### IN THE UNITED STATES DISTRICT COURT FOR THE DISTRICT OF DELAWARE

## MASSACHUSETTS INSTITUTE OF TECHNOLOGY, and ETHANOL BOOSTING SYSTEMS, LLC,

Plaintiffs,

C.A. No. 19-cv-196-CFC-SRF

JURY TRIAL DEMANDED

 $\mathbf{V}_{\bullet}$ 

FORD MOTOR COMPANY,

Defendant.

## 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 <sup>1</sup>
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"

<sup>&</sup>lt;sup>1</sup> 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"	"direct injection of fuel into a cylinder" <sup>2</sup>
['839 (Claims 1, 8), '166 (Claims 1, 5, 16, 18, 19, 21-22, 26-28, 30), '826 (Claims 1, 12)] / ['166 (Claims 1, 19)]	
"first fueling system that directly injects fuel" / "first fueling system" / "first fueling system that uses direct injection"	Plain and ordinary meaning <sup>3</sup>
['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)]	
"second fueling system that injects fuel into a region outside of the cylinder" / "second fueling system" / "second fueling system using port fuel injection"	Plain and ordinary meaning
['519 (Claim 1)] / ['826 (Claims 1, 12, 21, 23, 24, 30, 31)] / ['826 (Claims 21, 31)]	

 $<sup>^2</sup>$  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.

<sup>&</sup>lt;sup>3</sup> 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"	"uses spark retard so as to reduce the amount of fuel that is introduced into the cylinder by direct injection"
['519 (Claim 1)]	
"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"	"information, including one or more signals"
['519 (Claim 13-14)]	

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:

"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:	Intrinsic Support:
• Ex. 1 (Orig. Appl.) at <i>passim</i> .	• 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,	and 20.
7-8.	• Ex. 3 ('519 Patent) at 5:61-6:45;
• Ex. 3 ('519 Patent) at Claims 1, 3-	Claims 1, 3, 4, 6, 7, 10, 11, 15,
4, 6, 10-11, 15, 18-20, 22, 26, 29.	18, 19, 20, 22, 26, and 29.
• Ex. 4 ('166 Patent) at Claims 1-4,	• Ex. 4 ('166 Patent) at 6:4-55;
7-8, 10, 14-16, 19-21, 23, 26-28.	Claims 1, 2, 3, 4, 6, 7, 8, 9, 10,
• Ex. 5 ('826 Patent) at Claim 1-8,	14, 15, 16, 19, 20, 21, 23, 26, 27,
10-15, 20-24, 29-33.	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"
<ul> <li>Intrinsic Support:</li> <li>Ex. 1 (Orig. Appl.) at 8:21-24, 9:3-10.</li> <li>Ex. 3 ('519 Patent) at Claim 20.</li> <li>Ex. 4 ('166 Patent) at Claim 8; see also Ex. 4 ('166 Patent) at Claims 9, 10, 20, 29.</li> <li>Ex. 5 ('826 Patent) at Claim 1; see also Ex. 5 ('826 Patent) at Claims 12, 22-25, 30, 31.</li> </ul>	<ul> <li>Intrinsic Support:</li> <li>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.</li> <li>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.</li> <li>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.</li> </ul>

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:	Intrinsic Support:
<ul> <li>Ex. 1 (Orig. Appl.) at 4:17-26, 9:13-14, 5:25-26, 6:5-7, 10:16-20, 12:8-9.</li> <li>Ex. 2 ('839 Patent) at Claims 1-6.</li> <li>See also Ex. 6 ('033 File History) at EBS00000018-28, at -21, -26; and EBS00000091-103, at -94, -100.</li> </ul>	<ul> <li>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.</li> <li>Ex. 6 ('033 Patent Pros. History) at EBS00000034-38; and EBS00000054-103.</li> </ul>

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	"a fuel that contains an anti-knock
needed).	agent that is not gasoline, and that is
	different from the fuel used for port
Alternatively, if construed, "fuel is	injection/in the second fueling system"
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	

"fuel that is directly injected into a cylinder."	
<ul> <li>Interinat is directly injected into a cylinder."</li> <li>Intrinsic Support: <ul> <li>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.</li> <li>Ex. 2 ('839 Patent) at Claims 1, 8-11, 15.</li> <li>See also Ex. 6 ('033 File History) at EBS0000018-28, at -21, -26; and EBS0000091-103, at -97-99.</li> <li>See also Ex. 7 ('166 File History) at EBS00001959-75, at -1964, -1971-72.</li> </ul> </li> </ul>	<ul> <li>Intrinsic Support:</li> <li>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.</li> <li>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.</li> <li>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.</li> <li>Ex. 6 ('033 Patent Pros. History) at EBS00000034-38; and EBS00000054-103.</li> </ul>
	at EBS-00001998-2033.

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

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

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

## 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:	Intrinsic Support:			
<ul> <li>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.</li> <li>Ex. 3 ('519 Patent) at Claims 1-3, 5-6, 9-11.</li> <li>See also Ex. 6 ('033 File History) at EBS00000018-28, at -21, -26; and EBS00000091-103, at -97-100.</li> </ul>	<ul> <li>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;</li> <li>Ex. 6 ('033 Patent Pros. History) at EBS00000034-38; and EBS00000054-103.</li> </ul>			

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

Dated: September 24, 2019

FARNAN LLP

/s/ Michael J. Farnan Brian E. Farnan (Bar No. 4089) Michael J. Farnan (Bar No. 5165) 919 North Market Street, 12th Floor Wilmington, DE 19801 (302) 777-0300 (302) 777-0301 bfarnan@farnanlaw.com mfarnan@farnanlaw.com

Attorneys for Plaintiff

Respectfully submitted,

MORRIS, NICHOLS, ARSHT & TUNNELL LLP

/s/ Rodger D. Smith II Rodger D. Smith II (#3778) Michael J. Flynn (#5333) Taylor M. Haga (#6549) 1201 North Market Street P.O. Box 1347 Wilmington, DE 19899 (302) 658-9200 rsmith@mnat.com mflynn@mnat.com thaga@mnat.com

Attorneys for Defendant

# EXHIBIT 1

an and the second second

FORD Ex. 1144, page 11 IPR2020-00013

### 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:

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

> EBS-00000175 FORD Ex. 1144, page 12 IPR2020-00013

## 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
- 15 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

20 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)

- 25 (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
- 30 limited amount of biomass that is available for its production. An object of the present invention

Attorney Docket No.: 0492811-0598 Express Mall No. EV196632874US Date of Filing: November 18, 2004 Customer Number: 24280 Page 2 of 14

EBS-00000176 FORD Ex. 1144, page 13 IPR2020-00013 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

5 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

- 10 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
- 15 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

- 20 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
- 25 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.

Page 3 of 14

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

> EBS-00000177 FORD Ex. 1144, page 14 IPR2020-00013

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.

5

### 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 directinjection 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.

15

### 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
- 25 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

Page 4 of 14

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

> EBS-00000178 FORD Ex. 1144, page 15 IPR2020-00013

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

5 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 energing as a frater of four smaller. Thus, the pet effect of scoling the air charge is

- 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
- 25 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

Page 5 of 14

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

> EBS-00000179 FORD Ex. 1144, page 16 IPR2020-00013

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%.

- 5 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,
- 10 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
- 15 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.

25 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.

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

20

Page 6 of 14

EBS-00000180 FORD Ex. 1144, page 17 IPR2020-00013 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

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-deadcenter (TDC) and then dissipates. It should be pointed out that relatively modest swirls result in

Page 7 of 14

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

5

25

EBS-00000181 FORD Ex. 1144, page 18 IPR2020-00013 large separating (centrifugal) forces. A 3m/s swirl motion in a 5cm radius cylinder generates accelerations of about 200m/s<sup>2</sup>, 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
5 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

15 manifold that is void of ethanol.

211

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.

Page 8 of 14

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

> EBS-00000182 FORD Ex. 1144, page 19 IPR2020-00013

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

5 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 10 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.

- 15 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
- 20 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 25 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 30

ethanol tank 16 as an input to control the turbocharger 22 (or supercharger or spark retard, not

Page 9 of 14

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

> EBS-00000183 FORD Ex. 1144, page 20 IPR2020-00013

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.

5 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

15 applications.

20

140

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 arnyl 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:

Attorney Docket No.: 0492611-0598 Express Mall No. EV196632874US Date of Filing: November 18, 2004 Customer Number: 24280 Page 10 of 14

EBS-00000184 FORD Ex. 1144, page 21 IPR2020-00013

1 2	1.	Fuel management system for efficient operation of a spark ignition gasoline engine comprising:					
3		a gasoline engine;					
4		a source of an anti-knock agent;					
5		an injector for direct injection of the anti-knock agent into a cylinder of the engine; and					
6 7		a fuel management control system for controlling injection of the anti-knock agent into the cylinder to control knock.					
8 9	2.	The system of claim 1 wherein the injectors stratify the anti-knock agent to provide non- uniform deposition within a cylinder.					
10 11	3,	The system of claim 2 wherein the anti-knock agent is deposited near the walls of the cylinder.					
12 13	4.	The system of claim 2 wherein the stratification is obtained through direct injection and charge swirl.					
14 15	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.					
16 17 18	б.	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.					
19 20 21	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.					
22	8.	The system of claim 1 wherein the anti-knock agent is cthanol.					
23	9.	The system of claim 8 wherein the ethanol is mixed with water.					

3

S - S

Page 11 of 14

Attomey Docket No.: 0492611-0598 Express Mail No. EV196632874US Date of Filing: November 16, 2004 Customer Numbor: 24280

> EBS-00000185 FORD Ex. 1144, page 22 IPR2020-00013

1	10.	The system of claim 8 wherein the ethanol is mixed with a lubricant.
2	11.	The system of claim 1 wherein the engine has substantial organized motion such as swirl.
3 4 5	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.
6 7	13.	The system of claim 1 wherein the anti-knock agent is added only during portions of a drive cycle requiring knock resistance.
8	14.	The system of claim 1 wherein gasoline is port injected into the engine.
9	15.	The system of claim 1 wherein the gasoline is directly injected into the cylinder.
10 11	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.
12 13	17.	The system of claim 1 wherein the fuel management system substantially minimizes the amount of anti-knock agent used over a drive cycle.
14 15	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.
16 17	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.
18 19	20.	The system of claim 8 wherein ethanol is injected proximate to a cylinder wall and swirl creates a ring of ethanol.
20	<b>2</b> 1.	Fuel management system for efficient operation of a spark ignition engine comprising:
21		a gasoline engine;
22		a source of anti-knock agent;
23		a means for port fuel injection of the anti-knock agent; and
	Attomey	Page 12 of 14

Express Mall No. EV196632874US Date of Filing: November 18, 2004 Customer Number: 24280

•••

\*

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

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

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

6

Attorney Docket No.: 0492611-0598 Express Mall No. EV196632874US Date of Filing: November 18, 2004 Customer Number: 24280 Page 13 of 14

EBS-00000187 FORD Ex. 1144, page 24 IPR2020-00013

### 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.

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

te n∂i

Page 14 of 14

3765091v1

EBS-00000188 FORD Ex. 1144, page 25 IPR2020-00013



EBS-00000189 FORD Ex. 1144, page 26 IPR2020-00013



EBS-00000190 FORD Ex. 1144, page 27 IPR2020-00013 Applicant: Cohn, et al. Title: Fuel Management System for Variable Ethanol Octane Enhancement of Gasoline Engines Reference No.: 0492611-0598 Sheet 3 of 3



EBS-00000191 FORD Ex. 1144, page 28 IPR2020-00013

# EXHIBIT 2

FORD Ex. 1144, page 29 IPR2020-00013



### (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: Danlel R. Cohn, Cambridge, MA (US); Leslle 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)
- 123/299, 300, 525, 27 GE, 198 A, 575, 1 A, 123/559.1, 527

See application file for complete search history.

## References Cited

(56)

U.S. PATENT DOCUMENTS

2,741,230	A	4/1956	Reynolds
3.089.470	A	5/1963	Payne
3.106.194	A	10/1963	Cantwell et al.
3 557 763	A	1/1971	Probst
4 031 864	A	6/1977	Crothers
4,056,087	Λ	11/1977	Boyce
4,182,278	A	1/1980	Coakwell
4,230,072	Λ	10/1980	Noguchi et al.
4,312,310	Λ	1/1982	Chivilo' et al.
4,402,296	A	9/1983	Schwarz
4,480,616	A	11/1984	Takeda
4,541,383	Λ	9/1985	Jessel
4,594,201	A	6/1986	Phillips et al.
		(Cont	inued)

### OTHER PUBLICATIONS

A. Modak and L S. Caretto, Engine Cooling by Direct Injection of Cooling Water, Society of Automotive Engineers, Inc. 700887

(Continued)

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



### US 8,069,839 B2

Page 2

U.S.	PAI	ENT	DO	CUN	1EN	TS

4,721,081 4,958,598 4,967,714	A A	1/1988 9/1990	Krauja et al. Fosseen Inoue	
4,907,714	A .	12/1000	Taylor	
4,974,410	A	2/1001	Orașa et al	
5 170 023	1	1/1003	Tennintani at al	
5 733 044	4	8/1003	Moghizuki	
5 407 744	~	2/1006	Nagaosa at al	
5 560 7.44	4	10/1006	Chan	
5 7 15 788	^	7/1008	Tour at al	
5011210	A .	6/1000	Flach	
5 037 700	<u>^</u>	8/1000	Binion	
5 083 855	3	11/1000	Bonodikt at al	
6 073 607	^	6/2000	Liber	
6 076 487	~	6/2000	Mulf at al	
6 260 525		7/2000	Mount	
6 287 351	BI	0/2001	Wulff ot al	
6 207,551	DI	10/2001	Huff of al	
6 222 148	DI	12/2001	Ilympa at al	
6 340 015	BI	1/2001	Bonodikt at al	
6358180	BI	3/2002	Furoda et al.	
6 508 733		1/2002	Subro et al	
6 5 13 505	D1 D1	2/2003	Watanaba at al	
6 536 405	112	3/2003	Riogar et al	
6 543 423	137	4/2003	Dobradan at al-	
6 561 157	82	5/2003	zur Love et al.	
6 575 147	H2	6/2003	Wulff et al	
6 677 663	112	0/2003	Waissman at al	
6 655 324	B2 +	12/2003	Cohn et al	123/1-4
6 668 804	B2	12/2003	Dobryden et al	120/17
6 725 827	Н2	4/2004	Lleda et al:	
6 745 744	87	6/2004	Suckewer et al.	
6 748 918	B2	6/2004	Rieper et al.	
6 7 55 1 75	AT .	6/2004	McKay et al	
6 799 551	132	10/2004	Nakakita et al.	
6,892,691	BI	5/2005	[[h] et al	
6.951.202	132	10/2005	Oda	
6,955,154	BI	10/2005	Douglas	
6.990.956	B2	1/2006	Niimi	
7.013.847	132	3/2006	Auer	
7.021.277	132	4/2006	Kuo et al.	
7.028.644	B2 *	4/2006	Cohn et al	123/17
7.077.100	B2	7/2006	Vogel et al.	
7.086.376	B2	8/2006	McKay	
7.107.942	B2	9/2006	Weissman et al.	
7.156.070	B2	1/2007	Strom et al.	
7,188,607	B2	3/2007	Kobayashi	
7.201.136	B2	4/2007	McKay et al	
7,320,302	B2	1/2008	Kobayashi	
7,444,987	B2 *	11/2008	Cohn et al.	123/43
2008/0168966	AI*	7/2008	Bromberg et al	123/528
2010/0175659	AI*	7/2010	Cohn et al.	123/304

### OTHER PUBLICATIONS

Julian A. LoRusso and Harry A. Cikanek, Direct Injection Ignition Assisted Alcohol Engine, Society of Automotive Engineers, Inc. 880495, International Congress and Exposition in Detroit Michigan (Feb. 29-Mar. 4, 1998).

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. 982476, International Fall Fuels and Lubricants Meeting and Exposition in San Francisco, California (Oct. 19-22, 1998).

Borje Grandin and Hans-Erik Angstrom, Replacing Fuel Enrichment in a Turbo Charged SI Engine: Lean Burn or Cooled EGR, Society of Automotive Engineers, Inc. 199-01-3505.

C. Stan, R. Troeger, S. Guenther, A. Stanciu, L. Martorano, C. Turantino and R. Lensi, Internal Mixture Formation and Combustion—from Gasoline to Ethanol. Society of Automotive Engineers, Inc. 2001-01-1207.

PCT International Search Report and Written Opinion, Appl. No. PCT/US05/041317, Apr. 6, 2006.

PCT International Search Report and Written Opinion, Appl. No. PCT/US06/012750, Jun. 28, 2007

USPTO Notice of Allowance, U.S. Appl. No. 11/684,100, Mar. 3, 2009.

USPTO Non-Final Office Action, U.S. Appl. No. 11/840,719, Jul. 11, 2008.

J.B. Heywood, "Internal Combustion Engine Fundamentals," McGraw Hill, 1998, p. 477.

J. Stokes et al. "A gasoline engine concept for improved fuel economy—the lean-boost system," SAE paper 2001-01-2902, pp. 1-12.

 H.J. Curran et al., "A comprehensive modeling study of iso-octane oxidation," Combustion and Flame 129:263-280 (2002) pp. 253-280.
 B. Leconte and G. Monnier, "Downsizing a gasoline engine using turbocharging with direct injection" SAE paper 2003-01-0542.

USPTO Non-Final Office Action, U.S. Appl. No. 10/991,774, Apr. 25, 2006

USPTO Final Office Action, U.S. Appl. No. 10/991,774. Sep. 27, 2006.

USPTO Non-Final Office Action, U.S. Appl. No. 10/991,774, May 25, 2007.

USPTO Non-Final Office Action, U.S. Appl. No. 11/100,026, Aug. 3, 2006.

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.

USPTO Non-Final Office Action, U.S. Appl. No. 11/229,755, Mar. 22, 2007.

USPTO Non-Final Office Action, U.S. Appl. No. 11/229,755, Oct. 4, 2007.

USPTO Non-Final Office Action, U.S. Appl. No. 11/682,372, Jan. 2, 2008.

USPTO Final Office Action, U.S. Appl. No. 11/682,372, Oct. 7, 2008.

USPTO Non-Final Office Action,  $U_4S_8$  Appl. No. 11/684,100, Jun. 3, 2008.

PCT International Search Report and Written Opinion, Application No. PCT/IB07/03004, Jul. 9, 2008.

PCT International Search Report and Written Opinion, Application No. PCT/US07/05777, Mar 24, 2008

PCT International Search Report and Written Opinion. Application No. PCT/US07/74227, Feb. 25, 2008

PCT International Search Report and Written Opinion, Application No. PCT/US08/69171, Oct. 3, 2008.

\* cited by examiner

FORD Ex. 1144, page 31 IPR2020-00013



**FIG.** 1



**FIG. 2** 







**FIG. 4** 



**FIG. 5** 

30

### 1 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, 10 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 15 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 20 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 percenta

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 35 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 enhance- 40 percent of the engine's energy coming from the ethanol. ment 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 45 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 50 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  $^{-55}$ 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 rela- 60 tively 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

### 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 man- 10 agement 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 20 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 25 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 etha- 35 nol 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 40 for gasoline than for ethanol (for stoichiometric mixtures wherein the amount of air contains oxygen that is just sufficient to combust ail of the fuel).

In the case of ethanol direct injection according to one aspect of the invention, the charge is directly cooled. The 45 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 50 denature the ethanol and make it unattractive for human conis 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, 55 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. 60 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%. 65

The octane enhancement effect can be estimated from the data in FIG. 2. Direct injection of gasoline results in approxi4

mately 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 octaneenhancement 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 sumption.

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 10 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 15 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<sup>2</sup>, or about 20 g's.

FIG. 3 illustrates ethanol direct injection and swirl motion for achieving thermal stratification. Ethanol is predominantly 20 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 25 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 3 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 regious 3 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 40 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 den-45 sity, 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 50 knock free operation with gasoline alone. The amount of octane enhancement that is required is determined by the torque level.

À rough illustrative calculation shows that only a small amount of ethanol might be needed over the drive cycle. 55 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 60 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 65 linearly to zero at 50 percent of maximum torque, the energy fraction provided by ethanol is about 30 percent. During a 6

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 10 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 15 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 20 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 25 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.

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

fucled with ethanol. 10. The spark ignition engine of claim 1 where the engine 35

is fueled with methanol.

8

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

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.

 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

FORD Ex. 1144, page 39 IPR2020-00013



# (12) United States Patent Cohn et al.

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

- (71) Applicant: Massachusetts Institute of Technology, Cambridge, MA (US)
- (72) Inventors: Danlel R. Cohn, Cambridge, MA (US); John B. Heywood, Newtonville, MA (US); Leslie Bromberg, Sharon, 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.
   This patent is subject to a terminal dis-

claimer.

- (21) Appl. No.: 14/478,069
- (22) Filed: Sep. 5, 2014

(65) Prior Publication Data

US 2014/0373811 A1 Dec. 25, 2014

#### Related U.S. Application Data

(63) 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

#### (Continued)

(51) Int. Cl. *F02M 25/14* (2006.01) *F02B 47/04* (2006.01)

(Continued)

(52) U.S. Cl. CPC . F02B 47/04 (2013.01); F02B 7/00 (2013.01); F02B 17/005 (2013.01); F02B 47/00 (2013.01);

(Continued)

# (10) Patent No.: US 9,255,519 B2 (45) Date of Patent: \*Feb. 9, 2016

 (58) Field of Classification Search CPC ...... F02D 19/12; F02D 19/08; F02D 41/402; F02D 35/027; F02B 47/00; F02M 25/14; F02P 5/152 USPC ....... 123/1 A, 27 GE, 525, 431, 299, 300, 123/198 A, 575, 406.21, 406.29, 406.37 See application file for complete search history.

#### (56) References Clted

#### U.S. PATENT DOCUMENTS

2,741,230 3,089,470	A A	4/1956 5/1963	Reynolds Payne	
		(Con	tinued)	
	O.	THER PUI	BLICATION	NS

Julian A. Lorusso and Harry A. Cikanek, Direct Injection Ignition Assisted Alcohol Engine, Society of Automotive Engineers, Inc. 880495, International Congress and Exposition in Detroit, Michigan (Feb. 29-Mar 4, 1998).

(Continued)

Primary Examiner ---- Hai Huynh

(74) Attorney, Agent, or Firm-Sam Pasternack; MJT 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 increase the efficiency or the engine.

#### 31 Claims, 3 Drawing Sheets



# US 9,255,519 B2

Page 2

#### Related U.S. Application Data

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. 13/817,448, 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.

(51) Int. Cl.

F02B 51/00	(2006.01)
F02D 41/00	(2006.01)
F02D 19/08	(2006.01)
F02B 17/00	(2006.01)
F02B 7/00	(2006.01)
F02B 47/00	(2006.01)
F02M 25/00	(2006.01)

(52) U.S. Cl.

#### (56) References Cited

#### U.S. PATENT DOCUMENTS

3.106.194	Α	10/1963	Cantwell et al.
3,557,763	Λ	1/1971	Probst
4 031 864	Λ	6/1977	Crothers
4,056,087	Α	11/1977	Boyce
4,182,278	A	1/1980	Coakwell
4,230,072	A	10/1980	Noguchi et alt
4,312,310	A	1/1982	Chivilo' et al.
4,402,296	Α	9/1983	Schwarz
4,480,616	Λ	11/1984	Takeda
4.541.383	A	9/1985	Jessel
4,594,201	A	6/1986	Phillips et al
4.721.081	Λ	1/1988	Krauja et al.
4,958,598	A	9/1990	Fosseeл
4 967 714	Α	11/1990	lnoue
4,974,416	Λ	12/1990	Taylor
4,993,386	A	2/1991	Ozasa et al.
5,179,923	Α	1/1993	Tsurutani et al
5,233,944	Λ	8/1993	Mochizuki
5,497,744	A	3/1996	Nagaosa et al
5,560,344	A	10/1996	Chan
5,715,788	A	2/1998	Tarr et al.
5,911,210	A	6/1999	Flach
5.937.799	A	8/1999	Binion
5,983,855	Α	11/1999	Benedikt et al.
6.073.607	Λ	6/2000	Liber
6.076.487	A	6/2000	Wulff et al
6.260.525	BI	7/2001	Moyer
6.287.351	BL	9/2001	Wulff et al.
6.298.838	Bl	10/2001	Huff et al
6,332,448	BI	12/2001	Ilyama et al
6,340,015	BI	1/2002	Benedikt et al.
6,358,180	BI	3/2002	Kuroda et al.
6.508.233	BI	1/2003	Suhre et al
6.513.505	B2	2/2003	Watanabe et al
6,536,405	BL	3/2003	Rieger et al.
6,543,423	B2	4/2003	Dobryden et al.
6.561.157	B2	5/2003	zur Loye et al.

0,070,147	Dź	0/2005	WIIII CI II		
6,622,663	B2	9/2003	Weissman et al		
6,668,804	B2	12/2003	Dobryden et al		
6,725,827	B2	4/2004	Ueda et al		
6,745,744	B2	6/2004	Suckewer et al.		
6,748,918	B2	6/2004	Rieger et al.		
6,755,175	B1	6/2004	McKay et al		
6,799,551	B2	10/2004	Nakakita et al.		
6,892,691	B1	5/2005	Uhl et al.		
6,951,202	B2	10/2005	Oda		
6,955,154	B1	10/2005	Douglas		
6,990,956	B2	1/2006	Niimi		
7,013,847	B2	3/2006	Auer		
7,021,277	B2	4/2006	Kuo et al.		
7,077,100	B2	7/2006	Vogel et al		
7,086,376	B2	8/2006	Mckay		
7,107,942	B2	9/2006	Weissman et al.		
7,156,070	B2	1/2007	Strom et al.		
7,188,607	B2	3/2007	Kobayashi		
7,314,033	B2 *	1/2008	Cohn et al		
			123/198 A		
7,320,302	B2	1/2008	Kobayashi		
7,740,004	B2 *	6/2010	Cohn et al F02D 43/00		
			123/406.29		
7,762,233	B2 *	7/2010	Cohn et al		
			123/431		
8,857,410	B2 *	10/2014	Cohn et al. F02M 25/14		
	_				
	OT	HER PUI	BLICATIONS		

C/2002 11/ 102 - 1

Borje Grandin, Hans-Erik Angstrom, Per Stalhammar and Eric Olofsson, Knock Supression in a Turbocharged SI Engine by Using Cooled EGR, Society of Automotive Engineers, Inc. 982476, International Fall Fuels and Lubricants Meeting and Exposition in San Francisco, California (Oct. 19-22, 1998).

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. Jan. 2001–1207.

PCT International Search Report and Written Opinion, Appl. No. PCT/US05/041317, Apr. 6, 2006

PCT International Search Report and Written Opinion, Appl. No. PCT/US06/012750, Jun. 28, 2007.

USPTO Notice of Allowance, U.S. Appl. No. 11/684,100, Mar. 3, 2009.

USPTO Non-Final Office Action, U.S. Appl. Not 11/650,719, Jul. 11, 2008.

J.B. Heywood, "Internal Combustion Engine Fundamentals," McGraw Hill, 1998, p. 477.

J. Stokes et al., "A gasoline engine concept for improved fuel economy—the iean-boost system," SAE paper Jan. 2001—2902, pp. 1-12.

H.J. Curran et al., "A comprehensive modeling study of iso-octane oxidation," Combustion and Flame, 129: 263-280, 2002,  $pp_{\rm e}$  253-280,

B. LeCointe and G. Monnier, "Downsizing a gasoline engine using turbocharging with direct injection", SAE paper, Jan. 2003—0542. USPTO Non-Final Office Action, U.S. Appl. No. 10/991,774, Apr. 25, 2006.

USPTO Final Office Action, U.S. Appl. No. 10/991,774, Sep. 27, 2006.

USPTO Non-Final Office Action, U.S. Appl. No. 10/991,774, May 25, 2007.

USPTO Non-Final Office Action, U.S. Appl. No. 11/100,026, Aug. 3, 2006. Fikret Yuksel and Bedri Yuksel, "The Use of Ethanol-Gasoline Blend

as a Fuel in an SI Engine." Renewable Energy, vol. 29 (2004) pp. 1161-1191

USPTO Non-Final Office Action, U.S. Appl. No. 11/229,755, Mar. 22, 2007

USPTO Non-Final Office Action, U.S. Appl. No.  $11/229,755,\,Oet.\,4,\,2007_{\rm e}$ 

USPTO Non-Final Office Action, U.S. Appl. No. 11/682.372, Jan. 2, 2008.

# FORD Ex. 1144, page 41 IPR2020-00013

### US 9,255,519 B2 Page 3

#### References Clted

(56)

#### OTHER PUBLICATIONS

USPTO Final Office Action, U.S. Appl. No. 11/682,372, Oct. 17, 2008: USPTO Non-Final Office Action, U.S. Appl. No. 11/684,100, Jun. 3,

USPTO Non-Final Office Action, U.S. Appl. No. 11/684,100, Jun. 3, 2008.

PCT International Search Report and Written Opinion, Application No. PCT/IB07/03004, Jul. 9, 2008.

PCT International Search Report and Written Opinion, Application No. PCT/US07/06777, Mar. 24, 2008.

PCT International Search Report and Written Opinion, Application No PCT/US07/74227, Feb. 25, 2008.

PCT International Search Report and Written Opinion, Application No. PC1/US08/69171, Oct. 3, 2008.

\* cited by examiner







FIG. 2

FORD Ex. 1144, page 43 IPR2020-00013





FIG. 3



FIG. 4



FIG. 5

FORD Ex. 1144, page 45 IPR2020-00013

#### FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES

1

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. 15 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 20 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 25 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) gaso- 35 line 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 40 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. 45 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 50

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 55 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 60 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 65 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 30 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  $13^{\circ}$  C<sub>\*</sub> 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 20 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 25 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 combi- 30 nation of open and closed loop control.

As show in FIG. 1 it is preferred that ethanol be directly injected into the engine  $10_{\pm}$  Direct injection substantially increases the benefits of ethanol addition and decreases the required amount of ethanol. Recent advances in fuel injector 35 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 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 cylinder is preferred because it is advantageous in obtaining good air/fuel mixing and combustion stability that are diffiered into this 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 50 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 60 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 *a* 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.

<sup>10</sup> The temperature decrement because of the vaporization energy of the ethanol decreases with lean operation and with FGR, as the thermal capacity of the cylinder charge increases. If the engine operates at twice the stoichiometric air/fuel
 <sup>15</sup> 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 octaneenhancement 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 10 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 a 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 decre- 20 drive cycle about 20 percent of the total fuel energy is conments 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 25 The amount of ethanol energy consumed during the drive 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 30 needed averaged over the drive cycle. The ethanol is much 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 35 3 m/s swirl motion in a 5 cm radius cylinder generates accelerations of about 200 m/s<sup>2</sup>, 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 addi tion 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 50 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, 55 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 sumed 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. 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 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 presentday 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 45 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 60 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 15 as tertiary butyl alcohol, or ethers such as methyl tertiary butyl ether (MTBE), ethyl tertiary butyl ether (ETBE), or tertiary anyl methyl ether (TAME).

It is recognized that modifications and variations of the invention disclosed herein will be apparent to those of ordi-20 nary 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 30 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 40 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 50 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 55 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 60 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 65 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 luel 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 5 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 10 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 15 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 20 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.

#### 10

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

FORD Ex. 1144, page 51 IPR2020-00013



# (12) United States Patent Cohn et al.

- (54) FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES
- (71) Applicant: Massachusetts Institute of Technology, Cambridge, MA (US)
- (72) Inventors: Daniel R. Cohn, Cambridge, MA (US); John B. Heywood, Newtonville. MA (US); Leslie Bromberg, Sharon, MA (US)
- (73) Assignce: 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.
   This patent is subject to a terminal disclaimer.
- (21) Appl. No.: 15/463,425
- (22) Filed: Mar. 20, 2017
- (65) Prior Publication Data

US 2017/0191431 A1 Jul. 6, 2017

#### **Related U.S. Application Data**

- (63) Continuation of application No. 14/982,086, filed on Dec. 29, 2015, which is a continuation of application (Continued)
- (51) Int. Cl. *F02D 41/30* (2006.01) *F02D 41/00* (2006.01)

(Continued) (52) U.S. Cl.

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

(58) Field of Classification Search CPC ...... F02D 41/0025; F02D 41/3094; F02D 35/027; F02D 2200/1002; F02D 2041/389;

(Continued)

(56) References Cited

U.S. PATENT DOCUMENTS

2.741,230	۸	4/1956 Reynolds
3,089,470	A	5/1963 Payne
		(Continued)

#### OTHER PUBLICATIONS

A. Modak and L.S. Caretto, Engine Cooling by Direct Injection of Cooling Water, Society of Automotive Engineers, Inc. 700887. (Continued)

Primary Examiner — Hai Huynh (74) Attorney, Agent, or Firm — Sam Pasternack; MIT 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 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.

(51) Int. Cl.

(56)

F02M 25/14	(2006.01)
F02D 35/02	(2006.01)
F02P 5/04	(2006.01)
F02B 47/04	(2006.01)
F02D 41/38	(2006.01)

(58) Field of Classification Search

CPC = F02D 19/0615; F02D 37/02; F02D 2250/18; F02M 25/14; F02M 69/046; F02P 5/045;

F02B 47/04 USPC ..... 123/575, 576, 577, 578, 431, 198 A,

123/406.23; 701/110, 111

See application file for complete search history.

#### References Cited

#### U.S. PATENT DOCUMENTS

3,106,194	А	10/1963	Cantwell et al.
3,557,763	А	1/1971	Probst
4,031,864	А	11/1977	Crothers
4,056,087	А	11/1977	Boyce
4,182,278	А	1/1980	Coakwell
4,230,072	А	10/1980	Noguchi et al.
4,312,310	$\Lambda$	1/1982	Chivilo' et al
4,402,296	А	9/1983	Schwarz
4,480,616	А	11/1984	Takeda
4,541,383	А	9/1985	Jessel
4,594,201	А	6/1986	Phillips et al.
4,721,081	А	1/1988	Krauja et al
4,958,598	Λ	9/1990	Fosseen
4,967,714	А	11/1990	Inoue
4,974,416	Δ	12/1990	Taylor
4,993,386	А	2/1991	Ozasa et al
5,179,923	А	1/1993	Tsurutani et al
5,233,944	А	8/1993	Mochizuki
5,497,744	А	3/1996	Nagaosa et al
5,560,344	Δ	10/1996	Chan
5,715,788	А	2/1998	Tarr et al
5,911,210	Λ	6/1999	Flach

5.937,799 5.983,855 6.073,607 6.075,487 6.260,525 6.287,351 6.298,838 6.332,448 6.340,015 6.358,180 6.508,233 6.513,505 6.536,405 6.543,423 6.561,157 6.575,147 6.622,663 6.668,804 6.725,827 6.745,744 6.746,918 6.755,175 6.799,551 6.892,691 6.951,202 6.955,154 6.990,956 7.013,847 7.077,100 7.086,376 7.107,942 7,156,070 7,188,607	A A A BI BI BI BI BI B2 B2 B2 B2 B1 B1 B2 B2 B1 B1 B2 B1 B2 B1 B2 B1 B2 B1 B2 B1 B2 B1 B2 B1 B2 B1 B2 B1 B2 B1 B1 B1 B1 B1 B1 B1 B1 B1 B1 B1 B1 B1	8/1999 1/4999 6/2000 6/2000 7/2001 1/2002 3/2003 2/2003 3/2003 4/2003 5/2003 1/2003 1/2003 1/2003 1/2003 1/2004 6/2004 6/2004 6/2004 6/2004 1/2005 1/2005 1/2005 1/2006 3/2006 4/2006 6/2006 3/2007	Binion Benedikt et al. Liber Wullf et al. Moyer Wullf et al. Huff et al. Huff et al. Ilyama et al. Benedikt et al. Kuroda et al. Subre et al. Wutanabe et al. Rieger et al. Dobryden et al. Zur Loye et al. Wulff et al. Wulff et al. Wufff et al. Wufff et al. Suckewer et al. Dobryden et al. Dobryden et al. Dobryden et al. Ueda et al. Suckewer et al. McKay et al. Oda Douglas Niimi Auer Kuo et al. Vogel et al. McKay Weissman et al. Suck wer et al. Makakita et al. Uhf et al. Oda Douglas Niimi Auer Kuo et al. Strom et al. Strom et al.
7,200,000	101	0/20077	123/1 A
7,320,302	B2	1/2008	Kobayashi
8,857,410	B2 *	10/2014	Cohn F02B 47/04
9 255 519	B2 *	2/2016	Cohn F02B 47/04
2005/0098157	AI*	5/2005	Ohtani F02D 41/3029
2007/0215101		0/2007	123/431
2007/0215101	AI	9/2007	123/310
2007/0215102	$\Delta L^{\bullet}$	9/2007	Russell
2007/0215104	AL*	9/2007	Hahn F02D 35/021
2007/0215111	A *	9/2007	Surnilla
0005/0014100		0.000	123/431
2007/0215130	AI*	9/2007	Shelby F02D 19/084
2009/0282810	A1*	11/2009	Leone F02D 19/081
2015/0285179	A1*	10/2015	Cohn F02D 41/3094
2015/0369162	A1 *	12/2015	Cohn 1/02D 13/0215 123/406.27

#### OTHER PUBLICATIONS

Julian A. Lorusso and Harry A. Cikanek, Direct Injection Ignition Assisted Alcohol Engine, Society of Automotive Engineers. Inc. 880495, International Congress and Exposition in Detroit, Michigan (Feb. 29-Mar) 4, 1998).

Borje Grandin, Hans-Erik Angstrom, Per Stalhammar and Eric Olofsson, Knoek 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 (Oct. 19-22, 1998).

Borje Grandin and Hans-Erik Angstrom, Replacing Fuel Enrichment in a Turbo Charged SI Engine: Lean Burn or Cooled EGR. Society of Automotive Engineers. Inc. 962476

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.

Page 2

# US 9,810,166 B2

#### Page 3

#### (56) References Clted

#### OTHER PUBLICATIONS

PCT International Search Report and Written Opinion, Appl. No. PCT/US05/041317, dated Apr. 6, 2006.

PCT International Search Report and Written Opinion, Appl. No. PCT/US06/012750, dated Jun. 28, 2007

USPTO Notice of Allowance, U.S. Appl. No. 11/684,100, dated Mar. 3, 2009.

USPTO Non-Final Office Action, U.S. Appl. No. 11/850,719, dated Jul. 11, 2008.

J.B. Heywood, "Internal Combustion Engine Fundamentals," McGraw Itill, 1998, p. 477.

 $J_{\pm}$  Stokes et al. "A gasoline engine concept for improved fuel economy—the lean-boost system," SAE paper 2001-01-2902, pp. 1-12.

H.J. Curran et al., "A comprehensive modeling study of iso-octane oxidation," Combustion and Flame, 129: 263-280, 2002, pp. 253-280.

B. Lecointe and G. Monnier, "Downsizing a gasoline engine using turbocharging with direct injection", SAE paper, 2003-01-0542. USPTO Non-Final Office Action, U.S. Appl. No. 10/991,774, dated

Apr. 25, 2006. USPTO Final Office Action, U.S. Appl. No. 10/991,774, dated Sep.

27, 2006-

USPTO Non-Final Office Aciton, U.S. Appl. No. 10/991,774, dated May 25, 2007.

USPTO Non-Final Office Action, U.S. Appl. No. 11/100,026, dated Aug. 3, 2006.

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.

USPTO Non-Final Office Action, U.S. Appl. No. 11/229,755, dated Mar. 22, 2007.

USPTO Non-Final Office Action, U.S. Appl. No. 11/229,755, dated Oct. 4, 2007.

USPTO Non-Final Office Action, U.S. Appl. No. 11/682,372, dated Jan. 2, 2008.

USPTO Final Office Action, U.S. Appl. No. 11/682,372, dated Oct. 17, 2008.

USPTO Non-Final Office Action, U.S. Appl. No. 11/684,100, dated Jun. 3, 2008.

PCT International Search Report and Written Opinion, Application No. PCT/IB07/03004, dated Jul. 9, 2008.

PCT International Search Report and Written Opinion, Application No. PCT/US07/05777, dated Mar. 24, 2008-

PCT International Search Report and Written Opinion, Application No. PCT/US07/74227, dated Feb. 25, 2008.

PCT International Search Report and Written Opinion, Application No. PCT/US08/69171, dated Oct. 3, 2008.

\* cited by examiner



**FIG. 1** 



**FIG. 2** 



**FIG. 3** 



FIG. 4



FIG. 5

FORD Ex. 1144, page 57 IPR2020-00013

#### 1 FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENIIANCEMENT 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 1 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 20 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 25 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 30 issued as U.S. Pat. No. 7.314,033.

#### BACKGROUND

This invention relates to spark ignition gasoline engines 35 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 40 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 55 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 65 amounts of ethanol added at the refinery. Ethanol has a blending octane number (ON) of 110 (versus 95 for pre2

mium gasoline) (see J. B. Heywood, "Internal Combustion Engine Fundamentals," McGraw Hill, 1988, p. 477) and is also attractive because it is a renewable energy, biomassderived 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.

40 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 to a fuel management microprocessor system to minimize to a fuel management microprocessor system to minimize to pathon.

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 5 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 15 the amount of ethanol in a fuel tank.

#### DETAILED DESCRIPTION

With reference first to FIG. 1, a spark ignition gasoline 20 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 2 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 30 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 3 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 40 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 45 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 is 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 55 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 combus-60 tion energy is 0.031 for ethanol and 0.008 for gasoline. That is, for equal amounts of energy the required heat of vaporization per unit air required for stoichiometric combustion is about 94 kJ/kg of 65 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 octaneenhancement 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  $^{-5}$  removed from the ethanol.

5

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<sup>10</sup> 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. <sup>15</sup> 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 <sup>20</sup> 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 (GD1) can be avoided. <sup>25</sup>

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 <sup>30</sup> 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 40 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 (centrifu-45 gal) forces. A 3 m/s swirl motion in a 5 cm radius cylinder generates accelerations of about 200 m/s<sup>2</sup>, 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. 50 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. 55

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 60 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 65 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 percentx(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 10 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 19 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 20 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 25 vaporization energies such as methanol (with higher vaporization energy per unit fuel), and other anti-knock agents such as tertiary butyl alcohol, or others such as methyl tertiary butyl ether (MTBE), ethyl tertiary butyl ether (ETBE), or tertiary amyl methyl ether (TAME). 30

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:

 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 45 is changed so as to obtain knock-free operation and the amount of directly injected fuel used to provide knockfree operation is minimized.

**2.** The fuel management system of claim 1 where as torque is increased the fraction of fuel that is directly 50 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 55 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 60 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. 65

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 injec-

tion 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.

 $12_{\circ}$  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.

FORD Ex. 1144, page 61 IPR2020-00013 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 5 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 <sup>10</sup> 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 fucl <sup>15</sup> provided by direct injection increases with increasing torque.

#### 10

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

FORD Ex. 1144, page 63 IPR2020-00013



# (12) United States Patent Cohn et al.

- (54) FUEL MANAGEMENT SYSTEM FOR VARIABLE ETHANOL OCTANE ENHANCEMENT OF GASOLINE ENGINES
- (71) Applicant: Massachusetts Institute of Technology, Cambridge, MA (US)
- (72) Inventors: Daniel R. Cohn, Cambridge, MA (US); John B. Heywood, Newtonville, MA (US); Leslie Bromberg, Sharon, 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.
   This patent is subject to a terminal disclaimer.
- (21) Appl. No.: 15/716,675
- (22) Filed: Sep. 27, 2017
- (65) Prior Publication Data

US 2018/0016998 A1 Jan. 18, 2018

#### Related U.S. Application Data

- (63) Continuation of application No. 15/463.425, filed on Mar. 20, 2017, now Pat. No. 9,810,166, and a (Continued)
- (51) Int. Cl.

F02D 41/30	(2006.01)
F02D 41/00	(2006.01)
	(Continued)

# (10) Patent No.: US 10,138,826 B2 (45) Date of Patent: \*Nov. 27, 2018

- - (Continued)
- (58) Field of Classification Search CPC ...... F02D 41/0025; F02D 41/3094; F02D 35/027; F02D 11/105; F02D 2250/18; (Continued)
- (56) References Cited

U.S. PATENT DOCUMENTS

2,741,230 A	4/1956 Reynolds
3,089,470 A	5/1963 Payne
	(Continued)

#### OTHER PUBLICATIONS

[No Author Listed] "Alternative Automotive Fuels," J1297\_ 200209, Society of Automotive Engineers (SAE) Information Report, Sep. 13, 2002.

(Continued)

Primary Examiner — Hai Huynh

(74) Attorney, Agent, or Firm -- Nutter McClennen & Fish LLP

#### (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.

(51) Int. Cl.

F02B 47/04	(2006.01)
F02B 51/00	(2006.01)
F02M 25/14	(2006.01)
F02D 19/08	(2006.01)
F02B 17/00	(2006.01)
F02B 7/00	(2006.01)
F02B 47/00	(2006.01)
F02M 25/00	(2006.01)
F02D 35/02	(2006.01)
F02P 5/04	(2006.01)
F02D 41/38	(2006.01)

(52) U.S. Cl.

CPC ...... F02B 47/00 (2013.01); F02B 47/04 (2013.01); F02B 51/00 (2013.01); F02D 19/08 (2013.01); F02D 19/081 (2013.01); F02D 35/027 (2013.01); F02D 41/3094 (2013.01); F02M 25/00 (2013.01); F02M 25/14 (2013.01); F02P 5/045 (2013.01): F02D 2041/389 (2013.01); F02D 2200/1002 (2013.01); Y02T 10/148 (2013.01) Field of Classification Search

(58)CPC ..... F02D 2200/1002; F02D 2041/389; F02M 25/14; F02M 69/046: F02P 5/045; F02B 47/04

USPC ...... 123/431, 198 A, 406.23, 575, 576, 577,

123/578: 701/103. 110, 111 See application file for complete search history.

#### (56) **References** Cited

#### U.S. PATENT DOCUMENTS

3,106,194	Δ	10/1963	Cantwell et al.
3,557,763	A	1/1971	Probst
3,822,119	А	7/1974	Freeh et al.
4 031 864	А	6/1977	Crothers
4.056.087	А	11/1977	Boyce
4.182,278	Λ	1/1980	Coakwell
4 230 072	А	10/1980	Noguchi et al.
4 312 310	Λ	1/1982	Chivilo' et al.

4 402 206	A	0/1093	Sahaara
4,402,290	~	9:1965	OCHWINZ .
4,480,616	A	11/1984	Takeda
4 405 930	Λ	1/1985	Makaiima
1.1751250	<u>_</u>	01000	Hakajina
4,541,383	A	9/1985	Jessel
4 504 201	٨	6/1986	Phillips et al.
4.506.277	1	6.1000	rinnips of m.
4,590,277	Δ	0/1980	Djordjevic
4 721 081	Δ	1/1088	Krauia et al-
1 0 0 0 0 0 0	~	1 1 200	ivinaja et al
4,876,988	A	10/1989	Paul et al
1 058 508	4	0/100/1	Foregoin
7,200,020	0	21220	i viacen
4 967 714	A	11/1990	Inoue
1071116	A	12/1000	Taulor
4.974,410	2	12/1990	Taylor
4 993 386	A	2/1991	Ozasa et al.
5 170 022	A	1/1002	Tourutani at al
5 119 925	~	1/1/2/20	istitutani et al
5 233 944	Δ	8/1993	Mochizuki
5 407 744	4	2/1006	Magagan at al
5 497 744	A	3/1990	Nagaosa et al
5.560.344	Δ	10/1996	Chan
6 716 700		3/10/09	Teau at al.
5./15./00	A	2/1998	farr et al
5.911.210	Δ	6/1999	Flach
6 022 200		0/1000	Distant and
5 951 199	A	9,1222	Bimon
5.983.855	A	11/1999	Benedikt et al.
6 072 607		6/20/00	I. Dene
0.073.007	1	0/2000	Liber
6.076.487	A	6/2000	Wulff et al.
6 112 205		0.2000	Mada and a
0,112,705	Δ	9/2000	ivakayama et al
6.260.525	BL	7/2001	Mover
6 207 261	111	0.2001	World' at al.
0,287,331	101	9/2001	wuith et al
6.298.838	B1	10/2001	Huffetal
( 221 (02	D 1	112001	D
0.321.092	D1	11/2001	Kayner
6.332.448	BI	12/2001	Ilvama et al:
6 340 016	D.I.	1/2002	Descalible at al
0,340,015	ы	1/2002	Benedikt et al
6.358.180	131	3/2002	Kuroda et al.
6 606 670	DI	1/2/102	
0,202,279	ы	1/2003	lee
6.508.233	B1	1/2003	Subre et al
6 612 605	D.2	2:0000	
0,513,505	BZ	2/2003	watanabe et al.
6.536.405	BL	3/2003	Rieger et al
6 6 40 400	D.2	4/2003	Deleterated
0,343,423	B2	4/2003	Dobryden ei al
6.561.157	B2	5/2003	zur Love et al.
6 676 147	0.5	6 (2002	1V-10 - 1
0,575,147	BZ	6/2003	wulff et al.
6.622.663	132	9/2003	Weissman et al.
6 655 224	D 2	10/0000	Calaria
0,000,024	B2	12/2003	Conn et al.
6.668.804	B2	2/2003	Dobryden et al
6 776 977	10.2	4:2004	These states
0,123,021	D.	4/2004	Uega et al.
6.745.744	B2	6/2004	Suckewer et al.
6 740 010	11.2	6/30/04	Dimmental
0,748,918	D2	0/2004	Rieger et al
6.755.175	BI	6/2004	McKay et al
6 700 551	11.7	10:2004	Maladian at all
0.799.551	D2	10/2004	INARAKITA UTAL
6.892.691	BL	5/2005	Uhl et al.
6 061 202	12.2	10/2005	(Ada
0.951.202	D2	10/2005	C/Ga
6.955.154	B1	10/2005	Douglas
6 050 602	D 2	1120006	() he
0,323,032	BZ	11/2005	Oda
6.981.487	132	1/2006	Ohtani
6 000 056	122	1,2006	Millioni
0.990.900	D2	1/2000	INITIAL
7.013.847	B2	3/2006	Auer
7 021 227	<b>D</b> 2	4/2006	Kuo at al
7.021.277	112	9/2000	Kuo er ar
7.028.644	B2	4/2006	Cohn et al.
7 077 100	B2	7/2006	Vogel et al
10077100	174	112000	toger er m
7.086.376	B2	8/2006	мскау
7.107.942	B2	9/2006	Weissman et al.
7 160 365	112	12/2000	Mathematical Station
7 150 265	132	12/2006	Shibagaki
7 152 574	B2	12/2006	Mashiki et al.
7 166 070	0.2	1/2007	China and a lateral
1 1 20 0 10	197	1/2007	Shom et al.
7 159 568	BI	1/2007	Lewis et al.
7.159,500	BI	2/2007	Dentis et in.
7,178,503	191	2/2007	Brehob
7 188 607	H2	3/2007	Kohavashi
7 301 134	12.2	1/2007	Makan
7.201,1.50	132	4/2007	wickay of all
7.225.787	B2	6/2007	Bromberg et al.
7 756 000	D.	0/2007	Linning of m
1.255,080	B1	8/2007	Leone
7.258 102	132	8/2007	Kinose et al.
7 3 60 1 02	Do	0/2007	Takana A I
7,258,103	B2	8/2007	rahara et al
7.263 973	132	9/2007	Akita et al.
7 200 0 10	112	0.0007	171
7,270.112	B2	9/2007	Kinose
7 275 515	B2	10/2007	Ikoma
1,213,313	D2	10/2007	INUTINI
7,275,519	B2	10/2007	Miyazaki et al-
7 779 207	42	10/2007	Kobayashi
1,210,391	02	10/2007	1x00aya5III
7.302.933	B2	12/2007	Kerns
7 3 4 0 3 3	22	1/3/\00	Cohn at al
1,514,033	DZ	1/2008	Comi et all.
7,320.302	B2	1/2008	Kobayashi
7 3 70 600	100	5/300P	Vanio
7,370,009	192	5/2008	Namio
7,395.786	B2	7/2008	Leone et al.
7 404 0 45	112	0/2000	Landa et al
7 400 947	102	ð/2008	Lewis et al.

### US 10,138,826 B2

#### Page 3

## (56) References Cited U.S. PATENT DOCUMENTS

7,444,987 B.	2 11/2008	Cohn et al.
7,401,028 B.	2 12/2008	Blumberg et al.
7,484,492 B.	2 2/2009	Sumilla
7.546 835 B	1 6/2009	Hilditch
7.556.030 B	7/2009	Ashida et al
7.578.281 B	8/2009	Russell et al.
7.581.528 B	9/2009	Stein et al.
7.587.998 B	9/2009	Hotta et al.
7,594,498 B	2 9/2009	Lewis et al.
7,640,914 B	2 1/2010	Lewis et al.
7,640,915 B	2 1/2010	Cohn et al
7,681,554 B	2 3/2010	Stein et al.
7,721,703 B.	2 5/2010	Kakuho et al_
7,740,004 B.	2 6/2010	Cohn et al.
7,762,233 B.	2 7/2010	Cohn et al
7,700,982 0.	2 0/2010	Cohn at al
7 840 842 13	12/2010	Lowie of al
7.869.930 B	0 1/2011	Stein et al
7.971.572 B	7/2011	Cohn et al.
8,069,839 B	2 12/2011	Cohn et al.
8,078,386 B	2 12/2011	Stein et al.
8,132,555 B;	3/2012	Lewis et al.
8,146,568 B	2 4/2012	Cohn et al
8,171,915 B.	2 5/2012	Cohn et al
8,276,565 B	2 10/2012	Cohn et al.
8,302,580 B.	2 11/2012	Cohn et al
8,353,209 B.	2 1/2013	Kasseris et al.
8 522 746 B	0 0/2013	Cohn of al
8 707 913 B	4/2014	Cohn et al.
8.733.321 B	5/2014	Cohn et al.
8,857,410 B.	2 10/2014	Cohn et al.
8,997,711 13:	4/2015	Cohn et al.
9,255,519 B:	2* 2/2016	Cohn
9,695,784 B.	7/2017	Cohn et al.
9,810,166 B	11/2017	Cohn
2002/0014226 A	1 2/2002	Wulfi et al.
2004/0003274 A	5/2004	Obtani
2006/0102136 A	5/2006	Bromberg et al.
2006/0102145 A	5/2006	Cohn et al
2006/0102146 A	5/2006	Cohn et al.
2007/0039588 A	2/2007	Kobayashi
2007/0119391 A	5/2007	Fried et al.
2007/0119414 A	5/2007	Leone et al.
2007/0119422 A.	0/2007	Lewis et al.
2007/0215102 A	0/2007	Russell of al
2007/0215104 A	9/2007	Hahn
2007/0215111 A	9/2007	Sumilla
2007/0215130 A	9/2007	Shelby et al.
2008/0060612 A	3/2008	Cohn et al.
2008/0110434 A	5/2008	Cohn et al
2008/0168966 A	7/2008	Bromberg et al.
2008/0228382 A	9/2008	Lewis et al.
2009/0043478 A	2/2009	Laborie Calenarity at al
2009/00/070705 //	4/2009	Colesworiny et al
2009/0282810 A	+ 11/2009	Leone F02D 19/081
2000/0202442	* 11/2000	60/285
2009/0292443 A	- 11/2009	Stein 102D 19/081 701/103
2009/0308367 A	12/2009	Glugla
2010/0006050 A	1/2010	Bromberg et al
2010/0037859 A	2/2010	Mashiki
2010/00/0150 A	5/2010	Conn et al.
2010/0121559 A	7/2010	Cohn et al:
2010/0288232 4	1/2010	Bromberg et al.
2011/0030653 A1	2/2011	Cohn et al.
2011/0067674 A1	3/2011	Kasseris et al.
-2011/0162620 AI	7/2011	Bidner et al.

2011/0226210	AL	9/2011	Cohn et al.
2012/0029795	AL	2/2012	Surnilla et al
2012/0042857	Δ1	2/2012	Cohn et al.
2012/0048231	A1	3/2012	Bromberg et al.
2012/0138015	Δ1	6/2012	Cohn et al.
2012/0152204	AL	6/2012	Cohn et al.
2012/0199100	AL	8/2012	Kamio et al
2012/0312284	AI	12/2012	Cohn et al.
2013/0019839	AL	1/2013	Cohn et al.
2013/0261937	AL	10/2013	Cohn et al.
2013/0312701	AL	11/2013	Cohn et al.
2014/0216395	AL	8/2014	Cohn et al.
2014/0261345	AL	9/2014	Bromberg et al
2014/0297159	Δ1*	10/2014	Surnilla F02D 41/3094
			701/103
2014/0343825	$\Delta I$	11/2014	Cohn et al.
2014/0373811	A1	12/2014	Cohn et al.
2015/0167590	Δ1*	6/2015	Otto zur Love F02M 21/0287
			60/601
2015/0240737	Δ1*	8/2015	Surnilla F02D 41/008
			123/435
2015/0285179	AL	10/2015	Cohn et al.
2015/0369162	AL	12/2015	Cohn et al
2016/0138529	AL	5/2016	Cohn et al
2017/0191431	AT	7/2017	Cohn et al.
2017/0321616	A   #	11/2017	Miller 10/0615
		1 1. 2017	1020 19/0019

#### OTHER PUBLICATIONS

Bromberg, L., et al. Calculations of Knock Suppression in Highly Turbocharged Gasoline/Ethanol Engines Using Direct Ethanol Injection, 2006, pp. 1-17, MIT Laboratory for Energy and the Environment Report, Cambridge, MA.

\*\*Curran, II.J. et al., "A comprehensive modeling study of isooctane oxidation," Combustion and Flame 129:263-280 (2002) pp. 253-280

\*\*Grandin, Borje and Hans-Erik Angstrom, Replacing Fuel Enrichment in a Turbo Charged SI Engine: Lean Burn or Cooled EGR. Society of Automotive Engineers, Inc., technical paper, 1999-01-3505, 1999 <a href="https://doi.org/10.4271/1999-01-3505">https://doi.org/10.4271/1999-01-3505</a>

\*\*Grandin, Borje, Hans-Erik Angstrom, Per St Alhammar and Eric Olofsson, Knock Suppression in a Turbocharged SI Engine by Using Cooled EGR, Society of Automotive Engineers, Inc. 982476, International Fall Fuels and Lubricants Meeting and Exposition in San Francisco, California (Oct. 19-22, 1998).

\*\*Heywood, J. B., "Internal Combustion Engine Fundamentals," McGraw Hill, 1988, p. 477,

\*\*PCT International Search Report and Written Opinion, Appl. No. PCT/US05/041317, dated Aprl. 6, 2006

\*\*PCT International Search Report and Written Opinion, Appl. No. PCT/US06/012750, dated Jun. 28, 2007.

\*\*PCT International Search Report and Written Opinion, Application No. PCT/1807/03004, dated Jul. 9, 2008.

\*\*PCT International Search Report and Written Opinion, Application No. PCT/US07/05777, dated Mar. 24, 2008.

\*\*PCT International Search Report and Written Opinion. Application No. PCT/US07/74227, dated Feb. 25, 2008

\*\*PCT International Search Report and Written Opinion, Application No. PCT/US08/69171, dated Oct, 3, 2008.

PCT Invitation to Pay Additional Fees, Application No. PCT/US11/ 59911, dated Feb. 6, 2012

\*\*B. Lecointe and G. Monnier. "Downsizing a gasoline engine using turbocharging with direct injection" SAE paper 2003-1-0542. Lee, R. J., et al., CHEMKIN 4-0 Theory Manual; Reaction Design. Inc., San Diego, Calif. (2004).

\*\*LoRusso, Julian A., et al., Direct Injection Ignition Assisted Alcohol Engine, Society of Automotive Engineers, Inc. 880495, International Congress and Exposition in Detroit Michigan (Feb-29-Mar. 4, 1998).

\*\*Modak, A., et al., Engine Cooling by Direct Injection of Cooling Water, Society of Automotive Engineers, Inc. technical paper 700887, 1970. DOI: 10.4271/700887.

> FORD Ex. 1144, page 66 IPR2020-00013

### Page 4

#### References Clted

(56)

#### OTHER PUBLICATIONS

\*\*Stan, C., R., et al., Internal Mixture Formation and Combustion—from Gasoline to Ethanol, Society of Automotive Engineers, Inc., 2001 World Congress, Mar. 2001, DOI: 10.4271/2001-01-1207.
\*\*Stokes, J., et al., "A Gasoline Engine Concept for Improved Fuel

Economy—The Lean Boost System," SAE Technical Paper 2000-01-2902, 2000, <a href="https://doi.org/10.4271/2000-1-2902">https://doi.org/10.4271/2000-1-2902</a>>, pp. 1-12. Thomas, J., et al, "Fuel-Borne Reductants for NOx Aftertreatment: Preliminary EtOH SCR Study," 2003 DEER (Diesel Engine Emis-

sions Reduction] Workshop, Newport RI Aug. 2003]. \*\*USPIO Non-Final Office Action, U.S. Appl. No. 10/991,774,

dated Apr. 25, 2006. \*\*USPTO Final Office Action, U.S. Appl. No. 10/991,774, dated Sep. 27, 2006.

\*\*USPTO Non-Final Office Action, U.S. Appl. No. 10/991,774, dated May 25, 2007.

\*\*USPTO Non-Final Office Action, U.S. Appl. No. 11/100,026, dated Aug. 3, 2006.
\*\*USPTO Non-Final Office Action, U.S. Appl. No. 11/229,755.

dated Mar. 22, 2007. \*\*USPTO Non-Final Office Action, U.S. Appl. No. 11/229,755,

dared Oct. 4, 2007. \*\*USPTO Non-Final Office Action, U.S. Appl. No. 11/682,372,

dated Jan. 2, 2008. \*\*USPTO Final Office Action, U.S. Appl. No. 11/682,372, dated Oct. 17, 2008.

\*\*USPTO Non-Final Office Action. U.S. Appl. No 11/684,100, dated Jun. 3, 2008.

\*\*USPTO Notice of Allowance, U.S. Appl. No. 11/684,100, dated Mar. 3, 2009.

\*\*USPTO Non-Final Office Action, U.S. Appl. No. 11/840,719, dated Jul. 11, 2008.

\*\*Yuksel, F., et al, The Use of Ethanol-Gasoline Blend as a Fuel in an SI Engine, Renewable Energy, vol 29, Jun. 2004, pp. 1181-1191.

\* cited by examiner



FIG. 1



**FIG. 2** 



FIG. 3



FIG. 4



**FIG. 5** 

FORD Ex. 1144, page 70 IPR2020-00013

#### 1 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 15 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 20 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 25 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, 30 719 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 40 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 45 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 55 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 60 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 65 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, biomassderived 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 35 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 5

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 <sup>10</sup> 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 strati- 15 fied 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 25 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 35 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 40 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 45 required amount of ethanol. Recent advances in fuel injection 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 50 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 is injected into the manifold rather than directly injected into the cylinder is preferred because it is advan-55 tageous 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 60 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 octaneenhancement 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.

> FORD Ex. 1144, page 72 IPR2020-00013

3
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 20 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 25 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 3 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 he achieved by stratifying the ethanol.

In the case of the engine 10 having substantial organized 35 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 40 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 45 (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<sup>2</sup>, or about 20 g's.

FIG. 3 illustrates ethanol direct injection and swirl motion 50 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 55 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. 60 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 65 therefore lower concentrations of gasoline in the regions where the ethanol is injected). This situation can be

6

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 I 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 10 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 15 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 20 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 25 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 30 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 35 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 40 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 45 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: 50

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. 55

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 60 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 65 range; such that it is substantially equal to the fraction needed to prevent knock.

8

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.

II. 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.

FORD Ex. 1144, page 74 IPR2020-00013

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 <sup>5</sup> 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; 15

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 25 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; 30 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 lighest torque in the second torque range the engine is operated in the first torque range. 35

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; 40 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 45 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; 50 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;

use of both the first and second fueling systems; 55
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 60 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;

and where the highest torque in the first torque range is the 65 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 luel 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 s 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 10 is the highest torque at which the engine can be operation with the second fueling system alone without producing knock.

\* \* \* \* \*

# EXHIBIT 6

FORD Ex. 1144, page 77 IPR2020-00013

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE United States Patent and Trademark, Office Address: COMMISSIONER FOR PATENTS P.O. Ban 1430 Alexandia, Virginiu 22313-1450 www.usho.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: EL	IFL MANAGEMENT SYSTEM	FOR VARIABLE STUANOL OCTANE ENULA	OF UNENT OF CAROLINE PHOT	150

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. <u>PROSECUTION ON THE MERITS IS CLOSED</u>. 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 <u>THREE MONTHS</u> FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. <u>THIS STATUTORY PERIOD CANNOT BE EXTENDED</u>. 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:

1. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:	If the SMALL ENTITY is shown as NO:
A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.	A. Pay TOTAL FEE(S) DUE shown above, or
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	B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fce(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.

Page 1 of 3

EBS-0000018

FORD Ex. 1144, page 78 IPR2020-00013

#### PART B - FEE(S) TRANSMITTAL

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

INSTRUCTIONS: This appropriate. All further indicated unless correc maintenance fee notifier	form should be used correspondence includ- ed below or directed of ations.	for transmitting the ISS ng the Patent, advance o herwise in Block 1, by (	UE FEE and PUBLIC orders and notification a) specifying a new co	ATION FEE of maintenance prrespondence	(if required), c fees will be address, and/o	Blocks I through 5 sl mailed to the current r (b) indicating a sepa	tould be completed where correspondence address as trate "FEE ADDRESS" for
CURRENT CORRESPOND	DENCE ADDRESS (Noic: Une E	Bluck I for any change of address)		Note: A certif Fee(s) Transm papers. Each a	icate of mailin ittal. This certi dditional paper	g can only be used for licate cannot be used for , such as an assignment	r domestic mailings of the or any other accompanying nt or formal drawing, must
24280 CHOATE, HA TWO INTERN BOSTON, MA	7590 08/1 ALL & STEWAR ATIONAL PLACE 02110	6/2007 Г LLP		I hereby certif States Postal S addressed to t transmitted to	Certificate y that this Fee( ervice with sul he Mail Stop the USPTO (57	e of Mailing or Transr s) Transmittal is being licient postage for firs ISSUE FEE address 1) 273-2885, on the da	mission deposited with the United t class mail in an envelope above, or being facsimile ate indicated befow.
							(Depositor's name)
							(Signature)
							(Date)
APPLICATION NO.	FILING DATE		FIRST NAMED INVEN	FOR	ATTO	RNEY DOCKET NO.	CONFIRMATION NO.
10/991,774 TITLE OF INVENTION	11/18/2004 I: FUEL MANAGEME	NT SYSTEM FOR VARI	Daniel R. Cohn ABLE ETHANOL OC	TANE ENHAR	CEHMENT O	0492611-0598 IF GASOLINE ENGIN	8282 IES
APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE D	UE PREV. PA	ID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	YES	\$700	\$300		\$0	\$1000	11/16/2007
EXAN	INER	ART UNIT	CLASS-SUBCLASS				
ALI, H	IYDER	3747	123-19800A				
<ol> <li>Change of correspond CFR 1.363).</li> <li>Change of corresp Address form PTO/S</li> <li>"Fee Address" ine PTO/SB/47; Rev 03- Number is required</li> <li>ASSIGNEE NAME A PLEASE NOTE: Un recordation as set for (A) NAME OF ASSI</li> </ol>	ence address or indication pondence address (or Chi B/122) attached. fication (or "Fee Address 02 or more recent) attach ND RESIDENCE DAT. ND RESIDENCE DAT. Less an assignee is ident th in 37 CFR 3.11. Com GNEE	on of "Fee Address" (37 ange of Correspondence a" Indication form hed. Use of n Customer A TO BE PRINTED ON iffied below, no assignce pletion of this form is NO	2. For printing on the control of the names of up or agents OR, altern (2) the name of a strengistered attorney 2 registered attorney 2 registered patent listed, nu name will THE PATENT (print or data will appear on the T a substitute for filing (B) RESIDENCE: (C	he patent front p to 3 registern attively, ingle firm (hav or agent) and attorneys or agent) be printed. • type) • type) • e patent. If an an assignment ITY and STAT	page, list ed patent attorr ing as a memb the names of u ents. If no nam assignce is ic E OR COUNT	era 2 p to 3 lentified below, the do	eument has been filed for
Aa. The following fee(s) Issue Fee Publication Fee (1 Advance Order -	iate assignee category of are submitted: No small entity discount # of Copies	r categories (will not be pr 41 permitted)	<ul> <li>rinted on the patent) :</li> <li>Payment of Fee(s): (I</li> <li>A check is enclose</li> <li>Payment by credit</li> <li>The Director is her overpayment, to D</li> </ul>	Please first rea ed. card. Form PT reby authorized cposit Accoun	Corporati pply any prev O-2038 is atta to charge the r Number	on or other private grou lously paid issue fee s ched. required fec(s), any def (enclose an	up entity Government hown above) leiency, or credit any extra copy of this form).
5. Change in Entity Sto	tus (from status indicate	d abovc)	_				
NOTE: The Issue Fee ar interest as shown by the	is SMALL ENTITY state id Publication Fee (if req records of the United Sta	us. See 37 CFR 1.27. uired) will not be accepte ates Patent and Trademark	b. Applicant is no d from anyone other the Office.	longer claimin an the applican	g SMALL ENT t; a registered s	FITY status. See 37 CF attorney or agent; or the	R 1.27(g)(2). e assignce or other party in
Authorized Signature				Date			
Typed or printed nam	.c			Regist	ration No.		
This collection of inform an application. Confiden submitting the complete this form and/or suggest Box 1450, Alexandria, A Alexandria, Virginia 22. Under the Panerwork Re	tiality is governed by 37 C tiality is governed by 35 d application form to the ions for reducing this bu /irginia 22313-1450. DO i J-1450. duction Act of 1995, no	CFR 1.311. The informatic U.S.C. 122 and 37 CFR CUSPTO Time will vary rden, should be sent to th D NOT SEND FEES OR ( persons are required to re-	on is required to obtain 1.14. This collection is r depending upon the in c Chief Information Of COMPLETED FORMS spond to a collection of	or retain a ben estimated to t idividual case. ficer, U.S. Pat i TO THIS AE	efit by the publ ake 12 minutes Any comment ent and Tradem iDRESS. SENT nless it displays	ic which is to file (and to complete, including s on the amount of tim tark Office, U.S. Depat of TO: Commissioner for a valid OMB control of	by the USPTO to process) gathering, preparing, and te you require to complete triment of Commerce, P.O. or Patents, P.O. Box 1450, number.
PTOL-85 (Rev. 08/07)	Approved for use throug	h 08/31/2007.	OMB 0651-0033	U.S. Patent	and Trudemurk	Office; U.S. DEPART	MENT OF COMMERCE

EBS-00000019 FORD Ex. 1144, page 79 IPR2020-00013

	ted States Patent A	and Trademark Office	UNITED STATES DEPAR United States Patent and T Address: COMMISSIONER F P.O. Bax 1450 Alexandris, Vrgjinin 223 www.uspto.gov	IMENT OF COMMERCE Frademark Office OR PATENTS 13-1450
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 75	90 08/16/2007		EXAM	INER
CHOATE, HALL	& STEWART LLP		ALI, H	YDER
TWO INTERNATI	ONAL PLACE		ART UNIT	PAPER NUMBER
BOSTON, MA 021	10		3747 DATE MAILED: 08/16/200	7

#### 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.

-----

Page 3 of 3

EBS-00000020 FORD Ex. 1144, page 80 IPR2020-00013

	Application No.	Applicant(s)	
	10/001 774		
Notice of Allowability	Examiner	Art Unit	
		2747	
		3/4/	
The MAILING DATE of this communication claims being allowable, PROSECUTION ON THE MERI ewith (or previously mailed), a Notice of Allowance (PTO TICE OF ALLOWABILITY IS NOT A GRANT OF PATE he Office or upon petition by the applicant. See 37 CFR	appears on the cover sheet will IS IS (OR REMAINS) CLOSED in L-85) or other appropriate commin NT RIGHTS. This application is s 1.313 and MPEP 1308.	th the correspondence address- this application. If not included unication will be mailed in due cours subject to withdrawal from issue at the	ie. THIS he initiativ
This communication is responsive to Arguments/Ren	narks filed on 07/27/2007.		
The allowed claim(s) Is/are <u>57-60</u> .			
Acknowledgment is made of a claim for foreign prio	rity under 35 U.S.C. § 119(a)-(d)	or (f).	
a) 🗌 All b) 🗌 Some* c) 🗋 None of the:			
<ol> <li>Certified copies of the priority documents</li> </ol>	have been received.		
<ol><li>Certified copies of the priority documents</li></ol>	have been received in Application	n No	
3. 🔲 Copies of the certified copies of the prior	ity documents have been receive	In this national stage application fr	om the
International Bureau (PCT Rule 17.2(a)).			
* Certified copies not received:			
opplicant has THREE MONTHS FROM THE "MAILING D. oted below. Failure to timely comply will result in ABANE HIS THREE-MONTH PERIOD IS NOT EXTENDABLE.	ATE" of this communication to file OONMENT of this application.	a reply complying with the requiren	nents
A SUBSTITUTE OATH OR DECLARATION must be INFORMAL PATENT APPLICATION (PTO-152) whic	submitted. Note the attached EXA h gives reason(s) why the oath or	MINER'S AMENDMENT or NOTIC declaration is deficient.	E OF
CORRECTED DRAWINGS ( as "replacement sheets"	) must be submitted.		
(a) 🗍 including changes required by the Notice of Draft	sperson's Patent Drawing Review	v (PTO-948) attached	
1) 🔲 hereto or 2) 🔲 to Paper No./Mail Date _	;		
(b) including changes required by the attached Exam Paper No./Mail Date	niner's Amendment / Comment or	in the Office action of	
Identifying Indicia such as the application number (see 37 each sheet. Replacement sheet(s) should be labeled as such	CFR 1.84(c)) should be written on th thin the header according to 37 CF	ne drawings in the front (not the back R 1.121(d).	) of
DEPOSIT OF and/or INFORMATION about the attached Examiner's comment regarding REQUIREM	deposit of BIOLOGICAL MATI	ERIAL must be submitted. Note t DLOGICAL MATERIAL.	he
tachment(s)	_		
_] Notice of References Cited (PTO-892)	5. 🛄 Notice of In	formal Patent Application	
_] Notice of Draftperson's Patent Drawing Review (PTO-	948) 6. 🛄 Interview S	ummary (PTO-413), Mail Date	
Information Disclosure Statements (PTO/SB/08),	7. 🛛 Examiner's	Amendment/Comment	
Examiner's Comment Regarding Requirement for Dep	oosit B. 🗌 Examiner's	Statement of Reasons for Allowand	е
of Biological Material	9. 🗌 Other		
Hyle AL.			
S. Palent and Trademark Office			
TOL-37 (Rev. 08-06)	Notice of Allowability	Part of Paper No./Mail Da	ite 200708

EBS-00000021 FORD Ex. 1144, page 81 IPR2020-00013 € - ¥

Application/Control Number: 10/991,774 Art Unit: 3747

#### 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.

Hyle Al.

STEPHEN K. CRONIN SUPERVISORY PATENT EXAMINER

EBS-00000022 FORD Ex. 1144, page 82 IPR2020-00013

## 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
12	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

8/13/07 1:32:45 PM C:\Documents and Settings\hali1\My Documents\EAST\Workspaces\new.wsp Page 1

Application Number	Application/Control No.		Applicant(s)/Patent under Reexamination COHN ET AL.	
Document Code - DISQ	 	Internal	Document – I	

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

Approve	ed/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

A R

#### ATTORNEY DOCKET NO. 0492611-0598

#### IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Serial No.:	Cohn, <i>et al.</i> 10/991,774	Examiner:	ALI, HYDER
Filed:	November 18, 2004	Art Unit:	1714
For:	FUEL MANAGEMENT SY ENHANCEN	STEM FOR VARIABL	E ETHANOL OCTANE ENGINES

#### **RESPONSE TO OFFICE ACTION**

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

4235440v1

EBS-00000025 FORD Ex. 1144, page 85 IPR2020-00013

#### 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

EBS-00000026 FORD Ex. 1144, page 86 IPR2020-00013

PTO/SB/25 (04-07)
Approved for use through 09/30/2007 OMB 0651-0031
LLP, Delevised Techesterik Officer LLP, DEDARTHEAIT OF COMMERCE

U.S. Patent and Trademark Office; Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it	U.S. DEPARTMENT OF COMMERCE displays a valid OMB control number.
TERMINAL DISCLAIMER TO OBVIATE A PROVISIONAL DOUBLE PATENTING	Docket Number (Optional)
REJECTION OVER A FENDING REFERENCE AFFLICATION	
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*, <u>Maximuchues Institute of Technology</u> , of <u>100</u> percent interest in the institute except as provided below, the terminal part of the statutory term of any patent granted on the instant applic the expiration date of the full statutory term of any patent granted on pending reference Application Number on <u>04-06-2005</u> , as such term is defined in 35 U.S.C. 154 and 173, and as the term of any patent or the grant of any patent on the pending granted on the instant application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending granted on the reference application are commonly owned. This agreement runs with any patent granted binding upon the grantee, its successors or assigns.	ant application hereby disclaims, ation which would extend beyond <u>11/100,026</u> , filed Jatent granted on said reference reference application. The owner such period that it and any patent on the instant application and is
In making the above disclaimer, the owner does not disclaim the terminal part of any patent granted on extend to the expiration date of the full statutory term as defined in 35 U.S.C. 154 and 173 of any p application, "as the term of any patent granted on said reference application may be shortened by any te grant of any patent on the pending reference application," in the event that, any such patent: granted on the expires for failure to pay a maintenance fee, is held unenforceable, is found invalid by a court of competent ju in whole or terminally disclaimed under 37 CFR 1.321, has all claims canceled by a reexamination certificative terminated prior to the expiration of its full statutory term as shortened by any terminal disclaimer filed prior to the expiration of the full statutory term as shortened by any terminal disclaimer filed prior to the expiration of the statutory term as shortened by any terminal disclaimer filed prior to the expiration of the statutory term as shortened by any terminal disclaimer filed prior to the expiration of the statutory term as shortened by any terminal disclaimer filed prior to the expiration of the statutory term as shortened by any terminal disclaimer filed prior to the expiration of the statutory term as shortened by any terminal disclaimer filed prior to the expiration of the statutory term as shortened by any terminal disclaimer filed prior to the expiration of the statutory term as shortened by any terminal disclaimer filed prior to the expiration of the statutory term as shortened by any terminal disclaimer filed prior to the expiration of the statutory term as shortened by any terminal disclaimer filed prior to the expiration of	the instant application that would atent granted on said reference rminal disclaimer filed prior to the pending reference application vrisdiction, is statutorily disclaimed e, is reissued, or is in any manner ofts grant.
Check either box 1 or 2 below, if appropriate	
1. For submissions on behalf of a business/organization (e.g., corporation, partnership, university, gover etc.), the undersigned is empowered to act on behalf of the business/organization.	ernment agency,
I hereby declare that all statements made herein of my own knowledge are true and that all state belief are believed to be true; and further that these statements were made with the knowledge that willfur made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United State statements may jeopardize the validity of the application or any patent issued thereon. 2. Imprise The undersigned is an attorney or agent of record. Reg. No. 29576	ements made on information and I false statements and the like so s Code and that such willful false
/SamPasternack/	07/27/2007
Signature	Date
Sam Pasternack	
Typed or printed name	
	617-248-5143
	Telephone Number
F Terminal disclaimer fee under 37 CFR 1 20(d) is included	
WARNING: Information on this form may become public. Credit card information be included on this form. Provide credit card information and authorization on	should not 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.	
This collection of information is required by 37 CFR 1.321 The information is required to obtain or retain a banefit by the pute process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is esti- Including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upor the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Ch Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES ADDRESS, SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.	blic which is to file (and by the USPTO mated to take 12 minutes to complete, the individual case. Any commants on ief Information Officer, U.S. Patent and OR COMPLETED FORMS TO THIS

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

EBS-00000027 FORD Ex. 1144, page 87 IPR2020-00013

#### 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:

- 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.
- 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.
- 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.

EBS-00000028 FORD Ex. 1144, page 88 IPR2020-00013

	ed States Patent /	and Trademark Office	UNITED STATES DEPAR United States Patent und Address: COMMISSIONER F P.O. Box 1450 Alexandra, Virginia 223 www.uspia.gov	TMENT OF COMMERC Trademark Office OR PATENTS 13-1450
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		EXAM	INER .
TWO INTERN	ATIONAL PLACE		ALI, H	YDER
BOSTON, MA	02110		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.

PTOL-90A (Rev. 04/07)

EBS-00000034 FORD Ex. 1144, page 89 IPR2020-00013

4	Application No.	Applicant(s)
	10/991,774	COHN ET AL.
Office Action Summary	Examiner	Art Unit
	HYDER ALI	3747
- The MAILING DATE of this communication Period for Reply	appears on the cover sheet w	ith the correspondence address
A SHORTENED STATUTORY PERIOD FOR RE WHICHEVER IS LONGER, FROM THE MAILING - Extensions of time may be available under the provisions of 37 CFF after SIX (6) MONTHS from the mailing date of this communication, If NO period for reply is specified above, the maximum statutory per Failure to reply within the set or extended period for reply will, by siz Any reply received by the Office later than three months after the mi- earned patient term adjustment. See 37 CFB 170(th)	PLY IS SET TO EXPIRE <u>3</u> M DATE OF THIS COMMUNI 1.136(a). In no event, however, may a iod will apply and will expire SIX (6) MON atute, cause the application to become Al atiling date of this communication, even if	IONTH(S) OR THIRTY (30) DAYS, CATION. reply be timely filed NTHS from the mailing date of this communication. BANDONED (35 U.S.C. § 133). timely filed, may reduce any
Status		
1) Responsive to communication(s) filed on 00	March 2007	
(3) This action is <b>FINAL</b> . $(3)$	his action is non-final	
3) Since this application is in condition for allow	wance except for formal matt	ters prosecution as to the merits is
closed in accordance with the practice under	er Ex parte Quavle, 1935 C.D	). 11. 453 O.G. 213.
Disposition of Claims		
		2 P
4) Of the above cloim(a)		
5) Claim(c) 50 and 60 is/ore allowed	irawn from consideration.	
5)X Claim(s) 57 and 58 is/are reliated		
7) Claim(s) is/are objected to		
8) Claim(s) are subject to restriction and	d/or election requirement	
	·	
Application Papers		
9) The specification is objected to by the Exam	iner.	
10)⊠ The drawing(s) filed on <u>18 November 2004</u> i	s/are: a)⊠ accepted or b)[	] objected to by the Examiner.
Applicant may not request that any objection to t	he drawing(s) be held in abeyar	асе, See 37 CFR 1.85(a).
Replacement drawing sheet(s) Including the con	rection 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	d Office Action or form PTO-152.
Priority under 35 U.S.C. § 119		
12) Acknowledgment is made of a claim for fore	ian priority under 35 U.S.C. &	119(a)-(d) or (f)
a) All b) Some * c) None of:		
1. Certified copies of the priority docume	ents have been received.	
2. Certified copies of the priority docume	ents have been received in A	pplication No
3. Copies of the certified copies of the p	riority documents have been	received in this National Stage
application from the International Bure	eau (PCT Rule 17.2(a)).	
* See the attached detailed Office action for a l	ist of the certified copies not	received.
Attachment(s)		
) D Notice of References Cited (PTO-892)	4) 🗌 Interview S	Summary (PTO-413)
Notice of Draftsperson's Patent Drawing Review (PTO-948)	Paper No(s	s)/Mail Date
Information Disclosure Statement(s) (PTO/SB/08)	5) Notice of In	nrormal Patent Application
Paper No(s)/Mail Date	Of Children	

EBS-00000035 FORD Ex. 1144, page 90 IPR2020-00013 Application/Control Number: 10/991,774 Art Unit: 3747

#### 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

EBS-00000036 FORD Ex. 1144, page 91 IPR2020-00013

### Application/Control Number: 10/991,774 Art Unit: 3747

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 <u>provisional</u> 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).

Application/Control Number: 10/991,774 Art Unit: 3747

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.

Hister Al.

ha

M. Argenbright mary Examiner nit 3747

EBS-00000038 FORD Ex. 1144, page 93 IPR2020-00013



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

12/19/2006

PAPER

EBS-00000054 FORD Ex. 1144, page 94 IPR2020-00013

		T
	Application No.	Applicant(s)
Advisory Action	10/991,774	COHN ET AL.
Belore the Filling of an Appear Brief	Examiner	Art Unit
	HYDER ALI	3747
The MAILING DATE of this communication app	pears on the cover sheet with the	correspondence address
HE REPLY FILED 30 November 2006 FAILS TO PLACE TH	IS APPLICATION IN CONDITION F	FOR ALLOWANCE.
<ul> <li>. The reply was filed after a final rejection, but prior to or of this application, applicant must timely file one of the folloplaces the application in condition for allowance; (2) a N a Request for Continued Examination (RCE) in compliant time periods:</li> <li>a) The period for reply expiresmonths from the mail</li> </ul>	on the same day as filing a Notice o owing replies: (1) an amendment, a lotice of Appeal (with appeal fee) in nce with 37 CFR 1.114. The reply m ing date of the final rejection.	f Appeal. To avold abandonment of ffidavit, or other evidence, which compliance with 37 CFR 41.31; or (3) nust be filed within one of the following
b) The period for reply expires on: (1) the malling date of this no event, however, will the statutory period for reply expire Examiner Note: If box 1 is checked, check either box (a) o TWO MONTHS OF THE FINAL REJECTION. See MPEP	Advisory Action, or (2) the date set forth later than SIX MONTHS from the mailin r (b). ONLY CHECK BOX (b) WHEN TH 706.07(f).	h In the final rejection, whichever is later. In ng date of the final rejection. IE FIRST REPLY WAS FILED WITHIN
xtensions of time may be obtained under 37 CFR 1.136(a). The data ave been filed is the date for purposes of determining the period of ender 37 CFR 1.17(a) is calculated from: (1) the expiration date of the et forth in (b) above, if checked. Any reply received by the Office late ray reduce any earned patent term adjustment. See 37 CFR 1.704( <u>AOTICE OF APPEAL</u>	te on which the petition under 37 CFR 1. extension and the corresponding amoun a shortened statutory period for reply or er than three months after the mailing d b).	.136(a) and the appropriate extension fee t of the fee. The appropriate extension fee ginally set in the final Office action; or (2) a ate of the final rejection, even if timely filed
filing the Notice of Appeal was filed off A bitle in con filing the Notice of Appeal (37 CFR 41.37(a)), or any ext a Notice of Appeal has been filed, any reply must be file <u>MENDMENTS</u>	tension thereof (37 CFR 41.37 (e)), t ed within the time period set forth in	to avoid dismissal of the appeal. Since 37 CFR 41.37(a).
. X The proposed amendment(s) filed after a final rejection (a) They raise new issues that would require further c (b) They raise the issue of new matter (see NOTE be	<ul> <li>but prior to the date of filing a brie consideration and/or search (see NC low);</li> </ul>	f, will <u>not</u> be entered because DTE below);
(c) They are not deemed to place the application in b appeal; and/or	etter form for appeal by materially r	educing or simplifying the Issues for
(d) They present additional claims without canceling a	a corresponding number of finally re	ejected claims.
The amendments are not in compliance with 37 CER 1	121 See attached Notice of Non-C	omplight Amendment (PTOL 224)
. Applicant's reply has overcome the following rejection	s):	ompliant Amerianiant (F10E-324).
<ul> <li>Newly proposed or amended claim(s) would be non-allowable claim(s).</li> </ul>	allowable if submitted in a separate	, timely filed amendment canceling the
For purposes of appeal, the proposed amendment(s): a how the new or amended claims would be rejected is pr The status of the claim(s) is (or will be) as follows:	i) ⊠ will not be entered, or b) □ w ovided below or appended.	ill be entered and an explanation of
Claim(s) allowed:		
Claim(s) objected to:		
Claim(s) rejected. <u>7-76, 76-20 and 24-56</u> .		
FFIDAVIT OR OTHER EVIDENCE		
The affidavit or other evidence filed after a final action, because applicant falled to provide a showing of good a was not earlier presented. See 37 CFR 1.116(e).	but before or on the date of filing a h Ind sufficient reasons why the affida	Notice of Appeal will <u>not</u> be entered wit or other evidence is necessary and
The affidavit or other evidence filed after the date of filin entered because the affidavit or other evidence failed to showing a good and sufficient reasons why it is necessar	g a Notice of Appeal, but prior to the overcome <u>all</u> rejections under appeary and was not earlier presented.	e date of filing a brlef, will <u>not</u> be eal and/or appellant fails to provide a See 37 CFR 41.33(d)(1).
0. The affidavit or other evidence is entered. An explanation explanation of the second secon	ion of the status of the claims after	entry is below or attached.
1. I ne request for reconsideration has been considered b	out does NUT place the application	in condition for allowance because:
<ol> <li>Note the attached Information Disclosure Statement(s)</li> <li>Other: PTO-413 (Interview Summary)</li> </ol>	. (PTO/SB/08) Paper No(s).	
or the ways of the start man that the start of the start		
10 L 200	1090	
Hyse AP	SUPERVISOR	EN K. CHONIN Y PATENT EXAMINER

EBS-00000055 FORD Ex. 1144, page 95 IPR2020-00013

 $\epsilon$ 

	Application No.	Applicant(s)	
	10/991,774	COHN ET AL.	
Interview Summary	Examiner	Art Unit	
	HYDER ALI	3747	
All participants (applicant, applicant's representative, F	PTO personnel):		
1) <u>HYDER ALI</u> .	(3) <u>Dr. Daniel Cohr</u>		
2) <u>Sam Pasternack</u> .	(4)		
Date of Interview: 27 November 2006.			
Type: a)⊠ Telephonic b)⊟ Video Conference c)⊟ Personal [copy glven to: 1)⊟ applicant	t 2) applicant's repres	entative]	7
Exhibit shown or demonstration conducted: d) Yes If Yes, brief description:	s ө)⊠ No.		
Claim(s) discussed: Proposed amendments claims 57	<u>-60</u> .		
Identification of prior art discussed: Art of record Jesse	al (US 4,541,383) and Wate	nabe et al (US 6,513,50	<u>5)</u> .
Agreement with respect to the claims f) was reached	d. g)🛛 was not reached.	h) 🗌 N/A.	×
Substance of Interview including description of the ger reached, or any other comments: <u>Examiner Ali indicate</u> by the proposed amendments claims 57-60.	neral nature of what was ag <u>ed that there could be 35 U</u>	reed to if an agreement SC 112, 2 <sup>nd</sup> paragraph is	was isues raise
(A fuller description, if necessary, and a copy of the an allowable, if available, must be attached. Also, where allowable is available, a summary thereof must be atta	nendments which the exan no copy of the amendmen ached.)	niner agreed would rende ts that would render the o	r the claim claims
THE FORMAL WRITTEN REPLY TO THE LAST OFFIN NTERVIEW. (See MPEP Section 713.04). If a reply to BIVEN A NON-EXTENDABLE PERIOD OF THE LONG NTERVIEW DATE, OR THE MAILING DATE OF THIS FILE A STATEMENT OF THE SUBSTANCE OF THE I requirements on reverse side or on attached sheet.	CE ACTION MUST INCLU o the last Office action has GER OF ONE MONTH OR S INTERVIEW SUMMARY NTERVIEW See Summa	DE THE SUBSTANCE O already been filed, APPL THIRTY DAYS FROM T FORM, WHICHEVER IS y of Record of Interview	F THE .ICANT IS HIS LATER, TO
			2
			5
÷			
	-++	$\mathcal{A}$	AP
Examiner Note: You must sign this form unless it is an Attachment to a signed Office action.		Dale 7	<u> </u>

4

EBS-00000056 FORD Ex. 1144, page 96 IPR2020-00013

#### 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 exeminer, a complete written statement of the reasons presented at the interview as warranting lavorable 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 malled 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

S.

- 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.

EBS-00000057

FORD Ex. 1144, page 97 IPR2020-00013

NO. 663 P. 2

## RECEIVED CENTRAL FAX CENTER

Attorney Docket No: 0492611-0598

NOV 3 0 2006

#### IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Cohn, et al. Applicant:

10/991,774 Serial No.:

Hyder Ali Examiner: Art Unit: 3747

Filing Date: November 18, 2004

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

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

Sir:

	Certificate of Facsimile Transmission
I centify that this correspond	nce is being transmitted via facsimile to (mail stop if applica
Commissioner for Patents, P	O. Box 1450, Alexandria, VA 22313-1450, via facrimíte no
571-273-8300	
Manager 10, 2006	En
Date	Signaturo
(e)	Elizabeth Hutka
Typie	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.

0 not enter HA 12/12/06

Page 1 of 8

4149358v1

PACE 2/9 \* RCVD AT 11/30/2005 1:15:00 PM [Eastern Standard Time] \* SVR:USPTO-EFXRF-2/3 \* DNIS:2738300 \* CSID:5172484000 \* DURATION (mm-ss):03-04

EBS-00000058 FORD Ex. 1144, page 98 IPR2020-00013

		1	10	lex	•	of I	Cl	ail	ms				ł			Ą	ppli	Ca	tio	n/C	on	trol	No.			R	eex	ica. terr	nt( 1ni	s)/P atio	'ate n	inti	under
	1014	HI			11	211		H	m						ļ	10	)/8!	91,	77	4	_	_			_	С		IN I	ET	AL			
	1988	H.			ΗH	HH)	1111		m	hii	1					E	kan	nln	91							A	rtι	Init					
			11	111				UNN	UIL							н	YD	EF	R A	L						3	747	7					
		_	-				1			-		-	_				4	1	-					1	-								
		ł	R	teji	oct	ed			-		Thro	ugh Cano	nı eli	ed	ier:	a1)			N	N	on-	Elec	ted		A		A	ppi	eal				
		=	1	Allo	w	ed			+	1	a P	lest	rici	lec	1		٦	Ì	1	In	ter	fare	nce		0		Oł	ojec	te	d	1		
_	1	_	-	-	-	_	<u>ا</u>	_	L	1	-		-		_	-	_	1	-	-		-		1	<u> </u>	-	-	-	-		1		2
a	alm	-	P	9	Г	Dat	le T	Т	Т		14	laim	+	-4	1			ale	-	Т	1	-	a	aim	+		Т	-0	ate	T	T	T	{
12	- Ha	ŝ	141	10		Ľ			L	11	T T	Ę		\$	2	10/2				1				gha	1.8				1		L		
ι α	8	12	6			1		1			1 6	3		F	à	7				1			<u>م</u>	δ				1			1		
-	1	1	1-	tv	-	t		t	t			5	1		V	V				1				101						+	-	+	1
	2	Π	II	II					Γ			5	2	Π	V	V								102								1	1
*	3	#	4	44	1	+-	-	+	-	-		5	3	Н	V	V			-	-	-	-		103				-	-	_		-	
	4	₩	H	++	+	+-	-	+	╋	-	-	- 2	+	Н	¥	÷	-	-	-	-+	-	-	<u> </u>	104	+-		-	+	+	+	+	+-	-
-	6	Ħ	H	Ħ		+	1	t	+	1-1		15	5	3	ź	1			1	+	+	-	-	105	+		-	-	+	+	+	+	1
	7	Ħ	tt	Ħ	T		1	T				5	7							-1	1		-	107			-		-	+	+	1-	1
	8	Π	Π	Π	Γ				E			5	8			= 2							-	108									1
	8	Щ	Ц	11		-	-	-			1.11	5	9	_	_			_	_		_		-	109						-			]
-	10	#	μ	4	+	+-	+	┢	+-	-		- 6		-	-	_		-	-	-	-	-	-	110	-		-	_	-	-	+	-	
-	11	H	₽	++	-	-	-	ł	┝	-	-		1	-	-	-	+	+	-	-	-	-	-	111	-	-	-	-	-		+	+-	
-	13	H	₩	+	t	+-	+-	+	+	-	-	6	H	-		-	-	-	-	-	+	-	-	112	-	$\vdash$	-	+	+	÷	+	+	1
	14	Ħ	Ħ		t	+-	+	$^{+}$	t	+		18	4					-		-+	-			114	+		-	-	+	+	-	+	1
	15	Ħ	ŧ	11		+-	+	+	t	-	-	6	5		-				-	+	-	-		115	1	H	-	-	+	+	+	+	1
	16	П	L	10	T	T	T		T		E	6	6											116						1	1	1	1
	-12	H	-	-	+							6	7								_			117							T	1	1
-	18	μ.	-	1-	1	_	1.	1	+	1		6	8	_						_	_			118				_	_	_		1	
	19	1×	1	1	-	-	-	+	+	+	-	6	9	-	_	-	-	-	_	-	-	_	-	119	-		-	4	_	-	+	-	1
	20	Ľ	É	14	+	+-	+-	╈	+			-14	+	-	-	-		-	-	-	-	-	-	120	-		-	+	+	+	+	+	
-	22	E	E	E	+	+	-	t	+	+-	-	+7	2	-	-	-		-	-	-		-		122	+	-1	-	+	+	+	+	+	1
	23		=	F	$\mathbf{t}$	-	1	$^{+}$	1	-		7	31		-	-		-	-	-1	-	-		123	+			-	-	+	+	+-	1
	24	2	1	1-			1					7	4	-						1			-	124					-	+	+	+	1
	25	П	П	Т					L			7	5											125								T	1
-	26	44-	44	4	+	-	-	+	-	-		17	6					_	_	_	_	_	- 11	128			_	_		_			
-	27	#	₩	#	+	+	-	+	+		F	44	4	-	-	_		-	-	-	-	-	1	127	-		-	-	-	+	+	+-	4
	20	H	H	₩	+	+-	+	+	+		1	++		-	-	-		-	-	-	-	-	-	128	-		-	+	+	+	+	+-	-
-	30	Ħ	Ħ	Ħ	$\uparrow$	+	1	t	t	-		18	ōt	-	-	-			-	-	-	-	-	130	+	-	-	-	+	+	+	+	1
	31	П	П	11		1	-	1				8	1										-	131	+				-	+	+	1	1
	32	Π	Π	П	L	T		Γ				8	2											132	1						T	1	1
	33	H	П	11	L	F		F	L		E	8	3			1								133							T		]
-	34	H	H	41	+	+	+	+	+	-	-	8	4	-	_	_		_	-	_	-	_	-	134			-	-	1	1	F	F	1
-56	130	H	H	+	+	+	-	+	+	+-	-	18	2	-	_	-	+	-	-	-	-	-	-	135	-			-	-	-	+	+	1
-	37	H	H	+	+	-	+	+	+	+	-	A	7	-	-		-	-	-	-	-	-	-	136	-	-	-	+	+	-	-	+	1
	38	Ħ	tt	H	t	+	+	t	+	+	-	B	8	Η					-	-	-	-	-	138	+		-	+	+	+	+	+	1
	39	Ħ	Ħ	T	1	1	1		1			8	9		-							-	-	139	1	H					+	+	1
-	40	Π	Π		Γ			Г	Г			9	0										-	140							1	1	1
-	41	H			F	1	F	T	F		E	9	1											141								1	3
	42	#	H	-	+	-	-	+	+	+	-	9	2	_	-	-		_		_	_			142				_	_	-			1
-	43	₩	H	+	+	+-	-	+	+	H	-	19	1	-	-	- 2		-		-	-+	_	-	143	+-		-	-	-	+	+	1	4
-	45	H	H	H	+	+-	+	+	+	+	-	10	5	-	-	-	+	-		-	-	-	-	144	+		-	-	+	-	-	+	4
	48	Ħ	Ħ	+	t	+	1	t	t		-	9	8	-				1		-	+	-	-	146	1,		-	-	+	+	-	+	1
	47	IT	Ħ	Ħ	T	1	1	T	T			9	7		-						-1	-	-	147	++				+		+	+	1
_	48	T	П	T	T	1	1	Г	T		-	9	8		-	-		1		-	-+		1.	140	1		-		-	+	-	-	1
		- AL	A	- A	and the second se	- AL		10 C	-	- C - C - C - C - C - C - C - C - C - C		_											100	1 140									

U.S. Patent and Trademark Office

Part of Paper No. 20060414

•

	Searc!	h Notes		10/991,774 Examiner	COH	amination	
	III TTATI DETTY INTALIA IT	(8441)13 (8041) 1001) 6191		HYDER ALI	3747		
	SEAR	CHED		(INGLU	SEARCH NO DING SEARCH	TES STRATEGY	)
Class	Subclass	Date	Examiner			QATE	EXMR
123	1A	4/17/2006	на	SEARCHED EAST SEE EAST SEARCI	H PRINT OUT,	4/17/2008	на
123	198A	4/17/2008	HA				190 g.
123	525	4/17/2006	HA				
123	25A	4/17/2006	HA				
123	25J	4/17/2006	НА			-	
123	435	9/19/06	HA				
123	575	7/15/06	HA				
123	406.29	9/19/06	HA			-	-*
123	406.47	4/14/06	HA				
JEDAT	ED	9/19/06	HA			*	
UPD	ATED	12/12/06	HA				L
_				142 1		1	
<u> </u>	4V	· ·					
				*****		i.	
INT	ERFERENC	E SEARCH	ED	_			Ì
Ciass	Subclass	Date	Examinar				
-							
			]		8 8		l

U.5. Patent and Trademark Office

Pari of Paper No. 20080414

.

Page 1 of 1

.....

	TED STATES TATEM AN	D TRADEWORK OTFICE	UNITED STATES United States Pa Adress COMMISSIO PO. Box 140 Alexandria, Ma Www.app.gov	DEPARTMENT Mai and Trode NGE FOX PATER	TOP COMMERCE
Bib Cate Sheet				CONFIRM	MATION NO. 828
SERIAL NUMBE 10/991,774	FILING DATE R 11/18/2004 RULE	CLASS 123	GROUP ART UNIT 3747	ATTO	RNEY DOCKET NO. 92611-9598
Deniel R. Col Leslie Brombi John B. Hoyw * CONTINUING DAT * FOREIGN APPLIC	un, Chaslaut Hill, MA; arg, Sharon, MA; rood, Nowton, MA; A Ations Ations Ations Ations License granted	ONE JONE D "SMALLER	uut. –		
Foreign Priority distined IS USC 119 (s=d) conditions Vertilad and Acknowledged		Alowence STATE OR	SHEETS DRAWING	TOTAL CLAIMS	INDEPENDEN CLAIMS
ADDRESS 24280 CHOATE, HALL & ST TWO INTERNATION BOSTON , MA D02110 TITLE Fuel management av	EWART LLP AL PLACE	inhancehment of gesoline en	olnes	24	
FILING FEE RECEIVED 1312	FEES: Authority has been given I No to charge/credit C Na for following:	n Paper SEPOSIT ACCOUNT	All Fees	(Filing) (Processing (Issue)	Ext. of time )

http://neo:8000/PrexServlet/PrexAction?serviceName=BibDataSheet&Action=display&brow... 4/17/06

1

EBS-00000061 FORD Ex. 1144, page 101 IPR2020-00013

	- K	-						Amficati	nn or L	Inclust Nu	mber
	PATEN	APPLICAT	ION FEE	DETERM	11NAT	ION RECO	RD	(Ö'	99	1770	ſ
		CLAIMS	AS FILE	D - PART	l (Cat	umn 21	SMALL TYPE		ÓЯ	SMALL	A THAN
T	OTAL CLAIM	S	23	•			RATE	FEE		RATE	FEE
F	DA		NUMB	ER FILED	NUM	ARTICS REE	BASIC P	EE 395.0	P OR	BASIC FEI	790.0
T	TAL CHARGE	ABLE CLAIMS	23	minus 20=	•	3	XSP	27	708	X\$18-	1
DA	DEPENDENT	CLAIMS	2	minus 3 o	•		X44-	100	-	XB8=	1-
M	ATPLE DEPE	INDENT CLAIM	PRESENT			0	-	+	-10"		
• 11	min difference	a in column 1 i	a less that	1 26/0. enter		column 2	L+150	14. 1	- OR	13005	<u> </u>
			AMENID		<b>.</b>			922	OR	TOTAL	L
		(Column 1)	Amerud	Colur (Colur	nn 2)	(Column 3)	SMAL	LENTITY	OR	SMALL	ENTITY
BITA	6270	CLAIN'S REMADENG AFTER AMERICANENT	].	PREVIC PAID	EST SER JUSLY FOR	PRESENT	RATE	ADOI- TIONAL FEE-	]	RATE	ADDITIONA
5	Total *	1. 53	Minus	- 2	3	.33	XS	(Par	OR	X\$18a -	
MEN	Independent	1. 2	Minus	- 9		0	X44.		-	X88+	
a	<b>FIRST PRES</b>	ENTATION OF N	AULTIPLE (	REPENDENT	CLAIM			1	1		
1	21			•			1908	10.10	RO	+300m	
			× .			-	ADDIT. FE	Dep	gon ,	NOOIT. FEE	
	1-10-04	(Column 1)	T	Hadha	in 2) 51	(Column 3)		LADIDA	1 1		ADDL
ILENT B		APTER ANENDMENT		PREVIO PREVIO PAID P	er USLY Kor	PRESENT	Rake.	TIONAL		RATE	TIONAL
	Total	. 52	Minus	- 5	3		X8.9-	X	OR	X818a	
	Independent	<u>  3</u>	Minua	-	3		XAA		los l	X88-	
1	FIRST PRESE	INTATION OF M	ULTIPLE D	EPENDENT	CLAM		1	1			
							Korol		OH L	TOTAL	
17.	30.06	022030 00000000		8 22 2			ADDIT, HE	L	JOH ,	DONT. FEEL	-
T	100	(Cobirn 1)		(Colum	12)	(Column 3)		-	. N.		
		REMADING AFTER AMENDMENT		PREVIOL PAID-PA	ja Isly Da	PRESENT	RATE	ADDI- TIONAL FEE		RATE	ADDI- TIONAL
	Total	• 4.	Minus	4		•	X5 9-			X\$18=	and a state of the second s
L	ndepindeni	• 4	Minus	-			YAA		ŀ	YRA-	
Ľ	FURST PRESE	NTATION OF MI	JUTIPLE DE	PENDENT C	MAL				04		-
	ta entre in cons	n a la hara Roov de		within 9 weiter W	The section		+150=		OR	+300-	_
	the "Hoghant Har	aber Previously Pe	A For DI TH	CIS SPACE is h	in coo	20, enter "20."	TOTAL AGOIT PEE		OR	YOTAL	
n	a "Highest Nam	has Previously Pak	I For (local	or Independent	) is the f	ighest sumber 5	and it the sp	propriete bos	in colu	nn 1.	
					، منسرته			same and a second			

Post Diar 1000

Perant and Taxosmutt Onice, U.S. DEPARTICENT OF COMMERCE

2 9		4		ue,			<i>-</i> 1a		>					Ex	arni	( ner		9	9	[']	<u>''''</u>	1	Art	Uni	H			
			,	Reje	ecte	ed		-		(Thr	oug Can	h nu icell	ımer ed	al)	]	N	N	lon	-Elec	ted	•	A		App	pea	I,	]	
		-	=	Allo	owe	be		+			Res	trici	led			I	Ir	nter	ferer	ice		0		)bJe	ecte	ed		
	Cia	m		1		Dat		_			Clair	n T			Dat	e				CI	alm			1	Dale	9		
	Cia	-	T	T	T	T	ГT				T			П				Π			al							
	Final	Origina						i Set			LINA	Origina	<[ ]	-						Fina	Origin							
2		1	-		-	⊢	+	-	-	-		51	-		1		-		_		101						-	
		P										2	_								102			+-	-			-
	5775	1	-	-	-	-			-	-		18			+	-	-		-		103		-					
		1	+		-	-		1	1			\$									105					_		_
		6			-			_		_		*	-		-	-					106		-		-	+	+-	+
		1	+	-	-	-	-	-	-	-	1	彩			+				-		108							
		4	1		1				1		¢	591			_						109		-		-		+	
		10						_			(	60	-		-	-			-		110	+	-	+				
		10	-	-	-	-	-	-	-			62	-		f						112						1	
		18						-				63						_	_		113	-		+	-			-
		14	_	-	-	-		-	-		-	64	+		-	-	-		_	-	115		-	1	1		1	
		16	-		-		$\left  \right $	+		1		66			1				_		116						1	
		17									_	67			-			-		-	117	$\vdash$	+	+	-		+-	$\vdash$
		18	-	-	+-	-			-			68 69	-	++	-	+	-				119							
	1 <del>1</del>	10			1	1	1	T	1			70			1-	-					120	-					-	-
		11	_		-	-			-	+		71			-	+	-				122				-			1
		*	-	-	+	+-	+		-		-	73									123						-	-
		24						_	1		_	74	_		-	-			_	11	124	-		-	+	+		-
		2	-			-			-		-	75			+	+-	-				126						-	
	1	\$	-		+	1						77									127			-	-	-	-	-
	_	串				-			-			78			-		-	-		-	120	-		-				
22		30	-		-		+	-	+			80								10	130			-	-	-	-	-
		31			1	Ľ			1			81			-	-	-				131	-	-	+-		-	+	+
	-	32	_		-	-			+			82		-	+	+-		-		-	133							-
Ĩ.a		3			1	1			1			84									134		_	+	+-	++		-
		35	_	-	1							85	_			-	-	-		-	135	-		+	+			1
		35	-		+	-			-			87		++	-			100		-	137							-
	1	30			-							88	_			_	_				138	-		+	+	-		-
		39			_				-		-	89		++	-	-	-	-	$\vdash$	-	139	-	-	+				
		40			-	+		-	-	-	-	90		$\left  \right $	+	1	-		-		141				1			-
		49	-		1	T						92	_		_			-			142	-			+-	+-		
		43			1	-	-		-			93		++	-	-	-	-		-	143	-		+	1			
		4	-			-	+				-	95	-1-	+		1	1			-	145			-	-	-		+
		45							1	it		96			_			-		-	146	-	-	+	+-	-		+
		47	_						1		-	97		+-+	-	-	-	+	1	-	148			1	1			
	-	48	-	+	+	-	-	-	-		-	99	+		-						149			1	-		-	+
							+ +		-			100	-		-1-	1		1		1-11	150						-	

U.S. Patent and Trademark Office

41

2

8. ×

i a ce

EBS-00000063

Part of Paper No.

FORD Ex. 1144, page 103 IPR2020-00013

# - NOV. 30. 2006 1:15PM CHOATE HALL & STEWART 6172484000

CHOATE

CHOATE HALL & STEWART LLP

RECEIVED CENTRAL FAX CENTER

NOV 3 0 2006

Fax

Recipient Commissioner for Patents		Company	Fax		(a).	Phone	
		USPTO		571-273-8300		<b>571-272-2600</b>	
From	Sam Pasternack		Number of	Pages	9 (in	cluding fax cove	er sheet)
Date	November 30, 2006		Client Number 0492611-0598				
Phone	617-248-5000		Operator	Elizal Burke	beth	Time Sent	
Comments	Applicant:	Cohn, et al.		E	xaminer:	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

Hold for pick-up

Two International Place [ Boston MA 02110 ] t 617-248-5000 | f 817-248-4000 | choate.com 4149692v1

PAGE 1/9 \* RCVD AT 11/30/2006 1:15:00 PM [Eastern Standard Time] \* SVR: USPTO-EFXRF-2/3 \* DNIS: 2738300 \* CSID: 8172484000 \* DURATION (mm-ss): 03-04

EBS-00000064 FORD Ex. 1144, page 104 IPR2020-00013 CHOATE HALL & STEWART 6172484000

NO. 663 P. 2

RECEIVED CENTRAL FAX CENTER

#### Attorney Docket No: 0492611-0598

NOV 3 0 2006

## IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Cohn, et al. Serial No.: 10/991,774 Examiner: Hyder Ali 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 Fact	simile Transmission
I cortify that this corresponde	nco is being transmitte	d via facsimils to (mail stop if applicabl
Commissioner for Patents, P.	O. Box 1450, Alexand	ria, VA 22313-1450, via facsimile no.
571-273-8300		
November 30, 2006	ESP	h
Date	0	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.

Page 1 of 8

4149358v1

PAGE 29 \* RCVD AT 11/30/2006 1:15:00 PM [Eastern Standard Time] \* SVR:USPTO-EFXRF-2/3 \* DNIS:2738300 \* CSID:6172484000 \* DURATION (mm-ss):03-04

EBS-00000065 FORD Ex. 1144, page 105 IPR2020-00013

#### 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

Page 2 of 8

4149358v1

PAGE 3/9 \* RCVD AT 11/30/2005 1:15:00 PM [Eastern Standard Time] \* SVR:USPTO-EFXRF-2/3 \* DNIS:2738300 \* CSID:6172484000 \* DURATION (mm-ss):03-04

EBS-00000066 FORD Ex. 1144, page 106 IPR2020-00013 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

Page 3 of 8

4149358v1

PAGE 4/9 \* RCVD AT 11/30/2006 1:15:00 PM [Eastern Standard Time] \* SVR:USPTO-EFXRF-2/3 \* DNIS:2738300 \* CSID:6172484000 \* DURATION (mm-ss):03-04

EBS-00000067 FORD Ex. 1144, page 107 IPR2020-00013 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;

#### Page 4 of 8

4149358v1

PAGE 5/9 \* RCVD AT 11/30/2006 1:15:00 PM [Eastern Standard Time] \* SVR:USPTO-EFXRF-2/3 \* DNIS:2738300 \* CSID:8172484000 \* DURATION (mm-ss):03-04

EBS-00000068 FORD Ex. 1144, page 108 IPR2020-00013
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;

91 (G) (G)

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

Page 5 of 8

4149358v1

PAGE 6/9\* RCVD AT 11/30/2006 1:15:00 PM [Eastern Standard Time] \* SVR:USPTO-EFXRF-2/3 \* DNIS:2738300 \* CSID:6172484000 \* DURATION (mm-ss):03-04

EBS-00000069 FORD Ex. 1144, page 109 IPR2020-00013 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.

Page 6 of 8

4149358v1

PAGE 7/9 \* RCVD AT 11/30/2006 1:15:00 PM [Eastern Standard Time] \* SVR:USPTO-EFXRF-2/3 \* DNIS:2738300 \* CSID:6172484000 \* DURATION (mm-ss):03-04

EBS-00000070 FORD Ex. 1144, page 110 IPR2020-00013

#### 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 All, 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, 2<sup>nd</sup> 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.

Page 7 of 8

4149358v1

PAGE 8/9 \* RCVD AT 11/30/2006 1:15:00 PM [Eastern Standard Time] \* SVR: USPTO-EFXRF-2/3 \* DNIS:2738300 \* CSID:6172484000 \* DURATION (mm-ss):03-04

EBS-00000071 FORD Ex. 1144, page 111 IPR2020-00013 • NOV. 30. 2006 1:17PM

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

Page 8 of 8

PAGE 9/9 \* RCVD AT 11/30/2006 1:15:00 PM [Eastern Standard Time] \* SVR:USPTO-EFXRF-2/3 \* DNIS:2738300 \* CSID:6172484000 \* DURATION (mm·ss):03-04

EBS-00000072 FORD Ex. 1144, page 112 IPR2020-00013



# United States Patent and Trademark Office

	(6	94	United States DerARTMENT OF COMMERC United States Patent and Trademark Office Adures: COMMISSIONER FOR PATENTS P.O. Box 1450 Alexandria, Virginia 22313-1450 www.aspto.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 759	09/27/2006		EXAMI	NER				
CHOATE, HA	LL & STEWART LL	P	ALI, HY	DER				
BOSTON, MA	02110		ART UNIT	PAPER NUMBER				
,			3747					
			DATE MAILED: 09/27/2006	5				

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

PTO-90C (Rev. 10/03)

EBS-00000073 FORD Ex. 1144, page 113 IPR2020-00013

[	Application No	Applicant(s)
	10/001 774	
Office Action Summary	10/991,774	COHNETAL.
,,, ,, ,, ,, ,, ,, ,, ,, ,, ,, ,		
The MAILING DATE of this com	HYDER ALI	ith the correspondence address –
Period for Reply		
<ul> <li>A SHORTENED STATUTORY PERIO WHICHEVER IS LONGER, FROM TH</li> <li>Extensions of time may be available under the provis after SIX (6) MONTHS from the mailing date of this of If NO period for reply is specified above, the maximu</li> <li>Failure to reply within the set or extended period for Any reply received by the Office later than three mor earned patent term adjustment. See 37 CFR 1.704(</li> </ul>	D FOR REPLY IS SET TO EXPIRE 3 N E MAILING DATE OF THIS COMMUNI sions of 37 CFR 1 138(a). In no event, however, may a communication im statutory period will apply and will expire SIX (6) MOI reply will, by statute, cause the application to become A this after the mailing date of this communication, even if b).	IONTH(S) OR THIRTY (30) DAYS, CATION. reply be timely filed THS from the mailing date of this communication. BANDONED (35 U.S.C. § 133). timely filed, may reduce any
Status		
1) Responsive to communication(s)	) filed on <u>10 July 2006</u> .	
2a) This action is FINAL.	2b) This action is non-final.	
3) Since this application is in condit	ion for allowance except for formal mat	ters, prosecution as to the merits is
closed in accordance with the pra	actice under <i>Ex parte Quayle</i> , 1935 C.I	D. 11, 453 O.G. 213.
Disposition of Claims		
4) Claim(s) <u>1-16,18-20 and 24-56 is</u>	s/are pending in the application.	
4a) Of the above claim(s)	is/are withdrawn from consideration.	
5) Claim(s) is/are allowed.		
6)X Claim(s) <u>1-16,18-20 and 24-56</u> is	s/are rejected.	
7) Claim(s) is/are objected to	р.	
8) Claim(s) are subject to res	striction and/or election requirement.	
Application Papers		
9) The specification is objected to by	y the Examiner.	
10) The drawing(s) filed on <u>18 Noven</u>		objected to by the Examiner.
Applicant may not request that any c	bjection to the drawing(s) be held in abeya	nce. See 37 CFR 1.85(a).
Replacement drawing sheet(s) include	ding the correction is required if the drawing	(s) is objected to. See 37 CFR 1.121(d).
11) The oath or declaration is objecte	d to by the Examiner. Note the attache	d Office Action or form PTO-152.
Priority under 35 U.S.C. § 119		
12) Acknowledgment is made of a cla	im for foreign priority under 35 U.S.C.	\$ 119(a)-(d) or (f)
a) All b) Some * c) None o	f:	
1. Certified copies of the prior	rity documents have been received.	
2. Certified copies of the prior	rity documents have been received in A	Application No
3. Copies of the certified copi	ies of the priority documents have beer	received in this National Stage
application from the Internation	ational Bureau (PCT Rule 17.2(a)).	
See the attached detailed Office a	ction for a list of the certified copies not	received.
Attachment(s)		
1) Notice of References Cited (PTO-892)	4) 🗌 Interview 3	Summary (PTO-413)
<ul> <li>a) Information Disclosure Statement(s) (PTO/SB/(</li> </ul>	w (P10-948) Paper No( 08) 5) 🗌 Notice of I	nformal Patent Application
Paper No(s)/Mail Date <u>7/10/06</u> .	6) 🗌 Other:	
S. Patent and Trademark Office 'TOL-326 (Rev. 08-06)	Office Action Summary	Part of Paper No./Mail Date 20060914

EBS-00000074 FORD Ex. 1144, page 114 IPR2020-00013

#### 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.

EBS-00000075 FORD Ex. 1144, page 115 IPR2020-00013

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.

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

EBS-00000076 FORD Ex. 1144, page 116 IPR2020-00013

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 antiknock 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

> EBS-00000077 FORD Ex. 1144, page 117 IPR2020-00013

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.

EBS-00000078 FORD Ex. 1144, page 118 IPR2020-00013

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).

EBS-00000079 FORD Ex. 1144, page 119 IPR2020-00013

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.

EBS-0000081 FORD Ex. 1144, page 121 IPR2020-00013

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

Page 9

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

EBS-00000083 FORD Ex. 1144, page 123 IPR2020-00013

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).

der Al. ha

STEPHEN K. CRONIN SUPERVISORY PATENT EXAMINER

EBS-00000085 FORD Ex. 1144, page 125 IPR2020-00013

Substitute	for form 1499	AVPTO 4	Complete if Known							
	1	111 1 0 2006	Application Number	10/991,774						
INEC	RMATE	N DISCLOSURE	Filing Date	November 18, 2004						
STA	TEMEN	BY APRICANT	First Named Inventor	Daniel R. Cohn, et al.						
		CHRISTIAN BE	Art Unit	1714						
	(Use as many	sheets as necessary)	Examiner Name	Ali, Hyder						
Sheet	1	of	Attorney Docket Number	0492611-0598						

U.S. PATENT DOCUMENTS											
Doc.	ument Number	Publication Date	Name of Patentee or	Pages, Columns, Lines, Where Relevant							
». <sup>1</sup> Numb	ber-Kind Code <sup>2 AV</sup>	MM-DD-YYYY	Applicant of Cited Document	Passages or Relevant Figures Appear							
US 6,	990,956 B2	01/31/2006	Niimi								
1	e Doci Numb US 6,	e Document Number Number-Kind Code <sup>147</sup> US 6,990,956 B2	e Document Number Publication Date Number-Kind Code <sup>340</sup> MM-DD-YYYY US 6,990,956 B2 01/31/2006	e Document Number Publication Date Name of Patentee or Applicant of Cited Document US 6,990,956 B2 01/31/2006 Niimi							

		F	OREIGN PATEN	T DOCUMENTS		
Examiner	Cite	Foreign Patent Document	Publication Data	Name of Patentee or	Pages, Columns, Lines, Where	
Initials*	No.'	Country Code <sup>3-</sup> Number <sup>4-</sup> Kind Code <sup>3</sup> (If known)	MM-DD-YYYY	Applicant of Cited Document	Relevant Passages or Relevant Figures Appeal	۳
	- Contin					
		-				
		2				

Examiner Signature	/Hyder Ali/	Date Considered	07/21/2006
1. HILLS & M. C. SAMELING		and the second sec	

\*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. <sup>1</sup> Applicant's unique citation designation number (optional). <sup>1</sup> See Kinds Codes of USPTO Patent Documents at <u>www.uspto.gov</u> or MPEP 901.04. <sup>3</sup> Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3.) <sup>4</sup> For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. <sup>3</sup> Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST. 16 if possible. <sup>4</sup> 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.

4099729v1

EBS-00000086 FORD Ex. 1144, page 126 IPR2020-00013

			- 0:4		Application/C 10/991,774	ontrol No.	Applicant(s)/ Reexamination COHN ET AL	(s)/Patent Under nation FAL.				
		Notice of Reference	s Citea		Examiner		Art Unit					
					HYDER ALI		3747	Page 1 of 1				
				U.S. PA	TENT DOCUM	ENTS						
		Document Number Country Code-Number-Kind Code	Date MM-YYYY			Name		Classification				
	A	US-6,513,505	02-2003	Watana	be et al.			123/525				
	В	US-4,541,383	09-1985	Jessel,	Alfred J.			123/435				
	С	US-6,799,551	10-2004	Nakakit	a et al.			123/295				
	D	US-6,892,691	05-2005	Uhl et a	ıl.			123/198A				
	E	US-4,958,598	09-1990	Fossee	n, Dwayne		123/1A					
	F	US-										
	G	US-										
	н	US-										
	Ť.	US-										
	J	US-										
	к	US-										
1	L	US-										
	м	US-										
				FOREIGN	PATENT DOC	UMENTS						
		Document Number Country Code-Number-Kind Code	Date MM-YYYY	0	Country	N	ame	Classification				
	N											
	0											
1	Р	and the second			14							
ł	Q							<u> </u>				
_	R											
_	S	-										
_	Т	L		NON		ENTR						
-		la alla	de se segliceti	NUN-P	Title Date, Rubil	tention or Vol	ume Pertinent Pages					
			iue as applicabl	e. Aumur,		ster, Eulion of Vol	une, Forment Pages	,				
	υ											

V  $\tilde{k}$ W х 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.

U.S. Palent and Trademark Office PTO-892 (Rev. 01-2001)

Notice of References Cited

Part of Paper No. 20060914

EBS-0000087 FORD Ex. 1144, page 127 IPR2020-00013

	ITED STATES PATENT AND	TRADEM	IARK OFFICE		UNITED ST United Stat Addres COM PO. Bo Alexan	ATES DEI cs Patent (ISSIONER 1450 bis, Vigibis 7 ph.gor	ARTMENT and Trade FOR PATER 2013-1450	OF COMMERCE		
Bib Data Sheel	ATTA FILL FILL FILL FILL						CONFIRM	ATION NO. 8282		
SERIAL NUMBE 10/991,774	IMBER     FILING DATE       11/18/2004     CLASS     GROUP ART UNIT     ATTORNEY DOCKE       174     123     3747     0492611-0598									
APPLICANTS Daniel R. Col Leslie Bromb John B. Heyy ~ CONTINUING DAT ** FOREIGN APPLIC IF REQUIRED, FORE ~ 03/01/2005	nn, Chesinut Hill, MA; erg, Sharon, MA; vood, Newton, MA; -A ( ATIONS EIGN FILING LICENSE GRANTED	אכ וטו	E V E "SMALL.ENT	1TY <del>~•</del>				¥		
Foreign Priority cleaned 25 USC 119 (a-d) conditions Vantiad and Acknowledged	mei 4 yss mo Kali efter Al	lowance A- als	STATE OR COUNTRY MA	SH DR	IEETS AWING 3	то СЦ	TAL	INDEPENDENT CLAIMS 2		
ADDRESS 24280 CHOATE, HALL & ST TWO INTERNATION BOSTON, MA 02110	'EWART LLP AL PLACE					vi				
TITLE Fuel management sy:	stem for variable ethanol octane eni	hancehmer	nt of gasoline engi	nes				9C 		
FILING FEE       FEES: Authority has been given in Paper         No.      to charge/credit DEPOSIT ACCOUNT         No.      for following:         1312      for following:										

http://neo:8000/PrexServlet/PrexAction?serviceName=BibDataSheet&Action=display&brow... 4/17/06

EBS-00000088 FORD Ex. 1144, page 128 IPR2020-00013

	Search	Notes		Application/Control No.	Applicant( Reexamina	Applicant(s)/Patent under Reexamination					
				10/991,774	COHN ET	AL.					
				Examiner	Art Unit						
					3747		-				
	SEAR	CHED		SEAR (INCLUDING SE	CH NOTES	ATEGY	)				
Class	Subclass	Date	Examiner			DATE	EXMR				
123	1A	4/17/2005	HA	SEARCHED EAST SEE EAST SEARCH PRINT (	олт. <sup>4/</sup>	17/2008	на				
123	198A	4/17/2006	НА				а.,				
123	525	4/17/2006	HA	92							
123	25A	4/17/2008	HA								
123	25J	4/17/2006	НА								
123	435	9/19/06	HA								
123	575	9/15/06	HA								
123	406.29	9/14/06	HA								
123	406.47	9/14/06	HA								
JPDAT	TED	9/19/06	HA		- 1°						
8											
	1										
						5					
Clean	Subolase	Date	EV								
	0000839	Date	Ckantaler								
*							-				
			L		······						

U.S. Patent and Trademark Office

ŧ,

Part of Paper No. 20060414

		// 	nde	x of	F CI	ain IIII	75     {						Ар 10/	plic 99	atic 1,77	on/ 74	Co	ntrol	No.			Aļ Re C(	opiio exe OHI	cant amtr N E	t(s)/ tati T A	IPat on L.	ent	under
													Exe	imi DE	ner R A							Ar 37	t Ui 747	nit				
		1	Rej	ecte	d		_	(Thro	ugi Can	n n	um	ier:	al)	]	N	N	lon	-Eloc	ted	ľ	A		Ap	pea	.1			
		=	ILA	owed	4		+	. F	Rest	ric	tec	1			1	1	nto	rfere	nco	<b>1</b> 11	0		ОЪЈ	ecte	bd			
	laim	T		D	ate				lain					Da	te	-			CI	aim	Г			Date	8			1
Final	riginal	18/08	19/21					Final		IBUIGU	1 81 Oth	70/61							Inal	riginal								
	0	4	8-		-				- 4	2	7	9	4	-		L		Ц.	Ē	0						4	_	
	2	ř	i			H	+	+		2	H	Y		+	+	-		-	-	101	+	-	-			-	-	-
4	3	Ħ		1	_				E	3	Ħ	v								103								1
-	4	++	11	++		+	+		5	4	+	Y	-	1		-			-	104	+	-		+-		1		-
	6	+			-				5	6	3	ž		+-	-	-		-		105	-	-	-	-		-		
-	7		11		-				5	7		_		T	-	-				107				F			1	1
-	9	+		++	+-				-	9	-	-		+	+	-	-	-		108	$\left  \right $			-	-			4
	10						1		e	0				1						110								
-	11			++					6	1		-		-	-		-			111	-	_	_	-		1		
	13	++		+	+				te	3	-	-		+	-	-	+			112		-		+	$\vdash$	+		1
	14	1	III						E	4				1		E	1			114							-	1
	15	#	*	++						5	_	_		-	-	-	-		-	115		_	_	-		-	1-	-
Ħ	-17	#	Ħ		-		-		10	7				+		1	-		-	117		-		+				1
	18	I	4						E	8				T	1					118								1
	19	Ł	3	++		$\vdash$			6	9	_		-	-		-	-		-	119		-	-	-			-	4
· 🚝	21	É	H				1		17	1				+	T	-		-	-	121		-	-	+	H	1	+	1
	-22	-					_		7	2		_		1						122								1
21	23	F	D	+		+			+?	3		-		+	+	-	-	Н	-	123		-	-	-	-		-	4
	25	T	tit		-				17	5		-		+	+	-	1		-	125	-	-	-	+	H	-		
	26	1		H	-				1	6				1						126								
	28	++	+++	++		H			+	7	-	-	-+-	+	+	-	-	H	-	127	+	-		+	H	-		-
-	29	tt		T					17	9	-	-		+	+	-		-	-	129	+	-		+			-+-	1
_	30	H	HT	-	T		_		8	D		_		T						130								1
	31	+	+++	+	-				- E	12	_			+	+	-	-	H		131		-		-				-
-	33	Ħ		t	-				10	3	-			+	-	1	T		-	133	-	-	-	+			-	1
	34	H	H	11	-				8	4	_			1						134				1				1
-	36	+		++	- 127	+	-			8		-		+	+-	-	-	-	-	135	-	-		-		-		-
-	37	I					-		E	17	-			1	1		t	H		130				-	-		-	1
	38	H	Ш			$\square$			8	8	_			-						138								1
	40	++	111	++					0	10	-		-	+	+	-	+	H		139	-			-		$\vdash$		4
-	41	#								11				1	T					141			+				1	1
	42	Ŧ	H	T	_		-		8	2		_	_	1	-	E			_	142				1				1
	43	++		+-+	-					J H	-	-		-	+	-	+	-	-	143	-	-	-	-	-			4
	45	Ħ					-	1 E	5	5				1		-			-	145			-	+			-	1
<u> </u>	46	#	4		_	-			5	8		_		-	F	E				146	1							1
	48	++-	++	++		+			6	8	_	-		+-	+-	-	-		-	147	+	-		+	-	$\vdash$		4
1.00	49	1	1					1 1	9	9					b	-	1			149	H	-		+	H	+	+	1
	50	V	1						1	00		1			1					150		1						1

U.S. Patent and Trademark Office

Part of Paper No. 20060414

J



#### IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	Cohn, et al.	Ĩ		
Serial No.:	10/991,774	-	Examiner:	Ali, Hyder
Filed:	November 18, 2004	8	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 Murd

#### 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.

4099747v1

EBS-00000091 FORD Ex. 1144, page 131 IPR2020-00013

#### AMENDMENTS TO THE CLAIMS:

This listing of claims will replace all prior versions and listing of claims in the abovereferenced 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 <u>liquid fuel</u> anti-knock agent into a cylinder of the engine for vaporization in the cylinder to provide charge cooling; and

a fuel management control system <u>including a microprocessor</u> for controlling injection of the <u>liquid fuel</u> anti-knock agent into the cylinder to control knock <u>wherein the fuel management</u> <u>control system microprocessor substantially minimizes the amount of anti-knock agent used over</u> <u>a drive cycle</u>.

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.

4099747v1

EBS-00000092 FORD Ex. 1144, page 132 IPR2020-00013 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.

#### 4099747v1

3

EBS-00000093 FORD Ex. 1144, page 133 IPR2020-00013 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 <u>liquid</u> ethanol into a cylinder of the engine <u>for</u> <u>vaporization in the cylinder to provide charge cooling</u>; and

a fuel management control system for controlling injection of the <u>liquid</u> 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.

4099747v1

EBS-00000094 FORD Ex. 1144, page 134 IPR2020-00013 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 nonuniform 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.

4099747v1

EBS-00000095 FORD Ex. 1144, page 135 IPR2020-00013 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.

4099747v1

EBS-00000096 FORD Ex. 1144, page 136 IPR2020-00013

#### **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 antiknock 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.

4099747v1

EBS-00000097 FORD Ex. 1144, page 137 IPR2020-00013

7

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

4099747v1

EBS-00000098 FORD Ex. 1144, page 138 IPR2020-00013 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."

9

40997471

EBS-00000099 FORD Ex. 1144, page 139 IPR2020-00013 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 antiknock 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

4099747v1

10

EBS-00000100 FORD Ex. 1144, page 140 IPR2020-00013 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.

4099747v1

11

EBS-00000101 FORD Ex. 1144, page 141 IPR2020-00013 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.

4099747v1

EBS-00000102 FORD Ex. 1144, page 142 IPR2020-00013 Respectfully submitted, CHOATE, HALL & STEWART LLP

12

Sám Pasternack Registration No. 29,576

Date: July 6, 2006

.

×

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

4099747v1

EBS-00000103 FORD Ex. 1144, page 143 IPR2020-00013

# EXHIBIT 7

FORD Ex. 1144, page 144 IPR2020-00013
UNITED STATES PATENT AND TRADEMARK OFFICE



UNITED STATES DEPARTMENT OF COMMERCE United States Tateni and Trademark Office Address: COMMISSIONER FOR PATENTS P.O. Box 1450 Alexandia, Viginia 22313-1450 www.uspio.gov

### NOTICE OF ALLOWANCE AND FEE(S) DUE

91197 7590 09/12/2017 MIT''s Technology Licensing Office 255 Main Street NE 18-501 Cambridge, MA 02142-1493

EXAMINER	
HUYNH, HALH	

ART UNIT PAPER NUMBER

DATE MAILED: 09/12/2017

APPLICATION NO.	FILINO DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/463,425	0.3/20/2017	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. <u>PROSECUTION ON THE MERITS IS CLOSED</u>. 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 ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 utled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

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\_02/11)

Page 1 of 3

EBS-00001959 FORD Ex. 1144, page 145 IPR2020-00013

#### PART B - FEE(S) TRANSMITTAL

# Complete and send this form, together with applicable fee(s), to: <u>Mail</u> 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)

09/12/2017

7590

Cambridge, MA 02142-1493

MIT's Technology Licensing Office

91197

255 Main Street NE 18-501

Note: A certificate of mailing can only be used for domestic mailings of the Fee(6) 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 USP1O (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.
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			
ENAN	liner	ARTUNIT	CLASS-SUBCLASS	]					
IIUYNI	I, 11AI II	3747	123-431000						
1. Change of correspond CER 1, 163)	lence address or indicatio	n of "Fee Address" (37	2. For printing on the	patent front page, list	141				
Change of corresp	ondence address (or Cha	inge of Correspondence	<ul> <li>(1) The names of up or agents OR, alternat</li> </ul>	to 3 registered patent attore ively,	neys I				
"Fee Address" inc	B/122) attached lication (or "Fee Address	" Indication form	(2) The name of a sin	gle firm (having as a memb	era 2				
PTO/SB/47: Rev 03-0 Number is required	02 or more recent) attach	cd. Use of a Customer	2 registered patent alt listed, no name will b	orneys or agents. If no nam e printed	ir is 3				
3. ASSIGNEE NAME A	ND RESIDENCE DAT	A TO BE PRINTED ON	THE PATENT (print or ty	(pe)					
PLEASE NOTE: Un recordation as set for	less an assignee is ident	ified below, no assignce	data will appear on the	patent. If an assignee is id	lentified below, the docur	ment has been filed for			
(A) NAME OF ASSI	GNEE	piedon of this form is two	(B) RESIDENCE: (CIT	Y and STATE OR COUNT	'RY)				
				i wid stitte ok cociti					
Please check the uppropr	inte assignee category or	categories (will not be p	rinted on the patent) :	Individual 🔲 Corporati	on of other private group	entity 🗖 Government			
4a. The following fee(s)	are submitted:	4	b. Payment of Fee(s): (Plo	ease first reapply any prev	iously paid issue fee sho	wn above)			
D Publication Fac. (	In anall and the discussion	5. C. C.	A check is enclosed.						
Advance Order	t of Copies	permitted)	The director is berefy	ud. Form PTO-2038 is attac	ched	and the second			
			overpayment, to Dep	osit Account Number	(enclose an ex	tra copy of this form).			
5. Change in Entity Sta	tus (from status indicated	d above)							
Applicant certifying	ig micro entity status. Se	e 37 CFR 1 29	NOTE: Absent a valid e	ertification of Micro Entity	Status (see forms PTO/SI	15A and 15B), issue			
Applicant assertin	g omall entity status. See	37 CFR 1 27	NOTE. If the application was previously under micro entity status, checking this box will be taken						
Applicant changin	g to regular undiscounted	d fee status.	to be a notification of loss of entitlement to micro entity status.						
			entity status, as applicable.						
NOTE: This form must b	e signed in accordance w	vith 37 CFR 1.31 and 1.3.	3. See 37 CFR 1.4 for sign	nature requirements and cer	tifications.				
Authorized Signature				Date					
Typed or printed nam	e			Registration No.					
M									
			Page 2 of 3						
PTOL-85 Part B (10-13)	Approved for use throug	h 10/31/2013.	OMB 0651-0033	U.S. Patent and Trademark	Office: U.S. DEPARTME	ENT OF COMMERCE			
						EBS-00001960			
				F	ORD Ex. 1144	, page 146			
					IPR2	020-00013			



### UNITED STATES PATENT AND TRADEMARK OFFICE

and the second s			UNITED STATES DEPAR United States Patent and T Address: COMMISSIONER FC P.O. Box (1450 Alexandia, Vigilida 223 www.uppto.gov	IMENT OF COMMERCI frademark Office JR PATENTS 13-1450
APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/463,425	0.3/20/2017	Daniel R. Cohn	11381,122998	3788
91197 75	00/12/2017		EXAM	INER
MIT's Technolog	y Licensing Office		IIUYNII	, IIAI II
NE 18-501			ART UNIT	PAPER NUMBER
Cambridge, MA 02	142-1493		3747	
			DATE MAILED: 09/12/2011	7

### 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)

Page 3 of 3

EBS-00001961 FORD Ex. 1144, page 147 IPR2020-00013

#### OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

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.

#### **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.
- 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.
- 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.

EBS-00001962 FORD Ex. 1144, page 148 IPR2020-00013

	Application No.	Applicant(s	\$) Al
Notice of Allowability	Examiner HAI HUYNH	Art Unlt 3747	AIA (First Inventor to File) Status No
The MAILING DATE of this communication app All claims being allowable, PROSECUTION ON THE MERITS IS herewith (or previously mailed), a Notice of Allowance (PTOL-85 NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT R of the Office or upon petition by the applicant. See 37 CFR 1.312	ears on the cover sheet with the co (OR REMAINS) CLOSED In this app ) or other appropriate communication IIGHTS. This application is subject to 3 and MPEP 1308.	o <b>rrespondenc</b> ollcation. If no will be mailed withdrawal fr	t included I included I in due course. THIS om issue at the initiative
<ol> <li>This communication is responsive to <u>Terminal Disclaimer to</u> A declaration(s)/affidavit(s) under 37 CFR 1.130(b) wa</li> </ol>	<i>iled on 08/08/17</i> . s/were filed on,		
<ol> <li>An election was made by the applicant in response to a requirement and election have been incorporated into this a</li> </ol>	striction requirement set forth during t action.	he interview o	n; the restriction
<ol> <li>The allowed claim(s) is/are <u>1-30</u>. As a result of the allowed Highway program at a participating intellectual property off <u>http://www.usole.gov/patents/init_events/pph/index.iso</u> or s</li> </ol>	claim(s), you may be eligible to bene ice for the corresponding application. end an inquiry to <u>PPHfeedback@usp</u>	fit from the Pa For more info <u>to gov</u> .	<b>Itent Prosecution</b> rmation, please see
4. 🔲 Acknowledgment is made of a claim for foreign priority und	er 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 hav	e been received.		
2. Certified copies of the priority documents nav	e been received in Application No.	·	annliaction from the
3. Copies of the certified copies of the priority ac	ocuments have been received in this	national stage	application from the
Thernational Bureau (PCT Rule 17.2(a)).			
Cardined copies not received			
Applicant has THREE MONTHS FROM THE "MAILING DATE" noted below. Failure to timely comply will result in ABANDON! THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.	' of this communication to file a reply MENT of this application.	complying with	n the requirements
5. CORRECTED DRAWINGS ( as "replacement sheets") mus	st be submitted.		
including changes required by the attached Examiner Paper No./Mail Date	's Amendment / Comment or in the C	Office action of	
Identifying Indicia such as the application number (see 37 CFR each sheet. Replacement sheet(s) should be labeled as such in	1.84(c)) should be written on the drawir the header according to 37 CFR 1.121(	ngs in the front d).	(not the back) of
<ol> <li>DEPOSIT OF and/or INFORMATION about the deposit of attached Examiner's comment regarding REQUIREMENT F</li> </ol>	BIOLOGICAL MATERIAL must be su OR THE DEPOSIT OF BIOLOGICAL	bmitted, Note MATERIAL.	the
Attachment(s)			
1.  Notice of References Cited (PTO-892)	5. 🔲 Examiner's Amend	ment/Commer	nt
2. Information Disclosure Statements (PTO/SB/08),	6. 🔲 Examiner's Statem	ent of Reason	s for Allowance
3. Examiner's Comment Regarding Requirement for Deposit of Biological Material	7. 🛛 Other <u>response to</u>	<u>TD</u> .	
4. [_] Intervlew Summary (PTO-413), Paper No./Mail Date			
/HAI HUYNH/			
Primary Examiner, Art Unit 3/4/			
U.S. Botest and Trademark Office			
PTOL-37 (Rev. 08-13)	otice of Allowability	Part of Pape	er No./Mail Date 20170828

EBS-00001963 FORD Ex. 1144, page 149 IPR2020-00013 Application/Control Number: 15/463,425 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

> EBS-00001964 FORD Ex. 1144, page 150 IPR2020-00013

Doc code: IDS

Occ description, Information Disclosure Statement (IDS) Filed

PTO/SB/556 (01-10) Approved for use through 67/31/2012, CMB 0551-K031 U.S. Patent and Tealement Oflice; U.S. DEPARTMENT OF DOMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid CMMB control number

	Application Number		15463425	
2.5. E 100 JOB, 200 B, 67 B, 200 D, 405 D, F, 405 J, 405 J, 676 J, 506 J, 676 930	Filing Date		2017-03-30	
INFORMATION DISCLOSURE	First Named Inventor Daniel		el R. Cohn et al.	
STATEMENT BY APPLICANT	Art Unit		9747	
funde une nerentitionanese reconner na milit tradaš	Examiner Name	HUY	NH, HAI H	
	Attomey Docket Numb	er	11381.122996	

	U.S.PATENTS								
Examiner Initial*	C <i>i</i> te No	Patent Number	Kind Code <sup>1</sup>	Issue Dale	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear			
	1	49933366		1991-02-19	Ozasa et al.				
	2	6990855		2006-01-31	Niimi				
	3	4480516		1984-11-06	Takeda				
	4	3106194		1963-10-08	Cantwell et al.				
	5	4721081		1986-01-26	Kraujs et al.				
	6	6508230		2003-01-21	Suhre, B. et ei.				
	7	6075487		2000-08-20	Wulff, J. et al.				
	8	6575147		2003-06-10	Wulff. J. et al.	-			

#### /HAI H HUYNH/

### 08/28/2017

EFS Web 2.1.17

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.H.H/

EBS-00001965

FORD Ex. 1144, page 151 IPR2020-00013

~1.4X1XXXXXXXX

Application Number		15463425		
Filing Date		2017-03-30		
First Named Inventor	Den	iel R. Cohn et al.		
Art Unit	udounnana	3747		
Examiner Name	HU	YNH, HAI H		
Aftomey Docket Numl		11381 122998		

	9	6513505		2003-02-04	Wantanabe et al.	
	10	4541383		1985-09-17	Jessel, A.J.	
	11	6799551		2004-10-05	Nakakita ei al.	
	12	6892891		2005-05-17	Uhi et al.	
	13	4958598		1990-09-25	Fosseen, D.	
	14	5497744		1995-03-12	Nagaosa et al.	
	15	5715788		1998-02-10	Tarr et al.	
	15	5983855		1099-11-18	Benediki et al.	
	17	6073607		2006-08-13	Liber, Bruno	
	18	\$340015		2002-01-22	Benedikt, et al.	
1	19	6536405		2003-03-25	Rieger et al.	
EFS Web 2.1.1	7	/HAI H H	UYNH/	,	08/28/2017	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.H.H/

Application Number		15463425	
Filing Date		2017-03-30	
First Named Inventor	Dan	iel R. Cohn et al	
Art Unit		3747	
Examiner Name	HL	IYNH, HAI H	
Attomey Docket Number		11381.122998	

20	5745744	2004-06-08	Suckewer at al.	
21	6743918	2004-06-15	Rieger et al.	
22	\$ <b>7</b> 55175	2004-06-29	McKay at al.	
23	6955154	2005-10-18	Douglas, Denis	
24	7077100	2006-06-18	Vogel et al.	
25	7086376	2006-08-08	Mokay, Mishaei	
26	7036376	2007-04-10	Mokay, et si.	
<b>2</b> 7	2741230	1055-04-10	Reynolds, Slake	
20	3557763	1971-01-26	Probst, Stephén C.	
29	4031864	1977-11-01	Crothers, William T.	
30	4056087	1977-11-01	Boyce, Leonard D.	

EFS Web 2.1 17

/HAI H HUYNH/

08/28/2017

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.H.H/ EBS-00001967

Application Number	15463425	
Filing Date	2017-03-30	. (******************
First Named Inventor	Danisi R. Cohn et al.	
Art Unit	3747	
Examiner Name	HUYNH, HAI H	
Attomey Docket Numb	er 11381.122998	**********

	31	4230072	1980-10-28	Noguchí et al.	
	32	4312310	1982-01-26	Ctilviïo' et al.	
	33	4402296	1983-09-06	Schwarz, Walter J.	
	34	4594201	1988-06-10	Phillips et al.	******
	35	4367714	1990-11-06	Inoue, Ryuzaburo	*****
	36	4974416	1990-12-04	Taylor, Jack R	
	37	5179923	1993-01-19	Tsurutani et al.	
	38	5233944	1995-08-10	Mochizski. Kenji	
	39	5560344	1996-10-01	Chan, Anthony K	
	40	5911210	1999-06-15	Flach, Thomas A	
	41	5937799	1969-08-17	Binion, W. Sidney	
EFS Web 2.1.1	17	/HAIHI	HUYNH/	08/28/2017	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.H.H/

FORD Ex. 1144, page 154 IPR2020-00013

ñ

Application Number		15463425
Filing Date		2017-03-30
First Named Inventor	Danii	s R. Cohn et al.
Art Unit		3747
Examiner Name	HU	YNH, HAI H
Attomey Docket Num	<b>X61</b>	11381.122998

	42	6280525		2001-07-17	Moyer, David F.	
	43	6287351		2001-09-11	Wulffetal.	
1	44	6298638	1	2001-10-09	⊢!บที ดเล!.	
1	45	\$332448		2001-12-25	llyama et ei.	
	46	6356180		2002-03-19	Kuroda et al.	
	47	6543423		2003-04-08	Dobryden et al.	
	48	6561157		2003-05-13	zur Loye et al.	
	49	6622683		2003-08-23	Weissman et al.	
	50	9668504		2003-12-30	Dobryden et al.	
	51	6725827		2664-04-27	Ueda et al	
	52	6951202		2005-10-04	Oda, Tomihisa	
EES Vais 2.1		/HAI	н нох	NH/	08/28/201	7

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.H.H/

Application Number		15463425
Filing Date	11000011111	2017-03-30
First Named Inventor	Dan	el R. Cohn et si.
Art Unit	- 41-24-11111	3747
Examiner Name	HU	IYNH, HAI H
Altomey Docket Number		11381.122998

	63	7021277		2008-04-04	Kuo et al	
	54	7107942		2006-09-19	Welssman <del>e</del> t al.	
	56	7156070		2007-01-02	Strom et al	
	56	7188607		2007-03-10	Kobayashi, Tatauó	
	57	7320302		2008-01-22	Kobayashi, Tatsuo	
	58	3089470		1963-05-14	Payne, W.H.	
	59	4182278		1980-01-08	Coakwell, Chiarles A.	
	60	7013847		2006-03-21	Auer, Gerhard	
If you wist	h to add	additional U.S. Pater	ri oitatio	n information pl	ease click the Add button.	
			U.S.P	ATENT APPLIC	CATION PUBLICATIONS	
Examiner Initial*	Cite No	Publication Number	Kind Code <sup>s</sup>	Publication Date	Name of Patentee or Applicant of cited Document	Pages Columns Lines where Relevant Passages or Relevant Figures Appear
It you wist	n to add	additional U.S. Publis	hed Ap	plication citation	information please click the Add	d bulton.
975 vind 2.1.	17	/HAI H All Reference	HUYNH	/ NSIDERED EX	08/28/2017 CEPT WHERE LINED THROUG	H. /H.H.H/

FORD Ex. 1144, page 156 IPR2020-00013

Construction and the second second

Application Number		15463425
Filing Date		2017-03-30
First Named Inventor	Danie	el R. Cohn et al.
Art Unit		3747
Examiner Name	HU	YNH, HALH
Atlomey Docket Numl	X91.	11381.122998

			FOI	REIGN PAT	TENT DOCUM	MENTS					
Examiner Initial*	Cite No	Fareign Document Number3	Country Code²í	Kind Code4	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	12			
	÷							D			
lf you wist	h to a	L 1d additional Foreign i	Patent Docum	lent citation	L information p	I lease click the Add butto					
			NON-PA	TENT LITE	RATURE DO	CUMENTS					
Examiner Initials*	Cite No	Include name of the (book, magazine, jou publisher, city and/o	author (in CAI imal, serial, s) r country when	PITAL LET ymposium, re publisher	TERS), title of catalog, etc), 1.	the article (when appro; date, pages(5), volume-i	priate), title of the item issue number(s),	<b>T</b> 5			
	4	A. MODAK and L.S. CARETTO, Engine Cooling by Direct Injection of Cooling Water, Society of Automotive Engineers, L.									
	2	JULIAN A. LORUSSO and HARRY A. CIKANEK. Direct Injection Ignition Assisted Alcohol Engine, Society of Automotive Engineers, Inc. 560495, 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 Engineera, Inc. 962476, International Fail Fuels and Lubricants Meeting and Exposition in San Francisco, California (October 19-22, 1996)									
	4	BORJE GRANDIN and Burn or Capied EGR, 5	I HANS-ERIC A Society of Autor	NGSTROM notive Engin	, Replacing Fue seers, Inc. 199-	si Enrichment In a Turbo Ch 01-3505	narged SI Enginer Lean				
	5	C. STAN, R. TROEGE Mixture Formation and	R. S. GUENTH Comtaxision fro	ER, A. STAI om Gasoline	NCIU, L. MART to Ethanol. So	ORANO, C. TARANTINO / ciety of Automotive Enginer	ANO R. LENSI, Internal ers, Inc. 2001-01-1207				
	8	PCT International Sea	rch Report and	Written Opir	ilon, Appl. No. I	PCT7US05/041317, April 6.	2006				
	7	PCT International Sea	rch Report and	Written Opir	nion, Appl. No. i	PCT/US06/012750/ June 2	8, 2007				
	1	<u></u>									

EFS 1486 2 1.17

/HAI H HUYNH/

08/28/2017

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH, /H.H.H/

EBS-00001971

FORD Ex. 1144, page 157 IPR2020-00013

1.1.64.8.5.66.5.4

Application Number		15463426
Filing Date	***********	2017-03-30
First Named Inventor	Qurtie	R. Cohn et al.
Art Unit	•••••••••••	3747
Examiner Name	HUY	NH, HAI H
Atlomey Docket Num	Der	11381.122998

EFS Vwb 2.1.1	7	/HAI H HUYNH/ 08/28/2017	t
	18	FIKRET YUKSEL and BEDRI YUKSEL, "The Use of Ethanol-Gasoline Bland as a Fuel in an SI Engine," Renewable Energy, Vol. 29 (2004) pp. 1181-1191.	
	17	USPTO Non-Final Office Action, Application No. 11/100026, August 3, 2006	
	16	USPTO Non-Fina: Office Action, Application No. 10/991774, May 25, 2007.	
	15	USPYO Final Office Action, Application No. 10/991774, September 27, 2006	
	14	USPTO Non-Final Office Action, Application No., 10/961774, April 25, 2006	D
	13	B. LECOINTE AND G. MONNIER, "Downsizing a gasoline engine using turbocharging with direct injection", SAE paper, 2003-01-0542	C
	12	H.J. CURRAN ET AL., "A comprehensive modeling study of iso-ociane exidation," Composition and Flame, 129: 263-280, 2002, pp. 255-260	
	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.	
	10	J.B. HEYWOOD, "Internal Combustion Engine Pundamentals," McGraw Hill, 1998, page 477	
	9	USPTO Non-Final Office Action, Application NO. 11/850719, July 11, 2008	
	8	USPTO Notice of Allowance, Application No. 11/684100, March 3, 2009	D

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.H.H/

FORD Ex. 1144, page 158 IPR2020-00013

INFORMATION DISCLOSURE	Application Number		15463425	
	Filing Date		2017-03-30	No.
	First Named Inventor	Danie	el R. Cohn et al	
(Not for submission under 37 CEP 1 99)	Art Unit		3747	
(notion submission under 57 orn 1.28)	Examiner Name	HUN	YNH, HALH	
	Attomey Docket Num	oer	11381 122998	

*EXAMIN citation if	IER: In not in	aure /HAT H HUYNH/ hitial if reference considered, whether or not citation is conformance and not considered, include copy of th	in conformance with MPEP 609. It is form with next communication to	08/28/2017 Traw line through a applicant.				
(C	- Cline	EXAMINER SIG	NATURE					
h you wis	n to a	dd additional non-patent illerature documient citation i	nformation please click the Add but	0n				
	27	7 PCT International Search Report and Written Opinion, Application No. PCT/US08/69171, October 3, 2008.						
	28	PCT International Search Report and Written Opinion. Ap	plication No. PCT/US07/74227, Februa	ry 25, 2008.				
	25	PCT International Search Report and Written Opinion, Ap	plication No. PCT/US67/05777, March	24, 2008				
	24	PCT International Search Report and Written Opinion, Ap	plication No. PCT/iB07/03004, July 9, 2	008.				
	23	USPTO Non-Final Office Action, Application No. 11/6641	00, June 3, 2008	C				
_	22	USPTO Final Office Action, Application No. 11/682372, C	otober 17., 2008.					
	21	USPTO Non-Final Office Action, Application No. 11/6823	72. January 2. 2008					
	20	USPTO Non-Final Office Action; Application No. 11/2297	PTO Non-Final Office Action; Application No. 11/229755. October 4, 2007					
	19	UPSTD Non-Final Office Action, Application No. 11/229755, March 22, 2607.						

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.H.H/

EBS-00001973 FORD Ex. 1144, page 159 IPR2020-00013

Application Number		15463425		
Filing Date		2017-03-30		
First Named Inventor Danie		iel R. Cohn et al.		
Art Unit	****	3747		
Examiner Name HUY		YNH, HAI H		
Attomey Docket Number		11381 122998		

<sup>1</sup> See Kind Codes of USPTO Patent Documents at <u>more USPTO, GOV</u> or MPEP 901.04. <sup>2</sup> Enter office that issued the document, by the two-letter code (MPO Standard ST.3). <sup>5</sup> For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the senial number of the patent document. <sup>4</sup> Kind of document by the supportate symbols as indicated on the document under WIPO Standard ST.16 if possible. <sup>5</sup> Applicant is to place a check mark here a English language translation is strached;

EFS Web 2.1.17

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.H.H/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		Application Number	15463425	
		Filing Date	2017-03-30	
		First Named Inventor	Danisi R. Cohn et :	٤٤.
		Art Unit	3747	
		Examiner Name	HUYNH, HAI H	
		Attorney Docket Numbe	11361 1229	98
Please see 37 CFR 1.97	and 1.98 to make the	CERTIFICATION STATE	MENT	
That each item of i	nformation contained nt office in a counter re statement. See 37	in the information disclosup part foreign application no CFR 1.97(e)(1).	re statement wa I more than thre	is first cited in any communication the months prior to the filing of the
OR				
statement See 17 (	1000000000			
<ul> <li>See attached certific</li> <li>The fee set forth in the set forth in the fee set forth in the fee set forth in the set forth in the signature.</li> </ul>	cation statement. 37 CFR 1.17 (p) has t nent is not submitted ant or representative	een submitted herewith. herewith. SIGNATURE Is required in accordance w	ith CFR 1.33, 10	.18 Please see CFR 1.4(d) for the
<ul> <li>See attached certific</li> <li>The fee set forth in t</li> <li>A certification stater</li> <li>A signature of the applic form of the signature.</li> </ul>	cation statement. 37 CFR 1.17 (p) has t nent is not submitted ant or representative	Seen submitted herewith. herewith. SIGNATURE Is required in accordance w	ith CFR 1.33, 10	.18 Please see CFR 1.4(d) for the
See attached certific         The fee set forth in 1         A certification stater         A signature of the applic form of the signature.         Signature         Signature         Name/Print	cation statement. 37 CFR 1.17 (p) has t nent is not submitted ant or representative	been submitted herewith. herewith. Is required in accordance w Date ( Regist	ith CFR 1.33, 10 (YYY-MM-DD) ration Number	.18 Please see CFR 1.4(d) for the 2017-08-10 29576
See attached certific         The fee set forth in 1         A certification stater         A signature of the applic form of the signature.         Signature         Signature         Name/Print         Sa         This collection of information public which is to file (and 1.14. This collection is e application form to the U require to complete this f Patent and Trademark O FEES OR COMPLETED	tion is required by 37 d by the USPTO to pr stimated to take 1 hoi SPTO. Time will vary orm and/or suggestio fice, U.S. Departmen FORMS TO THIS AD	CFR 1.97 and 1.98. The in ocess) an application. Con- ur to complete, including gat depending upon the individ ns for reducing this burden. it of Cemmerce, P.O. Box 1 DRESS. SEND TO: Comm	ith CFR 1.33, 10 (YYY-MM-DD) ration Number formation is requidentiality is gow hering, preparing ual case. Any co should be sent to 450, Alexandria, nissioner for Pa	.18. Please see CFR 1.4(d) for the 2017-09-10 29576 29576 and submitting the completed comments on the amount of time you o the Chief Information Officer, U.S VA 22313 1459. DO NOT SEND tents, <b>P.O. Box 1450, Alexandria</b>

EFS Web 2,1.17

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /H.H.H/

EBS-00001975 FORD Ex. 1144, page 161 IPR2020-00013

## PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: SAM PASTERNACK	PCT
CHOATE, HALL & STEWART TWO INTERNATIONAL PLACE BOSTON, MA 02110	NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION
8	(PCT Rule 44.1)
ð	Date of mailing (day/month/year) 0 9 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	
<ol> <li>The applicant is hereby notified that the international sear have been established and are transmitted herewith.</li> </ol>	ch report and the written opinion of the International Searching Authority
Filing of amendments and statement under Article 19: The applicant is entitled, if he so wishes, to amend the cla	ims of the international application (see Rule 46):
When? The time limit for filing such amendments is search report.	normally two months from the date of transmittal of the international
Where? Directly to the International Bureau of WIPO 1211 Geneva 20, Switzerland, Facsimile No.	), 34 chemin des Colombertes : (41-22) 338.82.70.
For more detailed instructions, sao the notes on the av	companying cheet.
<ol> <li>The applicant is hereby notified that no international searcher Article 17(2)(a) to that effect and the written opinion ofth</li> </ol>	th report will be established and that the declaration under e International Searching Authority are transmitted herewith.
3. With regard to the protest against payment of (an) addit	ional fee(s) under Rule 40.2, the applicant is notified that:
. the protest logether with the decision thereon has bee request to forward the texts of both the protest and the	n transmitted to the International Bureau together with the applicant's decision thereon to the designated Offices
no decision has been made yet on the prosst; the app	licant will be hotified as soon as a decision is made.
4. Reminders	
Shortly after the expiration of 18 months from the priority date Bureau. If the applicant wishes to avoid or postpone publicatio priority claim, must reach the International Bureau as provided in technical preparations for international publication.	, the international application will be published by the International n, a notice of withdrawal of the international application, or of the Rules 90 <i>bls</i> .1 and 90 <i>bls</i> .3, respectively, before the completion of the
The applicant may submit comments on an informal basis on international Bureau. The international Bureau will send a copy preliminary examination report has been or is to be established. before the expiration of 30 months from the priority date.	the written opinion of the International Searching Authority to the of such comments to all designated Offices unless an international These comments would also be made available to the public but not
Within 19 months from the priority date, but only in respect or examination must be filed if the applicant wishes to postpone the (in some Offices even later); otherwise, the applicant must, with entry into the national phase before those designated Offices.	of some designated Offices, a demand for international preliminary entry into the national phase until 30 monities from the priority date in 20 months from the priority date, perform the prescribed acts for
in respect of other designated Offices, the time limit of 30 months	s (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 app Volume II, National Chapters and the WIPO Internet site.	plicable time limits, Office by Office, see the PCT Applicant's Guide,
Name and mailing address of the ISA/US	Authorized officer
Commissioner for Patents	Stephen K Cronin Mun Health
P.O. Box 1450 Alexandria, Virginia 22313-1450	Telephone Nn (571) 272-4383
Facsimile No. (571) 273-3201	1010/1010 1101 (071/2/2-430)

.

### PATENT COOPERATION TREATY

16 - AF

 $\overline{\mathbf{a}}$ 

# PCT

2

### INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

pplicant's or agent's file reference 006734-0002	FOR FURTHER see ACTION as well as, w	Form PCT/ISA/220 here applicable, item 5 below
ternational application No. CT/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)
pplicant THANOL BOOSTING SYSTEMS. LLC	5 <sup>1</sup>	
his international search report has been coording to Article 18. A copy is bein	n prepared by this international Searching A g transmitted to the international Bureau.	uthority and is transmitted to the applicant
It is also accompanie	d by a copy of each prior art document cited	i in this report.
Basis of the Report a. With regard to the language, the the international	e international search was carried out on the ba I application in the language in which it was fl	sis of: led
a translation of a translation of a	the international application into	, which is the language ch (Rules 12.3(a) and 23.1(b))
b. This international search re authorized by or notified to	port has been established taking into account to this Authority under Rule 91 Rule 43.6 bis(a)	he rectification of an obvious mistake
c. With regard to any nucleot	tide and/or amino acid sequencedisclosed in	the international application, see Box No. 1.
Certain claims were found	d unsearchable (See Box No. II)	
Unity of Invention is lack With regard to the title,	ing (See Box No. III)	10
the text is approved as subr	nitted.by the applicant.	
the text has been establishe	d by this Authority to read as follows:	
3 N		2
e <sup>2</sup> a <sup>3</sup>	· · · · · ·	
	· · · · ·	
8 E	× *	6
With regard to the abstract,		39 mm
the text is approved as sub-	mitted by the applicant.	
the text has been established may, within one month fro	ed, according to Rule 38.2(b), by this Authority m the date of maling of this international search	as it appears in Box No. IV. The applicant ch report, submit comments to this Authority.
. With regard to the drawings, a, the figure of the drawings to be	published with the abstract is Figure No. 1	. <u>*</u> *
as suggested by th	e applicant.	
as selected by this	Authority, because the applicant failed to sug	gest a figure.
as selected by this	Authority, because this figure better character	izes the invention.
	•	

EBS-00001999 FORD Ex. 1144, page 163 IPR2020-00013

# PCT/IB2007 03004 09.07.2008

	INTERNATIONAL SEARCH REPO	RT	International ap	olication No.
			РСТ/ЛВ07/0300	4
A. CLA	SSIFICATION OF SUBJECT MATTER	2.21		2 010000
IPC;	F02M 17/00(2006.01)			
LICDO.	107/447			JI 100
According to	123/447 Dinternational Patent Classification (IPC) or to both na	tional clas	ssification and IPC	
-				10
B. FIEL	DS SEARCHED			
Minimum do U.S. : 12	cumentation searched (classification system followed   23/447	oy classifi	ication symbols)	
Documentati	ion searched other than minimum documentation to the	autant the		te dha Gelde e - 1 - 1
Documentan	ion searched other than mitimum documentation to the	extent int	at such documents are included	in the fields searched
×	(1)			
Electronic da	ata base consulted during the International search (name	s of data b	base and, where practicable, sea	rch terms used)
EAST				
C DOC	UMENTS CONSIDERED TO BE BELEVANT			lit.
Category #	Citation of document, with indication, where a	ppropriate	a of the relevant correspond	Deleverate state 21
A	LIS 2005/0056264 A1 (WEISSMAN et al) 17 Mars	ppropriate	e, of the relevant passages	Relevant to claim No.
		1 2005, F	iguie 2, clatin 11,	1-15
A	US 5,560,344 A (CHAN) 1, October 1996 (01 10.19	96), whol	le document	1-15
	4		2 I.	
	20			
2	¥	~		
	~		*	
	2			
			× 3	
				(a)
Further	r documents are listed in the continuation of Box C.		See patent family annex,	
• S	pecial categories of cited documents:	، <del>سل</del> رو،	later document published after the in	ternational filing date or priority
"A" document	t defining the general state of the art which is not considered to be of		date and not in conflict with the appl principle or theory underlying the in-	cation but elled to understand the vention
particular	relevance .	"X"	document of particular relevance; the	claimed invention cannot be
"E" earlier ap	plication or patent published on or after the international filing date		<ul> <li>considered novel or cannot be consid when the document is taken alone</li> </ul>	lered to involve an inventive step
"L." document . establish	t which may throw doubts on priority claim(s) or which is cited to the publication date of another citation or other special reason (as	ייץיי	document of particular relevance: the	staimed invention cannot be
specified)	)		considered to involve an inventive at with one or more other such docume	ep when the document is combine
"O" document	t referring to an oral disclosure, usa, exhibition or other means		obvious to a person skilled in the art	
"P" document	t published prior to the international filing date but inter than the inter chained	"&"	document member of the same pater	I family
priority di	ctual completion of the international search	Date of	mailing of the international sea	rch report
priority di Date of the ac			1111 2008	
priority di Date of the ac 08 June 2008	(08.06.2008)	09		
priority di Date of the ac 08 June 2008 Name and ma	(08.06.2008) ailing address of the ISA/US	09 Authori:	zed officer	
priority di Date of the ac 08 June 2008 Name and ma Mal Con	(08.06.2008) ailing address of the ISA/US Il Stop PCT, Aun: ISA/US mmissioner for Patents	09 Authori: Stepher	zed officer	North
priority di Date of the ac 08 June 2008 Name and ma Mai Con P Q	8 (08.06.2008) ailing address of the ISA/US Il Stop FCT, Attn: ISA/US mmissioner for Patents . Box 1450	09 Authori: Stepher	zed officer n K Cronin Auro	Verette

¥

## PCT/IB2007/( 3004 09.07.2008

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:

SAM PASTERNACK CHOATE, HALL & STEWART

BOSTON, MA 02110

TWO INTERNATIONAL PLACE

 $\mathbf{s}$ 

 $\epsilon^{i_i}$ 



## 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 seathave been established and are transmitted herewith.	rch report and the written opinion of the International Searching Authority		
Filing of amendments and statement under Article 19 The applicant is entitled, if he so wishes, to amend the cla	: ims of the international application (see Rule 46):		
When? The time limit for filing such amendments is search report.	normally two months from the date of transmittal of the international		
Where? Directly to the International Bureau of WIP( 1211 Geneva 20, Switzerland, Facsimile No	D, 34 chemin des Colombettes .: (41-22) 338.82.70.		
For more detailed instructions, see the notes on the a	accompanying sheet.		
2. The applicant is hereby notified that no international sear Article 17(2)(a) to that effect and the written opinion of i	ch report will be established and that the declaration under he international Searching Authority are transmitted herewith.		
3. With regard to the protest against payment of (an) addi	itional foe(s) under Rule 40.2, the applicant is notified that:		
the protest together with the decision thereon has be request to forward the texts of both the protest and	en transmitted to the International Bureau together with the applicant's the decision thereon to the designated Offices.		
no decision has been made yet on the protest; the ap	plicant will be notified as soon as a decision is made.		
4. Reminders			
Shortly after the expiration of 18 months from the priority dat Bureau. If the applicant wishes to avoid or postpone publicati priority claim, must reach the International Bureau as provided i technical preparations for international publication.	ie, the international application will be published by the International on, a notice of withdrawal of the international application, or of the n Rules 90 <i>bis</i> , 1 and 90 <i>bis</i> .3, respectively, before the completion of the		
The applicant may submit comments on an informal basis on International Bureau. The International Bureau will send a cop preliminary examination report has been or is to be established before the expiration of 30 months from the priority date.	t the written opinion of the International Searching Authority to the by of such comments to all designated Offices unless an international . These comments would also be made available to the public but not		
Within 19 months from the priority date, but only in respect examination must be filed if the applicant wishes to postpone th (in some Offices even later); otherwise, the applicant must, with entry into the national phase before those designated Offices.	of some designated Offices, a demand for international preliminary to entry into the national phase until 30 months from the priority date his 20 months from the priority date, perform the prescribed acts for		
In respect of other designated Offices, the time limit of 30 month	hs (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 a Volume II, National Chapters and the WIPO Internet site.	pplicable time limits, Office by Office, see the PCT Applicant's Guide,		
Name and mailing address of the ISA/ US Mail Stop PCT, Attn: ISA/US Commissioner for Patents PLO Roy 1450	Authorized officer Stephen K Cronin		
Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201	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	FOR FURTHER See	Form PCT/ISA/220
2006734-0002	ACTION B5 well as, wh	ere applicable, item 5 below,
International application No.	International filing date (day/month/year)	(Earliest) Priority Date (day/month/year)
PCT/IB07/03004	06 March 2007 (06.03.2007)	08 March 2006 (08.03.2006)
Applicant ETHANOL BOOSTING SYSTEMS. LLC This international search report has been according to Article 18. A copy is being This international search report consists of It is also accompanied 1. Basis of the Report a. With regard to the language, the the international the international the international search report authorized by or notified to to c. With regard to any nucleotic 2. Certain claims were found 3. Unity of invention is lackin 4. With regard to the title, the text is approved as submind the text has been established	prepared by this International Searching Au transmitted to the International Bureau. of a total of sheets. by a copy of each prior art document cited International search was carried out on the bas application in the language in which it was file e international application into	in this report. is of: ed. 
5. With regard to the abstract, the text is approved as submi	tted 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	a report, submit comments to this Authority.
<ul> <li>6. With regard to the drawings,</li> <li>a. the figure of the drawings to be p</li> <li>as suggested by the</li> <li>as selected by this A</li> <li>as selected by this A</li> <li>b. none of the figures is to be p</li> </ul>	ublished with the abstract is Figure No. <u>1</u> applicant. uthority, because the applicant failed to sugge uthority, because this figure better characteriz ublished with the abstract.	est a figure.

Form PCT/ISA/210 (first sheet) (April 2007)

## PCT/IB2007/0 3004 09.07.2008

	INTERNATIONAL SEADOU DEPOUT		International appli	Eation NOPY
	INTERNATIONAL SEARCH REFOR	X1		
A. CLAS IPC:	SSIFICATION OF SUBJECT MATTER F02M 17/00( 2006.01)			
USPC: According to	123/447 International Patent Classification (IPC) or to both nat	ional classification a	nd IPC	
B. FIEL	DS SEARCHED			
Minimum do U.S. ; 12	cumentation searched (classification system followed b 23/447	y classification symb	ols)	
Documentati	on searched other than minimum documentation to the	extent that such docu	ments are included in	the fields searched
Electronic da EAST	ata base consulted during the international search (name	e of data base and, wh	ere practicable, search	n terms used)
C. DOC	UMENTS CONSIDERED TO BE RELEVANT			
Category *	Citation of document, with indication, where a	ppropriate, of the rele	evant passages	Relevant to claim No
A	US 2005/0056264 A1, (WEISSMAN et al) 17 Marc	h 2005, Figure 2, cla	m 11.	1-15
14				Ť
Furthe	r documents are listed in the continuation of Box C.	See pater	nt family annex.	
* 4 "A" documen	Special estegories of elted documents: n defining the general state of the art which is not considered to be of relevance	"T" later docu date and n principle a	nent published after the inter at in conflict with the applica r theory underlying the inven	national filing date or priority tion but clied to understand th tion
"E" carller op	pplloation or patent published on or after the international filing date	"X" document considered when the o	of particular relevance; the c novel or cannot be consider locument is taken alone	isimed invention cannot be ad to involve an inventive step
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another cliotion or other special reason (as specified) "Y" document is taken alone "Y"				
"pr documen	n published prior to the International filing date but later than the date claimed	"&" document	member of the same patent fi	amily
Date of the a	actual completion of the international search	Date of mailing of	the international searc	h report
08. June 2001	8 (08,06,2008)			
Name and m Ma Co	ailing address of the ISA/US ail Stop PCT, Attn: ISA/US immissioner for Patents	Authorized officer Stephen K Cronin	Sou	
P.C Ali Facsimile No	O. Box 1450 exandria, Virginia 22313-1450 o. (571) 273-3201	Telephone No. (57	71) 272-4383	

82

28

1

Form PCT/ISA/210 (second sheet) (April 2007)

(4)

æ

¥1)

## PCT/IB2007/ 3004 09.07.2008

PATENT	COOPER	ATION	TREATY
--------	--------	-------	--------

). M

TERNATIONAL SEARCHING AUTHORITY			ORITY	1%	FILE COPY	
To: SAM PASTERNACK CHOATE, HALL & STEWART TWO INTERNATIONAL PLACE BOSTON, MA 02110		WI INTERNATI	PCT RITTEN OPINION OF THE ONAL SEARCHING AUTHORITY			
					(PCT Rule 43bis.1)	
				Date of mailing		
Applicant	's or agent's file :	eference		FOR FURTHER	ACTION	
2006734-0	0002				See paragraph 2 below	
Internation	nal application N	D.	International filing date	(day/month/year)	Priority date (day/month/year)	
PCT/IB07	/03004		06 March 2007 (06.03.2	007)	08 March 2006 (08.03.2006)	
PC: JSPC: Applicant ETHANO	L BOOSTING S	YSTEMS, LL	75,577,198C,198A;701/10 C	DI		
I, This c	opinion contains i	ndications rela	ating to the following item	15:	2	
$\boxtimes$	Box No. I	Basis of the	opinion			
	Box No. II	Priority		egard to novelty, inventive step and industrial applicability		
	Box No. III	Non-establi	shment of opinion with re			
	Box No. IV	Lack of uni	ty of invention			
$\boxtimes$	Box No. V	Reasoned st applicability	atement under Rule 43 <i>bls</i> y; citations and explanatio	b/s. I (a)(i) with regard to novelty, inventive step or industrial tions supporting such statement		
	Box No. VI	Certain doc	uments cited			
	Box No. VII	Certain defe	ects in the International ap	plication		
	Box No. VIII	Certain obs	ervations on the internatio	nal application		
2. FUR'	THER ACTIO	N				
If a d Intern Autho that w	emand for intern ational Prelimina rity other than the ritten opinions of	ational prelim by Examinin its one to be to this Internation	inary examination is man g Authority ("IPEA") ex he IPEA and the chosen onal Searching Authority	de, this opinion will scept that this does IPEA has notified th will not be so consid	be considered to be a written opinion of the e not apply where the applicant chooses an he International Bureau under Rule 66.1 <i>bis(b)</i> ered.	
lf this IPEA of For	a written reply to m PCT/ISA/220	rovided above gether, where or before the e	e, considered to be a writ appropriate, with amend expiration of 22 months fr	ten opinion of the 11 ments, before the ex om the priority date,	PEA, the applicant is invited to submit to the piration of 3 months from the date of mailing whichever expires later.	
3. For fu	rther details, see	notes to Form	рстлsa/220.			
Name and	mailing address	of the ISA/110	Data of some la	tion of this ant-to	Authorized officer	
N C P	Mail Stop PCT, Atta Commissioner for Pr P.O. Box 1450	ISA/US	08 June 2008 ((	08.06.2008)	Stephen K Cronin	
A acsimile 1	Vexandria, Virginia No. (571) 273-320	22313-1450 )1			Telephone No. (571) 272-4383	
m PCT/I	SA/237 (cover sh	eet) (April 20	07)		l	

# PCT/IB2007 3004 09.07.2008

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY	PCT/IB07/03004
Box No. 1 Basis of this opinion	
<ol> <li>With regard to the language, this opinion has been established on the basis of:         <ul> <li>the international application in the language in which it was filed</li> <li>a translation of the international application into, which is the lang international search (Rules 12.3(a) and 23.1(b)).</li> </ul> </li> <li>This opinion has been established taking into account the rectification of Authority under Rule 91 (Rule 43bis.1(a))</li> <li>With regard to any nucleotide and/or amino acid sequence disclosed in the established on the basis of:</li> </ol>	uage of a translation furnished for the purposes of f an obvious mistake authorized by or notified to this ne international application, this opinion has been
<ul> <li>в. type of material</li> <li>a sequence listing</li> <li>table(s) related to the sequence listing</li> </ul>	
b. format of material	
<ul> <li>c. time of filing/furnishing</li> <li>contained in the international application as filed.</li> <li>filed together with the international application in electronic form.</li> <li>furnished subsequently to this Authority for the purposes of search</li> </ul>	
4. In addition, in the case that more than one version or copy of a sequence or furnished, the required statements that the information in the subseq application as filed or does not go beyond the application as filed, as app	listing and/or table(s) relating thereto has been filed quent or additional copies is identical to that in the ropriate, were furnished.
5. Additional comments:	

14.5

EBS-00002005 FORD Ex. 1144, page 169 IPR2020-00013

# PCT/IB2007/0 )004 09.07.2008

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY		Υ	PCT/IB07/03014 ILE COPY		
Box No. V Reasoned statement under Rule 43 bis.1(a)(i) with rega		with regar	d to novelty, inventive step or industrial		strial
1. Statement				,	
Novelty (N)	Claims	1-15			YE
	Claims	NONE			
Inventive step (IS)	Claims	1.15			V
	Claims	NONE			
Industrial and task title. (14)	<b>a</b> :				
moustrial applicability (IA)	Claims	NONE		·	YE
2. Citations and explanations:		1.0			
Claims 1-15 meet the criteria set out in PCT Article	33(2)-(3) heenu	se the prior of	art does not tench or fa	rly monort ables	dinuntior
12					
			ŭ.		
					50
	a.				
e.					

3

Form PCT/ISA/237 (Box No. V) (April 2007)

EBS-00002006 FORD Ex. 1144, page 170 IPR2020-00013

# PCT/IB2007 / 3004 09.07.2008

WRIT INTERNATIO Supplemental Box	TEN OPINION O	F THE IG AUTHORITY		PCT/IB07/01004	ECOPY
Continuation of IPC: F02M 63/00( 2006.01),43/0	0( 2006.01);F02B 47	/00( 2006.01),47/04( 2	006.01),13/	00( 2006.01),13/10( 200	5.01)
2					
	iā.		22		a ž
і 5 <sup>- 8</sup>					
Ŧ		0.8			
		2		X.	
12					۰
		S <b>9</b> 0		15	9 <b>*</b> 5
		54			24 242

Form PCT/ISA/237 (Supplemental Box) (April 2007)

°.E

EBS-00002007 FORD Ex. 1144, page 171 IPR2020-00013

ŝ

÷	DECEIVED
. ¥	MAR 2 6 2008
	PATENT DEPARTMENT
F	РСТ

From the INTERNATIONAL SEARCHING AUTHORITY

T <sub>o:</sub> Sam Pasternack Choate, Hail & 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
1	(PCT Rule 44.1)
	(day/monik/year)
Applicant's or agent's file reference	FOR FUEL ACTION See assembly Land 4 holes
2006734-0003PC	FOR FOR A CHON 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	
	4
1. The applicant is hereby notified that the international Authority have been established and are transmitted h	search report and the written opinion of the International Searching serewith.
Filing of amendments and statement under Article The applicant is entitled, if he so wishes, to amend the When? The time limit for filing such amendment international search report.	19: e claims of the international application (see Rule 46): nents is normally two months from the date of transmittal of the
Where? Directly to the International Burcau of W 1211 Geneva 20, Switzerland, Facsimile For more detailed instructions, see the notes on the	/IPO, 34 chemin des Colombettes No.: +41 22 740 14 35 he accompanying sheet.
2. The applicant is hereby notified that no international Article 17(2)(a) to that effect and the written opinion	al search report will be established and that the declaration under of the International Searching Authority are transmitted herewith.
3. With regard to the protest against payment of (an) a	additional fce(s) under Rule 40.2, the applicant is notified that:
the protest together with the decision thereon applicant's request to forward the texts of both	has been transmitted to the International Burcau together with the 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.
<ol> <li>Reminders         Shortly after the expiration of 18 months from the prior International Bureau. If the applicant wishes to avoid or application, or of the priority claim, must reach the International before the completion of the technical preparations for inter-     </li> </ol>	ority date, the international application will be published by the postpone publication, a notice of withdrawal of the international ional Bureau as provided in Rules 90 <i>bis</i> .1 and 90 <i>bis</i> .3, respectively, national publication.
The applicant may submit comments on an informal basis o International Bureau. The International Bureau will sen international preliminary examination report has been or is t the public but not before the expiration of 30 months from t Within 10 months from the second	n the written opinion of the International Searching Authority to the d a copy of such comments to all designated Offices unless an to be established. These comments would also be made available to he priority date.
examination must be filed if the applicant wishes to postpon date (in some Offices even later); otherwise, the applicant m acts for entry into the national phase before those designated	of some designated Offices, a demand for international preliminary e the entry into the national phase until 30 months from the priority ust, within 20 months from the priority date, perform the prescribed d Offices.
In respect of other designated Offices, the time limit of 30 months.	months (or later) will apply even if no demand is filed within 19
See the Annex to Form PCT/IB/301 and, for details about the Guide, Volume II, National Chapters and the WIPO Interne	ne applicable time limits, Office by Office, see the PCT Applicant's t site.
Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22010-1450	Lao W. Young

P.O. Box 1450, Alexandria, Virgir Facsimile No, 571-273-3201 313-1450 PCT Helpdask: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/220 (January 2004)

(See notes on accompanying sheet)

I

## PATENT COOPERATION TREA.Y

From the INTERNATIONAL SEARCHING AUTHORITY

ţ

(4.)

To: Sam Pastemack Choate, Hall & Stewart Two International Place Boston, Massachusetts 02110 Applicant's or agent's file reference 2006734-0003PC	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) 24 MAR 2008 FOR FURTHER ACTION See paragraphs 1 and 4 below
PCT/US 07/05777	(day/month/year) 08 March 2007 (08.03.2007)
Applicant       Ethanol Boosting Systems, LLC         1.       Image: Constraint is hereby notified that the international set Authority have been established and are transmitted here	earch report and the written opinion of the International Searching ewith
<ul> <li>Filing of amendments and statement under Article 1: The applicant is entitled, if he so wishes, to amend the of When? The time limit for filing such amendment international search report.</li> <li>Where? Directly to the International Bureau of WII 1211 Geneva 20, Switzerland, Facsimile N For more detailed instructions, see the notes on the</li> <li>2. The applicant is hereby notified that no international Article 17(2)(a) to that effect and the written opinion of</li> <li>3. With regard to the protest against payment of (an) ad the protest together with the decision thereon h applicant's request to forward the texts of both t no decision has been made yet on the protest; th</li> <li>4. Reminders Shortly after the expiration of 18 months from the prior</li> </ul>	9: claims of the international application (see Rule 46): nts is normally two months from the date of transmittal of the PO, 34 chemin des Colombertes) CKCECO lo.: +41 22 740 14 35 accompanying sheet. Search report will be established and that the declaration didder F the International Searching Authority are transmitted herewith. ditional fee(s) under Rule 40.2, the applicant is notified that: as been transmitted to the International Bureau together with the he protest and the declsion thereon to the designated Offices. The applicant will be notified us soon as a decision is made.
application, or of the priority claim, must reach the International before the completion of the technical preparations for international The applicant may submit comments on an informal basis on International preliminary examination report has been or is to the public but not before the expiration of 30 months from the Within 19 months from the priority date, but only in respect of examination must be filed if the applicant wishes to postpone date (in some Offices even later); otherwise, the applicant mu acts for entry into the national phase before those designated In respect of other designated Offices, the time limit of 30 r months. See the Annex to Form PCT/IB/301 and, for details about the <i>Guide</i> , Volume II, National Chapters and the WIPO Internet	and Bureau as provided in Rules 90 <i>bis</i> . 1 and 90 <i>bis</i> . 3, respectively, ational publication. the written opinion of the International Searching Authority to the a copy of such comments to all designated Offices unless an be established. These comments would also he made available to a priority date. of some designated Offices, a demand for international preliminary the entry into the national phase <b>until 30 months</b> from the priority st, within <b>20 months</b> from the priority date, perform the prescribed Offices. <b>months</b> (or later) will apply even if no demand is filed within 19 exampleable time limits, Office by Office, see the <i>PCT Applicant's</i> site.
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandrie, Viginia 22313-1450 Facsimile No. 571-273-3201 Form PCT/(SA/220) (January 2004)	Authorized officer: Lee W. You MAR 2 6. 2008 PCT Helpdesk: 671-272-4300 PCT OSP: 671-272-7774 (See In other Appendix DEPARTMENT

5P

### PATENT COOPERATION TREASY

# PCT

### INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 2006734-0003PC	FOR FURTHER ACTION as well	see Form PCT/ISA/220 as, where applicable, item 5 below.
International application No. PCT/US 07/05777	International filing date <i>(day/month/year)</i> 08 March 2007 (08.03.2007)	(Earliest) Priority Date (day/month/year) 10 March 2008 (10.03.2006)
Applicant Ethanol Boosting Systems, LLC		de
This international search report has been according to Article 18. A copy is being This international search report consists This international search report consists It is also accompanied by a 1. Basis of the report a. With regard to the language, the main the international app a translation of the ir a translation furnishe b. This international search re authorized by or notified to c. With regard to any nucleof 2. Certain claims were four 3. Unity of invention is lack 4. With regard to the tille, The text is approved as sub-	en prepared by this International Searching A g transmitted to the International Bureau. of a total of	Authority and is transmitted to the applicant report. asis of: which is the language of ites 12.3(a) and 23.1(b)). In the rectification of an obvious mistake i)). In the international application, see Box No. 1.
the text has been established	d by this Authority to read as follows:	
<ul> <li>5. With regard to the abstract,</li> <li>the text is approved as submit the text has been established may, within one month from</li> <li>6. With regard to the drawings,</li> <li>a. the figure of the drawings to be</li> </ul>	nitted by the applicant. d, according to Rule 38.2(b), by this Authorit n the date of mailing of this international scare published with the abstract is Figure No. 1	y as it appears in Box No. IV. The applicant the report, submit comments to this Authority.
as suggested by the a as selected by this At as selected by this At b. none of the figures is to be	pplicant_ athority, because the applicant failed to sugge athority, because this figure better characteriz- published with the abstract.	st a figure. es the invention. PATENT DEPARTMEN

Form PCT/ISA/210 (first sheet) (April 2007)

#### INTERNA ... ONAL SEARCH REPORT

 $_{g}=-2$ 

	INTERNA . 10NAL SEARCH REPORT	International	application No.
		PCT/U	S 07/05777
A. CLA IPC(8) - USPC - According	SSIFICATION OF SUBJECT MATTER F02B 77/04 (2007.10) 123/198A to International Patent Classification (IPC) or to both ma	ational classification and IPC	
B. FIEL	LDS SEARCHED		
Minimum d USPC: 123/	ocumentation searched (classification system followed by 198A	classification symbols)	
Documental USPC: 123/	ion searched other than minimum documentation to the ex 198R, 406.29, 406.47 (text search - see terms below)	ent that such documents are included i	n the fields searched
Electronic d PubWEST(U Search Terr Injection, mo	ata base consulted during the international search (name of JSPT,PGPB,EPAB,JPAB); Google Patents; Google Scho ns: gasoline engine, ethanol, direct injection, engine know otor	data base and, where practicable, sea blar sk, emissions, restart, control system	ch terms used) , shut down, deceleration, port
C. DOCU	MENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where ap	propriate, of the relevant passages	Relevant to claim No.
Y	Calculations of Knock Suppression in Highly Turbocha Direct Ethanol Injection (L. Bromberg et al.) 23 Februar especially Abstract, Section I, para [0003], Section II, p	ged Gasolin/Ethanol Engines Using y 2006 (23.02.2006), enlire documer ara (0001], [0003], [0006]	1-18 it
Y	US 4,312,310 A (Chivilo' et al.) 26 January 1982 (26.01	i.1982), col 2, in 20-26 and in 36-54	1-18
Y	US 6,358,180 B1 (Kuroda et al.) 19 March 2002 (19.03 -15, col 8, In 3-27col 12, In 54-56	.2002), Flg 4, col 3, In 65-67 to col 4,	In 1 2, 9-10, 13-18
Y	US 4,974,416 A (Taylor) 04 December 1990 (04.12.19	90), col 4, ln 15-21	5
Y	US 6,260,525 B1 (Moyer) 17 July 2001 (17.07.2001), c	col 3, in 5-8	6, 8, 13-18
Y	US 4,967,714 A (Inoue) 06 November 1990 (06.11.199	90), col 3, in 27-30 and in 66-67	11
Furth	er documents are listed in the continuation of Box C.		
* Specia "A" docum to be c "E" earlier	I categories of cited documents: end defining the general state of the art which is not considered of particular relevance application or patent but published on or after the international	"T" later document published after the date and not in conflict with the the principle or theory underlyin "X" document of particular relevance	e international filing date or priority application but cited to understand g the invention e; the claimed invention cannot be
filing "L" docum cited t specia	date tent which may throw doubts on priority claim(s) or which is o establish the publication date of another citation or other reason (as specified) tent reference to an oral disclosure use exhibition or other	considered novel or cannot be or slep when the document is taken "Y" document of particular relevance considered to involve an inver- combined with our or more other	considered to involve an inventive alone e; the claimed invention cannot be tive step when the document is such documents, such combination
"P" docum the pri	then published prior to the international filing date but later than original date claimed	"&" document member of the same p	in the art natent family
Date of the	actual completion of the international search per 2007 (03.12.2007)	Datc of mailing of the internationa 24 MAR 2008	l search report
Name and Mall Stop PC P.O. Box 14	mailing uddress of the ISA/US CT, Attn: ISA/US, Commissioner for Patents 50, Alexandria, Virginia 22313-1450	Authorized officer: Lee W. Y PCT Helpfresk: 571-272-4300	oung
racsimile h	סי. 571-273-3201	PCT OSP: 671-272-7774	

v

7

Form PCT/ISA/210 (second sheet) (April 2007)

# PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORING	ORITY			
To: Sam Pasternack Choate, Hall & Stewart Two International Place			РСТ	
Boston, Massachusetts 02110		WI INTERNAT	RITTEN OPINION OF THE IONAL SEARCHING AUTHORITY	
			(PCT Rule 43 <i>bis</i> .1)	
		Data of mailing		ĺ.
		(day/month/year)	24 MAR 2008	
Applicant's or agent's file reference 2006734-0003PC		FOR FURTHER A	ACTION See paragraph 2 below	
International application No.	International filing date	(day/month/year)	Priority date (day/month/year)	
International Patent Classification (IPC) of	of Warch 2007 (08.	ion and IPC	10 March 2006 (10.03.2006)	
IPC(8) - F02B 77/04 (2007.10) USPC - 123/198A				
Applicant Ethanol Boosting System	ms, LLC			
12		-		
<ol> <li>This opinion contains indications relations</li> <li>Box No. I Basis of the op</li> </ol>	iting to the following iterr	15:	Docketed	
Box No. II Priority			DUB Prinner & Ulton	
Box No. III Non-establishm	nent of opinion with regar	d to novelty, inventiv	e step and industrial applicability	ila.
Box No. IV Lack of unity o	finvention		92	MPL
Box No. V Reasoned states citations and ex	ment under Rule 43 <i>bis</i> , I (a planations supporting suc	a)(i) with regard to now	velty, inventive step or industrial applicability;	
Box No. VI Certain docume	ents cited			
Box No. VII Certain defects	in the international applie	cation		
Box No. VIII Certain observe	itions on the international	application		
2. FURTHER ACTION				
If a demand for international prelim: International Preliminary Examining other than this one to be the IPEA an opinions of this International Searchi	inary examination is mad Authority ("IPEA") excep d the chosen IPEA has no ng Authority will not be s	de, this opinion will but that this does not ap otified the Internation of considered.	be considered to be a written opinion of the uply where the applicant chooses an Authority nal Bureau under Rule 66.1 <i>bis</i> (b) that written	
If this opinion is, as provided above, on a written reply together, where approproprot (ISA/220 or before the expiration of the expiration	considered to be a written priate, with amendments,	opinion of the IPEA, before the expiration	the applicant is invited to submit to the IPEA of 3 months from the date of mailing of Form	_
For further options, see Form PCT/IS	A/220.	nong outo, mionore	RECEIVEN	
3. For further details, see notes to Form	PCT/ISA/220.		MAR 2 6 2008	N
Name and mailing address of the ISA JIC	Date of completion of th		Authorized officer	-
Mail Stop PCT, Atin: ISA/US Commissioner for Patents	03 Decomposition of th		Lee W. Young	
P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	55 December 2007	(03.12.2007)	PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774	

Form PCT/ISA/237 (cover sheet) (April 2007)

	WRITTEN OPINION OF THE	International application No.
	INTERNATIONAL SEARCHING AUTHORITY	PCT/US 07/05777
Box No. I	Basis of this opinion	
1 11/64	and to the language this epision has been established on the hads of	
	ard to the language, this opinion has been established on the basis of.	
	e international application in the language in which it was med.	which is the locuses of a
L A.	translation of the international application into	and 23.1(b)).
2. T	his opinion has been established taking into account the rectification of an this Authority under Rule 91 (Rule 43 <i>bis</i> .1(a))	obvious mistake authorized by or notified
<ol> <li>With reg establish</li> </ol>	ard to any nucleotide and/or amino acid sequence disclosed in the inter- ed on the basis of:	national application, this opinion has been
a. type	ofmaterial	
	a sequence listing	
	table(s) related to the sequence listing	
h form	t of -statis	
	on paper	
	in electronic form	
a timea	of filles/furnishing	0
	antined in the international application as filed	
	Contained in the international approaction as inco	
	filed together with the international application in electronic form	
	fumished subsequently to this Authority for the purposes of search	
4. []] [] [] []	a addition, in the case that more than one version or copy of a sequence listi led or furnished, the required statements that the information in the subseq a the application as filed or does not go beyond the application as filed, as	ing and/or table(s) relating thereto has been uent or additional copies is identical to that appropriate, were furnished.
5. Addition	al comments:	
	e	
	*	

ţ,

1

Form PCT/ISA/237 (Box No. I) (April 2007)

1

EBS-00002013 FORD Ex. 1144, page 177 IPR2020-00013

Bun Nu Y     Research at tennent under Rule 4366.1(4)(0) with regard to novelty, Investive step or Industrial applicability     diations and explanations supporting such statement     Novelty (N)     Claims     Novelty (N)     Claims     None     Investive step (IS)     Claims     None     Investive step (IS)     Claims     None     Investive step (IS)     Claims     None     Claims     None     Investive step (IS)     Claims     None     Claims     None     Investive step (IS)     Claims     None     Investive step (IS)     Claims     None     Claims     None     Claims     None     Claims     None     Investive step (IS)     Claims     None     Claims		WRITTEN OPINION OF THE		International application No.		
Bark Ne. Y         Reasoned statement under Rule 43/b.5 1(4)(1) with regard to anvelty, inventive step or industrial applicability citations and explanations supporting such statement           1.         Statement         Novelty (N)         Claims         1-18         No           Inventive step (TS)         Claims         No         No         No           Inventive step (TS)         Claims         1-18         No         No           Industrial applicability (IA)         Claims         1-18         No         No           Industrial applicability (IA)         Claims         1-18         No         No           .         Citations and explanations:         Industrial applicability (IA)         Claims         1-4.7         No           .         Citations and explanations:         Industrial applicability (IA)         Claims         1-4.7         No           .         Citations and explanations:         Industrial applicability (IA)         Claims         1-4.7         No         No           .         Citations and explanations:         Industrial applicability (IA)         Claims         1-4.7         No         Industrial applicability (IA)         Industrial applicabilit	ė.	INTERNATIONAL SEARCHING AUTHORITY		PCT/US 07/05777		
1.       Statement         Novelty (N)       Claims       1-18       YE         Claims       None       No       No         Inventive step (IS)       Claims       None       YE         Industrial applicability (IA)       Claims       1-18       No         Industrial applicability (IA)       Claims       1-18       No         2.       Claims       1-18       No       No         3.       Claims       1-18       No       No         2.       Claims       1-18       No       No         3.       Claims       1-18       No       No         2.       Claims       1-18       No       No         3.       Claims       1-34       And 12 lack an inventive step under PCT Article 33(3) as being obvious over the article anticle a	Bux No. V	Rensoned statement ur citations and explanati	ider Rule 43/ ons supporti	bis.1(a)(i) with regard to no ng such statement	velty, inventive step or industrial app	licability;
Novely (N)       Claims       1-18       YEE         Claims       None       No         Javentive step (IS)       Claims       Name       YEE         Industrial applicability (IA)       Claims       1-18       No         Industrial applicability (IA)       Claims       1-18       No         Industrial applicability (IA)       Claims       1-16       YEE         Claims       No       No       No         Industrial applicability (IA)       Claims       1-16       No         .       Claims       1-14       No       No         .       Claims       1-16       No       No         .       Claims       1-16       No       No         .       Claims       1-16       No       No         .       Claims       1-126       No       No         .       Claims       1-126       No       No         .       Claims       1-126       No       No <td< th=""><th>1. Statemen</th><th>t</th><th></th><th></th><th></th><th></th></td<>	1. Statemen	t				
Claims         None         No           Inventive step (IS)         Claims         1-18         No           Industrial applicability (IA)         Claims         No         No           Industrial applicability (IA)         Claims         Industrial applicability (IA)         No           Interview         Industrial applicability (IA)         Industrial applicability (IA)         Industrial applicability (IA)         Industrial applicability (IA)           Interview         Industrial applicability (IA)         Industrial applicability (IA)         Industrial applicability (IA)         Industrial applicability (IA)           Interview         Industrial applicability (IA)         Industrial applicability (IA)         Industrial applicabili	Novel	ty (N)	Claims	1-18		YES
Inventive step (IS)         Claims         None         YEE           Claims         1-18         No           Industrial applicability (IA)         Claims         1-18         No           Claims         None         No         No           Claims         None         No         No           Claims         None         No         No			Claims	None		NO
Claims       1-18       No         Industrial applicability (IA)       Claims       1-18       No         Claims       No       No       No         Supression       Highly Turbocharged Gasoline/Ethanol Englines Using Direct Ethanol Injection" by L. Bromberg et al. (hereinster "Chivio).         ap claim       Bromberg docides a legit management system for operation of a spark (gnitton gasoline engline in a vehicle comprising the only operation of a spark (gnitton gasoline engline in a vehicle comprising the only operation of a spark (gnitton gasoline engline in a vehicle comprising the only operation of a spark (gnitton gasoline engline in a vehicle comprising the only operation of a spark (gnitton gasoline engline in a vehicle construing and massing the operating the engline uper anothing down the engline during vehicle declaration and thing and restarting the engline uper anothing down the engline during (legit docides during the use anoger evoluting the use anoger of only operation during in the estarting the engline uper anoger start as one of the operating conditions show the spine during (legit docides during legit docides during legit docides during legit docides during legit docide stars operation.	Inven	ive sten (IS)	Claims	None		VEC
Industrial applicability (IA)       Claims       1-18       YES         Claims       Non       Non       Non         Image: Claims       Non       Non       Non         Claims       Non       Non       Non         Image: Science Scienc		(10)	Claims	1-18		NO
Claims Noa     Noa     Claims N	Inclust	riat applicability (IA)	Claima	1-18		1/200
2. Clations and explanations: laims 1, 3-4, 7 and 12 lack an inventive step under PCT Article 33(3) as being obvious over the article entitled "Calculations of Knoc uppression in Highly Turbocharged Gascilne/Ethanol Engines Using Direct Ethanol Injection" by L. Bromberg et al. (hereinefter romberg) in view of US 4,312:310 A to Chilub et al. (hereinetter "Chivilo"). s per claim 1. Bromberg discloses a fuel management system for operation of a spark ignition gesoline engine (see Section II, para (1000)); apprate source of sharnol (see Section II), para (1000); an injector for direct injection of the engine by stepping gasoline and ethanol into a cylinder of the engine (see Section II, para (1000)); Bromberg deas not disclose a control system for shutting down the engine by stepping gasoline and ethanol into a cylinder of the engine (see Section II, para (1000); Bromberg does not disclose a control system for shutting down the engine by stepping gasoline and ethanol into a cylind down the engine by stopping gasoline ding and restaining the engine upon driver downand. Chiluio discloses a control system stem as disclosed by Bromberg with the control system stepping uso in supping disclose and the engine by stem as disclosed by Bromberg with the control system stupping USD. Bromberg does not specificatly disclose direct thanol Injection during a range of engine oper atifficants o prevent engine knock. However, it would have been obvious to one of ordinary skill in the art to include ethanol Injection during engine restart and one of the objects of Brom to prevent engine knock. a per claim 4, Bromberg discloses the system wherein the engine used direct ethanol injection during engine restart to minize hydrocarbon emissions. 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 engine restart to minize hydrocarbon emissions. However, it would have	muust	narapplicability (IX)	Claims	None		NO YES
Proceeding of the second second experiment of thighness of any Direct channel injection by L. Bromberg et al. (Interementer Chaino) in second second experimenter chaino) in second second experimenter chainos introduction into the engine (see Section II, para (1003)); as pare (1003); as	2. Citations Claims 1, 3-4, 7	and explanations: and 12 lack an inventive i	step under PC	CT Article 33(3) as being obvi	ous over the article entitled "Calculations	of Knock
aims 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 o 358,180 B1 to Kuroda et al. (hereinalter 'Kuroda'). a per claim 2, Chivilo discloses a control system for shutting down the engine by stopping gasoline flow into the engine during vehicle inceleration and idling and resterting the engine upon driver demand (col 2, in 20-26 and in 36-54). Chivilo does not specifically discl- terein the control system disables the shutting down of the engine during deceleration and idling when an auxiliary power or energy quirement exceeds a selected level. Kuroda discloses wherein the control system disables the shutting down of the engine during celeration and idling when an auxiliary power or energy requirement exceeds a selected level (col 3, in 65-67 to col 4, in 1-15). It we we been obvious to one of ordinary skill in the art to modify the control system as disclosed by Chivilo with the system as aught by iroda, since both relate to the technology of shutting engines down to conserve fuel and since such would avoid having the engine as when the batteries are unable to perform Important functions such as restarting. i per claim 9, Kuroda further discloses the system further including a 12V motor to restart the engine after shutdown during deceleration d/or idle (Fig 4; col 12, in 54-56). Please See Continuation Sheet	to the engine of hutting down th river domand (ri ystem as discle iromberg is fuel is per claim 3, if onditions to pre- ngine restart to uring engine re- s to prevent eng- s oper claim 4, if ecction 11, para 1 missions. How inimize hydrood is per claim 7, if is per claim 7, if is per claim 12, hereof are used	luring vehicle deceleration e engine by stopping gas col 2, in 20-26 and in 38-5 ised by Bromberg with the conservation and an obv Bromberg further disclose: event engine knock (see S prevent engine knock. H start as one of the operati- line knock. Bromberg discloses the sy 00061). Bromberg does n ever, it would have been ever, it would have been arbon emissions since hy carbon emissions. Bromberg further discloses Bromberg further discloses as the only fuel (see Abs	a and iding ar and iding ar idine flow into i4). It would h s control system lous way to co s the system vi- ection i, para owever, it wo ing conditions stem wherein ot specifically obvious to one drocarbon em s the system vi- a the system vi- the system	Ind restarting the engine upon the engine during vehicle de lave been obvious to one of o im as taught by Chillo since onserve fuel is to shut down to wherein the engine uses direc (0003)). Bromberg does not uid have been obvious to one since engine uses direct ethan of disclose direct ethanol injec e of ordinary skill in the art to sissions can be high during re- wherein the engine is turboch wherein gasoline is not used larg states direct ethanol injec	driver demand. Chivilo discloses a cont eccleration and Idling and restarting the e ordinary skill in the art to modify the fuel r a major development in the system discl the engine during Idle or deceleration. It et also a system disclose direct ethanol inject a of ordinary skill in the art to include etha curs during restart and one of the objects not injection to minimize hydrocarbon em tion during engine restart to minimize hydrocarbon include ethanol injection during engine r astart and one of the objects of Bromberg harged or supercharged (see Section II, p and ethanol, E85, methanol, other alcohi citon could be be used to displace gasoli	rol system ngine upor manageme osed by ine operatil ion during anol injectio s of Bromb dissions (se dirocarbon estart to y is to bara (0001] ois or a ble ne.
a per claim 2, Chivilo discloses a control system for shutting down the engine by stopping gasoline flow into the engine during vehicle coloration and idling and restarting the engine upon driver demand (col 2, in 20-26 and in 36-54). Chivilo does not specifically disclose herein the control system disables the shutting down of the engine during deceleration and idling when an auxiliary power or energy quirement exceeds a selected level. Kuroda discloses wherein the control system disables the shutting down of the engine during iccleration and idling when an auxiliary power or energy requirement exceeds a selected level (col 3, in 65-67 to col 4, in 1-15). It we we 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 iroda, since both relate to the technology of shutting engines down to conserve fuel and since such would avoid having the engine a win when the batteries are unable to perform important functions such as restarting.	laims 2, 9 and .358,180 B1 lo	10 iack an Inventive step Kuroda et al. (hereinalter	under PCT Ar 'Kuroda').	ticle 33(3) as being obvious (	over Bromberg in view of Chivilo, further	In view of L
: per claim 9, Kuroda further discloses the system further including a 12V motor to restart the engine after shutdown during deceler; id/or idle (Fig 4; col 12, in 54-56). Please See Continuation Sheet	s per claim 2, C accleration and herein the cont quirement exce accleration and ave been obvio uroda, since bo own when the t	chivilo discloses a control idling and restarting the of rol system disables the sh aeds a selected level. Ku idling when an auxiliary p us to one of ordinary skill th relate to the technology atterfes are unable to per	system for sh engine upon d nutting down o roda discloses ower or energ in the art to m y of shutting e	utting down the engine by ste Iriver demand (col 2, In 20-26 of the engine during decelera is wherein the control system gy requirement exceeds a se hodify the control system as c engines down to conserve fue the fueler nucleon system as conserve fue	opping gasoline flow into the engine durit 5 and in 36-54). Chivilo does not specific tion and idling when an auxiliary power or disables the shutting down of the engine lacted level (col 3, in 65-67 to col 4, in 1- disclosed by Chivilo with the system as te al and since such would avoid heaving the	ng vehicle ally disclos r energy during
Please See Continuation Sheet			form Importar	in iunciuns such as restarting	g,	15). It wou rught by engine shu
	s per claim 9, k nd/or idie (Fig 4	uroda further discloses th ; col 12, ln 54-56).	form Importar le system furti	her including a 12V motor to	g. restart the engine after shutdown during	15). It wou aught by engine shu deceleratio
	s per claim 9, k nd/or idie (Fig 4 - Please See Ci	uroda further discloses th ; col 12, In 54-56). onlinuation Sheet	form Importar ie system furti	her including a 12V motor to	g. • restart the engine after shutdown during	15). It wou bught by engine shu deceleratio

EBS-00002014 FORD Ex. 1144, page 178 IPR2020-00013

#### 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: Box V. 2. Citations and explanations:

As per claim 10, Kuroda further discloses the system including a restart motor (Fig 4; col 12, in 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 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, in 15-21). It would have been obvious to one of ordinary skill 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, in 20-26 and in 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. Moyer discloses the system further including a valve disabler for all engine valves (col 3, in 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, in 27-30 and in 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, in 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 during 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 ---

Form PCT/ISA/237 (Supplemental Box) (April 2007)

EBS-00002015 FORD Ex. 1144, page 179 IPR2020-00013

#### 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 hydrocarbon 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, in 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. Kuroda discloses where the engine is shut down during periods of deceleration and idle (col 8, In 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, In 5-8). Kuroda further discloses where a low voltage motor is used for engine restart. Moyer discloses a means to engine cylinder deactivation through valve disabling (col 3, In 5-8). Kuroda further discloses where a low voltage motor is used for engine restart. Moyer discloses a means to engine restart (Fig 4; col 12, In 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 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 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 costs, in 3-27). Moyer discloses a means to engine restart (Fig 4; col 12, in 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 disabiling 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.

Form PCT/ISA/237 (Supplemental Box) (April 2007)

EBS-00002016 FORD Ex. 1144, page 180 IPR2020-00013
s SP (av				
PATENT COOPE	RATION TREATY DOCKOLO			
From the INTERNATIONAL SEARCHING AUTHORITY	DUBCIERS			
To: SAM PASTERNACK CHOATE, HALL & STEWART ILP TWO INTERNATIONAL PLACE ROSTON, MA 02110 DOCKSTED	NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION (PCT Rule 44.1)			
LUK 4.92.00	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	· · · · · · · · · · · · · · · · · · ·			
The applicant is hereby notified that the international search have been established and are transmitted herewith. Filing of amendments and statement under Article 19:	ch report and the written opinion of the International Searching Authority			
The applicant is entitled, if he so wishes, to amend the clui	ins 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.				
8. With regard to the protest against payment of (an) addit	tional fee(s) under Rule 40.2, the applicant is notified that:			
the protest together with the decision thereon has bee request to forward the texts of both the protest and th	an transmitted to the International Bureau together with the applicant's te decision thereon to the designated Offices			
no decision has been made yet on the protest; the app	plicant will be notified as soon as a decision is made.			
4. Reminders Shortly after the expiration of 18 months from the priority date Bureau. If the applicant wishes to avoid or postpone publicatio priority claim, must reach the International Bureau as provided In technical preparations for international publication.	, the international application will be published by the International on, a notice of withdrawal of the international application, or of the n Rules 90bis.1 and 90bis.3, respectively, before the completion of the			
The applicant may submit comments on an informal basis on International Bureau. The International Bureau will send a copy preliminary examination report has been or is to be established. before the expiration of 30 months from the priority date.	the written opinion of the International Searching Authority to the y of such comments to all designated Offices unless an international These comments would also be made available to the public but not			
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/1B/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.	Authorized officer			
Name and mining address of the ISA/US Mail Stop PCT, Atm: ISA/US Commissioner for Patents	Stephen K Cronin Unice Meath			
Alexandria, Virginia 22313-1450 Fearingila Na. (571) 272-4383				
Facsimile No. (571) 273-3201 orm PCT/ISA/220 (January 2004)	FEB 2 7 2008			

4

EBS-00002017 FORD Ex. 1144, page 181 IPR2020-00013

200

PATENT DEPARTMENT

6

\$

1

# PCT

### INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 2006734-0015	FOR FURTHER sec ACTION as well as, who	Form PCT/ISA/220 ere 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 according to Article 18. A copy is being This international search report consists I It is also accompanied	prepared by this International Searching Au transmitted to the International Bureau. of a total of <u>F</u> sheets. I by a copy of each prior art document cited i	thority and is transmitted to the applicant in this report.				
Basis of the Report     a. With regard to the language, the     the International     a translation of the	international search was carried out on the basi application in the language in which it was file as international application into	is of: d. , which is the language				
of a translation fi	imished for the purposes of international search	h (Rules 12.3(a) and 23.1(b))				
2. Certain claims were found	unscarchable (See Box No. II)					
<ul> <li>Unity of invention is lackin</li> <li>With regard to the title,</li> <li>the text is approved as subm</li> <li>the text has been established</li> </ul>	g (See Box No. III) itted by the applicant. by this Authority to read as follows:					
5. With regard to the abstract, the text is approved as subm	itted by the applicant.					
the text has been established may, within one month from	, according to Rule 38.2(b), by this Authority a the date of mailing of this international search	as it appears in Box No. IV. The applicant report, submit comments to this Authority.				
<ul> <li>6. With regard to the drawings,</li> <li>a. the figure of the drawings to be as suggested by the</li> <li>as selected by this A</li> <li>us selected by this A</li> </ul>	published with the abstract is Figure No. 1 applicant. Authority, because the applicant failed to sugge Authority, because this figure better characteriz	est a figure. es the invention.				
b none of the figures is to be p	ublished with the abstract.					

Form PCT/ISA/210 (first sheet) (April 2005)

EBS-00002018 FORD Ex. 1144, page 182 IPR2020-00013

×9.,

			International and	lication No.
	INTERNATIONAL SEARCH REPOR	RT	PCT/I IS07/7/22	7
A. CLAS	SSIFICATION OF SUBJECT MATTER		101/050//1422	.,
IPC:	F02D 41/30( 2006.01);F02B 1/08( 2006.01)			
LICDO.	1000 4 401 440 505			
According to	Iterational Patent Classification (IPC) or to both nat	ional classific	ation and IPC	
				5
B. FIEL	DS SEARCHED			
Minimum do U.S. : 12	cumentation searched (classification system followed b 23/1A,300,304,431,447,478,575,577,198C,198A	y classificatio	n symbols)	
Documentati	on searched other than minimum documentation to the	exient that su	ch documents are included	in the fields searched
Electronic da	the base consulted during the international search (name	of data base	and, where practicable, sea	rch terms used)
Please See C	ontinuation Sheet			
C. DOC	UMENTS CONSIDERED TO BE RELEVANT			
Category *	Citation of document, with indication, where ap	opropriate, of	the relevant passages	Relevant to claim No.
X	US 2007/0119416 AI (Boyarski) 31 May 2007 (31.0 paragraphs [0066], [0107]-[0117], [0284]-[0318], cla	5.2007), figu alms 3, 5, 11,	res 16, 17, 23, 28, 37, 44, 15.	1-23, 26, 42-48, 56
$\mathbf{P}_{i}, \mathbf{Y}$				24,25,27-41,49-55
х	US 2002/01393321 A1 (Weissman et al.) 3 October 2	2002 (03.10.2	002), figure 2, paragraphs	24-25, 27-56
Y	[0022]-[0046].			1-23, 26
	· · · · · · · · · · · · · · · · · · ·			
Furthe	r documents are listed in the continuation of Box C.	s	ee patent family annex.	
1	Special eategories of cited documents:	-1., 1	ater document published after the t late and not in conflict with the app minerale or theory underlying the u	nternational ming date or priority distance but sited to understand the
particula	ir relevance	"X" (	locument of particular relevance; 1	ne claimed invention connot be
"E" carlier a	pplication or patent published on or after the international filling date		considered novel or cannot be cons when the document is taken alone	idered to involve an inventive step
"L" documen establish specified	nt which muy throw doubts on priority claim(s) or which is cited to the publication date of another clistion or othor special reason (as s)	"Y" (	locument of particular relevance; t considered to involve an inventive combined with one or more other s	he olaimed invention cannot be step when the document is uch documents, such combination
"O" docume	nt referring to an aral disclosure, use, exhibition or other means		eing abvious to a person skilled in	the art
"P" docume priority	nt published prior to the international filling date but later than the date claimed	"&" (	locument member of the same path	ut iumily
Date of the a	actual completion of the international search	Date of ma	illing of the international set $FB 2008$	arch report
Name and m	nailing address of the ISA/US	Authorized	officer	act in D.
M	ail Stop PCT, Attn: ISA/US	Stephen K	Cronin Man	it f lac
P ( Al-	D Box 1450 exandria, Virginia 22313-1450 o (571) 273-3201	Telephone	No. (571) 272-4383	fo
DET PCT/IS	A/210 (second sheet) (April 2005)			

8 . 8

EBS-00002019 FORD Ex. 1144, page 183 IPR2020-00013

C

From the	TIONAL SEARC	HINGAUTH	ORITY		
To: SAM PAS CHOATE TWO INT BOSTON	To: SAM PASTERNACK CHOATE, HALL & STEWART LLP TWO INTERNATIONAL PLACE BOSTON, MA 02110		WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHOR ITY		
					(PCT Rule 43bis.1)
_				Date of mailing (day/month/year)	25 FEB 2008
Applicant	's or agent's file r	eference		FOR FURTHER	ACTION
2006734-0	0015			1	See paragraph 2 below
Internation	nal application No	).	International filing date	(day/month/year)	Priority date (day/month/year)
PCT/US0	1/74227	(10.0)	24 July 2007 (24.07.200	7)	24 July 2006 (24.07.2006)
Internation	al Patent Classifi	cation (IPC) o	or both national classificat	ion and IPC	
USPC:	F <b>02D 41/30(</b> 2000 123/1A,431,447,5	5.01);F <b>02B 1</b> / 75	08(2006.01)		
Applicant					
ETHANO	L BOOSTING SY	STEMS, LL	<u>c</u>	2	
1 This c	pinion contains it	ndications rela	ting to the following item	s:	
$\square$	Box No. I	Basis of the	opinion		
	Box No. II	ox 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 <i>bls</i> .1(a)(i) with regard to novelty, inventive step or industrial applicability: citations and explanations supporting such statement			o novelty, inventive step or industrial tatement
	Box No. VI	Certain documents cited			
	Box No. VII	Certain defects in the international application			
	Βοχ Νο. VIΠ	Certain obse	ervations on the internatio	nel application	
2. FUR	THER ACTIO	N			
If a de Intern Autho that w	emand for interna ational Prelimina rity other than th ritten opinions of	ational prelim ry Examining is one to be t this Internation	inary examination is may g Authority ("IPEA") ex he IPEA and the chosen onal Searching Authority	de, this opinion will accept that this does IPEA has notified the will not be so consid	be considered to be a written opinion of the not apply where the applicant chooses an he International Bureau under Rule 66.1 <i>bls(b</i> ) cred.
If this IPEA of For	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 fu	For further options, see Form PCT/ISA/220.				
3. For fu	rther details, sec r	totes to Form	PCT/ISA/220.		
Name and	mailing address of	of the ISA/119	Date of comple	tion of this opinion	Authorized officer
N C	fall Stop PCT, Attn	: ISA/US	18 February 20	08 (18.02.2008)	Stephen K Cronin hun Office k
P.O. Box 1450 Alexandria, Virginia 22313-1450				Anna	
Facsimile 1	No. (571) 273-320	)1			Lejephone No. (571) 272-4383 JCA
Form PCT/L	Form PCT/ISA/237 (cover sheet) (April 2007)				

EBS-00002020 FORD Ex. 1144, page 184 IPR2020-00013

	<b>(</b>
WRITTEN OPINION OF THE	International application No.
INTERNATIONAL SEARCHING AUTHORITY	PCT/US07/74227
ox No. I Basis of this opinion	
With regard to the language, this opinion has been established on the basis	s of:
the international application in the language in which it was i	filed
international scarch (Rules 12.3(a) and 23.1(b)).	e language of a translation furnished for the purposes of
This opinion has been established taking into account the rectificat	tion of an obvious mistake authorized by or notified to this
With regard to any nucleotide and/or amino acid sequence disclosed	d in the international application, this opinion has been
a. type of material	
	(#)
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 s	search.
In addition, in the case that more than one version or copy of a sequence or furnished, the required statements that the information in the sapplication as filed or does not go beyond the application as filed, a	uence listing and/or table(s) relating thereto has been filed subsequent or additional copies is identical to that in the as appropriate, were furnished.
Additional comments:	

. . . T

EBS-00002021 FORD Ex. 1144, page 185 IPR2020-00013

WRITTEN OPINION O INTERNATIONAL SEARCHIN	F THE 3 AUTHORITY	International application N PCT/US07/74227	0.
Box No. V Reasoned statement under Rule applicability; citations and expl	43 <i>bis</i> .1(a)(i) with a anations supporting	regard to novelty, inventive step y such statement	or industrial
1. Statement			
Novelty (N)	Claims <u>1-56</u>		YE
	Claims NON	<u> </u>	NO
Inventive step (IS)	Claims 1-56		YE
	Claims <u>NON</u>	E	NO
Industrial applicability (IA)	Claims 1-56		YE
	Claims NON	Е	NO
. Citations and explanations:		3	
ר Claims 1-56 meet the criteria set out in PCT Article חירפולוסה.	33(2)-(3), because the	prior art does not teach or fairly sugg	est the claimed
Claim I-56 meet the criteria set out in PCT Article 3	i3(4), and thus have ind	iustrial applicability because the subje	et matter claimed car
e made or used in industry.	J(4), and ann. na. 2	unulu approacting seemes are seen.	AL INITIAL CLOSING -
			545
	< #C	E.	

Form PCT/ISA/237 (Box No. V) (April 2007)

11.72

ĩ

SPIJ	DL	15	66
SKS			

From the INTERNATIONAL SEARCHING AUTHORITY				
To: SAM PASTERNACK Choate, Hall & Stewart LLP Two International Place Boston, Massachusetts 02110 Amend Clair Cite Profine S	PCT NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL			
Action: <u>Resp to writh</u> . Opin.	SEARCHING AUTHORITY, OR THE DECLARATION			
Final Due Date 1213/08-113/09-51	(PCT Rule 44.1)			
Docket Administration NHDate: 101	Content of mailing			
Applicant's of agent's file reference				
2006734-0021	FOR FURTHERACTION See paragraphs 1 and 4 below			
International application No. PCT/US2008/069171	International filing dute (daymonth year) 03 July 2008			
Applicant ETHANOL BOOSTING SYSTEMS LLC				
<ol> <li>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.</li> <li>Filing of umendments and statement under Article 19: The applicant is cuited, 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.</li> <li>Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 740 14 35</li> <li>For more detailed instructions, see the notes on the accompanying sheet.</li> <li>The applicant is hereby notified that no international search report will be established and that the declaration unde Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.</li> <li>With regard to the protest against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:         <ul> <li>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.</li> <li>no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.</li> </ul> </li> </ol>				
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 90bis.1 and 90bis.3, respectively, before the completion of the technical preparations for international publication. The applicant may submit comments on an Informal busis 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 due. Within 19 months from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be fold if the applicant wishes to postpone the enury 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 firm entry into the national phase before these designated Offices.				
months. See the Annex to Form PCT/IB/301 and, for details about the Guide, Volume II, National Chapters and the WIPO Internet	e applicable time limits, Office by Office, see the PCT Applicant's site.			
Name and mailing address of the ISA/US     Authorized officer:       Mail Stop PCT, Alth: ISA/US     Blaine R. Copenheever       P.O. Box 1450, Alexandria, Virginia 22313-1450     Telephone No. 571-272-7774				

Form PCT/ISA/220 (January 2004)

\*

÷.

(See notes on accompanying sheet)

EBS-00002023 FORD Ex. 1144, page 187 IPR2020-00013

· · ·

# PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 2006734-0021	FOR FURTHER ACTION DS well	see Form PCT/ISA/220 as, where applicable, item 5 below.					
International application No.	International filing date (day/month/year) (Earliest) Priority Date (day/month/year)						
PCT/US2008/069171	03 July 2008	10 July 2007					
Applicant ETHANOL BOOSTING SYSTEMS LLC	Applicant ETHANOL BOOSTING SYSTEMS LLC						
This international sparsh sparsh bas has							
according to Article 18. A copy is being	a prepared by this international Searching A g transmitted to the international Burcau.	Authority and is transmitted to the applicant					
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	e international search was carried out on the b	asis of:					
the international app	lication in the language in which it was filed						
a translation of the in of a translation furni	nternational application into shed for the purposes of international search	(Rules 12.3(a) and 23.1(b))					
b. With regard to any nucleo	tide and/or amino acid sequence disclosed in	the international application, see Box No. $I_{\rm s}$					
2 🔀 Certain claims were foun	d unscarchable (see Box No. 11)						
3. Unity of invention is lack	ing (see Box No. (11)						
4. With regard to the title,							
the text is approved as sub	mitted by the applicant						
the text has been established	ed by this Authority to read as follows:						
1							
5 With regard to the abstract							
the text is approved as sub	mitted by the applicant						
the text has been established, according to Rule 38.2(b), by this Authority as it annears 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,	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 a	pplicant						
as selected by this A	is Authority, because the applicant failed to suggest a figure						
as selected by this A	uthority, because this figure better characteriz	zes the invention					
b none of the figures is to be	be published with the abstract						

Form PCT/ISA/210 (first sheet) (April 2005)

эï

d.

EBS-00002024 FORD Ex. 1144, page 188 IPR2020-00013

1

INTERNATIONAL SEARCH REPORT	International application No.				
	PCT/US200B/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 unde	er Article 17(2)(a) for the following reasons:				
Claims Nos.: because they relate to subject matter not required to be searched by this Author	rity, namely:				
<ol> <li>Claims Nos.: because they relate to parts of the international application that do not comply extent that no meaningful international search can be carried out, specifically:</li> </ol>	v with the prescribed requirements to such an				
3. Claims Nos.: 15-17, 31-33 because they are dependent claims and are not drafted in accordance with the s	second and third sentences of Rule 6.4(a).				
Box No. III Observations where unity of invention is lacking (Continuation of ite	m 3 of first sheet)				
This international Searching Authority found multiple inventions in this international ap	plication, as follows:				
	141 1				
1. As all required additional search fees were timely paid by the applicant, this in claims.	ternational scarch report covers all searchable				
2. As all searchable claims could be searched without effort justifying additional additional fees	fees, this Authority did not invite payment of				
3. As only some of the required additional search fees were timely paid by the ap only those claims for which fees were paid, specifically claims Nos.:	plicant, this international search report covers				
4. No required additional search fees were timely paid by the applicant. Con- restricted to the invention first mentioned in the claims; it is covered by claim	isequently, this international search report is is Nos.:				
Remark on Protest The additional search fees were accompanied by the payment of a protest fee.	applicant's protest and, where applicable, the				
The additional search fees were accompanied by the fee was not paid within the time limit specified in L     No protest accompanied the payment of additional	e applicual's protest but the applicable protest he invitation. search fees.				

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2005)

## INTERNATIONAL SEARCH REPORT

International application No. PCT/US2008/069171

A. CLA IPC(8) - USPC - According	ASSIFICATION OF SUBJECT MATTER F02B 77/04 (2008.04) 123/198A to International Patent Classification (IPC) or to both 1	national classification a	nd IPC	
B, FIEI	LDS SEARCHED			
Minimum d IPC(8) - F0: USPC - 123	documentation searched (classification system followed by 28 77/04 (2008.04) 3/198A, 406.29, 435	classifica(ion symbols)		
Documenta	tion searched other than minimum documentation to the e	ktent that such document	s are included in the	Jields searched
Electronic d MicroPatoni	late base consulted during the international search (name o t, DialogPro, IP.com	of data base and, where p	racticable, search te	ศทร used)
C. DOCU	MENTS CONSIDERED TO BE RELEVANT			
Category*	Citation of document, with indication, where a	ppropriate, of the releva	nt passages	Relevant to claim No
Y	US 7,225,787 B2 (BROMBERG et al) 05 June 2007 (0	5.06.2007) enlire docur	nent	1-14, 18-30, 34-35
Y	US 2006/0102145 A1 (COHN et al) 18 May 2006 (18.0	05.2006) enlire documer	nt	1-14, 18-30, 34-35
Y	US 6,561,157 B2 (ZUR LOYE et al) 13 May 2003 (13	05,2003) entire docume	nt	6, 23, 35
A	US 3,557,763 A (PROBST) 26 January 1971 (26.01.1	971) entire document		1-35
A	US 4,055,087 A (BOYCE) 01 November 1977 (01.11.1977) entire document 1-35			1-35
A	US 4,230,072 A (NOGUCHI et al) 28 October 1980 (28.10,1980) entire document 1-35			1-35
A	US 4,504,201 A (PHILLIPS et al) 10 June 1986 (10.06.1986) entire document 1-35			1-35
A	US 5,179,923 A (TSURUTANI et al) 19 January 1993 (19.01.1993) entira document 1-35			1-35
A	US 7,156,070 B2 (STROM et al) 02 January 2007 (02.01.2007) entire document			1-36
А	US 2007/0119421 A1 (LEWIS et al) 31 May 2007 (31.	05.2007) entire docume	nt	1-35
A	US 2007/0125321 A1 (RITTER) 07 June 2007 (07.06.2007) entire document 1-35			1-35
Furthe	er documents are listed in the continuation of Box C.	Π	· · · · · ·	
Special     A'' docume	I categories of cited documents: on defining the seneral state of the art which is not considered	"1" later document put	blished after the intern affict with the applic	national filing date or priority
to be of "E" carliers filing d "L" docume	f particular relevance application or patent but published on or after the international late on which may throw doubts on priority claim(s) or which is	the principle or th "X" document of parti considered novel step when the doc	eory underlying the i cular relevance; the or cannot be conside ument is taken alone	nvention claimed invention cannot be ared to involve an inventive
cited to special 'O'' documo means	<ul> <li>establish the publication date of another citation or other reason (as specified)</li> <li>ent referring to an oral disclosure, use, exhibition or other</li> </ul>	"Y" document of parti considered to ins combined with on being obvious to a	cular relevance; the colve an inventive s roi more other such d person skilled in the	claimed invention cannot be tep when the document of locuments, such combination int
the priority date claimed				
Date of the i 25 Septemb	actual completion of the international search per 2008	OBOCT 2	international searc	ch report
Name and mailing address of the ISA/US     Authorized officer:       Vall Stop PCT, Attn: ISA/US, Commissioner for Patents     Blaine R. Copenheaver       P.O. Box 1450, Alexandria, Virginia 22313-1450     PCT Holpdusk: 571-272-4300       Facsimile No.     571-273-3201			NA9L	
and an and the set		and the second designed as a second se		

Form PCT/ISA/210 (second sheet) (April 2005)

From the NTERNATIONAL SEARCHING AUTHO	RITY			
To: SAM PASTERNACK Choate, Hall & Slewart LLP Two International Place Boston, Massachusetts 02110		WR INTERNATI	PCT JTTEN OPINION OF THE ONAL SEARCHING AUTHORITY	
			(PCT Rule 43bis.1)	
		Date of mailing (day/month/year)	9 OCT 2008	
Applicant's or agent's file reference 2006734-0021		FOR FURTHER A	CTION See paragraph 2 below	
International application No. PCT/US2008/069171	International filing date 03 July 2008	(day. month year)	Priority date (day month year) 10 July 2007	
International Patent Classification (IPC) of IPC(8) - F02B 77/04 (2008.04) USPC - 123/198A	r both national classifica	tion and IPC		
Applicant ETHANOL BOOSTING S	YSTEMS LLC			
1. This opinion contains indications relating to the following items.         Box No. I       Basis of the opinion         Box No. II       Priority         Sox 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. IV       Lack of unity of invention         Box No. V       Reasoned statement under Rule 43 <i>bis</i> .1(a)(i) with regard to novelty, inventive step or industrial applicability citations and explanations supporting such statement         Box No. VI       Certain documents oited         Box No. VIII       Certain defects in the international application         Box No. VIII       Certain observations on the international application         If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Bureau under Rule 66.1 <i>bis</i> (b) that writte opinions of this International Sacching Authority ("IPEA") except that this does not apply where the applicant chooses an Authorit other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1 <i>bis</i> (b) that writte opinion is, as provided above, considered to be a voriteu opinion of the IPEA, the applicant is invited to submit to the IPE a written opitos of section 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:           Mall Stop PCT, Alth: ISA/US         Date of completion of this opinion         Blaine Copenheaver           Commissioner for Palenta         25 September 2008         PCT Helpdesk: 571-272-3300           Port State         Dest of Completion of this opinion         PCT Helpdesk: 571-272-3400				

Facsinile No. 571-273-3201 Form PCT/ISA/237 (cover sheet) (April 2007)

•

	WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORIT	Y	International application No. PCT/US2008/069171
Bo	No. 1 Basis of this opinion		
1.	With regard to the language, this opinion has been established the international application in the language in which i a translation of the international application into translation furnished for the purposes of international sectors.	on the basis of: twas filed. carch (Rules 12.3(a)	which is the language of a ) and 23.1(b)).
2.	This opinion has been established taking into account the to this Authority under Rule 91 (Rule 13 <i>bis</i> .1(a))	e rectification of an	obvious mistake authorized by or notified
3.	With regard to any nucleotide and/or amino acid sequence of established on the basis of: a. type of material a sequence listing table(s) related to the sequence listing	lisclosed in the inter	national application, this opinion has been
	in electronic form		
	<ul> <li>c. time of filing/furnishing</li> <li>contained in the international application as filed</li> <li>filed together with the international application in e</li> <li>furnished subsequently to this Authority for the pure</li> </ul>	lectronic form poses of search	е.
4.	In addition, in the case that more than one version or co filed or furnished, the required statements that the infor in the application as filed or does not go beyond the ap	py of a sequence list mation in the subsey plication as filed, as	ing and/or table(s) relating thereto has been uent or additional copies is identical to that appropriate, were furnished.
5.	Additional comments:		

Form PCT/ISA/237 (Box No. I) (April 2007)

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 sat	id claims Nos. <u>15-17, 31-33</u>							
are so unclear that no meaning ful opinion could be formed (specify):	and third septences of Rule 6 4(a)							
Claims 15-17, 31-33 are multiple dependent claims not draited in accordance with the set								
	8							
	are so insdeminity supported							
by the description that no meaningful opinion could be formed (specify):								
	2 24 22							
no international search report has been established for said claims Nos.	//, 31+33							
a meaningful opinion could not be formed without the sequence listing; the applicant did not, within the prescribed time lin								
furnish a sequence listing on paper complying with the standard provided for in Annex C of the Administr Instructions, and such listing was not available to the International Searching Authority in a form and manner accept								
to it. furnish a sequence listing in electronic form complying with the standard provided for in Annex C of the Admir Instructions, and such listing was not available to the International Searching Authority in a form and manner ac								
to it. pay the required late furnishing fee for the furnishing of a sequen Rule 13 <i>ter</i> -1(a) or (b).	nce listing in response to an invitation under							
n meaningful opinion could not be formed without the tubles related to the sequence listings; the applicant prescribed time limit, furnish such tables in electronic form complying with the technical requirement Annex C-bis of the Administrative Instructions, and such tables were not available to the International Sear 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 technical requirements provided for in Annex C-bis of the Administrative Instructions.								
See Supplemental Box for further details.								

Form PCT/ISA/237 (Box No. III) (April 2007)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY			International application No. PCT/US2008/069171					
Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement								
1. Statement								
Novelty (N)	Claims	1-14, 18-30, 34-35		YES				
	Claims	Коле		NO				
Inventive step (IS)	Claims	None		VES				
	Claims	1-14, 18-30, 34-35		NO				
industrial applicability (IA)	Claims	1-14, 18-30, 34-35		NEG				
	Claims	None		NO				
2. Citations and explanations:								
Claims 1-5, 7-14, 18-22, 24-30, and 34 le	ck an Inventiv	e step under PCT Article 33(3) as b	eing obvious over Bromberg et al. In	view of				
engine (18): a fuel management control e provided in an amount needed to prevent lines 45-55). Bromberg et al. do not show needed to prevent knock as torque increa a fast burn. Colin et al. show a fuel mana provided in an amount needed to prevent was made to a person having ordinary ski Bromberg et al. in order to provide improv Regarding claim 2, Bromberg et al. and C burn occurs in 16-20 crank angle degrees (burn) occurs in a small crank angle range Regarding claim 3, Bromberg et al. and C lines 45-55) in the engine is provided by c Regarding claim 4, Bromberg et al. and C lines 45-55) in the engine is provided by c	yatem (Col. 1, knock (Fig. 3 controlling inj ses; and a m gement control knock as torre- al engine per ohn et al. disc in ti so obvious a including the ohn et al. disc ohn et al. disc ohn et al. disc ohn et al. disc creased term rk (Col. 4, line	Ines 45-50) for controlling injection ) as other conditions require; and a i jection of the second fuel into the cy earns for providing fast burn. It is doo of system (14) for controlling injectio use increases (paragraph 32). It wou employ the structures and processe formance. close that as applied above. Brombe from Bromberg et al. (Figs. 2A-2B) at claimed. plose that as applied above. Brombe (Col. 10, linos 15-20). close that as applied above. Brombe perature (Col. 4, lines 1-10) in the ui as 30-45).	of the second fuel into the cylinder i means for providing fast flame speed inder so that it is provided in an amp and obvious that a fast flame speed in of a second fuel into a cylinder so did have been obvious at the time the s as laught by Cohn et al. In the dev and a second fuel into a cylinder so rig et al. do not show where the 10% that a significant portion of the energy or g et al. show where the fast burn (C rig et al. show where the fast burn (C aburned zone of air/fuel mixture zone	so that it is d (Col. 10, ount d produces that it is e invention vice of a - 90% gy fraction Col. 10, Col. 10, c that burns				
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 siles 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 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 Co njection of the second fuel is adjusted to n	ohn et al. disc ninimize the e	lose that as applied above. Brombe Ithanol consumption (Col. 6, lines 46	rg et al. show where the time of the o 3-52, Col. 10, lines 25-35).	direci				
tegarding claim 9, Bromberg et al. and Co reated at or near the intake port. Cohn et lean obvious at the time the invention was aught by Cohn et al. In the device of Brom	ohn et al. disc al. show whe made to a p berg et al, in	lose that as applied above. Bromber re turbulence is created at or near a erson having ordinary skill in the art order to provide improved engine pr	rg et al. do not show where turbulen in Inteke port (paragraph 28). It woul to employ the structures and proces arformance.	ce is Id have isos as				
Regarding claim 10, Bromberg et al. and C y means of spark retard relative to what it	ohn et al. dis would be if fa	close that as applied above, Bromb ast burn ware not employed (Col. 8,	erg et al. show where combustion is lines 20-25).	relarded				
togarding claim 11, Bromberg et al. and Cohn et al. disclose that as spulled above. Bromberg et al. do not show where combustion, as neasured 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)

Form PCT/ISA/237 (Box No. V) (April 2007)

EBS-00002030 FORD Ex. 1144, page 194 IPR2020-00013

#### WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

## 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 epplied 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 (ue). Cohn et al. show where e 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 (ue) (Fig. 5, paragraphs 14 and 35). It would have been obvious at the time the levention was made to a person builton gain and the combination of efficiency data the time the levention was made to a person builton gain and the combination of the second fluid (ue). Invention was made to a person having ordinary skill in the art to employ the structures and processes as laught by Cohn et al. In the device of Bromberg et al. In order to provide improved engine performance. Regerding claim 18, Bromberg et al. disclose a fuel management system for a spark ignition gasoline engine (Abstract) comprisino; a gasoline engine (18) of compression rallo between 13 end 14 (Col. 7, lines 55-60); a source of a second liquid rule (Fig. 4a); a means for introducing gasoline (Fig. 4b) into the cylinders of the engine (18); injectors for direct injection of the second liquid rule (Col. 11, lines 23-50) into the cylinder of the engine (18); a fuel management control system (Col. 1, lines 45-50) for controlling justion 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, Brombarg at al. and Cohn at al. disclose that as applied above. Brombarg at 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, Brombarg et al. and Cohn et al. disclose that as applied above. Brombarg et al. do not show where the spray of the second fuel is almed toward the end gas on the exhaust valve side of the cylinder. Cohn et al. show where spray of the second fuel is almed toward an and gas on the exhaust valve side of the cylinder (peragraph 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 at al. and Cohn at al. disclose that as applied above. Brombarg at 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) Form PCT/ISA/237 (Supplemental Box) (April 2007)

EBS-00002031 FORD Ex. 1144, page 195 IPR2020-00013

12

## WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

#### 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 rotard 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 elcohol/gasoline ratio needed to prevent knock uses fast burn. Bromberg et al. do not show where the elcohol/gasoline ratio needed to prevent knock uses fast burn. Bromberg et al. do not show where the elcohol/gasoline ratio needed to prevent knock using fast flame speed. It is deemed obvious that a fast flame speed (Bromberg - Col. 10, lines 45-55) produces a fast burn. Conn et al show where an elcohol/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 parformance.

Claims 6, 23, 35 tack an inventive stop 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 (82) is located in a center of a cylinder (Fig. 1). It would have been obvious at the time the invention was made to a parson 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...

Form PCT/ISA/237 (Supplemental Box) (April 2007)

### 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:

- [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."
- [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."
- [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."

[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.

Notes to Form PCT/ISA/220 (second sheet) (Ootober 2005)

## ATTORNEY DOCKET NO.: 11381.122998 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.



EBS-00002038 FORD Ex. 1144, page 198 IPR2020-00013

Docket No.: 11381.122998

Application No.: 15/463,425 Date: 03-20-2017

## 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.

. A second s

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 lorque 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 forque range.

15. (Original) The foel 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.

EBS-00002041 FORD Ex. 1144, page 201 IPR2020-00013

### Application No.: 15/463,425 Date: 03-20-2017

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.

Application No.: 15/463.425 Date: 03-20-2017

Docke: No. 11381-122998

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.

EBS-00002043 FORD Ex. 1144, page 203 IPR2020-00013 Application No.: 15/463.425 Date: 03-20-2017

## <u>Remarks</u>

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.

Application No.: 15/463,425 Date: 03-20-2017

Excket No.: 11381.122998

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, potende Sam

Sam (Bo) Pasternack Registration Number: 29576 Massachusetts Institute of Technology One Cambridge Center Room NE18-501 Cambridge, MA 02142 617.258.7171

> EBS-00002045 FORD Ex. 1144, page 205 IPR2020-00013