline and knock can be avoided by reducing the maximum torque and horsepower relative to values when alcohol (ethanol) is directly injected into the cylinder.

With regard to claim 54, both Watanabe et al and Jessel discloses wherein the horsepower is reduced by at least a factor of two.

2. Claims 4,11,20,41,44 are rejected under 35 U.S.C. 103(a) as being unpatentable over Watanabe et al (US 6,513,505) in view of Jessel (US 4,541,383) as applied to claims 1-3,5,7,8,12-16,18,19,24-36,38-40,45-56 above, and further in view of Nakakita et al (US 6,799,551).

Watanabe et al in view of Jessel does not disclose swirl in the combustion chamber. Nakakita et al discloses as shown in FIG. 2 a state of the vertically stratified intake gas charge consisting of the swirl flows of the first and second intake gases 11,12 of different compositions. See col. 5, lines 5-10.

It would have been obvious to one of ordinary skill in the art at the time of the invention was made to further modify the invention of Watanabe et al by employing swirl in the combustion chamber as taught by Nakakita et al in order to provide Watanabe et al engine combustion chamber with non-uniform depositon of fuel.

3. Claims 6,37 are rejected under 35 U.S.C. 103(a) as being unpatentable over Watanabe et al (US 6,513,505) in view of Jessel (US 4,541,383) as applied to

claims 1-3,5,7,8,12-16,18,19,24-36,38-40,45-56 above, and further in view of Uhl et al (US 6,892,691).

Watanabe et al in view of Jessel does not disclose control apparatus with a microprocessor which has a program stored in a storage medium, which program is suited to carry out the entire control (**open loop**) of the engine.

Uhl et al discloses control apparatus 16 with a microprocessor which has a program stored in a storage medium, which program is suited to carry out the entire control (open loop) of the engine 1. See col. 3, lines 31-55.

It would have been obvious to one of ordinary skill in the art at the time of the invention was made to further modify the invention of Watanabe et al by employing open loop control as taught by Uhl et al in order to provide Watanabe et al engine control apparatus with a microprocessor which has a program stored in a storage medium, which program is suited to carry out the entire control (open loop) of the engine.

4. **Claims 9,10,42,43 are rejected under 35 U.S.C. 103(a) as being unpatentable over Watanabe et al (US 6,513,505) in view of Jessel (US 4,541,383) as applied to claims 1-3,5,7,12-16,18,19,24-36,38-40,45-56 above, and further in view of Fosseen (US 4,958,598).**

Watanabe et al in view of Jessel does not disclose ethanol is mixed with water as claimed in claims 9 and/or 42 and/or ethanol is mixed with lubricant as claimed in claims 10 and/or 43.

Fosseen discloses a mixture of water and ethanol, in the ratio to provide approximately

an eighty proof mixture, and a small amount of water-soluble oil, is held in a reservoir or fuel tank.. **See col. 2, lines 34-37.**

It would have been obvious to one of ordinary skill in the art at the time of the invention was made to further modify the invention of Watanabe et al by employing ethanol is mixed with water and/or oil as taught by Fosseen in order to replace the ethanol of Watanabe et al patent with a mixture of ethanol and water and/or mixture of ethanol, water and oil.

Response to Arguments

Applicant's arguments with respect to claims 1-16,18-20,24-56 have been considered but are moot in view of the new ground(s) of rejection.

Conclusion

Applicant's amendment necessitated the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL.** See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of

the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to HYDER ALI whose telephone number is (571) 272-4836. The examiner can normally be reached on M-F (8:30-5:00). The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status Information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

Hyder Ali

ha

STEPHEN K. CRONIN
SUPERVISORY PATENT EXAMINER

Substitute for form 1449A/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 1 of

Complete if Known	
Application Number	10/991,774
Filing Date	November 18, 2004
First Named Inventor	Daniel R. Cohn, et al.
Art Unit	1714
Examiner Name	Ali, Hyder
Attorney Docket Number	0492611-0598

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
HA		US 6,990,956 B2	01/31/2006	Niimi	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]-Number[4]-Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
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Examiner Signature	/Hyder Ali/	Date Considered	07/21/2006

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1] Applicant's unique citation designation number (optional). [2] See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3.) [4] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached.

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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Notice of References Cited	Application/Control No. 10/991,774	Applicant(s)/Patent Under Reexamination COHN ET AL.	
	Examiner HYDER ALI	Art Unit 3747	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6,513,505	02-2003	Watanabe et al.	123/525
*	B	US-4,541,383	09-1985	Jessel, Alfred J.	123/435
*	C	US-6,799,551	10-2004	Nakakita et al.	123/295
*	D	US-6,892,691	05-2005	Uhl et al.	123/198A
*	E	US-4,958,598	09-1990	Fosseen, Dwayne	123/1A
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NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
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*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

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Bib Data Sheet

CONFIRMATION NO. 8282

SERIAL NUMBER	FILING DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/991,774	11/18/2004 RULE	123	3747	0492611-0598

APPLICANTS

Daniel R. Cohn, Chestnut Hill, MA;

Leslie Bromberg, Sharon, MA;
John B. Heywood, Newton, MA;

** CONTINUING DATA ********** NONE

** FOREIGN APPLICATIONS ********** NONE

IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** SMALL ENTITY **
** 03/01/2005

Foreign Priority claimed	STATE OR COUNTRY	SHEETS DRAWING	TOTAL CLAIMS	INDEPENDENT CLAIMS
35 USC 119 (a-d) conditions met / Verified and Acknowledged (Examiner's Signature / Initials)	MA	3	56	2

ADDRESS
24280
CHOATE, HALL & STEWART LLP
TWO INTERNATIONAL PLACE
BOSTON , MA
02110

TITLE
Fuel management system for variable ethanol octane enhancement of gasoline engines

FILING FEE		
RECEIVED 1312	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit

Search Notes	Application/Control No.	Applicant(s)/Patent under Reexamination	
	10/991,774	COHN ET AL.	
	Examiner	Art Unit	
	HYDER ALI	3747	

SEARCHED			
Class	Subclass	Date	Examiner
123	1A	4/17/2006	HA
123	198A	4/17/2006	HA
123	525	4/17/2006	HA
123	25A	4/17/2006	HA
123	25J	4/17/2006	HA
123	435	9/19/06	HA
123	575	9/19/06	HA
123	406.29	9/19/06	HA
123	406.47	9/19/06	HA
UPDATED		9/19/06	HA

INTERFERENCE SEARCHED			
Class	Subclass	Date	Examiner

SEARCH NOTES (INCLUDING SEARCH STRATEGY)		
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Index of Claims

Application/Control No.	Applicant(s)/Patent under Reexamination
10/991,774	COHN ET AL.
Examiner	**Art Unit**
HYDER ALI	3747

√	Rejected	–	(Through numeral) Cancelled	N	Non-Elected	A	Appeal
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Cohn, et al.		
Serial No.:	10/991,774	Examiner:	Ali, Hyder
Filed:	November 18, 2004	Art Unit:	3747
For:	FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES	Atty. Docket:	0492611-0598

CERTIFICATE OF MAILING

I hereby certify that the foregoing document is being deposited with the United States Postal Service, postage prepaid, in an envelope addressed to Mail Stop Amendment, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on July 6, 2006.

Name: Marilyn Murphy

AMENDMENT AND RESPONSE TO OFFICE ACTION

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In response to the Office Action mailed April 25, 2006, please amend the application as follows:

Amendments to the Claims are reflected in the listing of claims which begin on page 2 of this paper.

Remarks begin on page 7 of this paper.

It is not believed that extensions of time or fees for net addition of claims are required, beyond those which may otherwise be provided for in documents accompanying this paper. However, in the event that additional extensions of time are necessary, then such extensions of time are hereby petitioned under 37 C.F.R. § 1.136(a), and any fees required for consideration of this paper (including fees for net addition of claims) are authorized to be charged in the Amendment Transmittal Letter filed herewith.

AMENDMENTS TO THE CLAIMS:

This listing of claims will replace all prior versions and listing of claims in the above-referenced application.

Listing of Claims:

1. (currently amended) Fuel management system for operation of a spark ignition gasoline engine comprising:

a gasoline engine;

a source of ~~an~~ a liquid fuel anti-knock agent;

an injector for direct injection of the liquid fuel anti-knock agent into a cylinder of the engine for vaporization in the cylinder to provide charge cooling; and

a fuel management control system including a microprocessor for controlling injection of the liquid fuel anti-knock agent into the cylinder to control knock wherein the fuel management control system microprocessor substantially minimizes the amount of anti-knock agent used over a drive cycle.

2. (previously presented) The system of claim 1 wherein the injectors deposit the anti-knock agent to provide non-uniform deposition within a cylinder.

3. (original) The system of claim 2 wherein the anti-knock agent is deposited near the walls of the cylinder.

4. (previously presented) The system of claim 2 wherein the non-uniform deposition is obtained through direct injection and charge swirl.

5. (original) The system of claim 1 wherein the anti-knock agent is selected from the group consisting of ethanol, methanol, tertiary butyl alcohol, MTBE, ETBE and TAME.

6. (previously presented) The system of claim 1 wherein the fuel management system includes a microprocessor that operates in an open loop fashion on a predetermined correlation between required octane number enhancement and fraction of fuel provided by the anti-knock agent.

7. (original) The system of claim 1 wherein the gasoline engine includes a knock sensor providing a feedback signal to a fuel management microprocessor to minimize the amount of the anti-knock agent added to prevent knock in a closed loop fashion.

8. (original) The system of claim 1 wherein the anti-knock agent is ethanol.

9. (original) The system of claim 8 wherein the ethanol is mixed with water.

10. (original) The system of claim 8 wherein the ethanol is mixed with a lubricant.

11. (original) The system of claim 1 wherein the engine has substantial organized motion such as swirl.

12. (original) The system of claim 1 wherein the system includes a measure of the amount of anti-knock agent in the source to control turbocharging, supercharging or spark retard when the amount of anti-knock agent is low.

13. (original) The system of claim 1 wherein the anti-knock agent is added only during portions of a drive cycle requiring knock resistance.

14. (original) The system of claim 1 wherein gasoline is port injected into the engine.

15. (original) The system of claim 1 wherein the gasoline is directly injected into the cylinder.

16. (original) The system of claim 8 wherein the direct injection of ethanol provides substantially a 13°C drop in temperature for every 10% of fuel energy provided by the ethanol.

17. (canceled)

18. (original) The system of claim 8 wherein an octane enhancement of at least 4 octane numbers is obtained when 20% of the fuel energy in a cylinder comes from ethanol.

19. (original) The system of claim 1 wherein turbocharging or supercharging are reduced or eliminated and/or spark retard is increased when the anti-knock agent is not available.

20. (original) The system of claim 8 wherein ethanol is injected proximate to a cylinder wall and swirl creates a ring of ethanol.

21-23. (cancelled)

24. (previously presented) The system of claim 8 wherein the engine is operated with substantially a stoichiometric air/fuel ratio.

25. (previously presented) The system of claim 8 wherein the ethanol is added only during portions of the drive cycle requiring knock resistance and its use is minimized during those times.

26. (previously presented) The system of claim 8 wherein the ethanol is separated from a gasoline/ethanol mixture.

27. (previously presented) The system of claim 8 wherein torque of the engine at which knock occurs can be increased by at least a factor of two by the direct injection of ethanol.

28. (previously presented) The system of claim 8 wherein horsepower of a given size engine can be at least doubled by using ethanol octane enhancement.

29. (previously presented) The system of claim 8 wherein gasoline consumption is reduced by at least 20% due to higher efficiency engine operation.

30. (currently amended) Fuel management system for operation of a spark ignition gasoline engine comprising:

a gasoline engine;

a source of liquid ethanol;

an injector for direct injection of the liquid ethanol into a cylinder of the engine for vaporization in the cylinder to provide charge cooling; and

a fuel management control system for controlling injection of the liquid ethanol into the cylinder when engine torque is above a selected fraction of maximum torque to control knock.

31. (previously presented) The system of claim 30 wherein torque levels at which the ethanol is directly injected are those where knock would occur absent the ethanol injection.

32. (previously presented) The system of claim 30 wherein the fraction of total fuel provided by the directly injected ethanol increases with increasing torque.

33. (previously presented) The system of claim 30 wherein gasoline is port fuel injected.

34. (previously presented) The system of claim 30 wherein up to and including substantially 100% of the fuel can be provided by the ethanol.

35. (previously presented) The system of claim 30 wherein octane number is enhanced with increasing torque.

36. (previously presented) The system of claim 30 wherein an octane enhancement of more than 20 octane numbers is achieved.

37. (previously presented) The system of claim 30 wherein the fuel management system includes a microprocessor that operates in an open loop fashion on a predetermined correlation between the required octane number enhancement and fraction of fuel provided by the ethanol.

38. (previously presented) The system of claim 30 wherein the gasoline engine includes a knock sensor providing a feedback signal to a fuel management microprocessor to minimize the amount of the ethanol added to prevent knock in a closed loop fashion.

39. (previously presented) The system of claim 30 wherein the injector provides non-uniform deposition of the ethanol within a cylinder.

40. (previously presented) The system of claim 39 wherein the ethanol is deposited near the walls of the cylinder.

41. (previously presented) The system of claim 39 wherein the non-uniform deposition is obtained through direct injection and charge swirl.

42. (previously presented) The system of claim 30 wherein the ethanol is mixed with water.

43. (previously presented) The system of claim 30 wherein the ethanol is mixed with a lubricant.

44. (previously presented) The system of claim 30 wherein the engine has substantial organized motion such as swirl.

45. (previously presented) The system of claim 30 wherein the system includes a measure of the amount of ethanol available to control turbocharging, supercharging or spark retard when the amount of ethanol is low.

46. (previously presented) The system of claim 30 wherein the gasoline is directly injected into the cylinder.

47. (previously presented) The system of claim 30 wherein the direct injection of ethanol provides substantially a 13°C drop in temperature for every 10% of the fuel energy provided by the ethanol.

48. (previously presented) The system of claim 30 wherein the fuel management system substantially minimizes the amount of ethanol used over a drive cycle.

49. (previously presented) The system of claim 30 wherein an octane enhancement of at least four octane numbers is obtained when 20% of the fuel energy in a cylinder comes from ethanol.

50. (previously presented) The system of claim 30 wherein turbocharging or supercharging are reduced or eliminated and/or spark retard is increased when ethanol is not available.

51. (previously presented) The system of claim 30 wherein the engine is operated with substantially a stoichiometric fuel/air ratio.

52. (previously presented) The system of claim 30 wherein the ethanol is separated from a gasoline/ethanol mixture.

53. (previously presented) The system of claim 30 wherein the engine can be operated with only gasoline and knock can be avoided by reducing the maximum torque and horsepower relative to values when ethanol is directly injected into the cylinder.

54. (previously presented) The system of claim 53 wherein the horsepower is reduced by at least a factor of two.

55. (previously presented) The system of claim 30 wherein the fuel management microprocessor control system uses ethanol level in the ethanol tank as an input to control a turbocharger, supercharger or spark retard.

56. (previously presented) The system of claim 55 wherein the turbocharger, supercharger or spark retard is adjusted to prevent knock.

REMARKS

Re-examination and reconsideration of the rejections are hereby requested.

First of all, the inventors, Daniel Cohn, Leslie Bromberg, and John Heywood, and the undersigned attorney wish to thank Examiner Ali for according them a telephone interview of sufficient length to discuss fully the issues in this prosecution. At the beginning of the interview, Dr. Cohn briefly described the present technology. Dr. Cohn explained that the knock limit in a gasoline engine can be greatly extended by the direct injection of an appropriate liquid fuel anti-knock agent such as ethanol into a cylinder of the engine. The liquid fuel anti-knock agent vaporizes in the cylinder providing a substantial charge cooling effect. The cooling effect along with a higher octane number of an anti-knock agent such as ethanol extends the knock limit so that more aggressive turbo charging can be used and/or the engine can operate at a higher compression ratio without knock. In this way, substantial fuel can be saved because smaller engines can be used. Dr. Cohn explained that the change of state of the liquid fuel anti-knock agent from liquid to gas provides the predominant effect for extending the knock limit. Dr. Cohn also pointed out that in order to achieve commercial attractiveness it is important to obtain a large knock suppression effect in order to justify the inconvenience of using two tanks and two fuels. He further explained that for the same reason it was important to minimize the amount of the liquid fuel anti-knock agent, such as ethanol, that is used over the drive cycle.

At this point in the interview the rejections and references were discussed. The applicants proposed amending claim 1 to recite a liquid fuel anti-knock agent for vaporization in the cylinder to emphasize the importance of direct injection of a liquid fuel anti-knock agent. As to U.S. Patent No. 4,480,616 to Takeda, applicants pointed out that this patent teaches introducing liquid alcohol into the intake manifold of an engine. Professor Heywood explained that the alcohol would vaporize before entering the combustion chamber so could not provide the evaporative cooling as set forth in the claims as amended herein. Thus, Takeda teaches neither direct injection nor the introduction of a liquid fuel into the combustion chamber.

U.S. Patent No. 3,106,194 to Cantwell was discussed next. It was pointed out to the Examiner that alkali metal compounds are vaporized and then introduced into the engine. These alkali metal compounds are not a fuel and are not introduced in the liquid state. The Examiner pointed to Cantwell at column 1 at line 32 suggesting that water is "an auxiliary fuel." Professor Heywood explained that water cannot be considered a fuel notwithstanding Cantwell's characterization. In any event, Cantwell teaches nothing beyond introducing a vaporized material into the combustion chamber rather than a liquid that would not provide the change-of-state cooling effect. Next, the applicant discussed the Krauja et al. reference, U.S. Patent No. 4,721,081. This patent teaches a modified compression ignition engine for use either with 100% ethanol or with gasoline. This reference does not teach the introduction of any anti-knock agent, but rather is designed to operate on 100% ethanol.

The Examiner maintained his position that the references in combination meet the limitations in claim 1. The applicant disagreed suggesting that the examiner was making an impermissible hindsight reconstruction based on the teachings in the present application. No agreement was reached.

The applicant then addressed many of the dependent claims pointing out that the Examiner had no basis for the rejections. At this point, the Examiner indicated that he should have made a restriction requirement when he issued the office action because of a large number of embodiments. The Examiner stated that he would likely give a restriction requirement in the next office action. The undersigned attorney urged the Examiner not to issue a restriction requirement at this time suggesting that the attendant substantial delays could have a serious adverse effect upon the applicant. The undersigned attorney suggested that it would be unfair to penalize the applicant by a post office action reversal in the Examiner's decision as to which claims he would consider. Applicants urged that if the independent claims were not allowable, that the Examiner should consider allowing the dependent claims that are clearly not met by the prior art.

During the interview, the examiner cited two new references, U.S. Patent No. 3,089,470 to Payne, and U.S. Patent No. 4,182,278 to Coakwell. The undersigned attorney has now had an

opportunity to review these references carefully and it is quite clear that the Payne reference does not suggest introducing a liquid fuel into an engine. The Examiner's attention is directed to column 3 beginning at line 15 wherein Payne states that the liquid auto-ignition suppressant "is preferably water" but that it is "to be clearly understood that any other liquid preparation suitable to suppress auto-ignition" is contemplated. The Examiner asserted that this section suggests injecting a liquid fuel. Applicants respectfully disagree. The Examiner has not shown that "any other liquid preparation to suppress auto-ignition" includes any liquid fuel.

As to the Coakwell patent, this reference teaches the addition of hydrogen peroxide to provide additional oxygen. The Examiner's attention is directed to Coakwell at column 9 beginning at line 7 where it is stated that the additional oxygen from the hydrogen peroxide "makes it possible to achieve combustion with leaner mixtures, to save fuel and to reduce air pollution by achieving more complete combustion." Thus, it is quite clear that the hydrogen peroxide is being introduced to provide free oxygen. Hydrogen peroxide is not itself a fuel.

Although Applicants and the Examiner continue to disagree about the patentability of the independent claims, claim 1 has been amended herein to incorporate the limitation of originally filed claim 17 and claim 17 has been cancelled. Thus claim 1 now includes the limitation "wherein the fuel management control system microprocessor substantially minimizes the amount of anti-knock agent used over a drive cycle." This amendment is being introduced in an effort to move prosecution forward. The specification speaks to the importance of minimizing the amount of anti-knock agent used over a drive cycle. For example, the specification beginning on the last line of page 2 states "An object of the present invention is to minimize the amount of ethanol or other anti-knock agent that is used to achieve a given level of engine efficiency increase. By restricting the use of ethanol to the relatively small fraction of time in an operating cycle when it is needed to prevent knock in a high load regime and by minimizing its use at these times, the amount of ethanol that is required can be limited to a relatively small fraction of the fuel used by the spark ignition gasoline engine." Moreover, page 3,beginning on line 23 of the specification states "Alternatively, the gasoline engine may include a knock sensor that provides a feedback signal to the fuel management microprocessor system to minimize the amount of ethanol added to prevent knock in a close loop fashion."

Claim 1 as amended herein (with the limitation of originally filed claim 17) has been examined and the Examiner rejected claim 17 as being unpatentable over Takeda in view of Cantwell. The Examiner states on page 5 of the Office Action "With regard to claim 17, Takeda discloses wherein the fuel management systems substantially minimizes the amount of anti-knock agent used over a drive cycle." The undersigned attorney and the inventors herein have reviewed Takeda carefully and can find no teaching whatsoever that the fuel management system substantially minimizes the amount of anti-knock agent used over a drive cycle. The Applicant remains puzzled at this assertion by the Examiner since Takeda is totally silent in this regard. Further, the undersigned attorney has reviewed all of the references of record including Payne and Coakwell and can find no teaching of a fuel management system that substantially minimizes the amount of anti-knock agent used over a drive cycle. It is urged that claim 1, as amended herein, is clearly in condition for allowance and reconsideration is requested. Claims 2-16, 18-20 and 24-29 ultimately depend from amended claim 1 and are therefore also allowable.

Independent claim 30 has been amended herein to recite a source of liquid ethanol for vaporization in the cylinder to provide charge cooling and to control knock. Claim 30 as originally filed included the limitation of a fuel management control system for controlling injection of the ethanol "when engine torque is above a selected fraction of maximum torque." During the interview, Applicant pointed out that this limitation is not present in the prior art. In the Office Action, the Examiner asserts that this limitation is disclosed by Takeda. Again, the undersigned attorney and the inventors have reviewed Takeda carefully and can find no teaching that injection is controlled "when engine torque is above a selected fraction of maximum torque." Such a teaching, in fact, is totally lacking in Takeda. It is urged that the Examiner review Takeda again and remove this rejection or describe with specificity where and how Takeda provides such a teaching.

During the interview, many of the dependent claims were discussed. For example, claim 4 states that non-uniform deposition is obtained through direct injection and charge swirl. The Examiner states, without support, that Cantwell meets this limitation. In fact, a careful review of Cantwell reveals no teaching whatsoever concerning charge swirl. The Examiner is asked to

remove the rejection of claim 4 or to explain with specificity where and how Cantwell discloses charge swirl.

Dependent claim 6 includes the limitation "wherein the fuel management system includes a microprocessor that operates in an open-loop fashion on a predetermined correlation between required octane number enhancement and fraction of fuel provided by the anti-knock agent." The Examiner asserts, again without support, that Takeda discloses such a limitation. The Examiner is asked to remove the rejection of claim 6 or provide, with specificity, those portions of Takeda that support the Examiner's position.

Claim 7 requires that the gasoline engine include a knock sensor to provide a feedback signal to minimize the amount of anti-knock agent added to prevent knock in a closed-loop fashion. The Examiner rejects this claim as "optional design choice". Reconsideration is requested. Claim 10 recites that the ethanol is mixed with a lubricant. As to this important limitation the Examiner again asserts that it is just an optional design choice. A careful review of the references of record shows no teaching or suggestion of adding a lubricant to the ethanol. Reconsideration is requested. Claim 11 adds the limitation "wherein the engine has substantial organized motion such as swirl." The Examiner asserts, without specifics, that "Takeda discloses engine has substantial organized swirl motion" and a careful review of Takeda shows that it is lacking in any such teaching. The Examiner is asked to remove this rejection of claim 11 or explain with specificity how and where Takeda discloses the organized swirl motion limitation.

Claim 12 includes the limitation "wherein the system includes a measure of the amount of anti-knock agent in the source to control turbocharging, supercharging or spark retard when the amount of anti-knock agent is low." The Examiner asserts that Takeda discloses this limitation. A careful review of Takeda indicates no teaching of such limitation. The Examiner is asked to point out where in Takeda this limitation is taught or suggested.

Claim 19 states that the turbocharging or supercharging are reduced or eliminated and/or spark retard is increased when the anti-knock agent is not available. The Examiner appears to conclude that Takeda includes this limitation. It is submitted that such limitation is not disclosed in Takeda. Claim 20 states that the ethanol is injected so that swirl creates a ring of ethanol. The Examiner, without support, states that Takeda discloses that swirl creates a ring of alcohol. Takeda provides no such teaching. Reconsideration is requested.

As another example of an unfounded rejection, Claim 26 states that the ethanol is separated from a gasoline/ethanol mixture. The Examiner, without support, states that Takeda discloses this limitation. It is submitted that Takeda clearly does not teach or suggest this limitation. With regard to claim 27, the Examiner asserts that Takeda teaches that the torque at which knock occurs can be increased by at least a factor of two by the direct injection of ethanol. It is submitted that such a teaching is lacking in Takeda. The Examiner also, without support, contends that Takeda teaches that horsepower of a given size engine can be at least doubled by using alcohol octane enhancement. It is submitted that Takeda provides no such teaching. The Examiner also states that the limitation in claim 29 concerning the gasoline consumption being reduced by at least 20% is also taught in Takeda. There is no such teaching in Takeda.

The Examiner has rejected the dependent claims depending from claim 30 with similarly sweeping, and unsupported, assertions about the prior art. The Examiner is asked either to remove the rejections of these dependent claims or provide a detailed set of specifics as to how the references meet the limitations in the claims depending claim 30.

In summary, in order to advance prosecution, the limitation of claim 17 has been introduced into claim 1. Claim 30 has been amended to provide more specificity. For the reasons discussed in detail above, it is submitted that the pending claims, as amended herein, are in condition for allowance. Early favorable action is requested.

Respectfully submitted,
CHOATE, HALL & STEWART LLP

Sam Pasternack
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Date: July 6, 2006

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EXHIBIT 7

UNITED STATES PATENT AND TRADEMARK OFFICE

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NOTICE OF ALLOWANCE AND FEE(S) DUE

91197 7590 09/12/2017
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Cambridge, MA 02142-1493

EXAMINER	
HUYNH, HAI H	
ART UNIT	PAPER NUMBER
3747	

DATE MAILED: 09/12/2017

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/463,425	03/20/2017	Daniel R. Cohn	11381.122998	3788

TITLE OF INVENTION: FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$960	$0	$0	$960	12/12/2017

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

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PTOL-85 (Rev. 02/11)

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(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/463,425	03/20/2017	Daniel R. Cohn	11381.122998	3788

TITLE OF INVENTION: FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$960	$0	$0	$960	12/12/2017

EXAMINER	ART UNIT	CLASS-SUBCLASS
HUYNH, HAI H	3747	123-431000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
- ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
- ☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

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1 _____
2
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

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Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☐ Corporation or other private group entity ☐ Government

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- ☐ Applicant asserting small entity status. See 37 CFR 1.27 — NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
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PTOL-85 Part B (10-13) Approved for use through 10/31/2013. OMB 0651-0033 U.S. Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

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Cambridge, MA 02142-1493

EXAMINER
HUYNH, HAI H

ART UNIT	PAPER NUMBER
3747	

DATE MAILED: 09/12/2017

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

PTOL-85 (Rev. 02/11)

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The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

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3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 15/463,425	Applicant(s) COHN ET AL.	
	Examiner HAI HUYNH	Art Unit 3747	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *Terminal Disclaimer filed on 08/08/17*.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on_____.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are *1-30*. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an Inquiry to PPHfeedback@uspto.gov .
4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:
      1. ☐ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☒ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
5. ☐ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☒ Other *response to TD*.

/HAI HUYNH/
Primary Examiner, Art Unit 3747

1. The present application is being examined under the pre-AIA first to invent provisions.

2. Applicant's arguments, see page 1, filed on August 8, 2017, with respect to claims 1-30 have been fully considered and are persuasive.

3. Claims 1-30 are allowed.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to HAI HUYNH whose telephone number is (571)272-4844. The examiner can normally be reached on Monday through Friday from 7:30 am to 6:00 pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Lindsay M. Low can be reached on (571) 272-1196. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/HAI HUYNH/
Primary Examiner, Art Unit 3747

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Not for submission under 37 CFR 1.99)

Application Number	15463425
Filing Date	2017-03-30
First Named Inventor	Daniel R. Cohn et al.
Art Unit	3747
Examiner Name	HUYNH, HAI H
Attorney Docket Number	11381.122996

U.S.PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	4993386		1991-02-19	Ozasa et al.	
	2	6990956		2006-01-31	Nimi	
	3	4480615		1984-11-06	Takeda	
	4	3106194		1963-10-08	Cantwell et al.	
	5	4721081		1988-01-26	Krauja et al.	
	6	6508233		2003-01-21	Suhre, B. et al.	
	7	6076487		2000-06-20	Wulff, J. et al.	
	8	6575147		2003-06-10	Wulff, J. et al.	

/HAI H HUYNH/ 08/28/2017

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	Art Unit	3747
	Examiner Name	HUYNH, HAI H
	Attorney Docket Number	11381.122998

	9	6513505		2003-02-04	Wantanabe et al.	
	10	4541383		1985-09-17	Jesset, A.J.	
	11	6799561		2004-10-05	Nakakita et al.	
	12	6892891		2005-05-17	Uhl et al.	
	13	4958598		1990-09-25	Fosseen, D.	
	14	5497744		1996-03-12	Nagaosa et al.	
	15	5715788		1998-02-10	Tarr et al.	
	16	5983855		1999-11-16	Benedikt et al.	
	17	6073607		2000-06-13	Liber, Bruno	
	18	6340015		2002-01-22	Benedikt, et al.	
	19	6536405		2003-03-25	Rieger et al.	

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	20	6745744		2004-06-08	Suckewer et al.	
	21	6748918		2004-06-15	Rieger et al.	
	22	6755175		2004-06-29	McKay et al.	
	23	6955154		2005-10-18	Douglas, Denis	
	24	7077100		2006-06-18	Vogel et al.	
	25	7086376		2006-08-08	Mckay, Michael	
	26	7086376		2007-04-10	Mckay, et al.	
	27	2741230		1956-04-10	Reynolds, Blake	
	28	3557763		1971-01-26	Probst, Stephen C.	
	29	4031864		1977-11-01	Crothers, William T.	
	30	4056087		1977-11-01	Boyce, Leonard D.	

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	Attorney Docket Number	11381.122998

	31	4230072		1980-10-28	Noguchi et al.	
	32	4312310		1982-01-26	Chivilo' et al.	
	33	4402296		1983-09-06	Schwarz, Walter J.	
	34	4594201		1986-06-10	Phillips et al.	
	35	4967714		1990-11-06	Inoue, Ryuzaburo	
	36	4974416		1990-12-04	Taylor, Jack R	
	37	5179923		1993-01-19	Tsurutani et al.	
	38	5233944		1993-08-10	Mochizuki, Kenji	
	39	5560344		1996-10-01	Chan, Anthony K	
	40	5911210		1999-06-15	Flach, Thomas A	
	41	5937799		1999-08-17	Binion, W. Sidney	

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	Art Unit	3747
	Examiner Name	HUYNH, HAI H
	Attorney Docket Number	11381.122998

	42	6260525		2001-07-17	Moyer, David F.	
	43	6287351		2001-09-11	Wulff et al.	
	44	6298838		2001-10-09	Huff et al.	
	45	6332448		2001-12-25	Ilyama et al.	
	46	6356180		2002-03-19	Kuroda et al.	
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	49	6622683		2003-09-23	Weissman et al.	
	50	6668804		2003-12-30	Dobryden et al.	
	51	6725827		2004-04-27	Ueda et al.	
	52	6951202		2005-10-04	Oda, Tomihisa	

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ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.H.H/

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	First Named Inventor	Daniel R. Cohn et al.
	Art Unit	3747
	Examiner Name	HUYNH, HAI H
	Attorney Docket Number	11381.122998

	53	7021277		2006-04-04	Kuo et al	
	54	7107942		2006-09-19	Weissman et al.	
	55	7156070		2007-01-02	Strom et al	
	56	7188607		2007-03-13	Kobayashi, Tatsuo	
	57	7320302		2008-01-22	Kobayashi, Tatsuo	
	58	3089470		1963-05-14	Payne, W.H.	
	59	4162278		1980-01-08	Coalwell, Charles A.	
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If you wish to add additional U.S. Patent citation information please click the Add button.

U.S.PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1					

If you wish to add additional U.S. Published Application citation information please click the Add button.

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	Examiner Name	HUYNH, HAI H
	Attorney Docket Number	11381-122998

FOREIGN PATENT DOCUMENTS								
Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1							☐

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NON-PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	1	A. MODAK and L. S. CARETTO, Engine Cooling by Direct Injection of Cooling Water, Society of Automotive Engineers, Inc. 700687	☐
	2	JULIAN A. LORUSSO and HARRY A. CIKANEK, Direct Injection Ignition Assisted Alcohol Engine, Society of Automotive Engineers, Inc. 980495, International Congress and Exposition in Detroit, Michigan (February 29-March 4, 1998)	☐
	3	BORJE GRANDIN, HANS-ERIK ANGSTROM, PER STALHAMMAR and ERIC OLOFSSON, Knock Suppression in a Turbocharged SI Engine by Using Cooled EGR, Society of Automotive Engineers, Inc. 962476, International Fall Fuels and Lubricants Meeting and Exposition in San Francisco, California (October 19-22, 1996)	☐
	4	BORJE GRANDIN and HANS-ERIC ANGSTROM, Replacing Fuel Enrichment in a Turbo Charged SI Engine: Lean Burn or Cooled EGR, Society of Automotive Engineers, Inc. 199-01-3505	☐
	5	C. STAN, R. TROEGER, S. GUENTHER, A. STANCIU, L. MARTORANO, C. TARANTINO AND R. LENSI, Internal Mixture Formation and Combustion from Gasoline to Ethanol, Society of Automotive Engineers, Inc. 2001-01-1207	☐
	6	PCT International Search Report and Written Opinion, Appl. No. PCT/US05/041317, April 6, 2006	☐
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/HAI H HUYNH/ 08/28/2017

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	Art Unit	3747
	Examiner Name	HUYNH, HAI H
	Attorney Docket Number	11381.122998

	8	USPTO Notice of Allowance, Application No. 11/684100, March 3, 2009	☐
	9	USPTO Non-Final Office Action, Application NO. 11/850719, July 11, 2008	☐
	10	J.B. HEYWOOD, "Internal Combustion Engine Fundamentals," McGraw-Hill, 1988, page 477	☐
	11	J. STOKES ET AL. "A gasoline engine concept for improved fuel economy - the lean-boost system," SAE paper 2001-01-2902, pp. 1-12.	☐
	12	H.J. CURRAN ET AL., "A comprehensive modeling study of iso-octane oxidation," Combustion and Flame, 129: 253-280, 2002, pp. 253-280	☐
	13	B. LECOINTE AND G. MONNIER, "Downsizing a gasoline engine using turbocharging with direct injection", SAE paper, 2003-01-0542	☐
	14	USPTO Non-Final Office Action, Application No. 10/991774, April 25, 2006	☐
	15	USPTO Final Office Action, Application No. 10/991774, September 27, 2006	☐
	16	USPTO Non-Final Office Action, Application No. 10/991774, May 25, 2007.	☐
	17	USPTO Non-Final Office Action, Application No. 11/100026, August 3, 2006	☐
	18	FIKRET YUKSEL and BEDRI YUKSEL, "The Use of Ethanol-Gasoline Blend as a Fuel in an SI Engine," Renewable Energy, Vol. 29 (2004) pp. 1181-1191.	☐

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/HAI H HUYNH/ 08/28/2017

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	15463426
	Filing Date	2017-03-30
	First Named Inventor	Daniel R. Cohn et al.
	Art Unit	3747
	Examiner Name	HUYNH, HAI H
	Attorney Docket Number	11381.122999

	19	USPTO Non-Final Office Action, Application No. 11/229755, March 22, 2007.	☐
	20	USPTO Non-Final Office Action, Application No. 11/229755, October 4, 2007.	☐
	21	USPTO Non-Final Office Action, Application No. 11/682372, January 2, 2008.	☐
	22	USPTO Final Office Action, Application No. 11/682372, October 17, 2008.	☐
	23	USPTO Non-Final Office Action, Application No. 11/664100, June 3, 2008.	☐
	24	PCT International Search Report and Written Opinion, Application No. PCT/IB07/03004, July 9, 2008.	☐
	25	PCT International Search Report and Written Opinion, Application No. PCT/US07/05777, March 24, 2008.	☐
	26	PCT International Search Report and Written Opinion, Application No. PCT/US07/74227, February 25, 2008.	☐
	27	PCT International Search Report and Written Opinion, Application No. PCT/US08/69171, October 3, 2008.	☐

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature	/HAI H HUYNH/	Date Considered	08/28/2017

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	Filing Date	2017-03-30
	First Named Inventor	Daniel R. Cohn et al.
	Art Unit	3747
	Examiner Name	HUYNH, HAI H
	Attorney Docket Number	11381 122998

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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Application Number	15463425
Filing Date	2017-03-30
First Named Inventor	Daniel R. Cohn et al.
Art Unit	3747
Examiner Name	HUYNH, HAI H
Attorney Docket Number	11381.122998

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2)

☐ See attached certification statement.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☐ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Sam Pasternack/	Date (YYYY-MM-DD)	2017-08-10
Name/Print	Sam Pasternack	Registration Number	29576

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.H.H/

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
SAM PASTERNACK
CHOATE, HALL & STEWART
TWO INTERNATIONAL PLACE
BOSTON, MA 02110

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing (*day/month/year*) 09 JUL 2008
Applicant's or agent's file reference 2006734-0002	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/IB07/03004	International filing date (*day/month/year*) 06 March 2007 (06.03.2007)
Applicant ETHANOL BOOSTING SYSTEMS, LLC	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: (41-22) 338.82.70.

   For more detailed instructions, see the notes on the accompanying sheet.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to the protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:**

   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

   The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

   In respect of other designated Offices, the time limit of**30 months** (or later) will apply even if no demand is filed within 19 months.

   See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the ISA/ US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Authorized officer Stephen K Cronin Telephone No. (571) 272-4383

Form PCT/ISA/220 (January 2004) *(See notes on accompanying sheet)*

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 2006734-0002	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below
International application No. PCT/IB07/03004	International filing date (*day/month/year*) 06 March 2007 (06.03.2007)	(Earliest) Priority Date (*day/month/year*) 08 March 2006 (08.03.2006)
Applicant ETHANOL BOOSTING SYSTEMS. LLC		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 2 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the Report**
   a. With regard to the language, the international search was carried out 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))
   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 Rule 43.6 *bis(a)*
   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.
2. ☐ **Certain claims were found unsearchable** (See Box No. II)
3. ☐ **Unity of invention is lacking** (See Box No. III)
4. With regard to the title,
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,
   a. the figure of the **drawings** to be published with the abstract is Figure No. 1
      ☐ as suggested by the applicant.
      ☒ as selected by this Authority, because the applicant failed to suggest a figure.
      ☐ as selected by this Authority, because this figure better characterizes the invention.
   b. ☐ none of the figures is to be published with the abstract.

Form PCT/ISA/210 (first sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB07/03004

A. CLASSIFICATION OF SUBJECT MATTER
IPC: F02M 17/00(2006.01)

USPC: 123/447
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)
U.S. : 123/447

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)
EAST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2005/0056264 A1, (WEISSMAN et al) 17 March 2005, Figure 2, claim 11,	1-15
A	US 5,560,344 A (CHAN) 1, October 1996 (01.10.1996), whole document	1-15

☐ 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 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	Date of mailing of the international search report
08 June 2008 (08.06.2008)	09 JUL 2008
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Authorized officer Stephen K Cronin Telephone No. (571) 272-4383

Form PCT/ISA/210 (second sheet) (April 2007)

PATENT COOPERATION TREATY

FILE COPY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
SAM PASTERNACK
CHOATE, HALL & STEWART
TWO INTERNATIONAL PLACE
BOSTON, MA 02110

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing (*day/month/year*)
Applicant's or agent's file reference 2006734-0002	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/IB07/03004	International filing date (*day/month/year*) 06 March 2007 (06.03.2007)
Applicant ETHANOL BOOSTING SYSTEMS, LLC	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: (41-22) 338.82.70.

   For more detailed instructions, see the notes on the accompanying sheet.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to the protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:**

   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

   The applicant may submit comments, on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later); otherwise, the applicant must, within **20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

   In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

   See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the ISA/ US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Authorized officer Stephen K Cronin Telephone No. (571) 272-4383

Form PCT/ISA/220 (January 2004) *(See notes on accompanying sheet)*

PATENT COOPERATION TREATY FILE COPY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 2006734-0002	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/IB07/03004	International filing date (*day/month/year*) 06 March 2007 (06.03.2007)	(Earliest) Priority Date (*day/month/year*) 08 March 2006 (08.03.2006)
Applicant ETHANOL BOOSTING SYSTEMS, LLC		

This International search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of _____ sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the Report**
   a. With regard to the language, the international search was carried out 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))
   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 Rule 43.6 *bis(a)*
   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.
2. ☐ **Certain claims were found unsearchable** (See Box No. II)
3. ☐ **Unity of Invention is lacking** (See Box No. III)
4. With regard to the **title**,
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,
   a. the figure of the drawings to be published with the abstract is Figure No. 1
      ☐ as suggested by the applicant.
      ☒ as selected by this Authority, because the applicant failed to suggest a figure.
      ☐ as selected by this Authority, because this figure better characterizes the invention.
   b. ☐ none of the figures is to be published with the abstract.

Form PCT/ISA/210 (first sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB07/03004

A. CLASSIFICATION OF SUBJECT MATTER
IPC: F02M 17/00(2006.01)

USPC: 123/447
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)
U.S. : 123/447

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)
EAST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2005/0056264 A1, (WEISSMAN et al) 17 March 2005, Figure 2, claim 11.	1-15
A	US 5,560,344 A (CHAN) 1, October 1996 (01.10.1996), whole document.	1-15

☐ 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 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	Date of mailing of the international search report
08 June 2008 (08.06.2008)	
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Authorized officer Stephen K Cronin Telephone No. (571) 272-4383

Form PCT/ISA/210 (second sheet) (April 2007)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

FILE COPY
PCT

To:
SAM PASTERNACK
CHOATE, HALL & STEWART
TWO INTERNATIONAL PLACE
BOSTON, MA 02110

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Applicant's or agent's file reference 2006734-0002	Date of mailing (*day/month/year*) FOR FURTHER ACTION See paragraph 2 below

International application No.	International filing date (*day/month/year*)	Priority date (*day/month/year*)
PCT/IB07/03004	06 March 2007 (06.03.2007)	08 March 2006 (08.03.2006)

International Patent Classification (IPC) or both national classification and IPC

IPC: Please See Continuation Sheet
USPC: 123/447,1A,300,304,431,478,575,577,198C,198A;701/101

Applicant

ETHANOL BOOSTING SYSTEMS, LLC

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 43*bis*.1(a)(i) with regard to novelty, inventive step or 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 66.1*bis*(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.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn. ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	08 June 2008 (08.06.2008)	Stephen K Cronin Telephone No. (571) 272-4383

Form PCT/ISA/237 (cover sheet) (April 2007)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/IB07/03004

Box No. I 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*.1(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. type of material

☐ a sequence listing

☐ table(s) related to the sequence listing

b. format of material

☐ on paper

☐ in electronic form

c. time of filing/furnishing

☐ contained in the international application as filed.

☐ filed together with the international application in electronic form.

☐ furnished subsequently to this Authority for the purposes of search.

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

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/IB07/03004

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

1. Statement

Novelty (N)	Claims 1-15	YES
	Claims NONE	NO
Inventive step (IS)	Claims 1-15	YES
	Claims NONE	NO
Industrial applicability (IA)	Claims 1-15	YES
	Claims NONE	NO

2. Citations and explanations:

Claims 1-15 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest claimed invention.

Claim1-15 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No
PCT/IB07/03004

Supplemental Box
In case the space in any of the preceding boxes is not sufficient.

Continuation of IPC:
F02M 63/00(2006.01),43/00(2006.01);F02B 47/00(2006.01),47/04(2006.01),13/00(2006.01),13/10(2006.01)

PATENT COOPERATION TREA. Y

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

To: Sam Pasternack
Choate, Hall & Stewart
Two International Place
Boston, Massachusetts 02110

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 2006734-0003PC	Date of mailing *(day/month/year)* FOR FUR[illegible] ACTION See paragraphs 1 and 4 below
International application No. PCT/US 07/05777	International filing date *(day/month/year)* 08 March 2007 (08.03.2007)
Applicant Ethanol Boosting Systems, LLC	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 740 14 35

For more detailed instructions, see the notes on the accompanying sheet.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/220 (January 2004) *(See notes on accompanying sheet)*

2006734-0013 SP

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: Sam Pasternack
Choate, Hall & Stewart
Two International Place
Boston, Massachusetts 02110

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 2006734-0003PC	Date of mailing *(day/month/year)* 24 MAR 2008 **FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US 07/05777	International filing date *(day/month/year)* 08 March 2007 (08.03.2007)
Applicant Ethanol Boosting Systems, LLC	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes, 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 740 14 35

   For more detailed instructions, see the notes on the accompanying sheet.

   Docketed Due Article 19 Amend. 5/24/08 MPL

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

   The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

   In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

   See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

RECEIVED MAR 26 2008 PATENT DEPARTMENT

Form PCT/ISA/220 (January 2004) *(See notes on accompanying sheet)*

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 2006734-0003PC	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US 07/05777	International filing date *(day/month/year)* 08 March 2007 (08.03.2007)	(Earliest) Priority Date *(day/month/year)* 10 March 2006 (10.03.2006)
Applicant Ethanol Boosting Systems, LLC		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 2 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out 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)).

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

a. the figure of the **drawings** to be published with the abstract is Figure No. 1

☐ as suggested by the applicant.

☒ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 07/05777

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F02B 77/04 (2007.10)
USPC - 123/198A
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)
USPC: 123/198A

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 123/198R, 406.29, 406.47 (text search - see terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST(USPT,PGPB,EPAB,JPAB); Google Patents; Google Scholar
Search Terms: gasoline engine, ethanol, direct injection, engine knock, emissions, restart, control system, shut down, deceleration, port injection, motor

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Calculations of Knock Suppression in Highly Turbocharged Gasolin/Ethanol Engines Using Direct Ethanol Injection (L. Bromberg et al.) 23 February 2006 (23.02.2006), entire document especially Abstract, Section I, para [0003], Section II, para [0001], [0003], [0006]	1-18
Y	US 4,312,310 A (Chivilo' et al.) 26 January 1982 (26.01.1982), col 2, ln 20-26 and ln 36-54	1-18
Y	US 6,358,180 B1 (Kuroda et al.) 19 March 2002 (19.03.2002), Fig 4, col 3, ln 65-67 to col 4, ln 1-15, col 8, ln 3-27col 12, ln 54-56	2, 9-10, 13-18
Y	US 4,974,416 A (Taylor) 04 December 1990 (04.12.1990), col 4, ln 15-21	5
Y	US 6,260,525 B1 (Moyer) 17 July 2001 (17.07.2001), col 3, ln 5-8	6, 8, 13-18
Y	US 4,967,714 A (Inoue) 06 November 1990 (06.11.1990), col 3, ln 27-30 and ln 66-67	11

☐ Further documents are listed in the continuation of Box C. ☐

* 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

Date of the actual completion of the international search	Date of mailing of the international search report
03 December 2007 (03.12.2007)	24 MAR 2008
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (April 2007)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: Sam Pasternack
Choate, Hall & Stewart
Two International Place
Boston, Massachusetts 02110

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	24 MAR 2008
Applicant's or agent's file reference 2006734-0003PC	FOR FURTHER ACTION See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US 07/05777	08 March 2007 (08.03.2007)	10 March 2006 (10.03.2006)

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - F02B 77/04 (2007.10)
USPC - 123/198A

Applicant Ethanol Boosting Systems, LLC

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

Docketed
Due Response to Written Opinion 6/24/08 MPL

- [X] 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
- [X] Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or 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 66.1*bis*(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.

3. For further details, see notes to Form PCT/ISA/220.

RECEIVED
MAR 26 2008
PATENT DEPARTMENT

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer:
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	03 December 2007 (03.12.2007)	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (April 2007)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 07/05777

Box No. I 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*.1(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. type of material

      ☐ a sequence listing

      ☐ table(s) related to the sequence listing

   b. format of material

      ☐ on paper

      ☐ in electronic form

   c. time of filing/furnishing

      ☐ contained in the international application as filed

      ☐ filed together with the international application in electronic form

      ☐ furnished subsequently to this Authority for the purposes of search

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

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 07/05777

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

1. Statement

Novelty (N)	Claims	1-18	YES
	Claims	None	NO
Inventive step (IS)	Claims	None	YES
	Claims	1-18	NO
Industrial applicability (IA)	Claims	1-18	YES
	Claims	None	NO

2. Citations and explanations:

Claims 1, 3-4, 7 and 12 lack an inventive step under PCT Article 33(3) as being obvious over the article entitled "Calculations of Knock Suppression In Highly Turbocharged Gasoline/Ethanol Engines Using Direct Ethanol Injection" by L. Bromberg et al. (hereinafter 'Bromberg') in view of US 4,312,310 A to Chivilo et al. (hereinafter 'Chivilo').

As per claim 1, Bromberg discloses a fuel management system for operation of a spark ignition gasoline engine in a vehicle comprising: a gasoline engine powering the vehicle (see Abstract); a source of gasoline for introduction into the engine (see Section II, para [0003]); a separate source of ethanol (see Section II, para [0003]); an injector for direct injection of the ethanol into a cylinder of the engine (see Section II, para [0001]). Bromberg does not disclose a control system for shutting down the engine by stopping gasoline and ethanol flow into the engine during vehicle deceleration and idling and restarting the engine upon driver demand. Chivilo discloses a control system for shutting down the engine by stopping gasoline flow into the engine during vehicle deceleration and idling and restarting the engine upon driver demand (col 2, ln 20-26 and ln 36-54). It would have been obvious to one of ordinary skill in the art to modify the fuel management system as disclosed by Bromberg with the control system as taught by Chivilo since a major development in the system disclosed by Bromberg is fuel conservation and an obvious way to conserve fuel is to shut down the engine during idle or deceleration.

As per claim 3, Bromberg further discloses the system wherein the engine uses direct ethanol injection during a range of engine operating conditions to prevent engine knock (see Section I, para [0003]). Bromberg does not specifically disclose direct ethanol injection during engine restart to prevent engine knock. However, it would have been obvious to one of ordinary skill in the art to include ethanol injection during engine restart as one of the operating conditions since engine knock often occurs during restart and one of the objects of Bromberg is to prevent engine knock.

As per claim 4, Bromberg discloses the system wherein the engine uses direct ethanol injection to minimize hydrocarbon emissions (see Section II, para [0006]). Bromberg does not specifically disclose direct ethanol injection during engine restart to minimize hydrocarbon emissions. However, it would have been obvious to one of ordinary skill in the art to include ethanol injection during engine restart to minimize hydrocarbon emissions since hydrocarbon emissions can be high during restart and one of the objects of Bromberg is to minimize hyrdrocarbon emissions.

As per claim 7, Bromberg further discloses the system wherein the engine is turbocharged or supercharged (see Section II, para [0001]).

As per claim 12, Bromberg further disclose the system wherein gasoline is not used and ethanol, E85, methanol, other alcohols or a blend thereof are used as the only fuel (see Abstract). Bromberg states direct ethanol injection could be be used to displace gasoline.

Claims 2, 9 and 10 lack an inventive step under PCT Article 33(3) as being obvious over Bromberg in view of Chivilo, further in view of US 6,358,180 B1 to Kuroda et al. (hereinafter 'Kuroda').

As per claim 2, Chivilo discloses a control system for shutting down the engine by stopping gasoline flow into the engine during vehicle deceleration and idling and restarting the engine upon driver demand (col 2, ln 20-26 and ln 36-54). Chivilo does not specifically disclose wherein the control system disables the shutting down of the engine during deceleration and idling when an auxiliary power or energy requirement exceeds a selected level. Kuroda discloses wherein the control system disables the shutting down of the engine during deceleration and idling when an auxiliary power or energy requirement exceeds a selected level (col 3, ln 65-67 to col 4, ln 1-15). It would have been obvious to one of ordinary skill in the art to modify the control system as disclosed by Chivilo with the system as taught by Kuroda, since both relate to the technology of shutting engines down to conserve fuel and since such would avoid having the engine shut down when the batteries are unable to perform important functions such as restarting.

As per claim 9, Kuroda further discloses the system further including a 12V motor to restart the engine after shutdown during deceleration and/or idle (Fig 4; col 12, ln 54-56).

— Please See Continuation Sheet —

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**

Continuation of:
Box V. 2. Citations and explanations:

As per claim 10, Kuroda further discloses the system including a restart motor (Fig 4; col 12, ln 54-56), wherein the low voltage motor is a low voltage motor (Fig 4 - the motor used for restarting the engine is a low voltage motor operating on 12 V).

Claim 5 lacks an inventive step under PCT Article 33(3) as being obvious over Bromberg in view of Chivilo, further in view of US 4,974,416 A (Taylor).

As per claim 5, Bromberg discloses the system wherein the engine uses direct injection (see Section II, para [0001]). Bromberg does not specifically disclose the system wherein the engine uses direct injection during engine restart to supplement port fuel injection while a fuel film that feeds the engine is established so as to minimize energy, emissions and time required for engine restart. Taylor discloses a system wherein the engine includes port fuel injection while a fuel film that feeds the engine is established (col 4, ln 15-21). It would have been obvious to one of ordinary skill in the art to modify the system as disclosed by Bromberg with the port fuel injection and fuel film as taught by Taylor, since it is well known in the art to supplement port injection with direct injection and since fuel films are well known and the use of such would have minimized energy, emissions and time required for engine restart.

Claims 6 and 8 lack an inventive step under PCT Article 33(3) as being obvious over Bromberg in view of Chivilo, further in view of US 6,260,525 B1 (Moyer).

As per claim 6, Chivilo discloses a control system for shutting down the engine by stopping gasoline flow into the engine (col 2, ln 20-26 and ln 36-54). Chivilo does not specifically disclose the system further including a valve disabler for all engine valves. Moyer discloses the system further including a valve disabler for all engine valves (col 3, ln 5-8). It would have been obvious to one of ordinary skill in the art to modify the system as disclosed by Chivilo and Bromberg with the valve disabler as taught by Moyer, since all relate to the technology of shutting engines down to conserve fuel and since such would have enagled the engine to be a variable displacement engine so that when less than maximum power is required some cylinders can be shut down and power increased in the remaining cylinders which will then operate at greater efficiency.

As per claim 8, Bromberg further discloses the system wherein maximum manifold pressure is increased by at least a factor of two over a non-pressure-boosted engine (see Abstract).

Claims 11 lacks an inventive step under PCT Article 33(3) as being obvious over Bromberg in view of Chivilo, further in view of US 4,967,714 A (Inoue).

As per claim 11, Bromberg further discloses the system wherein the ethanol is injected through a fuel injector (see Section II, para [0001]). Bromber does not specifically disclose wherein the gasoline and the ethanol are injected through the same fuel injector. Inoue discloses the system wherein the gasoline and the ethanol are injected through the same fuel injector (col 3, ln 27-30 and ln 66-67). It would have been obvious to one of ordinary skill in the art to modify the system as disclosed by Bromberg to enable the system to inject ethanol and gasoline through the same fuel injector as taught by Inoue, since both relate to the technology of ethanol burning systems and since such would have enabled the system to operate using only one fuel injector per cylinder which is a well known design to one of ordinary skill in the art.

Claims 13-18 lack an inventive step under PCT Article 33(3) as being obvious over Bromberg in view of Chivilo, further in view of Kuroda, further in view of Moyer.

As per claim 13, Bromberg discloses a turbocharged spark ignition engine which uses separately controlled direct injection of ethanol and port fuel injection of gasoline (see Abstract). Bromberg does not specifically disclose where the engine is shut down during periods of deceleration and idle. Kuroda discloses where the engine is shut down during periods of deceleration and idle (col 8, ln 3-27). Bromberg further discloses the engine comprising a first source of gasoline (see Section II, para [0003]); a second source of ethanol (see Section II, para [0003]); a gasoline engine (see Abstract). Bromberg does not specifically disclose a means to engine cylinder deactivation through valve disabling during engine deceleration and idling. Moyer discloses a means to engine cylinder deactivation through valve disabling (col 3, ln 5-8). It would have been obvious to one of ordinary skill in the art to modify the engine as disclosed by Bromberg with the shut down during deceleration and idle as taught by Kuroda and the disabling of the valves as taught by Moyer, since all relate to the technology of improving fuel economy and since the disabling of the valves is well known in the art as an effective way to shut down the engine and since shutting down the engine during deceleration and idle is an obvious means to conserving fuel.

As per claim 14, Bromberg further discloses the turbocharged spark ignition engine (see Section II, para [0001]) wherein the engine uses direct ethanol injection during a range of engine operating conditions to prevent engine knock (see Section I, para [0003]). Bromberg does not specifically disclose direct ethanol injection during engine restart to prevent engine knock. However, it would have been obvious to one of ordinary skill in the art to include ethanol injection during engine restart as one of the operating conditions since engine knock often occurs during restart and one of the objects of Bromberg is to prevent engine knock.

--- Please See Continuation Sheet ---

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 07/05777

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of:
Suplemental Box 1:

As per claim 15, Bromberg discloses the turbocharged spark ignition engine (see Section II, para [0001]) wherein the engine uses direct ethanol injection to minimize hydrocarbon emissions (see Section II, para [0006]). Bromberg does not specifically disclose direct ethanol injection during engine restart to minimize hydrocarbon emissions. However, it would have been obvious to one of ordinary skill in the art to include ethanol injection during engine restart to minimize hydrocarbon emissions since hydrocarbon emissions can be high during restart and one of the objects of Bromberg is to minimize hyrdrocarbon emissions.

As per claim 16, Bromberg discloses the turbocharged spark ignition engine (see Section II, para [0001]). Bromberg does not specifically disclose the turbocharged spark ignition engine where a low voltage motor is used to restart the engine. Kuroda discloses the system wherein the low voltage motor is a low voltage motor (Fig 4; col 12, ln 54-56). Furthermore, it would have been obvious to one of ordinary skill in the art to modify the engine as disclosed by Bromberg and Chivilo with the low voltage motor for restart since most vehicles currently operate with a 12 V battery and using a low voltage motor for restart would not require an additional battery for operating the restart motor.

As per claim 17, Bromberg discloses a turbocharged spark ignition engine which uses separately controlled direct injection of ethanol and port fuel injection of gasoline (see Abstract). Bromberg does not specifically disclose where the engine is shut down during periods of deceleration and idle. Kuroda discloses where the engine is shut down during periods of deceleration and idle (col 8, ln 3-27). Bromberg further discloses the engine comprising a first source of gasoline (see Section II, para [0003]); a second source of ethanol (see Section II, para [0003]); a gasoline engine (see Abstract). Bromberg does not specifically disclose a means to disable the engine cylinders and where direct ethanol injection is used during engine restart and further where a low voltage motor is used for engine restart. Moyer discloses a means to engine cylinder deactivation through valve disabling (col 3, ln 5-8). Kuroda further discloses where a low voltage motor is used for engine restart (Fig 4; col 12, ln 54-56). It would have been obvious to one of ordinary skill in the art to modify the engine as disclosed by Bromberg with the shut down during deceleration and idle and low voltage restart motor as taught by Kuroda and the disabling of the valves as taught by Moyer, since all relate to the technology of improving fuel economy and since the disabling of the valves is well known in the art as an effective way to shut down the engine and since shutting down the engine during deceleration and idle is an obvious means to conserving fuel.

As per claim 18, Bromberg discloses a turbocharged spark ignition engine which uses direct injection of ethanol (see Abstract). Bromberg does not specifically disclose where the engine is shut down during periods of deceleration and idle comprising a turbocharged spark ignition engine; and a means to shutdown the engine cylinders and where direct ethanol injection is used during engine restart and further where a low voltage motor is used for engine restart. Kuroda discloses where the engine is shut down during periods of deceleration and idle (col 8, ln 3-27). Moyer discloses a means to engine cylinder deactivation through valve disabling (col 3, ln 5-8). Kuroda further discloses where a low voltage motor is used for engine restart (Fig 4; col 12, ln 54-56). It would have been obvious to one of ordinary skill in the art to modify the engine as disclosed by Bromberg with the shut down during deceleration and idle and low voltage restart motor as taught by Kuroda and the disabling of the valves as taught by Moyer, since all relate to the technology of improving fuel economy and since the disabling of the valves is well known in the art as an effective way to shut down the engine and since shutting down the engine during deceleration and idle is an obvious means to conserving fuel.

Claims 1-18 have industrial applicability as defined by PCT Article 33(4) because the subject matter can be made or used in industry.

SP/Law

resp to Written Opinion Docketed Due 5-25-08

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
SAM PASTERNACK
CHOATE, HALL & STEWART LLP
TWO INTERNATIONAL PLACE
BOSTON, MA 02110

Amend Claims Docketed Due 4-25-08

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing (*day/month/year*) 25 FEB 2008
Applicant's or agent's file reference 2006734-0015	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US07/74227	International filing date (*day/month/year*) 24 July 2007 (24.07.2007)
Applicant ETHANOL BOOSTING SYSTEMS, LLC	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: (41-22) 338.82.70.

   For more detailed instructions, see the notes on the accompanying sheet.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices

   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

   The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

   In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

   See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the ISA/ US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Authorized officer Stephen K Cronin Telephone No. (571) 272-4383

Form PCT/ISA/220 (January 2004) (See notes on accompanying sheet)

RECEIVED FEB 27 2008 PATENT DEPARTMENT

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 2006734-0015	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US07/74227	International filing date (*day/month/year*) 24 July 2007 (24.07.2007)	(Earliest) Priority Date (*day/month/year*) 24 July 2006 (24.07.2006)
Applicant ETHANOL BOOSTING SYSTEMS, LLC		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 2 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the Report**
   a. With regard to the **language**, the international search was carried out 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))
   b. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I
2. ☐ **Certain claims were found unsearchable** (See Box No. II)
3. ☐ **Unity of invention is lacking** (See Box No. III)
4. With regard to the **title**,
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,
   a. the figure of the drawings to be published with the abstract is Figure No. 1
      ☒ as suggested by the applicant.
      ☐ as selected by this Authority, because the applicant failed to suggest a figure.
      ☐ as selected by this Authority, because this figure better characterizes the invention.
   b. ☐ none of the figures is to be published with the abstract.

Form PCT/ISA/210 (first sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US07/74227

A. CLASSIFICATION OF SUBJECT MATTER
IPC: **F02D 41/30**(2006.01);**F02B 1/08**(2006.01)

USPC: 123/1A,431,447,575
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)
U.S. : 123/1A,300,304,431,447,478,575,577,198C,198A

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)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- P, Y	US 2007/0119416 A1 (Boyarski) 31 May 2007 (31.05.2007), figures 16, 17, 23, 28, 37, 44, paragraphs [0066], [0107]-[0117], [0284]-[0318], claims 3, 5, 11, 15.	1-23, 26, 42-48, 56 --- 24,25,27-41,49-55
X --- Y	US 2002/01393321 A1 (Weissman et al.) 3 October 2002 (03.10.2002), figure 2, paragraphs [0022]-[0046].	24-25, 27-56 --- 1-23, 26

☐ 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 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 07 December 2007 (07.12.2007)	Date of mailing of the international search report 25 FEB 2008
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	Authorized officer Stephen K Cronin Telephone No. (571) 272-4383

Form PCT/ISA/210 (second sheet) (April 2005)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
SAM PASTERNACK
CHOATE, HALL & STEWART LLP
TWO INTERNATIONAL PLACE
BOSTON, MA 02110

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	25 FEB 2008
Applicant's or agent's file reference 2006734-0015	**FOR FURTHER ACTION** See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US07/74227	24 July 2007 (24.07.2007)	24 July 2006 (24.07.2006)

International Patent Classification (IPC) or both national classification and IPC

IPC: **F02D 41/30**(2006.01);**F02B 1/08**(2006.01)
USPC: 123/1A,431,447,575

Applicant

ETHANOL BOOSTING SYSTEMS, LLC

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 43*bis*.1(a)(i) with regard to novelty, inventive step or 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 66.1*bis*(*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.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	18 February 2008 (18.02.2008)	Stephen K Cronin Telephone No. (571) 272-4383

Form PCT/ISA/237 (cover sheet) (April 2007)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/74227

Box No. I 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*.1(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. type of material

☐ a sequence listing

☐ table(s) related to the sequence listing

b. format of material

☐ on paper

☐ in electronic form

c. time of filing/furnishing

☐ contained in the international application as filed.

☐ filed together with the international application in electronic form.

☐ furnished subsequently to this Authority for the purposes of search.

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

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US07/74227

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

1. Statement

Novelty (N)	Claims 1-56	YES
	Claims NONE	NO
Inventive step (IS)	Claims 1-56	YES
	Claims NONE	NO
Industrial applicability (IA)	Claims 1-56	YES
	Claims NONE	NO

2. Citations and explanations:

Claims 1-56 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest the claimed invention.

Claim 1-56 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

SP/JDL/JGG
SKS

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: SAM PASTERNACK
Choate, Hall & Stewart LLP
Two International Place
Boston, Massachusetts 02110

Amend Claims
cite PPA in US.
Resp to Writ. Opin.

Action:
Due Date
Final Due Date 12/3/08 - 1/3/09 - 5/10/09
Docket Administration NH Date: 10/6/08
Attorney:

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 2006734-0021	Date of mailing *(day/month/year)* 03 OCT 2008 FOR FURTHER ACTION See paragraphs 1 and 4 below
International application No. PCT/US2008/069171	International filing date *(day/month/year)* 03 July 2008
Applicant ETHANOL BOOSTING SYSTEMS LLC	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 740 14 35

   For more detailed instructions, see the notes on the accompanying sheet.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ With regard to the protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

   The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. These comments would also be made available to the public but not before the expiration of 30 months from the priority date.

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until **30 months** from the priority date (in some Offices even later); otherwise, the applicant must, within **20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

   In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months.

   See the Annex to Form PCT/IB/301 and, for details about the applicable time limits, Office by Office, see the *PCT Applicant's Guide*, Volume II, National Chapters and the WIPO Internet site.

Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver Telephone No. 571-272-7774

Form PCT/ISA/220 (January 2004) *(See notes on accompanying sheet)*

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 2006734-0021	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US2008/069171	International filing date *(day/month/year)* 03 July 2008	(Earliest) Priority Date *(day/month/year)* 10 July 2007
Applicant ETHANOL BOOSTING SYSTEMS LLC		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out 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))

   b. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☒ **Certain claims were found unsearchable** (see Box No. II)

3. ☐ **Unity of invention is lacking** (see Box No. III)

4. With regard to the **title**,

   ☒ the text is approved as submitted by the applicant

   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   ☒ the text is approved as submitted by the applicant

   ☐ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority

6. With regard to the **drawings**,

   a. the figure of the drawings to be published with the abstract is Figure No. 1

   ☐ as suggested by the applicant

   ☒ as selected by this Authority, because the applicant failed to suggest a figure

   ☐ as selected by this Authority, because this figure better characterizes the invention

   b. ☐ none of the figures is to be published with the abstract

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2006/069171

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.: 15-17, 31-33
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:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying 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 report covers 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.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2008/069171

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F02B 77/04 (2008.04)
USPC - 123/198A
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(8) - F02B 77/04 (2008.04)
USPC - 123/198A, 406.29, 435

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)
MicroPatent, DialogPro, IP.com

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 7,225,787 B2 (BROMBERG et al) 05 June 2007 (05.06.2007) entire document	1-14, 18-30, 34-35
Y	US 2006/0102145 A1 (COHN et al) 18 May 2006 (18.05.2006) entire document	1-14, 18-30, 34-35
Y	US 6,561,157 B2 (ZUR LOYE et al) 13 May 2003 (13.05.2003) entire document	6, 23, 35
A	US 3,557,763 A (PROBST) 26 January 1971 (26.01.1971) entire document	1-35
A	US 4,056,087 A (BOYCE) 01 November 1977 (01.11.1977) entire document	1-35
A	US 4,230,072 A (NOGUCHI et al) 28 October 1980 (28.10.1980) entire document	1-35
A	US 4,594,201 A (PHILLIPS et al) 10 June 1986 (10.06.1986) entire document	1-35
A	US 5,179,923 A (TSURUTANI et al) 19 January 1993 (19.01.1993) entire document	1-35
A	US 7,156,070 B2 (STROM et al) 02 January 2007 (02.01.2007) entire document	1-35
A	US 2007/0119421 A1 (LEWIS et al) 31 May 2007 (31.05.2007) entire document	1-35
A	US 2007/0125321 A1 (RITTER) 07 June 2007 (07.06.2007) entire document	1-35

☐ Further documents are listed in the continuation of Box C. ☐

* 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

Date of the actual completion of the international search	Date of mailing of the international search report
25 September 2008	03 OCT 2008
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (April 2005)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: SAM PASTERNACK
Choate, Hall & Stewart LLP
Two International Place
Boston, Massachusetts 02110

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)* 03 OCT 2008	
Applicant's or agent's file reference 2006734-0021	FOR FURTHER ACTION See paragraph 2 below

International application No.	International filing date *(day month year)*	Priority date *(day month year)*
PCT/US2008/069171	03 July 2008	10 July 2007

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - F02B 77/04 (2008.04)
USPC - 123/198A

Applicant
ETHANOL BOOSTING SYSTEMS LLC

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

- [X] Box No. I Basis of the opinion
- [ ] Box No. II Priority
- [X] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [X] Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or 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 66.1*bis*(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.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer:
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	25 September 2008	Blaine Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (April 2007)

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2008/069171

Box No. I 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*.1(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. type of material

☐ a sequence listing

☐ table(s) related to the sequence listing

b. format of material

☐ on paper

☐ in electronic form

c. time of filing/furnishing

☐ contained in the international application as filed

☐ filed together with the international application in electronic form

☐ furnished subsequently to this Authority for the purposes of search

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

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2008/069171

Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non obvious), or to be industrially applicable have not been examined in respect of

☐ the entire international application

☒ claims Nos. 15-17, 31-33

because:

☐ the said international application, or the said claims Nos. _____ relate to the following subject matter which does not require an international search *(specify)*:

☒ the description, claims or drawings *(indicate particular elements below)* or said claims Nos. 15-17, 31-33 are so unclear that no meaningful opinion could be formed *(specify)*:

Claims 15-17, 31-33 are multiple dependent claims not drafted in accordance with the second and third sentences of Rule 6.4(a).

☐ the claims, or said claims Nos. _____ are so inadequately supported by the description that no meaningful opinion could be formed *(specify)*:

☒ no international search report has been established for said claims Nos. 15-17, 31-33

☐ a meaningful opinion could not be formed without the sequence listing; the applicant did not, within the prescribed time limit:

- ☐ furnish a sequence listing on paper complying with the standard provided for in Annex C of the Administrative Instructions, and such listing was not available to the International Searching Authority in a form and manner acceptable to it.
- ☐ furnish a sequence listing in electronic form complying with the standard provided for in Annex C of the Administrative Instructions, and such listing was not available to the International Searching Authority in a form and manner acceptable to it.
- ☐ pay the required late furnishing fee for the furnishing of a sequence listing in response to an invitation under Rule 13*ter*.1(a) or (b).

☐ a meaningful opinion could not be formed without the tables related to the sequence listings; the applicant did not, within the prescribed time limit, furnish such tables in electronic form complying with the technical requirements provided for in Annex C-*bis* of the Administrative Instructions, and such tables were not available to the International Searching Authority in a form and manner acceptable to it.

☐ the tables related to the nucleotide and/or amino acid sequence listing, if in electronic form only, do not comply with the technical requirements provided for in Annex C-*bis* of the Administrative Instructions.

☐ See Supplemental Box for further details.

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No. PCT/US2008/069171

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

1. Statement

Novelty (N)	Claims	1-14, 18-30, 34-35	YES
	Claims	None	NO
Inventive step (IS)	Claims	None	YES
	Claims	1-14, 18-30, 34-35	NO
Industrial applicability (IA)	Claims	1-14, 18-30, 34-35	YES
	Claims	None	NO

2. Citations and explanations:

Claims 1-5, 7-14, 18-22, 24-30, and 34 lack an inventive step under PCT Article 33(3) as being obvious over Bromberg et al. in view of Cohn et al.

Regarding claim 1, Bromberg et al. disclose a fuel management system for a spark ignition gasoline engine (Abstract) comprising: a gasoline engine (18); a source of gasoline (Fig. 4a); a source of a second liquid fuel (Fig. 4a); a means for introducing gasoline (Fig. 4b) into the cylinders of the engine (18); injectors for direct injection of the second liquid fuel (Col. 11, lines 23-50) into the cylinders of the engine (18); a fuel management control system (Col. 1, lines 45-50) for controlling injection of the second fuel into the cylinder so that it is provided in an amount needed to prevent knock (Fig. 3) as other conditions require; and a means for providing fast flame speed (Col. 10, lines 45-55). Bromberg et al. do not show controlling injection of the second fuel into the cylinder so that it is provided in an amount needed to prevent knock as torque increases; and a means for providing fast burn. It is deemed obvious that a fast flame speed produces a fast burn. Cohn et al. show a fuel management control system (14) for controlling injection of a second fuel into a cylinder so that it is provided in an amount needed to prevent knock as torque increases (paragraph 32). It would have been obvious at the time the invention was made to a person having ordinary skill in the art to employ the structures and processes as taught by Cohn et al. in the device of Bromberg et al. in order to provide improved engine performance.

Regarding claim 2, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. do not show where the 10% - 90% burn occurs in 15-20 crank angle degrees. It is obvious from Bromberg et al. (Figs. 2A-2B) that a significant portion of the energy fraction (burn) occurs in a small crank angle range including that claimed.

Regarding claim 3, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. show where the fast burn (Col. 10, lines 45-55) in the engine is provided by charge motion (Col. 10, lines 15-20).

Regarding claim 4, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. show where the fast burn (Col. 10, lines 45-55) in the engine is provided by increased temperature (Col. 4, lines 1-10) in the unburned zone of air/fuel mixture zone that burns early in the cycle after the firing of the spark (Col. 4, lines 30-45).

Regarding claim 5, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. do not show where there are dual ignition sites on either side of the cylinder but show two ignition sources (Col. 1, lines 13-15, Col. 8, lines 23-30). It is obvious that the dual sites can be on opposite cylinder sides to promote complete combustion.

Regarding claim 7, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. do not show where the spray of the second fuel is aimed toward the end gas on the exhaust valve side of the cylinder and the injector is located near the periphery. Cohn et al. show where spray of the second fuel is aimed toward an end gas on an exhaust valve side of the cylinder and an injector is located near the periphery (paragraph 7). It would have been obvious at the time the invention was made to a person having ordinary skill in the art to employ the structures and processes as taught by Cohn et al. in the device of Bromberg et al. in order to provide improved engine performance.

Regarding claim 8, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. show where the time of the direct injection of the second fuel is adjusted to minimize the ethanol consumption (Col. 6, lines 46-52, Col. 10, lines 25-35).

Regarding claim 9, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. do not show where turbulence is created at or near the intake port. Cohn et al. show where turbulence is created at or near an intake port (paragraph 28). It would have been obvious at the time the invention was made to a person having ordinary skill in the art to employ the structures and processes as taught by Cohn et al. in the device of Bromberg et al. in order to provide improved engine performance.

Regarding claim 10, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. show where combustion is retarded by means of spark retard relative to what it would be if fast burn were not employed (Col. 8, lines 20-25).

Regarding claim 11, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. do not show where combustion, as measured by the 50% burn crank angle, is retarded using appropriate spark retard by an amount between 5 and 10 degrees but show spark retard (Col. 8, lines 20-25). It is deemed obvious that spark retard is a small but significant amount including that claimed.

(Continued in Supplemental Box)

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:
Box V

Regarding claim 12, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. show where the amount of second fuel that is used is reduced when the fast burn is provided (Col. 3, lines 25-30).

Regarding claim 13, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. show where the amount of combustion retard is varied as a function of load (Col. 1, lines 20-25) and speed by means of appropriate spark retard (Col. 8, lines 20-25).

Regarding claim 14, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. do not show where the degree of combustion retard is chosen so as to optimize the combination of efficiency gain and minimization of the required amount of the second fluid fuel. Cohn et al. show where a degree of combustion retard is chosen so as to optimize the combination of efficiency gain and minimization of the required amount of the second fluid fuel (Fig. 5, paragraphs 14 and 35). It would have been obvious at the time the invention was made to a person having ordinary skill in the art to employ the structures and processes as taught by Cohn et al. in the device of Bromberg et al. in order to provide improved engine performance.

Regarding claim 18, Bromberg et al. disclose a fuel management system for a spark ignition gasoline engine (Abstract) comprising: a gasoline engine (18) of compression ratio between 13 and 14 (Col. 7, lines 55-60); a source of a second liquid fuel (Fig. 4a); a means for introducing gasoline (Fig. 4b) into the cylinders of the engine (18); injectors for direct injection of the second liquid fuel (Col. 11, lines 23-50) into the cylinder of the engine (18); a fuel management control system (Col. 1, lines 45-50) for controlling injection of the second fuel into the cylinder so that it is provided in an amount needed to prevent knock (Fig. 3) as torque increases or other conditions require; and a means for fast flame speed (Col. 10, lines 45-55). Bromberg et al. do not show controlling injection of the second fuel into the cylinder so that it is provided in an amount needed to prevent knock as torque increases; and a means for providing fast burn. It is deemed obvious that a fast flame speed produces a fast burn. Cohn et al. show a fuel management control system (14) for controlling injection of a second fuel into a cylinder so that it is provided in an amount needed to prevent knock as torque increases (paragraph 32). It would have been obvious at the time the invention was made to a person having ordinary skill in the art to employ the structures and processes as taught by Cohn et al. in the device of Bromberg et al. in order to provide improved engine performance.

Regarding claim 19, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. do not show where the 10% - 90% burn occurs in 15-20 crank angle degrees. It is obvious from Bromberg et al. (Figs. 2A-2B) that a significant portion of the energy fraction (burn) occurs in a small crank angle range including that claimed.

Regarding claim 20, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. show where the fast burn (Col. 10, lines 45-55) in the engine is provided by charge motion (Col. 10, lines 15-20).

Regarding claim 21, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. show where the fast burn (Col. 10, lines 45-55) in the engine is provided by increased temperature (Col. 4, lines 1-10) in the unburned zone of air/fuel mixture zone that burns early in the cycle after the firing of the spark (Col. 4, lines 30-45).

Regarding claim 22, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. do not show where there are dual ignition sites on either side of the cylinder but show two ignition sources (Col. 1, lines 13-15, Col. 6, lines 23-30). It is obvious that the dual sites can be on opposite cylinder sides to promote complete combustion.

Regarding claim 24, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. do not show where the spray of the second fuel is aimed toward the end gas on the exhaust valve side of the cylinder. Cohn et al. show where spray of the second fuel is aimed toward an end gas on the exhaust valve side of the cylinder (paragraph 7). It would have been obvious at the time the invention was made to a person having ordinary skill in the art to employ the structures and processes as taught by Cohn et al. in the device of Bromberg et al. in order to provide improved engine performance.

Regarding claim 25, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. do not show where turbulence is created at or near the intake port. Cohn et al. show where turbulence is created at or near an intake port (paragraph 28). It would have been obvious at the time the invention was made to a person having ordinary skill in the art to employ the structures and processes as taught by Cohn et al. in the device of Bromberg et al. in order to provide improved engine performance.

Regarding claim 26, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. show where combustion is retarded by means of spark retard relative to what it would be if fast burn were not employed (Col. 8, lines 20-25).

Regarding claim 27, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. do not show where combustion, as measured by the 50% burn crank angle, is retarded using appropriate spark retard by an amount between 5 and 15 degrees but show spark retard (Col. 8, lines 20-25). It is deemed obvious that spark retard is a small but significant amount including that claimed.

Regarding claim 28, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. show where the amount of second fuel that is used is reduced when the fast burn is provided (Col. 3, lines 25-30).

Regarding claim 29, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. show where the amount of combustion retard is varied as a function of load (Col. 1, lines 20-25) and speed by means of appropriate spark retard (Col. 8, lines 20-25).

(Continued in next Supplemental Box)

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:
Previous Supplemental Box

Regarding claim 30, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. do not show where the degree of combustion retard is chosen so as to optimize the combination of efficiency gain and minimization of the required amount of the second fluid fuel. Cohn et al. show where a degree of combustion retard is chosen so as to optimize the combination of efficiency gain and minimization of the required amount of the second fluid fuel (Fig. 5, paragraphs 14 and 35). It would have been obvious at the time the invention was made to a person having ordinary skill in the art to employ the structures and processes as taught by Cohn et al. in the device of Bromberg et al. in order to provide improved engine performance.

Regarding claim 34, Bromberg et al. disclose a spark ignition gasoline engine (18) where alcohol and gasoline are both directly injected (Col. 1, lines 55-60) and where the alcohol/gasoline ratio needed to prevent knock uses fast burn. Bromberg et al. do not show where the alcohol/gasoline ratio needed to prevent knock is reduced by using fast flame speed. It is deemed obvious that a fast flame speed (Bromberg - Col. 10, lines 45-55) produces a fast burn. Cohn et al. show where an alcohol/gasoline ratio needed to prevent knock is reduced (paragraph 19). It would have been obvious at the time the invention was made to a person having ordinary skill in the art to employ the structures and processes as taught by Cohn et al. in the device of Bromberg et al. in order to provide improved engine performance.

Claims 6, 23, 35 lack an inventive step under PCT Article 33(3) as being obvious over Bromberg et al. in view of Cohn et al. and zur Loye et al.

Regarding claim 6, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. do not show where the direct injector is located in the center of the cylinder. zur Loye et al. show where a direct injector (62) is located in a center of a cylinder (Fig. 1). It would have been obvious at the time the invention was made to a person having ordinary skill in the art to employ the structures and processes as taught by Cohn et al. and zur Loye et al. in the device of Bromberg et al. in order to provide improved engine performance.

Regarding claim 23, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. do not show where the direct injector is located in the center of the cylinder. zur Loye et al. show where a direct injector (62) is located in a center of a cylinder (Fig. 1). It would have been obvious at the time the invention was made to a person having ordinary skill in the art to employ the structures and processes as taught by Cohn et al. and zur Loye et al. in the device of Bromberg et al. in order to provide improved engine performance.

Regarding claim 35, Bromberg et al. and Cohn et al. disclose that as applied above. Bromberg et al. do not show where a high energy spark plug is used to provide fast burn. zur Loye et al. show where a high energy spark plug (52) is used to provide fast burn. It would have been obvious at the time the invention was made to a person having ordinary skill in the art to employ the structures and processes as taught by Cohn et al. and zur Loye et al. in the device of Bromberg et al. in order to provide improved engine performance.

Claims 1-14, 18-30, and 34-35 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

NOTES TO FORM PCT/ISA/220 (continued)

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped), whether

(i) the claim is unchanged;
(ii) the claim is cancelled;
(iii) the claim is new;
(iv) the claim replaces one or more claims as filed;
(v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."
2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."
3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."
4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under Article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international application is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments and any accompanying statement, under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the time of filing the amendments (and any statement) with the International Bureau, also file with the International Preliminary Examining Authority a copy of such amendments (and of any statement) and, where required, a translation of such amendments for the procedure before that Authority (see Rules 55.3(a) and 62.2, first sentence). For further information, see the Notes to the demand form (PCT/IPEA/401).

If a demand for international preliminary examination is made, the written opinion of the International Searching Authority will, except in certain cases where the International Preliminary Examining Authority did not act as International Searching Authority and where it has notified the International Bureau under Rule 66.1*bis*(b), be considered to be a written opinion of the International Preliminary Examining Authority. If a demand is made, the applicant may submit to the International Preliminary Examining Authority a reply to the written opinion 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 (Rule 43*bis*.1(c)).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see the *PCT Applicant's Guide*, Volume II.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Massachusetts Institute of Technology Examiner: HUYNH, HAI H

Serial No.: 15/463,425 Art Unit: 3747

Filing Date: 03-20-2017 Confirmation No.: 3788

Title: FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES

Amendment

Via EFS-Web
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

In response to the office action dated June 22, 2017, please amend the application as follows.

Listing of Claims

1. (Original) A fuel management system for a spark ignition engine which utilizes port fuel injection and also utilizes direct fuel injection;

and where there is a first torque range where direct injection and port injection are both used at the same value of torque throughout the first torque torque range

and where in at least part of the first torque range as torque is increased the amount of fuel that is directly injected is changed so as to obtain knock-free operation and the amount of directly injected fuel used to provide knock-free operation is minimized.

2. (Original) The fuel management system of claim 1 where as torque is increased the fraction of fuel that is directly injected is increased to the value that prevents knock.

3. (Original) The fuel management system of claim 1 where active control using a knock detector is used to change the amount of fuel that is directly injected as torque is increased.

4. (Original) The fuel management system of claims 1 or 2 where open loop control using a lookup table is also used to change the amount of fuel that is directly injected as torque is increased.

5. (Original) The fuel management system of claim 4 where a predetermined correlation between knock resistance and fraction of fuel provided by direct injection is employed.

6. (Original) The fuel management system of claim 1 where if torque is increased beyond the highest value of torque in the first range of torque, direct injection alone would be required for knock-free operation.

7. (Original) The fuel management system of claim 1 where only port fuel injection is used in a second range of torque.

8. (Original) The fuel management system of claim 7 where as the torque increases beyond the highest value of torque in the second range of torque, the engine operates in the first range of torque.

9. (Original) The fuel management system of claim 7 where as the torque increased beyond the highest value in the second range of torque, the engine operates in the first range of torque;

and where if the torque were to be increased beyond the highest value in the first range of torque, direct injection alone would be required for knock-free operation.

10. (Original) The fuel management system of claim 7 where the highest torque in the second torque range is the highest torque at which knock-free operation can be obtained with port fuel injection alone.

11. (Original) The fuel management system of claim 7 where when spark retard is employed to enable operation with port fuel injection alone where it would not otherwise be used and where the spark retard is controlled by sensed information.

12. (Original) The fuel management system of claim 7 where spark retard is employed so that port fuel injection alone can be used where it would not otherwise be used.

13. (Original) The fuel management system of claim 1 where spark retard is used to reduce the fraction of fuel that is provided by direct injection.

14. (Original) The fuel management system of claim 1 where the amount of directly injected fuel is minimized throughout the first torque range.

15. (Original) The fuel management system of claim 1 where the amount of directly injected fuel is minimized from zero torque to the highest torque in the first torque range.

16. (Original) The fuel management system of claim 1 where there is third torque range where the highest torque is the highest torque in the first torque range of the operation and where within the third torque range as torque is increased the fraction of fuel provided by direct injection is changed to the value needed to prevent knock.

17. (Original) The fuel management system of claims 9 or 16 where the engine is turbocharged.

18 (Original) The fuel management system of claim 16 where the amount of direct injection is minimized.

19. (Original) A fuel management system for a turbocharged spark ignition engine which utilizes port fuel injection and also utilizes direct fuel injection;

and where there is a first range of torque throughout which direct injection and port injection are used at the same value of torque;

and wherein as torque is increased the fraction of fuel that is directly injected is increased to a value that prevents knock;

and where there is a second range of torque where only port fuel injection is used;

and where when torque exceeds the highest torque in the second range of torque the engine operates in the first range of torque.

20. (Original) The fuel management system of claim 19 where the second torque range starts at zero torque.

21. (Original) The fuel management system of claims 19 or 20 where the highest value of torque in the second region of torque is the highest value of torque at which direct injection is not needed to prevent knock.

22. (Currently Amended) A spark ignition engine where port fuel injection and direct injection are used and the fraction of fuel provided by direct injection is increased so as to prevent knock that would otherwise occur; and where spark retard is employed to ~~reduce~~ enable reduction of the amount of direct injection that would otherwise be employed.

23. (Original) The spark ignition engine of claim 22 where the engine is operated with port fuel injection alone at values of torque where port fuel injection alone would not otherwise be employed.

24. (Original) The spark ignition engine of claims 22 or 23 where the spark retard is controlled by detection of knock and by information from another sensed parameter.

25. (Original) The spark ignition engine of claims 22 or 23 where without the application of the spark retard the engine is operated with direct injection alone.

26. (Original) The spark ignition engine of claims 22 or 23 where without the application of the spark retard the engine is operated with both port fuel injection and direct injection at the same value of torque.

27. (Original) The spark ignition engine of claim 22 where without the employment of the spark retard the fraction of fuel provided by direct injection increases with increasing torque.

28. (Original) The spark ignition engine of claim 22 where there is a first torque range throughout which port fuel injection and direct injection are used at the same torque and wherein the fraction of fuel provided by direct injection increases with increasing torque in such a way as to enable knock -free operation and where there is a second torque range where only port fuel injection is used and where when the torque exceeds the highest torque in this range, the engine operates in the first torque range.

29. (Original) The spark ignition engine of claim 28 where the engine operates in the second torque range between zero torque and the highest torque in the second torque range.

30. (Original) The spark ignition engine of claim 22 where spark retard is used to reduce the amount of direct injection to zero from what it would otherwise have been.

Remarks

Reexamination and reconsideration of the rejections are hereby requested.

Claims 1-30 stand rejected on the ground on non-statutory double patenting as being unpatentable over claims 1-31 of US Patent Number 9,255,519 and as being unpatentable over claims 1-29 of US Patent Number 8,857,410. Enclosed herewith are terminal disclaimers with respect to these two earlier, commonly owned, patents. It is submitted that the enclosed terminal disclaimers overcome the rejection of claims 1-30 on the ground of non-statutory double patenting. Reconsideration is requested.

Claims 22-30 stand rejected under 35USC102(e) as being anticipated by Ohtani, US2005/0098157. In response to this rejection, independent claim 22 is being amended herein to improve its clarity and to highlight differences between the invention set out in amended claim 22 and the Ohtani reference.

As now claimed, claim 22 discloses a system in which the fraction of fuel provided by direct injection increases in order to prevent knock (unwanted self-ignition) which would otherwise occur when torque increases. In order to be able to use a lower fraction of directly injected fuel the invention in claim 22 uses spark retard (increased ignition delay) to allow the prevention of knock at a lower fraction of fuel that is directly injected.

In contrast, a review of paragraphs [0006] – [0009] shows that Ohtani decreases the fraction of fuel provided by direct injection (fuel provided by the in-cylinder valve) in order to prevent a combustion deterioration (different from knock) which would otherwise occur. Further, increased spark retard would worsen combustion deterioration.

For the foregoing reasons, we submit that claim 22, as amended herein, is not anticipated by Ohtani. Reconsideration is requested.

In view of the amendment to claim 22 and the terminal disclaimers accompanying this response, it is submitted that the application is in condition for allowance.

Early favorable action is requested.

Respectfully Submitted,

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