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*[Continued on next page]*

(54) Title: MIXING BLOCK

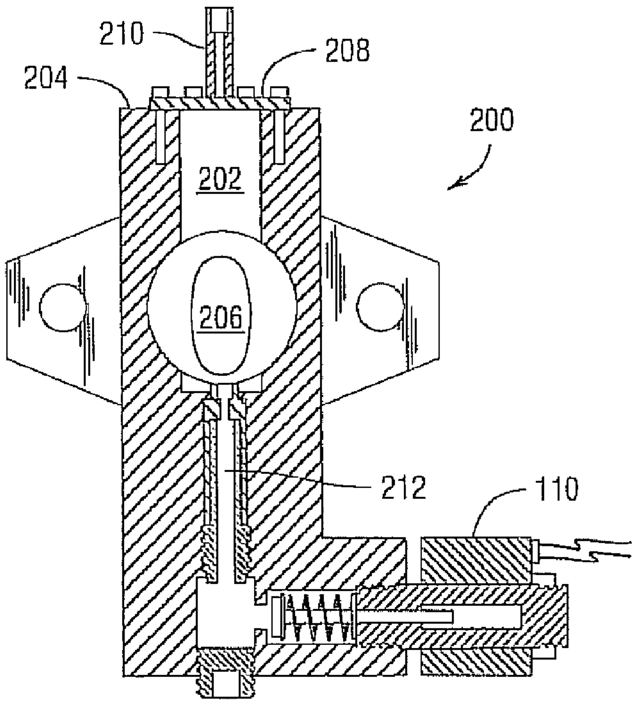


*Fig.2*

**(57) Abstract**: A mixing block (100) to supply a throttle-able hydrogen and air mixture to an internal combustion engine (107) includes a bore (106) through the mixing block between an air intake side (102) and an engine intake side (104). A slider chamber (202) is disposed orthogonal to and intersecting the bore, where the slider chamber houses a movable slider (330) biased to at least partially block the bore but throttle-able to overcome the bias and reduce blockage of the bore. A jet chamber (212) is disposed parallel to and intersecting the slider chamber (202) and extending away from the slider chamber- a-distance sufficient to accommodate a flow controller (340), where the flow controller (340) is connected to the slider on one side such that the flow controller (340) moves within the jet chamber as the slider (330) moves in the slider chamber (202).

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# Mixing Block

[0001] This application claims the benefit of U.S. Provisional Serial No. 61/470,902 filed April 1, 2011 and U.S. Serial No. 13/236,263 filed September 19, 2011.

[0002] There is a growing need in the internal combustion arts to improve engine longevity, reduce emissions and lessen dependence on fuels or raw materials from less stable trading partners. Modifications to currently available internal combustion engines are detailed below to accomplish some or all of these.

[0003] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate various example systems, methods, and so on that illustrates various example embodiments of aspects of the invention. It will be appreciated that the illustrated element boundaries (e.g., boxes, groups of boxes, or other shapes) in the figures represent one example of the boundaries. One of ordinary skill in the art will appreciate that one element may be designed as multiple elements or that multiple elements may be designed as one element. An element shown as an internal component of another element may be implemented as an external component and vice versa. Furthermore, elements in the drawings may not be to scale, emphasis instead being placed upon clearly illustrating the principles of the present disclosure.

BRIEF DESCRIPTION OF DRAWINGS

[0004] Figure 1 is a perspective view of an exemplary mixing block.

[0005] Figure 2 is a cross-sectional view of an exemplary mixing block.

[0006] Figure 3 is an exploded view of an embodiment of a slider assembly.

[0007] Figure 4 is bottom plan view taken along lines IV-IV of Figure 3.

[0008] Figure 5 is top plan view taken along lines V-V of Figure 3.

[0009] Figure 6 is top plan view of an exemplary mixing block.

[0010] Figure 7 is a view of an internal combustion engine system.

[0011] Figure 8 is a chart of cubic feet per hour hydrogen use at exemplary RPM's on a sample internal combustion engine.

DETAILED DESCRIPTION

[0012] With reference to Figure 1, an exemplary hydrogen and air mixing block **100** is shown. The mixing block **100** may be machined, cast, injection molded or otherwise formed to comprise an air intake side **102** which may be configured for attachment with an air-filter (not shown) to reduce particle or other contaminant entry into the mixing block. The mixing block **100** may also comprise an engine intake side **104** configured for connection with a fuel/air intake of an internal combustion engine (not shown). A bore **106** is formed through the mixing block **100** between the air intake side **102** and the engine intake side **104**. Mixing block **100** additionally includes a gas inlet **108** for connection with a source of pressurized hydrogen gas. As will be more completely discussed below, the mixing block **100** may also include a hydrogen gas interrupter, in other words, a fuel shut off shown in Figure 1 as an electrically controlled solenoid **110**.

[0013] With reference to Figure 2, a cross-sectional view of an exemplary mixing block **200** is shown. Formed within mixing block **200** is a slider chamber **202** shaped to accommodate a slider assembly (not shown) more completely described below. Slider chamber **202** extends from a first, top side **204** of the mixing block and continues partially through the mixing block body to intersect bore **206** that extends between the air intake side and the engine intake side. Connected to the top side **204** of the mixing block is a slider cap **208**. Slider cap **208** retains interior elements more completely discussed below and permits passage of a throttle cable through stay **210** threaded into slider cap **208**. Also formed within mixing block **200** is a jet chamber **212** shaped to accommodate a gas flow-control device (not shown) such as a shaped needle more completely described below. Jet chamber **212** connects the slider chamber **202** and a source of pressurized hydrogen gas and permits fluid communication therebetween.

[0014] With reference now to Figure 3, a slider assembly **300** is shown. In the illustrated embodiment, the slider assembly includes a biasing mechanism **310** such as a spring, a retainer **320**, a slider **330**, and a flow controller **340** such as a shaped needle. When installed in the mixing block, a first side **342** of biasing mechanism **310** is mechanically retained by a slider cap connected to the mixing block. Retainer **320** is disposed on a second side **344** of the biasing mechanism opposite the first side **342**. In the illustrated embodiment, retainer **320** includes a circumferential lip **346** to engage biasing mechanism at the second side **344**. Retainer **320** is further closely fitted into a retaining cavity **348** formed in slider **330**. In one embodiment, retainer **320** includes a lug **352** extending away from retainer and shaped for close fitting into a complementary receptacle (not shown) in the slider **330**. Flow controller **340** passes through the slider **330** and is connected to the retainer **320** at a flow controller connection **354**. Retainer **320** and flow controller **340** may be integrally made or connected by a clip, threads, and the like. The bias achieved causes the slider **330** to at least partially interrupt the bore between the air intake side and the engine intake side of the bore, reducing or preventing air from passing to the engine while also seating flow controller **340** in the jet chamber, reducing or preventing hydrogen from passing to the engine. In other embodiments, the slider **330** and complementary shaped slider chamber **202** and/or the bore **106** may be cylindrical as shown, rectangular, conical or other shapes and combinations of shapes capable of providing the desired function.

**[0015]** As best appreciated by reference to Figure 4, retainer **320** includes an interruption **410** extending partially radially inward and throughout the retainer body to permit a throttle cable to pass through the retainer. Retainer **320** also includes: lug **352** to engage the slider and retain the throttle cable; and a flow controller connection **354**.

**[0016]** As best appreciated by reference to Figure 5, slider **330** includes a throttle cable retainer **510**. In the illustrated embodiment, throttle cable retainer **510** comprises a key-hole shape to accept a cable-keeper end of a throttle cable. During installation, the cable end is inserted through the larger diameter side **520** and slid to the smaller side **530** to retain the cable end. Once positioned, the lug **352** on retainer **320** is fit into the larger diameter side **520** holding the cable in the slider.

**[0017]** Referring now to Figure 6, mixing block **600** may additionally include a fuel supply interlock system. In one embodiment, the fuel supply interlock system includes a source of electrical power **610** connected to a user switch **620** that may be user operated to place the system in a safe or in other words no electrical connectivity. User switch **620** can take the form of a toggle-type switch, a key, push button or other electrical circuit interrupters. The user switch **620** is connected in electrical series with a vacuum switch **630**. The vacuum switch **630** is disposed on the engine intake side of the mixing block and senses vacuum created when the internal combustion engine turns. When vacuum is sensed, the vacuum switch **630** closes establishing electrical connectivity through the switch. The vacuum switch **630** is connected in electrical series with solenoid **640** and in turn to ground completing the circuit. When energized, solenoid **640** operates to permit pressurized hydrogen gas into the mixing block **600**.

**[0018]** With reference to Figure 7, an internal combustion engine **700** includes a source of hydrogen **710** in fluid communication with a mixing block **720**. The mixing block sets the hydrogen / air calibration based on user input including a throttle **730** setting. The internal combustion engine further includes a crank output shaft or driver **740** that may be connected to any known and future varieties of machines **750** capable of being powered by an internal combustion engine including but not limited to a transmission to provide motive power to a vehicle, an alternator or generator to provide electrical power a battery system or electrically powered devices, or a pump for hydraulic or other fluid power devices. In another embodiment, a mixing block may include both an input for a source of hydrocarbon fuels such as gasoline or diesel and a source of hydrogen fuel.

**[0019]** Experimental mixing blocks have been applied to multiple internal combustion engines and have accumulated over 400 hours of operation with a fuel source of industrial grade, commercially available hydrogen. Several examples are informative.

**[0020]** Example 1 - 6 horsepower (HP) engine configured with High Pressure Washer.

Table 1

| | Stock ICE | Mixing Block ICE | Mixing Block, Modified ICE |
|---|---|---|---|
| Class: | Air Cooled Overhead Cam, Chain Drive, ICE | Air Cooled Overhead Cam, Chain Drive, ICE | Air Cooled Overhead Cam, Chain Drive, ICE |
| Shaft: | Horizontal | Horizontal | Horizontal |
| Cylinders: | 1 | 1 | 1 |
| Displacement: | 169 cc | 169 cc | 169 cc |
| Cycles: | 4 | 4 | 4 |
| Fuel: | Unleaded Gasoline | Hydrogen | Hydrogen |
| Max HP/RPM: | 4.89/4000 (Gross HP) | 2.0/4000 (Gross HP) | 3.7/4000 (Gross HP) |
| Bore X Stroke: | 67 x 48 (mm) | 67 x 48 (mm) | 67 x 48 (mm) |
| Compression: | 9 : 1 | 9 : 1 | 10.2 : 1 |
| Timing: | Factory set | Factory | Advanced |

| | | | |
|---|---|---|---|
| Governor System: | Centrifugal Flyweight | Centrifugal Flyweight | Centrifugal Flyweight |
| Fuel System: | Carbureted Float | Mixing block | Mixing block |
| $CO_2$ Emissions: | 13 PPM | 0 PPM | Not measured** |
| O2 Emissions: | 2.59 PPM | 0 PPM | Not measured** |
| HC Emissions: | 174 PPM | 2 PPM* | Not measured** |
| NOX Emissions: | 706 PPM | 38 PPM | Not measured** |
| CO Emissions: | 2.94 PPM | 0 PPM | Not measured** |
| * particulate detected believed to be lubrication oil breakdown<br>** not believed to materially differ from unmodified mixing block | | | |

[0021] In the column labeled "Mixing Block ICE," changes are shown from the stock ICE. Aside from replacing the carburetor with a mixing block, another change from stock was to increase the gap on the spark plug called for by the manufacturer. In this case, we doubled the gap. Additionally, we used a regulator to regulate the pressure from the commercial hydrogen tank (approximately 2200 psi) down to working pressure (about 5 psi). As is seen, there was a slight reduction in observed horse-power in the mixing block modified ICE. In the third column, namely, "Modified Mixing Block ICE," other modifications were made to improve performance. Specifically, the compression ratio was increased to 10.2 : 1 through a piston and head change and the timing was advanced by 2 degrees. These changes were able to increase observed horsepower by 1.5 HP. We believe that increasing the compression ratio to 14 : 1 will further increase observed horsepower.

[0022] Example 2 – 7.5 HP engine configured with Rototiller.

Table 2

| | Stock ICE | Mixing Block, Modified ICE |
|---|---|---|
| Class: | Air Cooled Overhead Cam, Chain Drive, Gasoline Engine | Air Cooled Overhead Cam, Chain Drive, Gasoline Engine |
| Shaft: | Horizontal | Horizontal |
| Cylinders: | 1 | 1 |
| Displacement: | 211 cc | 211 cc |

| | | |
|---|---|---|
| Cycles: | 4 | 4 |
| Fuel: | Unleaded Gasoline | Hydrogen |
| Max HP/RPM : | 5.1/4000 (Gross HP) | To be determined |
| Bore X Stroke: | 67 x 60 (mm) | 67 x 60 (mm) |
| Compression: | 8.5 : 1 | 10.2 : 1 |
| Timing: | Factory set | Advanced |
| Governor System: | Centrifugal Flyweight | Centrifugal Flyweight |
| Fuel System: | Throttle Body – Electronic Fuel Injection | Mixing block |
| $CO_2$ Emissions: | 13.2 PPM | 0 PPM |
| O2 Emissions: | 1.35 PPM | 0 PPM |
| HC Emissions: | 149 PPM | 1 PPM* |
| NOX Emissions: | 426 PPM | 26 PPM |
| CO Emissions: | 2.38 PPM | 0 PPM |
| * particulate detected believed to be lubrication oil breakdown | | |

[0023] Example 3 – 8 HP engine configured with Generator.

Table 3

| | Stock ICE | Mixing Block ICE |
|---|---|---|
| Class: | Air Cooled Overhead Cam, Chain Drive, Gasoline Engine | Air Cooled Overhead Cam, Chain Drive, Gasoline Engine |
| Shaft: | Horizontal | Horizontal |
| Cylinders: | 1 | 1 |
| Displacement: | 305 cc | 305 cc |
| Cycles: | 4 | 4 |
| Fuel: | Unleaded Gasoline | Hydrogen |
| Max HP/RPM : | 5.1/4000 (Gross HP) | To be determined |
| Bore X Stroke: | 3.12 x 2.44 (in.) | 3.12 x 2.44 (in.) |
| Compression: | 8.5 : 1 | 8.5 : 1 |

| | | |
|---|---|---|
| Governor System: | Centrifugal Flyweight | Centrifugal Flyweight |
| Fuel System: | Carbureted Float | Mixing block |

[0024] Example 4 – 13.5 HP engine configured with Garden Tractor.

Table 4

| | Stock ICE | Mixing Block ICE |
|---|---|---|
| Class: | Air Cooled Gasoline Engine | Air Cooled Gasoline Engine |
| Shaft: | Vertical | Vertical |
| Cylinders: | 1 | 1 |
| Displacement: | 405 cc | 405 cc |
| Cycles: | 4 | 4 |
| Fuel: | Unleaded Gasoline | Hydrogen |
| Max HP/RPM : | 12/3600 | To be determined |
| Bore X Stroke: | 3.43 x 2.66 (in.) | 3.43 x 2.66 (in.) |
| Compression: | 8.5 : 1 | 8.5 : 1 |
| Governor System: | Centrifugal Flyweight | Centrifugal Flyweight |
| Fuel System: | Carbureted Float | Mixing block |

[0025] Example 5 – 13 HP engine configured with EZ-Go 6 Passenger Shuttle.

Table 5

| | Stock ICE | Mixing Block ICE |
|---|---|---|
| Class: | Air Cooled Gasoline Engine | Air Cooled Gasoline Engine |
| Shaft: | Horizontal | Horizontal |
| Cylinders: | 1 | 1 |
| Displacement: | 401 cc | 401 cc |
| Cycles: | 4 | 4 |
| Fuel: | Unleaded Gasoline | Hydrogen |
| Max HP/RPM : | 13/3600 | To be determined |

| | | |
|---|---|---|
| Bore X Stroke: | 3.43 x 2.66 (in.) (87 x 67 mm) | 3.43 x 2.66 (in.) (87 x 67 mm) |
| Compression: | 8.4 : 1 | 8.4 : 1 |
| Governor System: | Centrifugal Flyweight | Centrifugal Flyweight |
| Fuel System: | Carbureted | Mixing block |

[0026] With reference to Figure 8, hydrogen usage at two exemplary RPM settings, 1200 and 3100 are shown with corresponding fuel consumption measured in cubic feet hydrogen per hour. At 9 : 1 compression the internal combustion engine used 29.5 cubic feet of hydrogen / hour at an idle set at about 1200 RPM. At a sample working speed of 3100 RPM, the engine used about 40.0 cubic feet of hydrogen / hour. Significant fuel economy was achieved by increasing the compression of the internal combustion engine to 10.2 : 1. For example, at the selected idle speed 1200 RPM the engine used about 18.0 cubic feet of hydrogen / hour, and at the selected working speed 3100 RPM the engine used about 28.5 cubic feet of hydrogen / hour. We expect further significant fuel economy will be achieved at higher compression ratios.

[0027] As used herein, "connection" or "connected" means both directly, that is, without other intervening elements or components, and indirectly, that is, with another component or components arranged between the items identified or described as being connected. To the extent that the term "includes" or "including" is employed in the detailed description or the claims, it is intended to be inclusive in a manner similar to the term "comprising" as that term is interpreted when employed as a transitional word in a claim. Furthermore, to the extent that the term "or" is employed in the claims (e.g., A or B) it is intended to mean "A or B or both". When the applicants intend to indicate "only A or B but not both" then the term "only A or B but not both" will be employed. Similarly, when the applicants intend to indicate "one and only one" of A, B, or C, the applicants will employ the phrase "one and only one". Thus, use of the term "or" herein is the inclusive, and not the exclusive use. See, Bryan A. Garner, A Dictionary of Modern Legal Usage 624 (2d. Ed. 1995).

Claims:

1. A mixing block adapted to supply a throttle-able hydrogen and air mixture to an internal combustion engine, the mixing block comprising:

A bore through the mixing block between an air intake side and an engine intake side;

A slider chamber orthogonal to and intersecting the bore, where the slider chamber houses a movable slider biased to at least partially block the bore but throttle-able to overcome the bias and reduce blockage of the bore;

A jet chamber parallel to and intersecting the slider chamber and extending away from the slider chamber a distance sufficient to accommodate a flow controller, where the flow controller is connected to the slider on one side such that the flow controller moves within the jet chamber as the slider moves in the slider chamber; and

A hydrogen inlet intersecting the jet chamber at a location substantially opposed from the slider chamber.

2. The mixing block as set forth in claim 1, further comprising:

A vacuum switch permitting electrical connection through the vacuum switch upon sensing at least a partial vacuum in the bore.

3. The mixing block as set forth in claim 1, further comprising:

A solenoid disposed to selectively permit a flow of hydrogen from the hydrogen inlet to the jet chamber upon application of an electrical signal; and

A vacuum switch in communication with the bore such that upon sensing at least a partial vacuum from the internal combustion engine electrical connectivity is established through the vacuum switch;

Where the solenoid is connected in electrical series with the vacuum switch.

4. The mixing block as set forth in claim 1, where the flow controller comprises a shaped needle that meters hydrogen flow and the movable slider meters air flow into the internal combustion engine.

5. A machine comprising:

An internal combustion engine having an engine intake;

A mixing block connected to the engine intake, the mixing block including:

a bore between an air intake side and the engine intake;

a slider chamber intersecting the bore, where the slider chamber houses a slider biased to at least partially obstruct fluid communication in the bore between the air intake side and the engine intake, where the slider is movable to overcome the bias and reduce obstruction of the bore; and

a jet chamber parallel to and intersecting the slider chamber and extending away from the slider chamber a distance sufficient to accommodate a shaped needle, where the needle is connected to the slider on one side such that the needle moves within the jet chamber as the slider moves in the slider chamber; and

A source of pressurized hydrogen in selective fluid communication with the jet chamber.

6. The machine as set forth in claim 5, where the mixing block further comprises a spring to bias the slider to at least partially obstruct fluid communication in the bore between the air intake side and the engine intake.

7. The machine as set forth in claim 5 where the source of pressurized hydrogen in selective fluid communication with the jet chamber comprises:

A source of electrical power;

A vacuum switch electrically in series with the source of electrical power, where the vacuum switch changes from a condition of electrical non-conductivity to a condition of electrical conductivity upon sensing at least a partial vacuum from the internal combustion engine; and

A solenoid electrically in series with the source of electrical power and the vacuum switch, where the solenoid permits pressurized hydrogen to flow into the jet chamber upon the vacuum switch changing from the condition of electrical non-conductivity to the condition of electrical conductivity.

8. The machine as set forth in claim 7, where the solenoid prevents pressurized hydrogen from flowing into the jet chamber upon a loss of vacuum in the internal combustion engine.

9. The machine as set forth in claim 5, where the mixing block further comprises a throttle cable stay to support a throttle cable permitting user throttling of the internal combustion engine by moving the slider and providing increased air and hydrogen to the internal combustion engine.

10. The machine as set forth in any of claims 5-9 further comprising a load connected to and powered by the internal combustion engine where the load is selected from an electrical generator, an alternator, a transmission, or a pump.

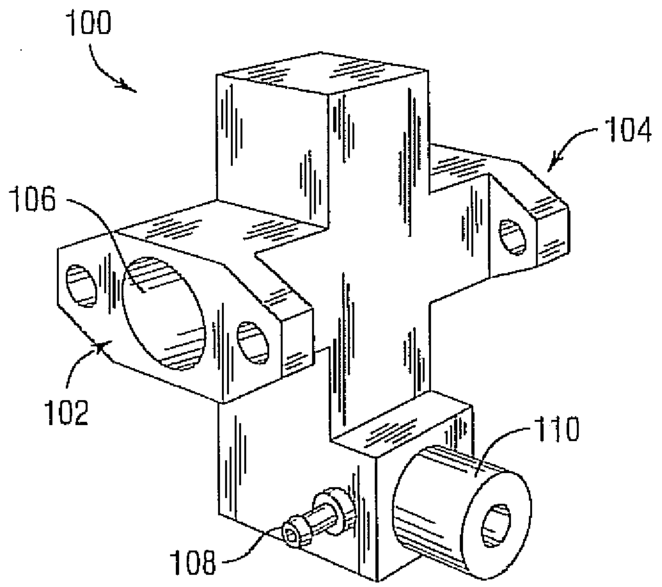


*Fig.1*

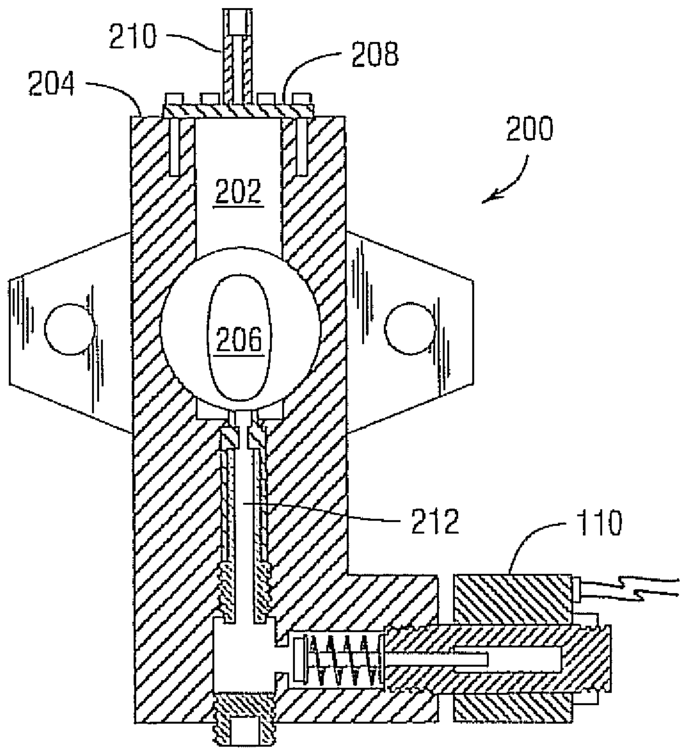


*Fig.2*

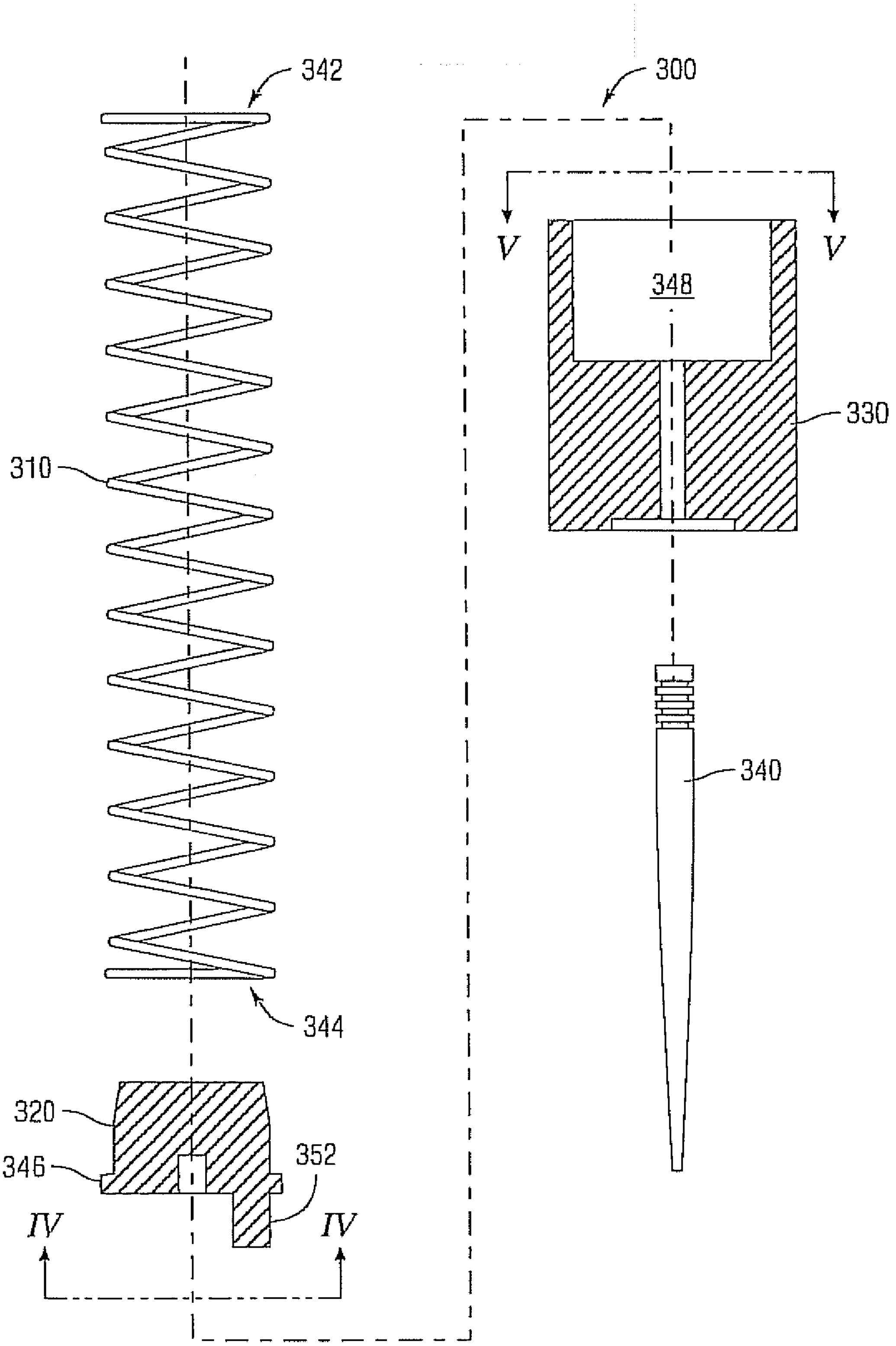


*Fig.3*

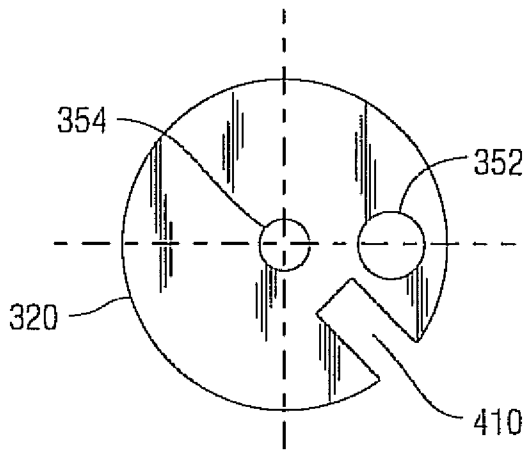


Fig.4

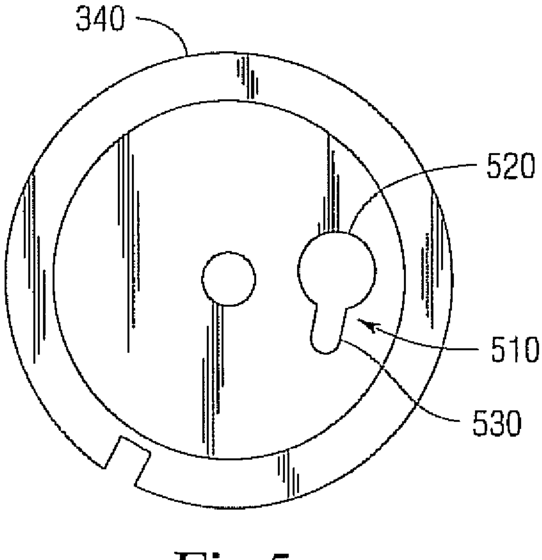


Fig.5

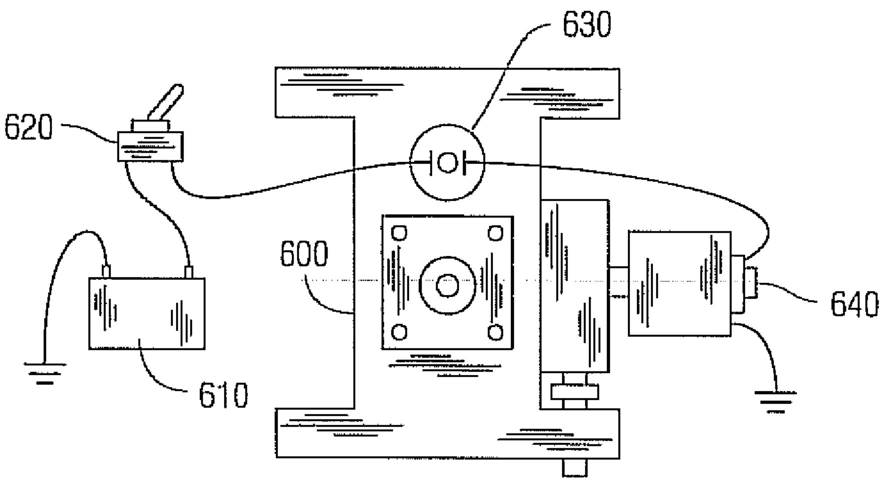


*Fig.6*

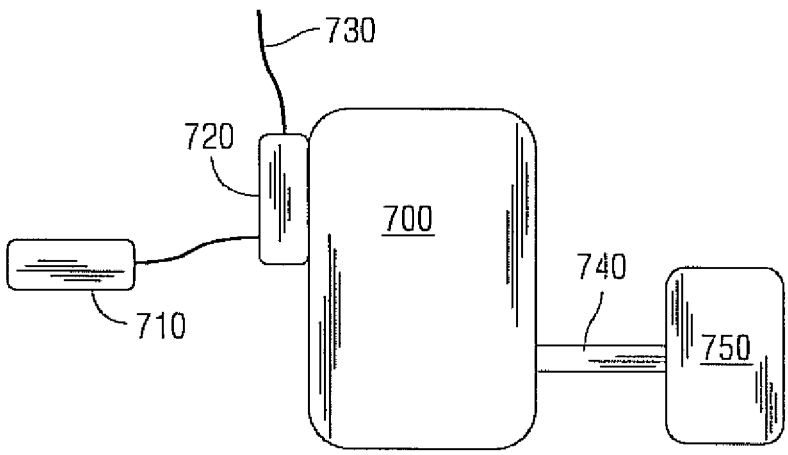


*Fig.7*

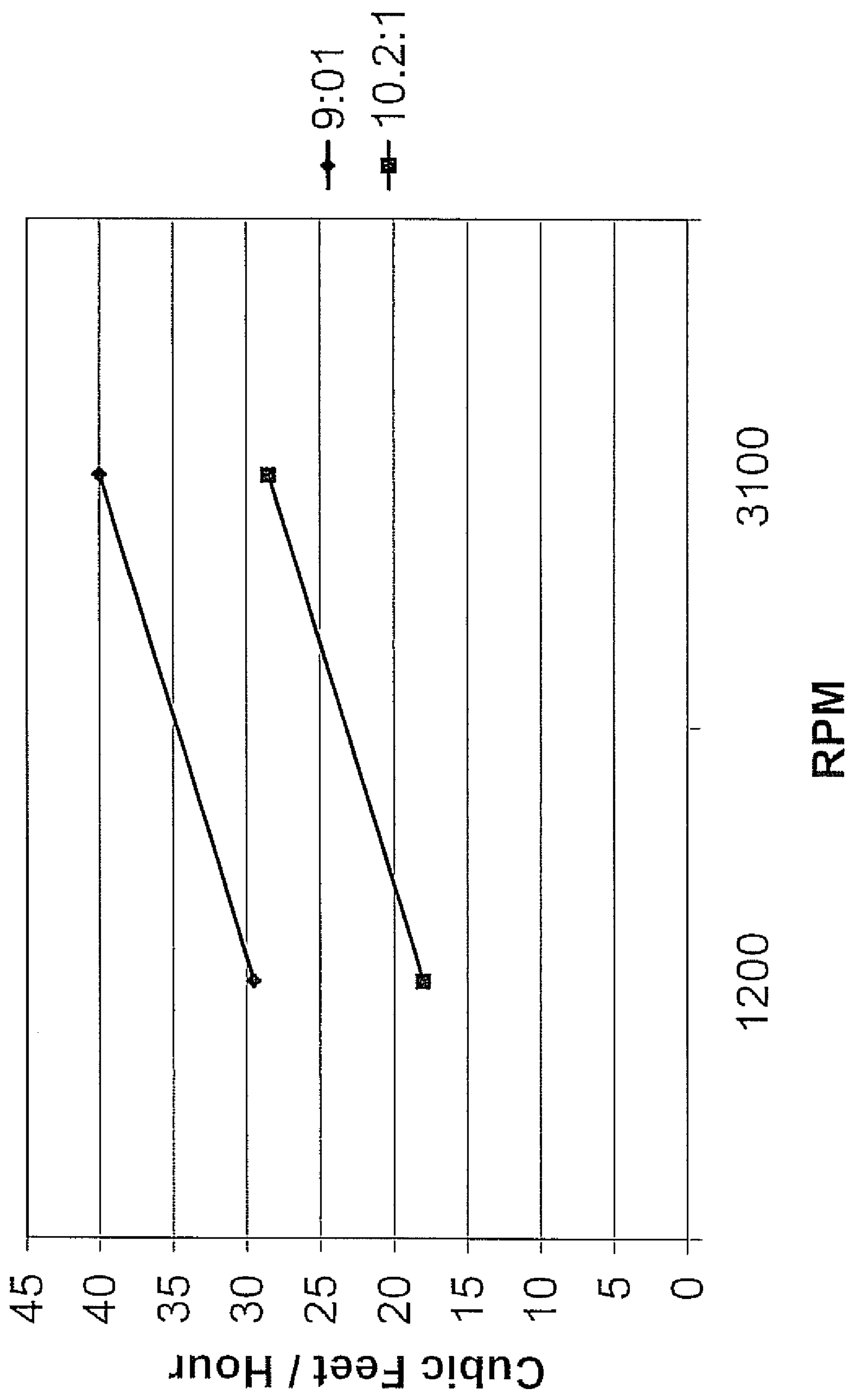


*Fig. 8*

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/031141

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC(8) - F02M 21/04 (2012.01)
USPC - 123/527
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - F02B 43/00, 43/10; F02D 19/00, 19/02; F02M 21/00, 21/02, 21/04, 25/00, 25/10 (2012.01)
USPC - 123/27GE, 304, 525, 526, 527, 528, 529, 533, Dig.12; 239/8, 418, 419, 432, 654

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y | US 2,109,963 A (KRUSE) 01 March 1938 (01.03.1938) entire document | 1-10 |
| Y | US 4,325,343 A (TURNER) 20 April 1982 (20.04.1982) entire document | 1-10 |
| Y | GB 138,661 A (ARTHUR et al) 19 February 1920 (19.02.1920) entire document | 1-10 |
| Y | US 4,433,664 A (RODRIGUES) 28 February 1984 (28.02.1984) entire document | 2, 3, 7, 8 |

☐ Further documents are listed in the continuation of Box C. ☐

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"A" document defining the general state of the art which is not considered to be of particular relevance
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|---|---|
| 11 June 2012 | 28 JUN 2012 |

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