

DuroMax[®] XP4400EH

NEXT GENERATION POWER SYSTEMS

FEATURES:

- Clean running pro
- Unlike gasoline, l
- Flexible fuel line
- Designed to run c
- Durable DuroMax
- Heavy duty steel
- Electric Key start
- Wheel kit w/ front
- Full power panel
- (2) Fully protecte
- Approximately 20
- All steel 4 gallon
- Low oil shut-off p
- Super quiet muffl
- Idle control holds



Fully Lo

OUTLETS:

- 120V 20A 3-Prong Outlet: (Standard Plug)
- 120V 20A 3-Prong Outlet: (Standard Plug)
- 120V/240V 30A Twist Lock: (NEMA L14-30 4 Pole Wire)
- 10A 12V Utility Connection

DUAL FUEL



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parts every time.

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rk arrestor.

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Output]: 12.0 hrs

Output]: 20.0 hrs

EXHIBIT H

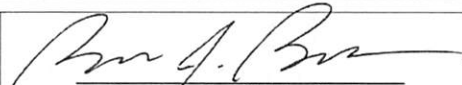


UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
2013 MODEL YEAR
CERTIFICATE OF CONFORMITY
WITH THE CLEAN AIR ACT OF 1990

OFFICE OF TRANSPORTATION
AND AIR QUALITY
ANN ARBOR, MICHIGAN 48105

Certificate Issued To: Chongqing Maifeng Power Machinery Co., Ltd
(U.S. Manufacturer or Importer)
Certificate Number: DCMGS.2081GL-004

Effective Date:
02/27/2013
Expiration Date:
12/31/2013


Byron J. Bunker, Division Director
Compliance Division

Issue Date:
02/27/2013
Revision Date:
N/A

Manufacturer: Chongqing Maifeng Power Machinery Co., Ltd
Engine Family: DCMGS.2081GL
Certificate Number: DCMGS.2081GL-004
Useful Life : 125 Hours / 2 Years
Engine Class : Nonhandheld-Class I
Fuel : LPG/Propane
Gasoline (up to and including 10% Ethanol)
Emission Standards : HC + NOx (g/kW-hr) : 10
CO (g/kW-hr) : 610

Pursuant to Section 213 of the Clean Air Act (42 U.S.C. section 7547), 40 CFR Part 1054, 40 CFR Part 1068 and 40 CFR Part 60 (stationary only and combined stationary and mobile), and subject to the terms and conditions prescribed in those provisions, this certificate of conformity is hereby issued for the following small nonroad engine family, more fully described in the documentation required by 40 CFR Part 1054 and produced in the stated model year.

This certificate of conformity covers only those new small nonroad engines which conform in all material respects to the design specifications that applied to those engines described in the documentation required by 40 CFR Part 1054 and which are produced during the model year stated on this certificate of the said manufacturer, as defined in 40 CFR Part 1054. This certificate of conformity does not cover small nonroad engines imported prior to the effective date of the certificate.

It is a term of this certificate that the manufacturer shall consent to all inspections described in 40 CFR 1068.20 and 1068, Subpart E and authorized in a warrant or court order. Failure to comply with the requirements of such a warrant or court order may lead to revocation or suspension of this certificate for reasons specified in 40 CFR Part 1054. It is also a term of this certificate that this certificate may be revoked or suspended or rendered void *ab initio* for other reasons specified in 40 CFR Part 1054, 40 CFR Part 1068.

This certificate does not cover small nonroad engines sold, offered for sale, or introduced, or delivered for introduction, into commerce in the U.S. prior to the effective date of the certificate.

EXHIBIT I

Duro
NEXT GENERATION

Max
POWER SYSTEMS

DUAL  FUEL



DUAL FUEL
HYBRID // XP4400EH
★ ★ ★ ★ ★ **ELITE**

OWNERS MANUAL

Product Support

Product Information, Application, Service Info & Warranty Questions

Please email us at support@duromaxgenerators.com
or call (800) 629-3325 Monday – Friday 6:00 am – 6:00 pm (PST)

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FEATURES

- Dual Fuel Option, LPG or Gasoline.
- Durable 7.0 HP, Air Cooled Overhead Valve Engine.
- Heavy Duty Steel Frame with Four Point Fully Isolated Motor Mounts for Smooth and Quiet Operation.
- Wheel and Handle Kit for Easy Transporting.
- Full Power Panel with Engine Shutoff Switch, Volt Meter, Circuit Breaker, and Power Outlets.
- (2) Fully Protected 120V Outlets & (1) 120V/240V Twist-Lock Outlet.
- 8 Hour Run Time.
- All Steel 4.0 Gal. Fuel Tank with EZ-Read Gauge.
- Low Oil Shut-Off Protects Engine.
- Super Quiet Muffler Reduces Engine Noise.
- Meets EPA Emission Standards.

This manual provides information regarding the operation and maintenance of these products. We have made every effort to ensure the accuracy of the information in this manual. We reserve the right to change this product at any time without prior notice.

Notice Regarding Emissions

Engines that are certified to comply with U.S. EPA emission regulations for SORE (Small off Road Equipment), are certified to operate on regular unleaded gasoline, and may include the following emission control systems: (EM) Engine Modifications and (TWC) Three-Way Catalyst (if so equipped).

GENERAL SAFETY PROCEDURES

Please familiarize yourself with the following safety symbols and words:

The safety alert symbol is used with one of the safety words (**DANGER**, **CAUTION**, or **WARNING**) to alert you of hazards. Please pay attention to these hazard notices both in this manual and on the generator.

DANGER: Indicates a hazard that will result in serious injury or death if instructions are not followed.

WARNING: Indicates a strong possibility of causing serious injury or death if instructions are not followed.

CAUTION: Indicates a possibility of personal injury or equipment damage if instructions are not followed.

⚠ **DANGER:** This generator produces poisonous carbon monoxide gas when running. This gas is both odorless and colorless. Even if you do not see or smell gas, carbon monoxide may still be present. Breathing this poison can lead to headaches, dizziness, drowsiness, and eventually death.

- Use outdoors **ONLY** in non-confined areas.
- Keep several feet of clearance on all sides to allow proper ventilation of the generator.

⚠ **WARNING:** The exhaust from this product contains chemicals known to the State of California to cause cancer, birth defects, or other reproductive harm.

⚠ **WARNING:** This generator may emit highly flammable and explosive gasoline vapors, which can cause severe burns or even death. A nearby open flame can lead to an explosion even if not directly in contact with gas.

- Do not operate near an open flame.
- Do not smoke near generator.
- Always operate on a firm, level surface.
- Always turn generator off before refueling. Allow generator to cool for at least 2 minutes before removing fuel cap. Loosen cap slowly to relieve pressure in tank.
- Do not overfill gas tank. Gas may expand during operation. Do not fill to the top of the tank.
- Always check for spilled gas before operating.
- Empty the gasoline tank before storing or transporting the generator.
- Before transporting, turn fuel valve to the off position and disconnect the spark plug.

GENERAL SAFETY PROCEDURES (Continued)

⚠ WARNING: This generator produces a powerful voltage, which can result in electrocution.

- ALWAYS ground the generator before using it (see the "Grounding the Generator" portion of the "PREPARING THE GENERATOR FOR USE section).
- Generator should only be plugged into electrical devices, either directly or with an extension cord. NEVER connect to a building electrical system without a qualified electrician. Such connections must comply with local electrical laws and codes. Failure to comply can create a backflow of power, which may result in serious injury or death to utility workers.
- Use a ground fault circuit interrupter (GFCI) in highly conductive areas such as metal decking or steel work. GFCIs are available in-line with some extension cords.
- Do not use uncovered in rainy or wet conditions.
- Do not touch bare wires or receptacles (outlets).
- Do not allow children or non-qualified persons to operate.

⚠ WARNING: This generator produces heat when running. Temperatures near exhaust can exceed 150°F (65°C).

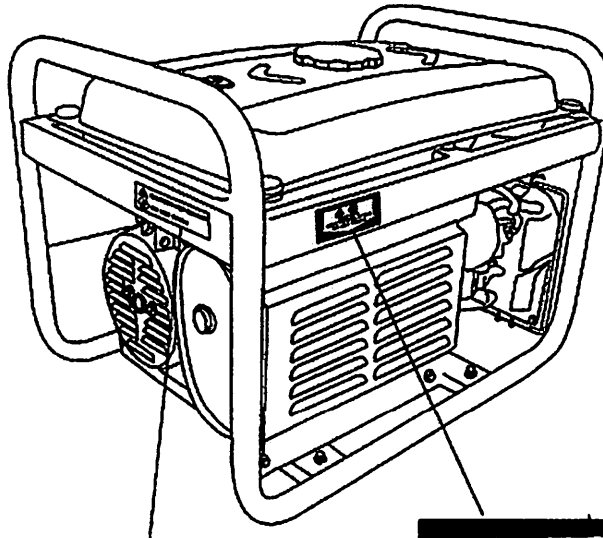
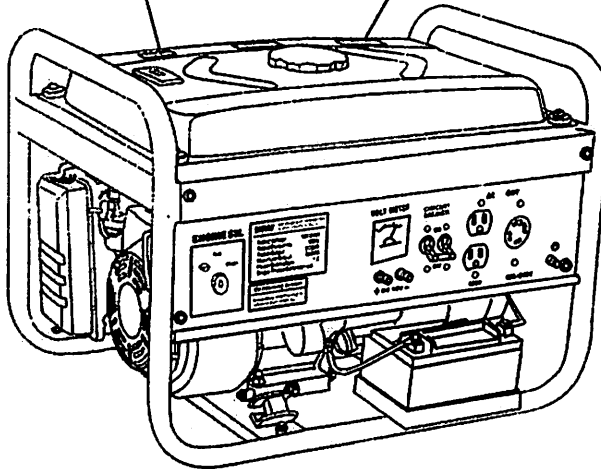
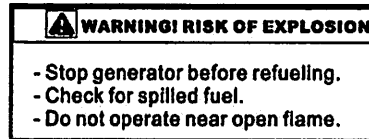
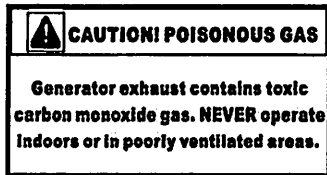
- Do not touch hot surfaces. Pay attention to warning labels on the generator denoting hot parts of the machine.
- Allow generator to cool several minutes after use before touching engine or areas which heat during use.

⚠ CAUTION: Misuse of this generator can damage it or shorten its life.

- Use the generator only for its intended purposes.
- Operate only on dry, level surfaces.
- Allow generator to run for 3 - 5 minutes before connecting any electrical devices.
- Shut off and disconnect any malfunctioning devices from generator.
- Do not exceed the Wattage capacity of the generator by plugging in more electrical devices than the unit can handle (see "PRECAUTIONS-OVERLOADING THE GENERATOR").
- Do not turn on electrical devices until after they are connected to the generator.
- Turn off all connected electrical devices, and turn off the breaker, before stopping the generator.

GENERAL SAFETY PROCEDURES (Continued)

In addition to the above safety notices, please familiarize yourself with the safety and hazard markings on the generator.



PACKAGE CONTENTS

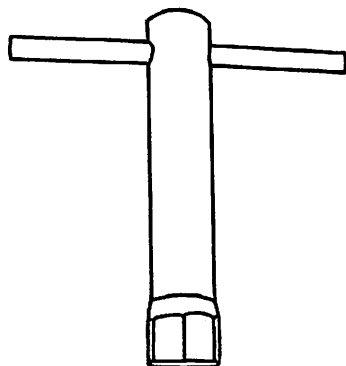
Your generator comes with the items listed below. Please check to see that all of the following items are included with your generator.



Screw driver



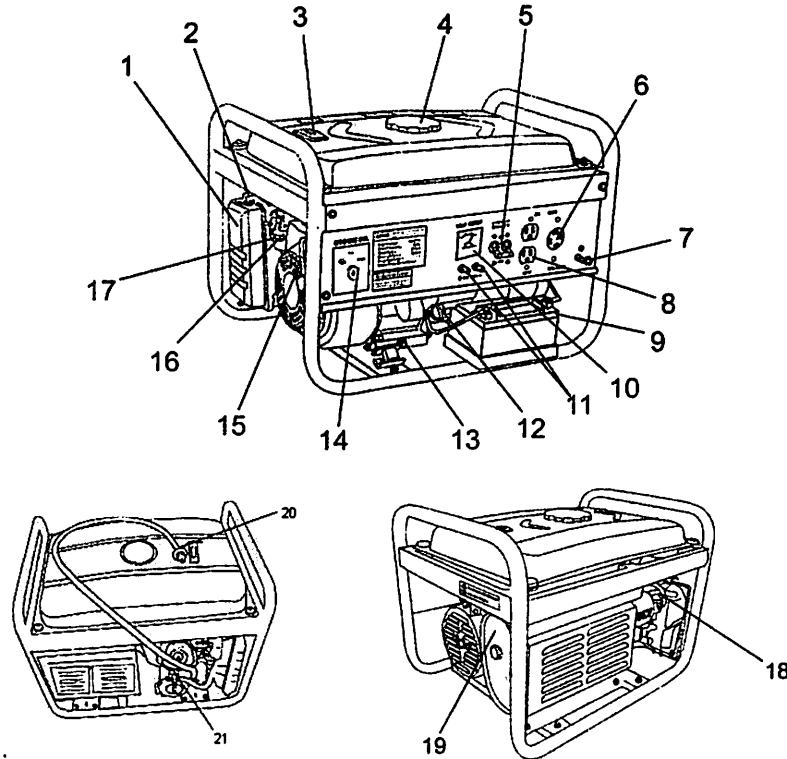
Spanner



Spark plug wrench

GENERATOR COMPONENTS

Please familiarize yourself with the locations and functions of the various components and controls of your generator.



1. **Air Cleaner** - a removable, cleanable, oiled, sponge-like element that cleans the air going into the engine.
2. **Choke Lever** - Allows the airflow into the carburetor to be restricted to assist in starting the engine.
3. **Fuel Gauge** - Indicates the amount of fuel in the gasoline tank.
4. **Fuel Cap** - Allows access to fill the gasoline tank.
5. **Circuit Breaker** - Resettable switch that protects the generator from electrical overload.
6. **120/240v 4-Prong Receptacle** - Use to connect electrical devices that run 120 or 240 Volt, 60Hz, single phase, AC current (NEMA L14-30).
7. **Ground Terminal** - Connect a ground wire here to properly ground the generator.
8. **120v 3-Prong Receptacle** - Use to connect electrical devices that run 120 Volt, 60 Hz, single phase, AC current (NEMA 5-20).
9. **Battery** - 12V DC 7ah Battery that powers the Electric Start System.
10. **Volt Meter** - Provides reading of voltage output.
11. **12v DC Charging Posts** - DC Output for charging batteries or running small DC powered items.
12. **Oil Filler Cap** - Use to add or check the oil.
13. **Oil Fill and Dipstick** - Use to add or check the oil.
14. **Engine Switch** - 3 Position Switch to "Start", "Run", or turn "Off" the generator.
15. **Recoil Start** - Easy Pull Recoil Start to start the engine without the electric start.

GENERATOR COMPONENTS (Continued)

16. **Fuel Filter Cup** - Traps dirt and water in gasoline before it enters the engine.
17. **Fuel Valve** - On/Off Valve that allows fuel into the engine.
18. **Spark plug** – Provides ignition to the engine.
19. **Muffler** – Reduces engine emissions and reduces noise.
20. **Propane Tank Connector and Hose** – Connects the LPG tank to the LPG Regulator.
21. **Propane Regulator and Pressure Release Valve** - Provides a regulated LPG Fuel supply to the engine. *(Intended for use with a LPG Source of 10 PSI or more.)*

PREPARING THE GENERATOR FOR USE

Using the Generator for the First Time

If you are using the generator for the first time, there are a few steps you must take to prepare it for operation.

Step 1 - Add oil

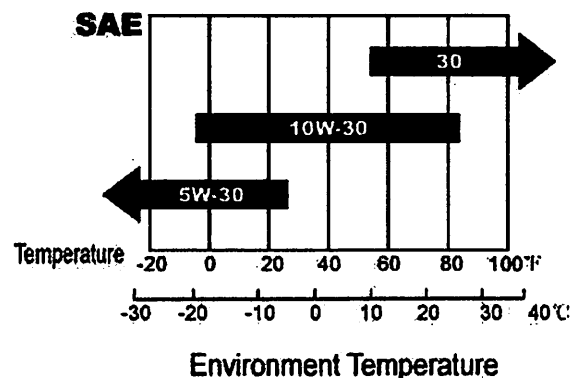
The generator requires engine oil to operate properly. The generator, when new from the package contains no oil in the crankcase. You must add the proper amount of oil before operating the generator for the first time. This amount, which is equal to the oil capacity of the engine crankcase can be found on the chart in figure 1. When filling the engine with oil in the future, please refer to this chart.

Model Number	XP4400EH
Engine Oil Capacity	20 fl. Oz. (0.6L)

Figure 1 – Generator Oil Capacity

• **Do not apply engine oil with additives or 2-stroke gasoline engine oil.** They don't have enough lubrication, and may shorten the engine's service life.

• **Engine oil recommended: SAE 10W-30.** Viscosity varies with regions and temperatures. Choose your oil viscosity using the chart to the right.



PREPARING THE GENERATOR FOR USE (Continued)

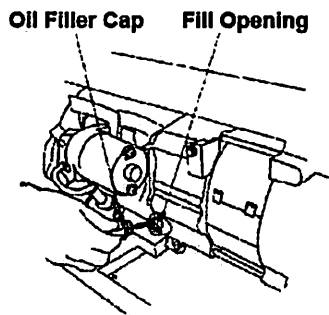


Figure 2 – Unscrewing the Oil Cap



Figure 3 – Adding Oil

To add Oil, follow these steps:

1. Make sure the generator is on a level surface.
2. Unscrew the oil filler/dipstick cap from the engine as shown in figure 2.
3. Using a funnel, add the appropriate amount of oil, as found in figure 1, into the crankcase. You will know the crankcase is full when the oil level has reached the lower lip of the opening you have just poured the oil into. (see figure 3.)
4. Replace oil filler cap.

Step 2 - Add Gasoline

- **WARNING: Gasoline and gas fumes are highly flammable.**
 - Do not fill tank near an open flame.
 - Do not overfill. Always check for fuel spills.

To ensure that the generator runs smoothly use only FRESH, UNLEADED GAS WITH AN OCTANE RATING OF 87 OR HIGHER.

To add gasoline:

1. Make sure the generator is on a level surface.
2. Unscrew gas cap and set aside (NOTE: the gas cap may be tight and hard to unscrew).
3. Slowly add unleaded gasoline to the fuel tank. Be careful not to overfill. Please refer to the chart in figure 4 to find the gas capacity of your generator model. The fuel gauge on the top of the gas tank indicates how much gasoline is in the generator gas tank.

NOTE: Gas can expand. Do not fill the gas tank to the very top.

4. Replace fuel cap and wipe up any spilled gasoline with a dry cloth.

PREPARING THE GENERATOR FOR USE (Continued)

IMPORTANT:

- Never use an oil/gasoline mixture.
- Never use old gas.
- Avoid getting dirt or water in the fuel tank.
- Gas can age in the tank and make it hard to start up the generator in the future.
- Never store generator for extended periods of time with fuel in the tank.

Model #	XP4400EH
Gas Tank Capacity	3.96 US Gallons (15L)

Figure 4 - Gas Tank Capacity

Step 3 - Ground the Generator

- **WARNING:** Failure to properly ground the generator can result in electrocution.

Ground the generator by tightening the grounding nut against grounding wire (see figure 5). A generally acceptable grounding wire is a No. 12 AWG (American Wire Gauge) stranded copper wire. This grounding wire should be connected at the other end to a copper or brass-grounding rod that is driven into the earth. Grounding codes can vary by location. Please contact a local electrician to check the grounding regulations for your area.

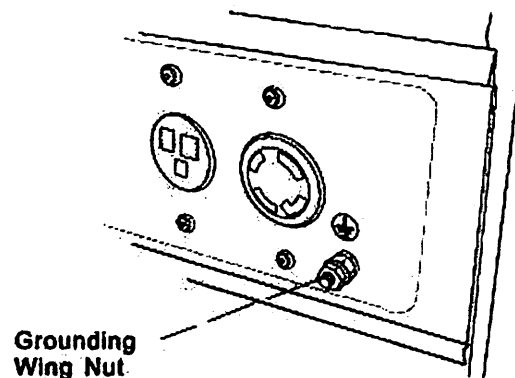


Figure 5 - Attaching the Grounding Wire to the Generator

Subsequent Use of the Generator

If this is not your first time using the generator there are still steps you should take to prepare it for operation.

IMPORTANT: At this point you should be familiar with the procedures described in the first portion of this section entitled "Using the Generator for the First Time." If you have not yet read this section, go back and read it now.

Step 1- Check the oil

The generator is equipped with an automatic shutoff to protect it from damage due to low oil. Nonetheless, you should check the oil level of the engine before each use to ensure that the engine crankcase has a sufficient amount.

To check the oil level:

1. Make sure the generator is on a level surface.
2. Unscrew the oil filler/dipstick cap.
3. With a dry cloth, wipe the oil off of the stick on the inside of the cap.
4. Insert the dipstick as if you were replacing the cap and then remove again. There should now be oil on the stick. If there is no oil on the stick, or oil only at the very end of the stick, you should add oil until the engine crankcase is filled (see "Adding Oil" portion of the "Maintenance" section).
5. Be sure to replace the cap when finished checking oil.

NOTE: The oil capacity for your generator can be found in the "Specifications" section of this manual.

Step 2 - Check the Gas Level

Before starting the generator, check to see that there is sufficient gasoline in the gas tank. The fuel gauge on top of the generator will indicate the gas level in the tank. Add gas if necessary according to the steps in the "Adding Gasoline" portion of the "Maintenance" section.

- **WARNING:** Gasoline and gasoline fumes are highly flammable.
 - Do not fill tank near an open flame.
 - Always allow engine to cool for several minutes before refueling.
 - Do not overfill (check the "Specifications" section for the tank capacity of your generator).
 - Always check for fuel spills.

Starting the Generator: Gasoline

⚠ CAUTION:

LPG must be shut off when using gasoline!

Gasoline must be shut off when using LPG!

Disconnect all electrical loads from the generator before attempting to start!

1. Make sure that the AC circuit breaker is in the OFF position. The generator may be hard to start if a load is connected.
2. Turn the fuel valve lever to the ON position.
3. The choke will need to be closed, slide the choke lever out to the CLOSED position.
4. Turn the engine switch to the START position and hold it there for 5 seconds or until the engine starts.

WARNING:

- Operating the starter motor for more than 5 seconds can damage the motor. If the engine fails to start, release the switch and wait 10 seconds before operating the starter again.
 - If the speed of the starter motor drops after a period of time, it is an indication that the battery should be recharged.
5. When the engine starts, allow the engine switch to return to the ON position.
 6. Push the choke to the OPEN position as the engine warms up.

Stopping the Engine

In an emergency:

⚠ To stop the engine in an emergency, move the engine switch to the OFF position.

In normal use:

1. Turn the AC circuit breaker to the OFF position. Disconnect any DC Load attached to the DC Output on the front panel.
2. Turn the engine switch to the OFF position.
3. Turn the fuel valve lever to the OFF position.

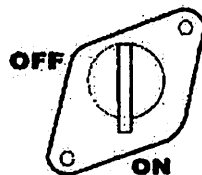


Figure 6 - fuel valve in the "on" position

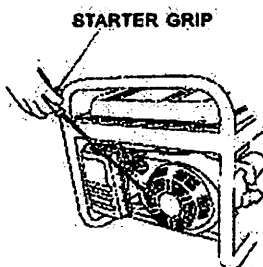


Figure 8 - Pulling the recoil start.



Figure 7 - Choke in the close position

Starting the Generator: Propane

⚠ CAUTION:

LPG must be shut off when using gasoline!

Gasoline must be shut off when using LPG!

Disconnect all electrical loads from the generator before attempting to start!

1. Make sure that the AC circuit breaker is in the OFF position. The generator may be hard to start if a load is connected.
2. Turn the gasoline fuel valve to the "OFF" position.
3. Connect the propane gas hose to the regulator/decompression valve.
4. Connect the propane collar to the gas supply and then turn on the propane gas supply.
5. Press the button on top of the pressure release valve down two or three times.
6. The choke operates differently on propane gas.
 - a. If the engine is warm (the unit was run recently) start with the choke half open.
 - i. Wait 30 seconds and then push the choke lever all the way to the "OPEN" position.
 - b. If the engine is cold (the unit was not run recently) start with the choke "OPEN".
7. Turn the engine key switch to the START position and hold it there for 5 seconds, or until the engine starts.

WARNING:

- Operating the starter motor for more than 5 seconds can damage the motor. If the engine fails to start, release the switch and wait 10 seconds before operating the starter again.
 - If the speed of the starter motor drops after a period of time, it is an indication that the battery should be recharged.
8. When the engine starts, allow the engine switch to return to the ON position.

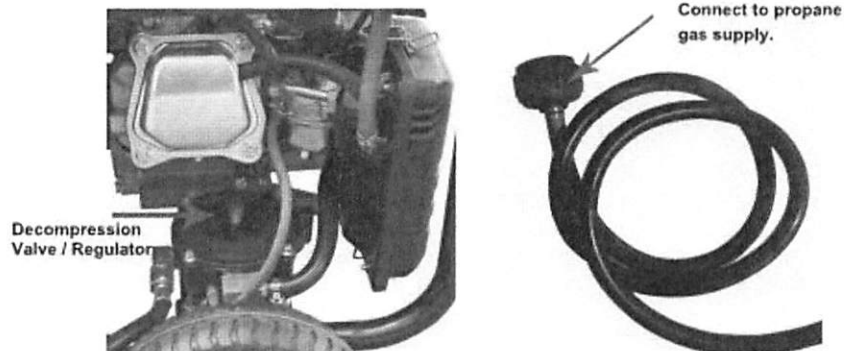
Stopping the Engine

In an emergency:

- ⚠ To stop the engine in an emergency, move the engine switch to the OFF position.

In normal use:

1. Turn the AC circuit breaker to the OFF position. Disconnect DC battery charging cables.
2. Turn the engine switch to the OFF position.
3. Turn OFF the Propane Gas Supply.



Starting the Generator: Propane (Continued)

⚠ WARNING: WHEN USING THE GENERATOR WITH LPG
MAKE SURE THERE IS NO POSSIBLE IGNITION SOURCE CLOSE TO THE GENERATOR.

1. Before using, make sure all of the LPG connectors and hoses are well connected and sealed.
2. Connect electrical devices to generator ONLY after the engine runs smoothly. (There may be remnant gasoline in the carburetor; this can cause unsteady engine performance for several minutes)
3. If the propane gas leaks, shut off the LPG supply first and then quickly unplug or turn off any electrical devices powered by the unit.
4. When stopping the engine, unplug or turn off any electrical devices, turn off the Main Circuit Breaker and then turn off the LPG Supply. After the engine has stopped turn the KEY to 'OFF' position.

Using the Generator

Once you have allowed the engine to run for several minutes, you may connect electrical devices to the generator.

AC Usage

- You may connect electrical devices running on AC current according to their wattage requirements.
- The chart in figure 9 shows the rated and surge wattage of your generator according to its model number.
- The *rated wattage* corresponds to the maximum wattage the generator can output on a continuous basis.
- The *surge wattage* corresponds to the maximum amount of power the generator can output for a short period of time. Many electrical devices such as refrigerators require short bursts of extra power, in addition the rated wattage listed by the device, to stop and start their motors. The surge wattage ability of the generator covers this extra power requirement.

Model Number	Rated (Running) Wattage	Surge (Peak) Wattage
XP4400EH	3500	4400

Figure 9 - Generator Wattage by Model Number

The total running wattage requirement of the electrical devices connected to the generator should not exceed the rated wattage of the generator itself. To calculate the total wattage requirement of the electrical devices you wish to connect, find the rated (or running) wattage of each device. This number should be listed somewhere on the device or in its instruction manual.

If you cannot find this wattage, you may calculate it by multiplying the Voltage requirement by the Amperage drawn: $\text{Watts} = \text{Volts} \times \text{Amps}$. If these specifications are not available you may *estimate* the Watts required by your device by using the chart in figure 10.

Using the Generator (Continued)

Tool or Appliance	Rated (Running) Watts	Additional Surge Watts
Electric water heater (40 gal)	4000	0
Hot plate	2500	0
Saw-radial arm	2000	2000
Electric stove	1500	0
Saw-circular	1500	1500
Air compressor (1HP)	1500	3000
Window air conditioner	1200	1800
Saw-miter	1200	1800
Microwave	1000	2000
Well water pump	1000	1500
Reciprocating saw	960	1040
Sump pump	800	1200
Refrigerator freezer	800	1200
Furnace blower	800	1300
Computer	800	0
Electric drill	600	900
Television	500	0
Deep freezer	500	800
Garage door opener	480	600
Stereo	400	0
Box fan	300	600
Clock radio	300	0
Security system	180	0
DVD player/VCD	100	0
Common light bulb	75	0

Figure 10- Estimated wattage requirements of common electrical devices.

Once you have found the rated wattage requirement of each electrical device, add these numbers to find the total rated wattage you wish to draw from the generator. If this number exceeds the rated wattage of the generator, DO NOT connect all these devices. Select a combination of electrical devices, which has a total rated wattage lower than or equal to the rated wattage of the generator.

⚠ CAUTION - The generator can only run at its surge wattage capacity for a very short time. Connect only electrical devices requiring a rated (running) wattage equal to or less than the rated wattage of the generator. Never connect devices requiring a rated wattage equal to the surge wattage of the generator.

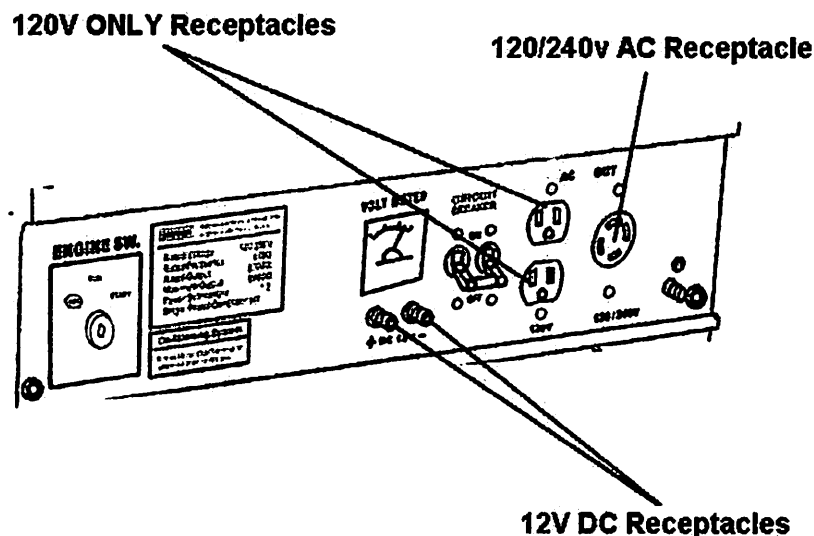
NOTE: The above wattage figures are estimates only. Try to check the wattage listed on your electrical devices before consulting this chart.

Connecting a Load to the Generator

NOTE: Be sure to attach devices to the correct receptacle (outlet).

- 120v devices can be directly connected to the 120v ONLY receptacles.
 - 120v devices can be connected to the 120/240v receptacle using an appropriate adapter.
 - 240v devices can ONLY be connected the 240v receptacle.
1. Plug in each electrical device with the device turned off.
 2. Switch the circuit breaker to the "ON" position.
 3. Turn on the connected electrical devices in the order of the amount of power they require beginning with the device with the highest rated Wattage requirement.

⚠ CAUTION: Do not connect 50Hz or 3-phase loads to the generator.



VOLTAGE SELECTOR SWITCH

The voltage selector switches the dual 120v AC windings of the generator to produce "120V ONLY" or "120/240V". If a 240V appliance is connected to the 4-prong receptacle, the switch must be in the "120/240V" position. If only 120V appliances are being connected to the generator select the "120V ONLY" position to double the 120v amperage.

WARNING:

Only change the Voltage Selector Switch with the main AC Circuit Breaker OFF. The generator can be seriously damaged if the Voltage Selector Switch is changed with the breaker ON.

Choosing the Right Power Cord

Long or thin cords can drain the power provided to an electrical device by the generator. When using such cords, allow for a slightly higher rated wattage requirement for the electrical device. See Figure 12 for recommended cords based on the power requirement of the electrical device.

DEVICE REQUIREMENTS		WIRE GAUGE BY LENGTH (ft.)				
AMPS	WATTS (120V/240V)	10	25	50	100	150
5	600/1200	18	16	14	12	10
10	1200/2400	16	14	12	10	8
15	1800/3600	14	12	10	8	6
20	2400/4800	12	10	8	6	4
25	3000/6000	10	8	6	4	4
30	3600/7200	8	6	4	4	NR
40	4800/9600	6	4	4	NR	NR
50	6000/1200	4	4	2	NR	NR
*NR = NOT RECOMMENDED						

Figure 12 – Minimum Extension Cord Requirements

DC Usage

- ⚠ **CAUTION:** The DC receptacle is for recharging 12 Volt automotive-type batteries only. Do not connect any other device to this receptacle.
- ⚠ **CAUTION:** Never try to jump start a car with your generator.

To connect a 12V battery to the DC battery charger on the front panel:

1. Connect one charging wire to the positive terminal on the battery and the other charging wire to the negative terminal on the battery.
 2. Connect the free end of the positive wire to the positive receptacle (outlet) on the generator.
 3. Start the generator.
 4. Carefully connect the free end of the negative wire to the negative receptacle on the generator.
 5. When disconnecting, always disconnect the wires from the generator first to avoid a spark.
- ⚠ **DANGER:** Stored batteries emit highly explosive hydrogen gas when charged. Batteries also contain acid, which can cause severe chemical burns.
 - ⚠ Do not allow open flames or cigarettes nearby for several minutes after charging a battery.
 - ⚠ Always wear protective goggles and rubber gloves when charging a battery.
 - ⚠ If battery acid gets on your skin, flush with water.
 - ⚠ If battery acid gets in your eyes, flush with water and call a physician immediately.
 - ⚠ If battery acid is swallowed, drink large quantities of milk and call a Physician immediately.

If your generator is the electric start model, once running, it will charge the battery on the generator automatically. While charging, you can see the recharge indicator light lit, after the battery is full, the light will turn off.

MAINTENANCE AND CARE

The Importance of Maintenance

Proper routine maintenance of your generator is essential for safe, economical, and trouble-free operation. It will also help reduce air pollution.

Warning

Improper maintenance, or failure to correct a problem before operation, can cause a malfunction in which you can be seriously injured or killed. Always follow the inspection and maintenance recommendations and schedules in this instruction manual.

⚠ Maintenance Safety

- Make sure the engine is off before you begin any maintenance or repairs.
- Let the engine and exhaust system cool before touching.
- To reduce the possibility of fire or explosion, be careful when working around gasoline. Use only a nonflammable solvent, not gasoline, to clean parts. Keep cigarettes, sparks, and flames away from all fuel related parts.

Maintenance Schedule

Remember that this schedule is based on the assumption that your machine will be used for its designed purpose. Sustained high-load, high temperature operation, or use in unusually wet or dusty conditions, will require more frequent service.

SERVICE		REGULAR SERVICE PERIOD				
		BEFORE EACH USE	1 MO. OR 20 HRS.	3 MO. OR 50 HRS.	6 MO. OR 100 HRS.	12 MO. OR 300 HRS.
ENGINE OIL	CHECK					
	CHANGE					
AIR CLEANER	CHECK					
	CHANGE					
SEDIMENT CUP	CLEAN					
SPARK PLUG	CLEAN - ADJUST					
	REPLACE					
SPARK ARRESTER	CLEAN					
IDLE SPEED	CHECK- ADJUST					
VALVE CLEARANCE	CHECK- ADJUST					
COMBUSTION CHAMBER	CLEAN	500 HRS.				
FUEL TANK AND FILTER	CLEAN					
FUEL TUBE	CHECK	EVERY 24 MO. (REPLACE IF NECESSARY)				
TO BE PERFORMED AT MONTH INDICATED OR HOUR INTERVAL WHICH EVER COMES FIRST						

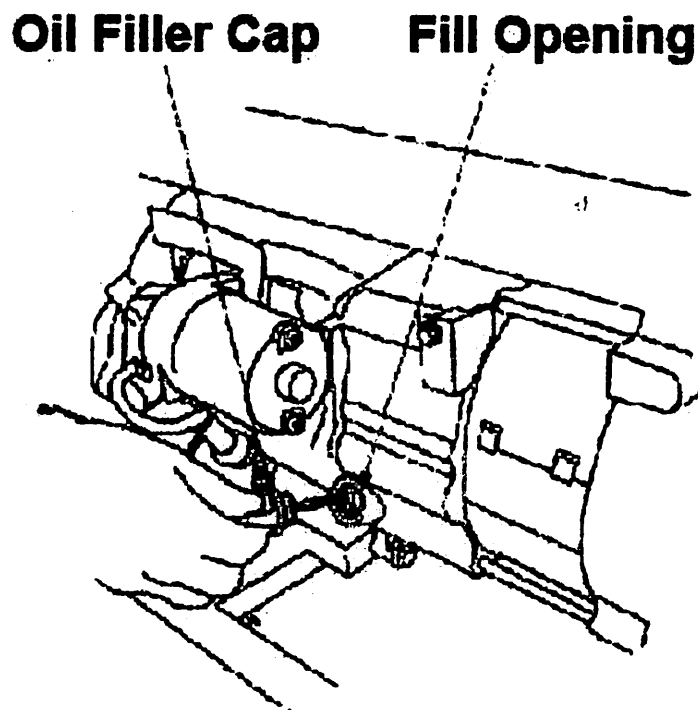
Figure 13 – Maintenance Schedule.

Checking the Oil

The generator is equipped with an automatic shutoff to protect it from running on low oil. Nonetheless, you should check the oil level of the generator before each use to ensure that the generator crankcase has a sufficient amount.

To check the oil level:

1. Make sure the generator is on a level surface.
2. Unscrew the oil filler/dipstick cap (see figure 14).
3. With a dry cloth, wipe the oil off of the stick on the inside of the cap.
4. Insert the dipstick as if you were replacing the cap and then remove again. There should now be oil on the stick. If there is no oil on the stick, or oil only at the very end of the stick you should add oil until the engine crankcase is filled. See "Changing/Adding Oil" in this section.
5. Be sure to replace cap when you are finished checking the oil.



You should check the oil level of your generator according to the maintenance schedule in figure 13. When the oil level is low you will need to add oil until the level is sufficient to run the generator. The oil capacity of your generator engine is listed in figure 15.

Model Number	XP4400EH
Engine Oil Capacity	20 fl. Oz.

Figure 15 – Generator Oil Capacity

Changing the Oil

It is only necessary to drain the oil from the crankcase, other than for regular oil changes, if it has become contaminated with water or dirt. In this case, you can drain the oil from the generator according to the following steps:

1. Place an approved oil disposal container underneath the generator to catch the oil as it drains.
2. Using a 10 mm hex wrench, unscrew the oil drain plug, which is located on the crankcase underneath the oil filler/dipstick cap (see figure 16). Allow all the oil to drain from the generator.
3. Replace the oil drain plug and tighten with a 10 mm hex wrench.

To add oil to the crankcase, follow these steps:

1. Make sure the generator is on a level surface.
2. Unscrew the oil filler/dipstick cap from the engine as shown in figure 14 above.
3. Using a funnel, add motor oil to the crankcase. We recommend SAE 10W30 motor oil for general use. When full, the oil level should come close in the top of the oil fill opening. (See figure 17).

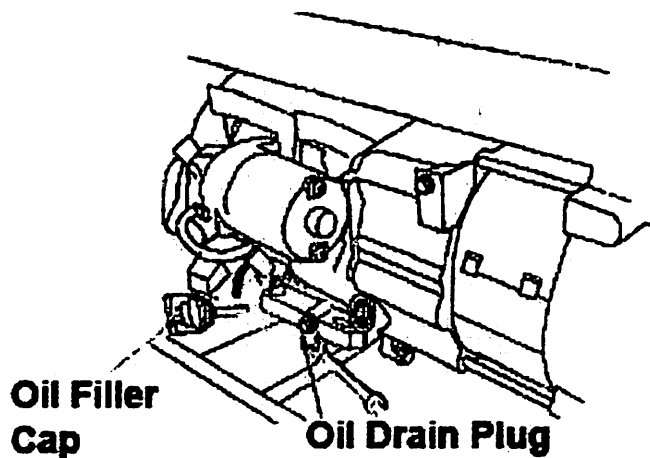


Figure 16: Draining the Oil



Figure 17: Adding Oil

Air Cleaner Maintenance

Routine maintenance of the air cleaner helps maintain proper airflow to the carburetor. Occasionally check that the air cleaner is free of excessive dirt.

1. Unhinge the clasps at the top and bottom of the air cleaner cover (see figure 18).
2. Remove the sponge-like elements from the casing.
3. Wipe the dirt from inside the empty air cleaner casing.
4. Wash the sponge-like elements in household dish detergent and warm water.
5. Allow the elements to dry completely.
6. Soak the dry elements in a small amount of engine oil. Ring out any excess oil.
7. Replace the sponge-like elements in the air cleaner casing and replace the cover.

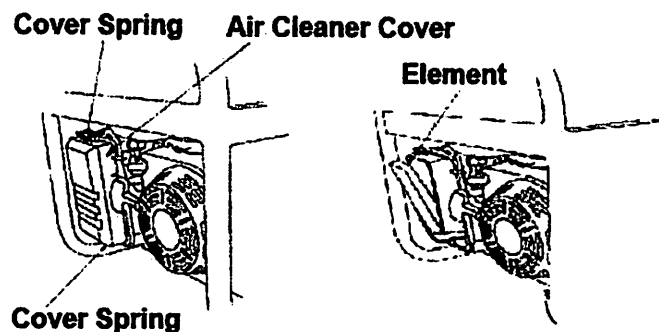


Figure 18 - Removing the Air Cleaner Casing.

Fuel Filter Cup Cleaning

The fuel filter cup is a small well underneath the fuel valve. It helps to trap dirt and water that may be in your fuel tank before it can enter the engine.

To clean the fuel filter cup:

1. Turn the fuel valve to the "OFF" position.
2. Unscrew the fuel filter cup from the fuel valve using a wrench. Turn the valve towards you to unscrew (see figure 19).
3. Clean the cup of all sediment using a rag or brush.
4. Reinstall the fuel filter cup.

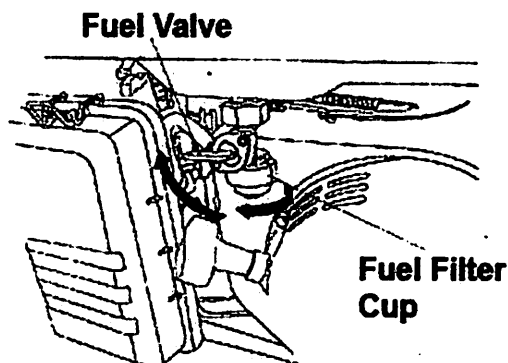


Figure 19 – Removing the Fuel Filter Cup

Spark Plug Maintenance

The spark plug is important for proper engine operation. A good spark plug should be intact, free of deposits, and properly gapped.

To inspect your spark plug:

1. Pull on the spark plug cap to remove it.
2. Unscrew the spark plug from the generator using the spark plug wrench included with this product (see figure 20).
3. Visually inspect the spark plug. If it is cracked or chipped, discard and replace with a new spark plug. We recommend using a F6RTC spark plug such as NGK BPR5ES.
4. Measure the plug gap with a gauge (see figure 21). The gap should be 0.7-0.8 mm (0.028-0.031 in).
5. If you are re-using the spark plug, use a wire brush to clean any dirt from around the spark plug base and then re-gap the spark plug.
6. Screw the spark plug back into its place on the generator using the spark plug wrench.
7. Replace the spark plug cap.

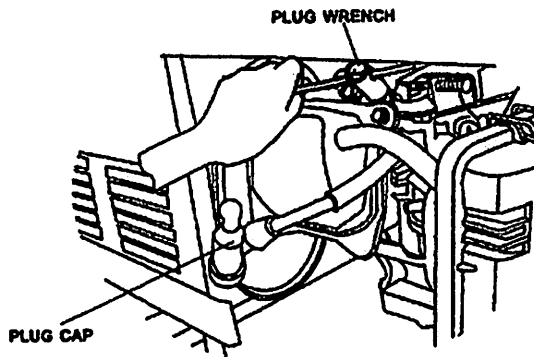


Figure 20- Removing the spark plug

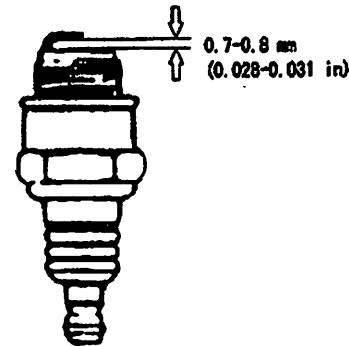


Figure 21- Measuring the spark plug gap

Emptying the Gas Tank

Before storing your generator for extended periods of time, you should drain your generator of gasoline.

To drain the generator of gas:

1. Turn the fuel valve to the "OFF" position.
2. Remove the fuel filter cup (see "Removing the Fuel Filter Cup" earlier in this section).
3. Empty the fuel filter cup of any fuel.
4. With a receptacle underneath the generator to catch the gas, turn the fuel valve to the "ON" position. Drain all the gas from the generator.
5. Turn the fuel valve to the "OFF" position.
6. Replace the fuel filter cup.
7. Store the emptied gasoline in a suitable place.

⚠ CAUTION: Do not store fuel from one season to another.

Storage and Transportation

⚠ CAUTION: Never place any type of storage cover on the generator while it is still hot.

When transporting your generator:

- Empty the gas tank (see "Emptying the Gas Tank" in the "Maintenance" section).
- Disconnect the spark plug.
- Do not obstruct any ventilation openings.
- Keep the generator in a cool dry area.

When storing your generator:

If you plan on starting the unit again the same day:

1. Turn off the main breaker.
2. Allow the unit to run 3 - 5 minutes.
3. Turn off the key.
4. Store.

If you plan on starting the unit again within 30 days:

1. Turn off the main breaker.
2. Allow the unit to run 3 - 5 minutes.
3. Turn off the fuel valve.
4. Allow the unit to stall out.
5. Turn off the key.
6. Add fuel stabilizer to the gas remaining in the tank.
7. Store.

If you do not plan to start the unit for longer than 30 days:

1. Turn off the main breaker.
2. Allow the unit to run 3 - 5 minutes.
3. Turn off the fuel valve.
4. Allow the unit to stall out.
5. Turn off the key.
6. Drain the fuel tank (See "Emptying the Gas Tank" in the "Maintenance" section)
7. Drain the carburetor
 - a. Remove the drain bolt from the carburetor.
 - b. Drain the small amount of remaining fuel from the carburetor bowl.
8. Oil the cylinder
 - a. Remove the spark plug.
 - b. Put 2 tbsp. of 10w30 motor oil directly into the spark plug hole
 - c. Pull the recoil start one time.
 - d. Replace the plug.
9. Remove the battery and place on tender indoors.

Generator Specifications		
AC Rated Wattage	3500W	
AC Surge Wattage	4400W	
AC Rated Voltage	120/240V	
AC Rated Frequency	60 Hz	
AC Phase	Single	
DC Voltage	12V	
DC Amperage	8.3A	
Dimensions (in.)	Length	23.2
	Width	17
	Height	17
Engine Type	4-Stroke OHV Forced-Air	
Ignition System	Non-Contact Transistor	
Displacement	210cc	
Starting Type	Electric	
Fuel Tank Capacity	3.96 US Gal. (15L)	
Oil Capacity	20 fl. oz. (0.6L)	
Run Time @ 50% (Gasoline)	12 hr.	
Run Time @ 50% (Propane)	16 hr. (5 Gallon)	
Noise Level	<69db	

Troubleshooting		
Problem	Cause	Solution
Engine will not start	Engine Switch is "Off"	Set Engine Switch to "Run"
	Fuel Valve is "Closed"	Turn Fuel Valve to "Open"
	Choke is open.	Close the Choke
	Engine is out of fuel.	Add Fuel
	Fuel is old or contaminated.	Change Fuel
	Spark Plug is dirty.	Clean Spark Plug
	Spark Plug is broken.	Replace Spark Plug
	Generator is not level.	Move generator to a level surface
	Oil is low.	Add/Change oil
Engine runs, but there is no electrical output.	Circuit Breaker is "Off"	Turn "On" Circuit Breaker
	Wiring connection is bad.	Replace Extension Cord(s)
	Device connected to generator is Malfunctioning.	Disconnect Malfunctioning Device
Generator runs, but does not support all electrical devices connected.	Generator is overloaded.	Disconnect 1 or more items to reduce the load
	Device connected to generator is bad.	Disconnect Malfunctioning Device
	Air Cleaner is Dirty.	Clean/Replace the Air Filter

Wheel Kit Assembly

The generator includes a wheel kit for easy transportation.

To install the wheel kit:

1. Please the generator on a flat, even surface. Temporarily place blocks under the generator to easy assembly.
- NOTE: DO NOT flip the generator upside down to install the wheel kit.**
2. Secure the support legs to the frame with provided bolts and lock nuts.
(See figure 22)
3. Secure the axle bracket welded to axle the frame with the provided bolts and lock nuts.
(See figure 23)
4. Secure the loose axle bracket to the frame with the provided bolts and lock nuts.
(See figure 24)
5. Slide one wheel over each axle end and secure with the provided retaining pins.
(See Figures 25)
6. Attach the handles to the brackets on the frame using the provided bolts and nuts.
(See Figures 26 and 27)
7. Check that all fasteners are tight.

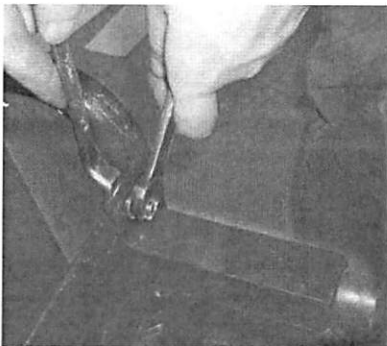


Figure 22



Figure 23



Figure 24



Figure 25



Figure 26

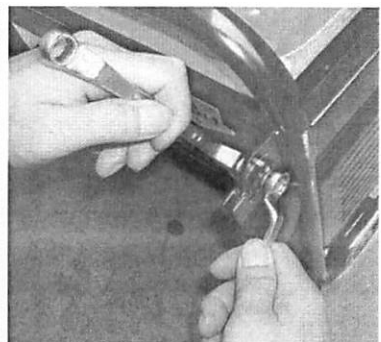
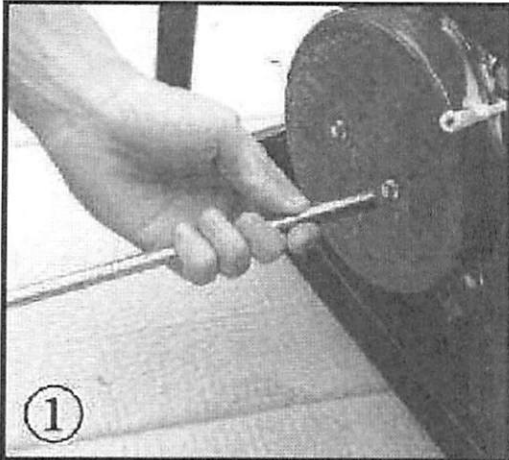
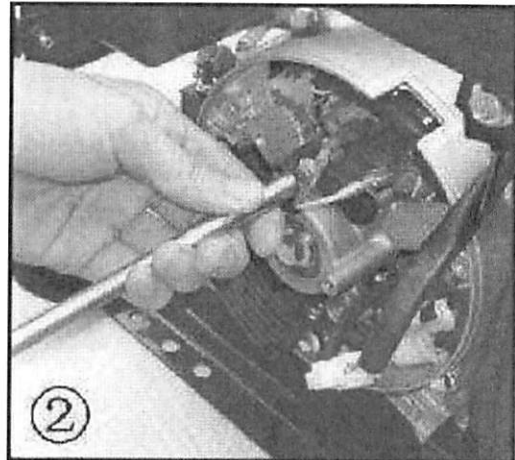


Figure 27

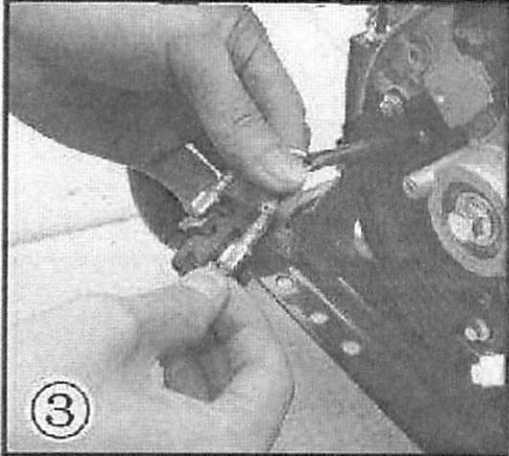
Changing/Inspecting the Carbon Brushes



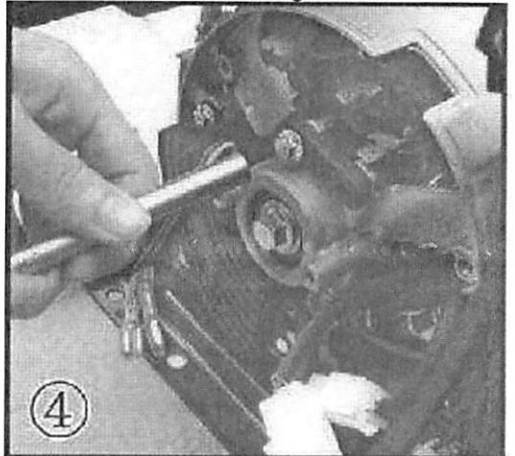
① Remove the 2 bolts on the generator cover.



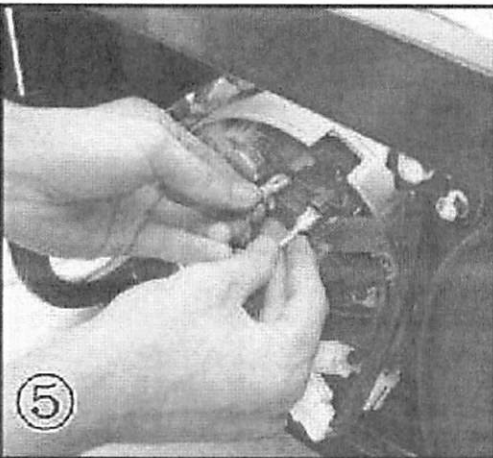
② Remove the bolt holding the carbon brush.



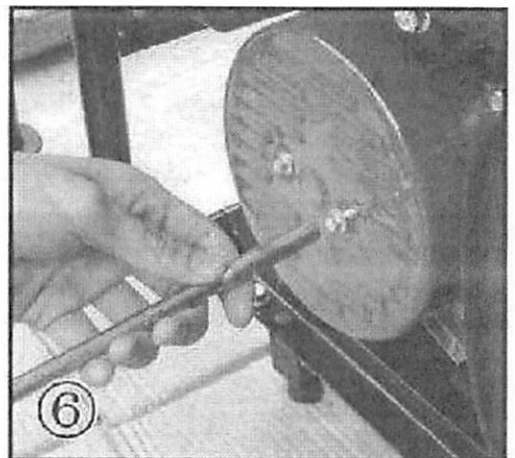
③ Remove the 2 wires from the AVR on the carbon brush.



④ Install a new carbon brush with bolt.

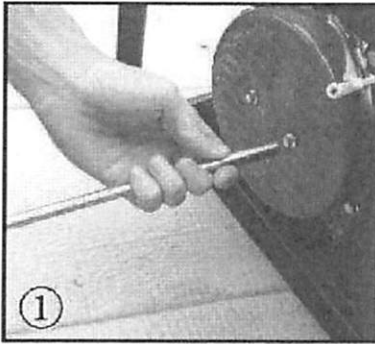


⑤ Insert and connect the 2 wires from the AVR, be sure to connect + and - correctly.

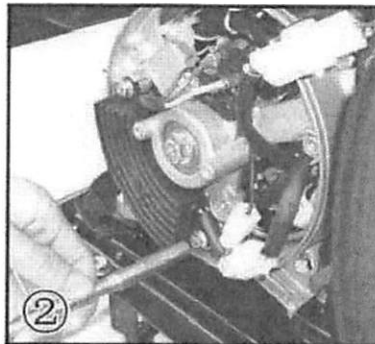


⑥ Replace the back cover of the generator and secure with the 2 bolts.

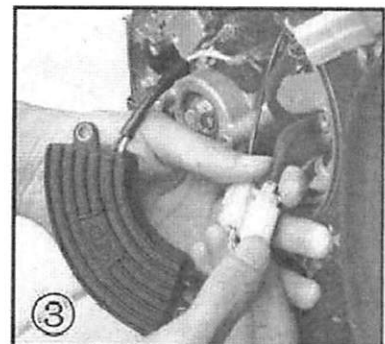
Changing/Inspecting the AVR



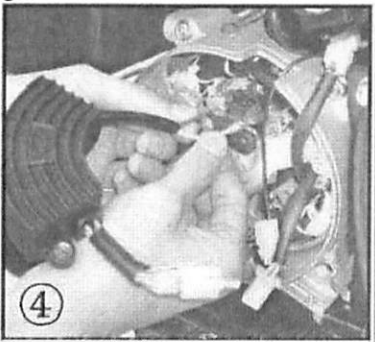
Remove the 2 bolts on the generator cover.



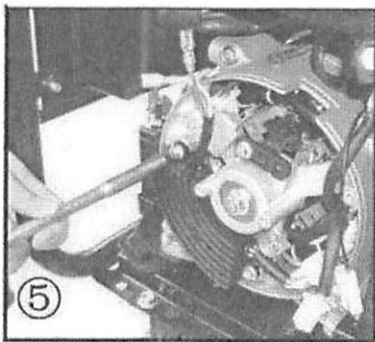
Remove the 2 bolts holding the AVR.



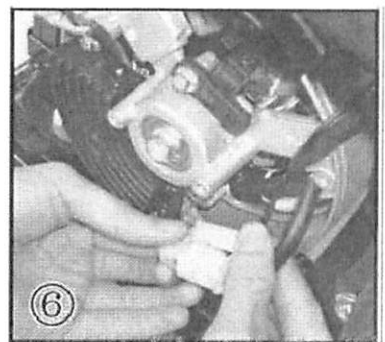
Disconnect the wire clip.



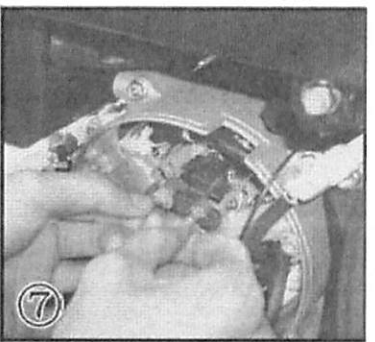
Remove the 2 wires from the AVR on the carbon brush.



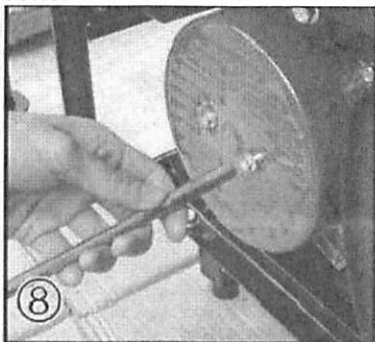
Install the new AVR with the 2 bolts.



Reconnect the wire clip.



Insert and connect the 2 wires from the AVR, be sure to connect + and - correctly

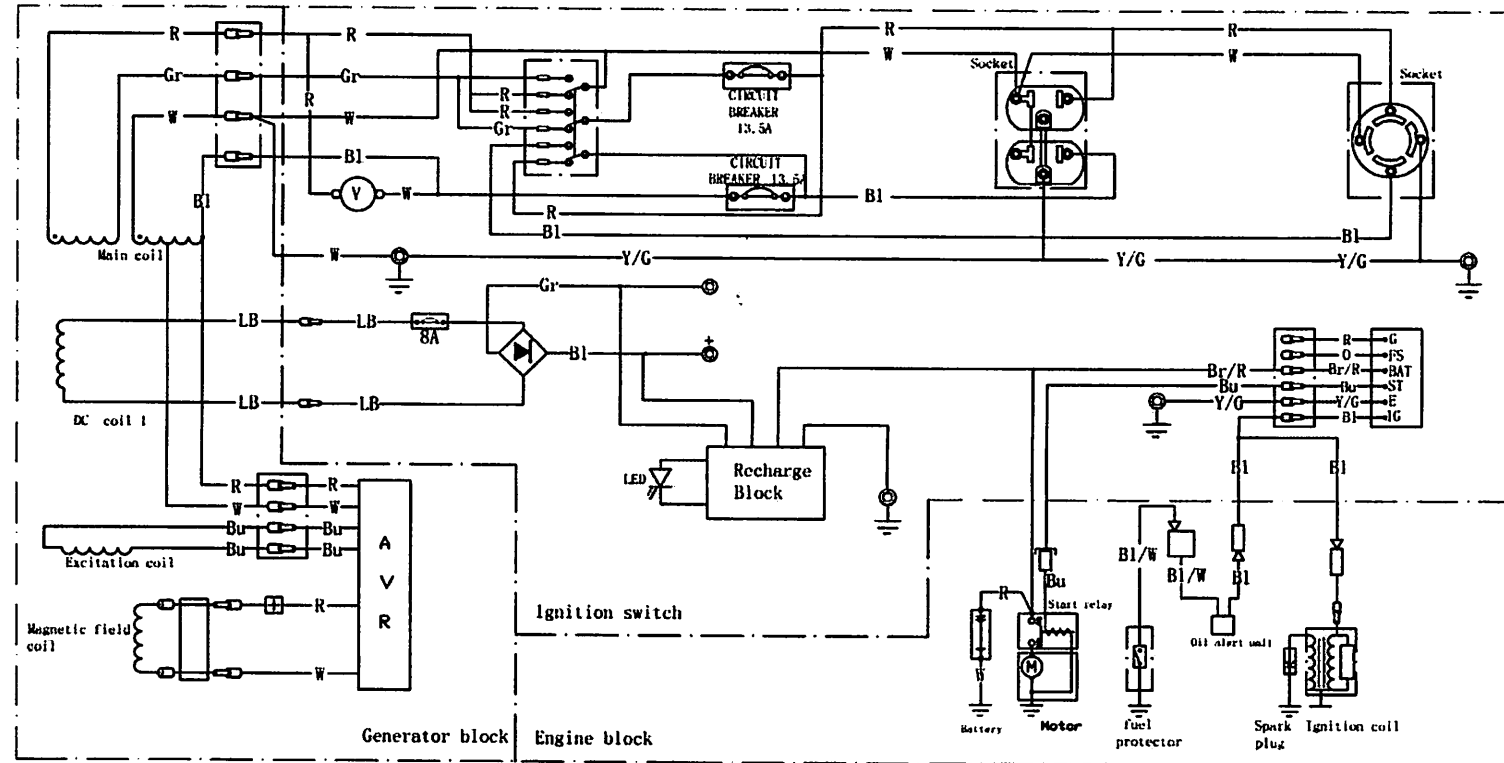


Replace the back cover of the generator and secure with the 2 bolts.

Maintenance Log

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Wiring Diagram



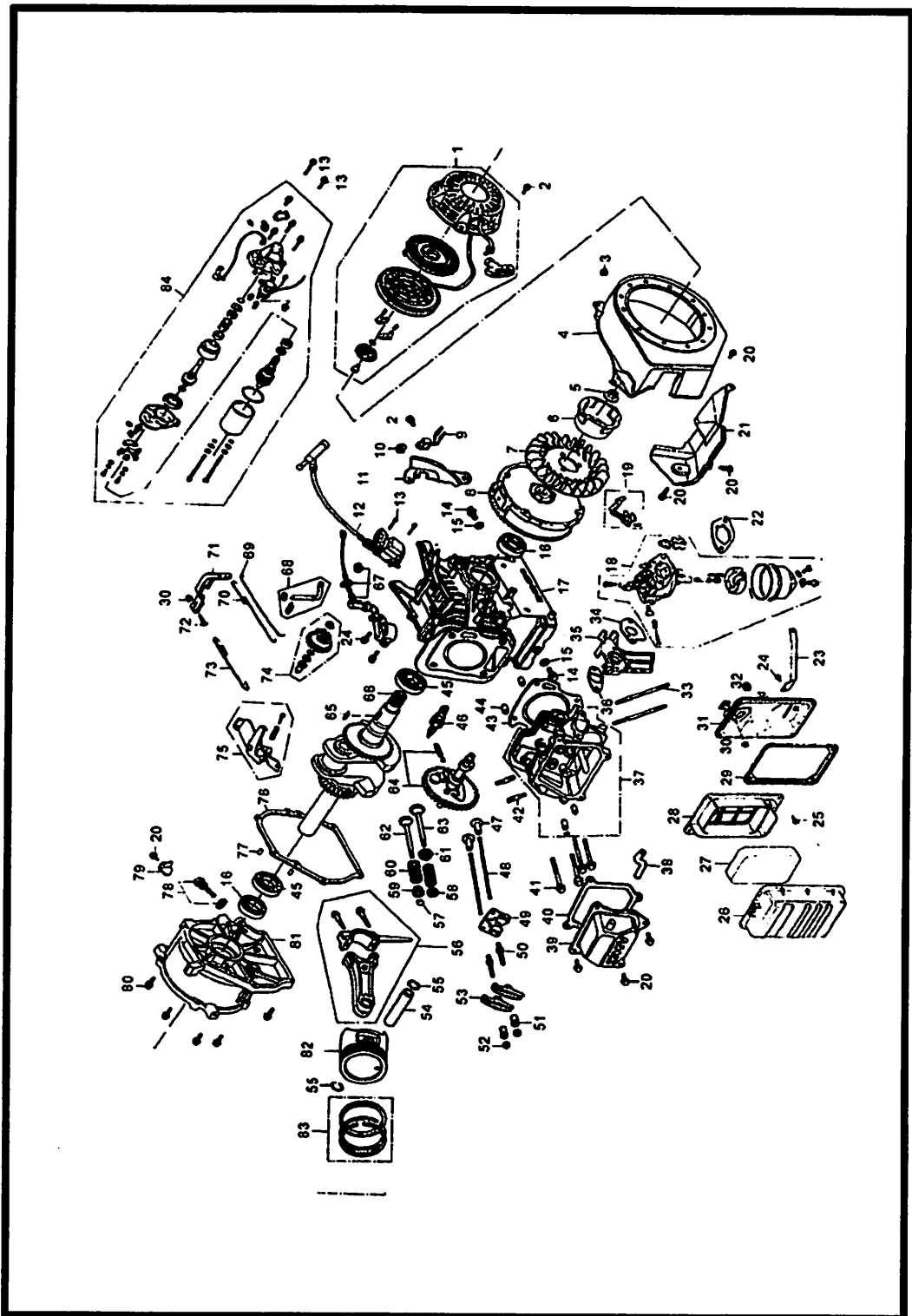
B1	Black	Br	Brown
O	Orange	Br/R	Brown/Red
Bu	Blue	LB	Light blue
Gr	Gray	Y/G	Yellow/Green
R	Red	W	White

Ignition switch connecting

	IG	E	BAT	ST	FS	G
OFF	○				○	
ON						
Start			○			

WIRING DIAGRAM OF 120V/240V GENERATOR SET

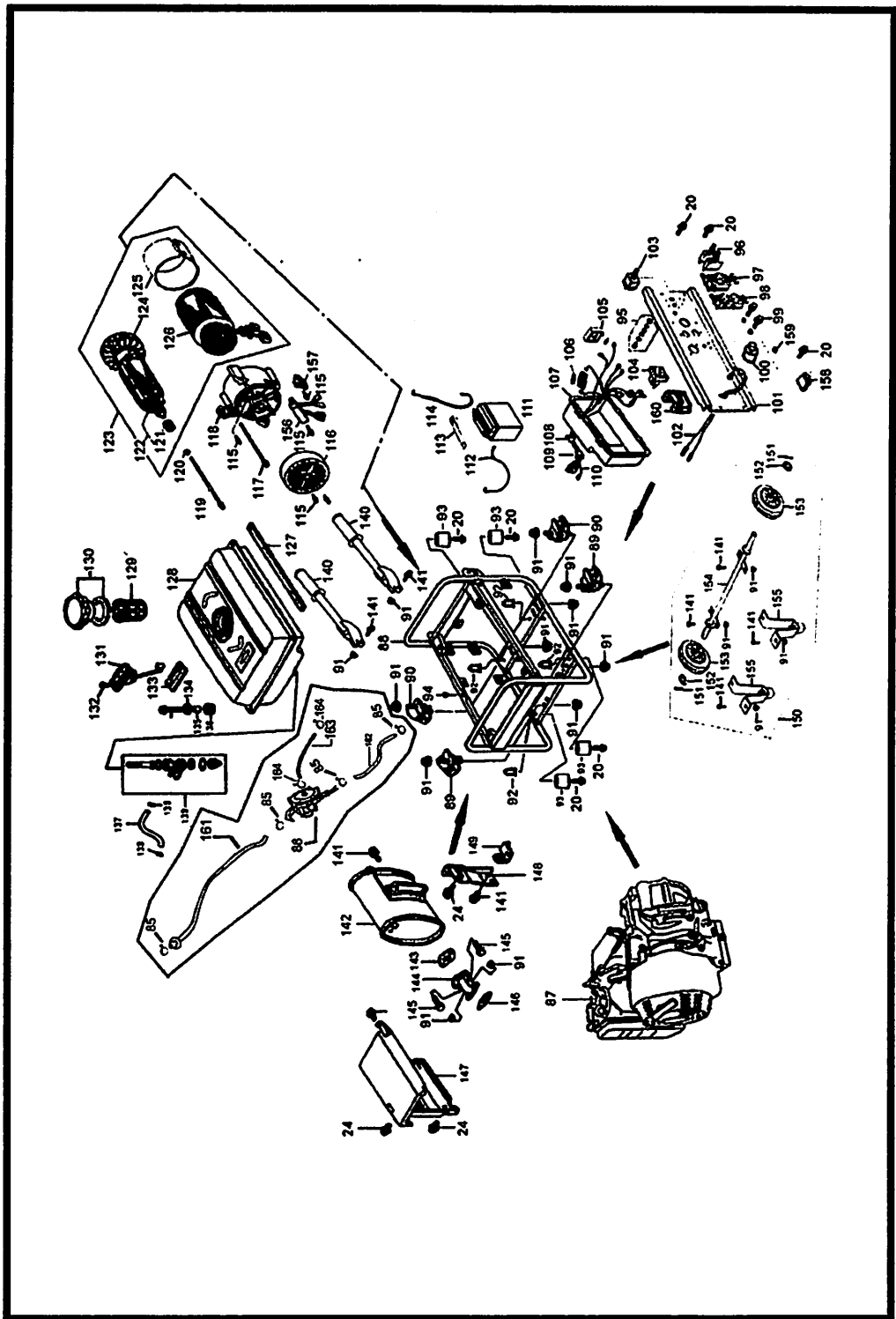
Engine Parts



Part #	Description	Qty	Item #	Cross-Reference
1	Recoil Starter (Complete)	1	XP4400EH-1	DJ168F-16121-K
2	Flange Bolt (M6x8)	4	XP4400EH-2	GBT5787-B6-8
3	Grommet, Drain Hole	1	XP4400EH-3	DJ168F-16118
4	Flywheel Fan Cover (Comp)	1	XP4400EH-4	DJ170N-16121-A
5	Flange Nut (M14)	1	XP4400EH-5	GBT8177/10-N-14
6	Starter Pulley	1	XP4400EH-6	DJ168F-16000-A
7	Flywheel Fan Cover (Comp)	1	XP4400EH-7	DJ168F-16002-A
8	Flywheel	1	XP4400EH-8	DJ168F-16200-I
9	Low Oil Switch	1	XP4400EH-9	DJ168F-18300-A
10	Low Oil Switch Clip	1	XP4400EH-10	XP4400EH-10
11	Side Plate	1	XP4400EH-11	DJ170S-11400-A
12	Ignition Coil Assy	1	XP4400EH-12	DJ168F-18100-C
13	Flange Bolt (M6x25)	2	XP4400EH-13	GBT5787-B6-25
14	Drain Lug Bolt	2	XP4400EH-14	DJ168F-11004-A
15	Drain Lug Washer	2	XP4400EH-15	DJ168F-11005-A
16	Oil Seal (25x41x6)	2	XP4400EH-16	DJ168F-11014-A
17	Crankcase Assy	1	XP4400EH-17	DJ170F-11100-C
18	LPG/Gasoline Carburetor Assy	1	XP4400EH-18	DJ170FD-14100-C
19	Carburetor Choke Lever	1	XP4400EH-19	DJ168F-14119
20	Flange Bolt (M6x12)	11	XP4400EH-20	GBT5787-B6-16
21	Shroud Complete	1	XP4400EH-21	DJ168F-11012-A
22	Gasket, Carb to Air	1	XP4400EH-22	DJ168F-14027-A
23	Air Cleaner Bracket	1	XP4400EH-23	DF2500H-14205-A
24	Flange Bolt (M6x12)	3	XP4400EH-24	GBT5787-B6-12
25	Bolt (M5x12)	4	XP4400EH-25	GBT5787-B5-14
26	Air Cleaner Cover	1	XP4400EH-26	DJ168F-14204
27	Air Cleaner Element	1	XP4400EH-27	DJ170F-14201
28	Air Cleaner Element Holder	1	XP4400EH-28	DJ168F-14202
29	Air Cleaner Seal	1	XP4400EH-29	DJ168F-14206
30	Flange Nut (M6)	2	XP4400EH-30	GBT6177-N-6
31	Air Cleaner Case (Comp)	1	XP4400EH-31	DJ168F-14205-A
32	Grommet, Fender	1	XP4400EH-32	DJ168F-14014-A
33	Guide Bolt (M6x94)	2	XP4400EH-33	DJ168FD-14001-A
34	Carburetor Gasket	1	XP4400EH-34	DJ168F-14005-A
35	Carburetor Heat Isolator	1	XP4400EH-35	DJ168F-14004-A
36	Carburetor Heat Isolator Gasket	1	XP4400EH-36	DJ168F-14003-B
37	Cylinder Head (Comp)	1	XP4400EH-37	DJ170F-11200-B
38	Cylinder Head Breather	1	XP4400EH-38	DJ168FD-11013-A
39	Cylinder Head Cover (Comp)	1	XP4400EH-39	DJ168F-11300-C
40	Cylinder Head Cover Gasket	1	XP4400EH-40	DJ168F-11011-A
41	Flange Bolt (M8x60)	4	XP4400EH-41	GBT5787-B8-60
42	Guide Bolt (M8x32)	2	XP4400EH-42	DJ168F-14002-A

Part #	Description	Qty	Item #	Cross-Reference
43	Cylinder Head Gasket	1	XP4400EH-43	DJ170F-11010-C
44	Cylinder Head Bolt Guide	2	XP4400EH-44	DJ168F-11009-A
45	Radial Ball Bearing (6025)	2	XP4400EH-45	GB276-89-6205
46	Spark Plug	1	XP4400EH-46	DJ168F-18500-A
47	Valve Tappet	2	XP4400EH-47	DJ170F-13009-A
48	Push Rod	2	XP4400EH-48	DJ170F-13008-A
49	Push Rod Guide Plate	1	XP4400EH-49	DJ168F-13300-A
50	Rocker Arm Pivot Bolt	2	XP4400EH-50	DJ168F-13202-A
51	Rocker Arm Nut	2	XP4400EH-51	DJ168F-13203-A
52	Rocker Arm Pivot Bolt Nut	2	XP4400EH-52	DJ168F-13204-A
53	Rocker Arm	2	XP4400EH-53	DJ168F-13201-A
54	Piston Pin	1	XP4400EH-54	DJ170F-12002-A
55	Piston Pin Clip	2	XP4400EH-55	DJ168F-12003-A
56	Connecting Rod	1	XP4400EH-56	DJ170F-12200-B
57	Valve Cap	1	XP4400EH-57	DJ168F-13006-A
58	Intake Valve Spring Retainer	1	XP4400EH-58	DJ168F-13004-A
59	Exhaust Valve Spring Retainer	1	XP4400EH-59	DJ168F-13005-A
60	Valve Spring	2	XP4400EH-60	DJ168F-13003-A
61	Valve Spring Seat	1	XP4400EH-61	DJ168F-13010-A
62	Exhaust Valve	1	XP4400EH-62	DJ168F-13001-A
63	Intake Valve	1	XP4400EH-63	DJ168F-13002-A
64	Camshaft	1	XP4400EH-64	DJ168F-13100-B
65	Crankshaft Key (25x18)	1	XP4400EH-65	DJ168F-12104
66	Crankshaft	1	XP4400EH-66	DJ168F-12100-BB
67	Low Oil Sensor	1	XP4400EH-67	DJ168F-18200-A
68	Governor Shaft	1	XP4400EH-68	DJ168F-15001-A
69	Governor Arm Rod	1	XP4400EH-69	DJ168F-15006-A
70	Throttle Return Spring	1	XP4400EH-70	DJ170F-15008-A
71	Governor Arm	1	XP4400EH-71	DJ168F-15004-A
72	Governor Arm Bolt	1	XP4400EH-72	DJ168F-15005-A
73	Governor Spring	1	XP4400EH-73	DJ170F-15007-A
74	Governor Assembly (Comp)	1	XP4400EH-74	DJ168F-15100-A
75	Throttle Stop Assy	1	XP4400EH-75	DJ168FD-15200-A
76	Crankcase Cover Gasket	1	XP4400EH-76	DJ170F-11003-B
77	Crankcase Bolt Guide (8x14)	2	XP4400EH-77	DJ168F-11002-F
78	Oil Fill Cap	1	XP4400EH-78	DJ168F-11007-A
79	Plate	1	XP4400EH-79	DF1800H-33016-A
80	Flange Bolt (M8x32)	6	XP4400EH-80	GBT5787-B8-35
81	Crankcase Cover	1	XP4400EH-81	DJ168FD-11001-C
82	Piston	1	XP4400EH-82	DJ170F-12001-B
83	Piston Ring Set	1	XP4400EH-83	DJ170F-12300-A
84	Starter Motor	1	XP4400EH-84	DJ168F-18600-A

Other Generator Parts



Other Generator Parts

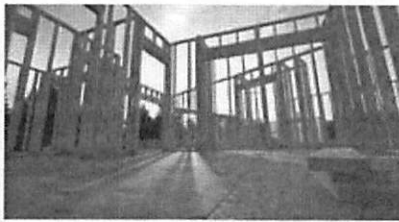
Part #	Description	Qty	Item #	Cross-Reference
85	Clip, Tube	4	XP4400EH-85	XP4400EH-85
86	Propane Regulator / Release Valve	1	XP4400EH-86	XP4400EH-86
87	Gasoline Engine Complete	1	XP4400EH-87	DJ170FD-8D
88	Generator Frame Complete	1	XP4400EH-88	XP4400E-31100-BK
89	Vibration Mount A	2	XP4400EH-89	DF2500H-31201-A
90	Vibration Mount B	2	XP4400EH-90	DF2500H-31202-A
91	Flange Nut (M8)	18	XP4400EH-91	GBT6177-N-8
92	Flange Nut (M8)	4	XP4400EH-92	GBT889-N-8
93	Rubber Foot, Frame	4	XP4400EH-93	XP4400EH-93
94	Fuel Tank Rubber Pad	2	XP4400EH-94	DF2500H-14304-A
95	Earth Terminal (Complete)	1	XP4400EH-95	34107
96	Circuit Breaker (15A 240v)	1	XP4400EH-96	34206-100
97	Receptacle (30A)	1	XP4400EH-97	34204-003
98	Receptacle (20A, Duplex)	2	XP4400EH-98	34204-005
99	DC Output Post (Set)	2	XP4400EH-99	34204-038
100	Engine Switch (Key)	1	XP4400EH-100	34203-002
101	Control Panel Face, Metal Only	1	XP4400EH-101	**SEE REF #
102	Sub-Wiring Harness	1	XP4400EH-102	634213-002
103	Voltage Selection Switch	1	XP4400EH-103	34202-006
104	Voltmeter	1	XP4400EH-104	34205-001
105	Diode Assy	1	XP4400EH-105	34210-001
106	Fuse	1	XP4400EH-106	XP4400EH-106
107	Control Panel Rear Cover	1	XP4400EH-107	34102-A
108	Rubber Boot, Main Wiring Harness	1	XP4400EH-108	34109
109	Rubber Boot, Generator AC Out	1	XP4400EH-109	34117
110	Main Wiring Harness	1	XP4400EH-110	34212-001
111	Battery (7Ah 12V DC)	1	XP4400EH-111	31300-001
112	Positive Battery Cable	1	XP4400EH-112	31038-001
113	Battery Support Bar	1	XP4400EH-113	DF1800H-31033-A
114	Negative Battery Cable	1	XP4400EH-114	31040-001
115	Flange Bolt (M5x12)	2	XP4400EH-115	GBT5789-B5-16
116	Generator End Cover	1	XP4400EH-116	DF1800H-33006-B
117	Flange Bolt (M6x125)	4	XP4400EH-117	DF3500H-33015-A
118	Generator End Support	1	XP4400EH-118	DF1800H-33005-A
119	Bolt (M8x180)	1	XP4400EH-119	DF1800H-33003-A
120	Plain Washer (10)	1	XP4400EH-120	GBT193-LW-8
121	Bearing 6204-2RS	1	XP4400EH-121	GBT276-89-6204
122	Rotor (Comp)	1	XP4400EH-122	DF3500H-33110-B
123	Stator and Rotor (Comp)	1	XP4400EH-123	DF3000H3103-B-23602
124	Generator Fan	1	XP4400EH-124	DF2500H-33023
125	Stator Cover	1	XP4400EH-125	DF3500H-33129
126	Stator (Comp)	1	XP4400EH-126	DF3500H-33120
127	Fuel Tank Rubber Pad	1	XP4400EH-127	DF2500H-14322-D
128	Fuel Tank	1	XP4400EH-128	DF2500H-14300-B
129	Fuel Tank Filler Cup	1	XP4400EH-129	14307
130	Fuel Tank Cap	1	XP4400EH-130	14306
131	Fuel Tank Sensor (Complete)	1	XP4400EH-131	14303
132	Screw (M5x10)	2	XP4400EH-132	GBT819-B-5
133	Fuel Tank Sensor Gasket	1	XP4400EH-133	14313
134	Washer	4	XP4400EH-134	14311
135	Collar	4	XP4400EH-135	14305
136	Cushion	4	XP4400EH-136	14304
137	Gas Tube (4.5x165)	1	XP4400EH-137	DF188FD-14007-C
138	Tube Clip	2	XP4400EH-138	DJ168F-14008-A
139	Fuel Valve	1	XP4400EH-139	DF2500H-14302-A
140	Handles	2	XP4400EH-140	DF3800H-31058-C
141	Flange Bolt (M8x16)	17	XP4400EH-141	GBT889-N-8X20
142	Muffler	1	XP4400EH-142	DH2500H-14400-E
143	Muffler Gasket	1	XP4400EH-143	DJ168F-14008-A
144	Exhaust Pipe	1	XP4400EH-144	DF2500H-14009
145	Flange Bolt (M8x25)	2	XP4400EH-145	GBT87-B-6
146	Exhaust Pipe Gasket	1	XP4400EH-146	DJ168F-14010-A
147	Muffler Heat Shield	1	XP4400EH-147	DF2500H-14018-B
148	Muffler Bracket	1	XP4400EH-148	XP4400E-149
149	Muffler Bracket Plate	1	XP4400EH-149	XP4400E-149
150	Wheel Kit (Assy)	1	XP4400EH-150	XP4400E-WK
151	Wheel Retaining Pin	2	XP4400EH-151	DF2500H-31019-B
153	Wheel, Semi-Solid 8"	2	XP4400EH-153	31017-F
154	Wheel Shaft	1	XP4400EH-154	DF3000H-31018-F
155	Wheel Shaft Bracket	2	XP4400EH-155	DF3000H-31070-E
156	Voltage Regulator	1	XP4400EH-156	DF2500H-33011-A
157	Brush (Assy)	1	XP4400EH-157	DF3500H-33001
158	Circuit Protector (10A, DC)	1	XP4400EH-158	34208-004
159	Recharge Indicator LED	1	XP4400EH-159	XP4400E-159
160	12V DC Regulator	1	XP4400EH-160	34224-001
161	Propane Hose w/ Collar	1	XP4400EH-161	XP4400E-161
162	Propane Hose to Carburetor A	1	XP4400EH-162	XP4400E-162
163	Propane Hose to Carburetor B	1	XP4400EH-163	XP4400E-163
164	Propane Hose Clip (8)	2	XP4400EH-164	XP4400E-164



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Recreation



Construction



Portable Power



Ice Storms



Hurricanes



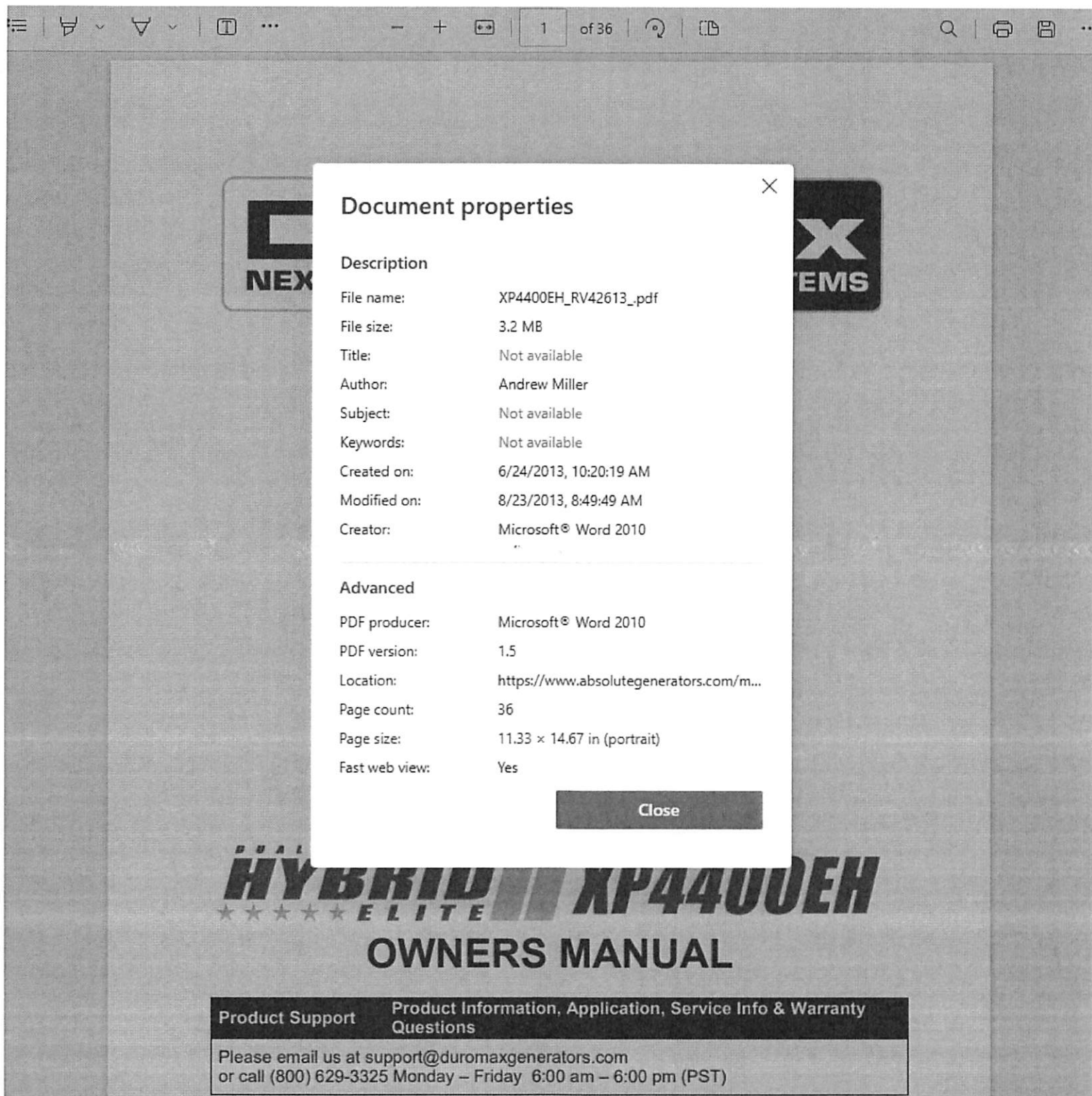
Electrical Storms

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EXHIBIT J



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EXHIBIT 1012



US005718265A

United States Patent [19]

Elsdon et al.

[11] Patent Number: 5,718,265
[45] Date of Patent: Feb. 17, 1998

[54] CAP AND SHIELD ASSEMBLY

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Arthur S. Cornford, Mississauga, both
of Canada

[73] Assignee: Emco Wheaton Fleet Fueling, Corp.,
Oakville, Canada

[21] Appl. No.: 393,674

[22] Filed: Feb. 24, 1995

[51] Int. Cl.⁶ F16L 55/10

[52] U.S. Cl. 138/89; 285/45; 285/901;
292/DIG. 4; 49/507

[58] Field of Search 285/901, 325,
285/45; 292/DIG. 4; 138/94.5; 49/171,
208, 385, 507

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Primary Examiner—Dave W. Arola

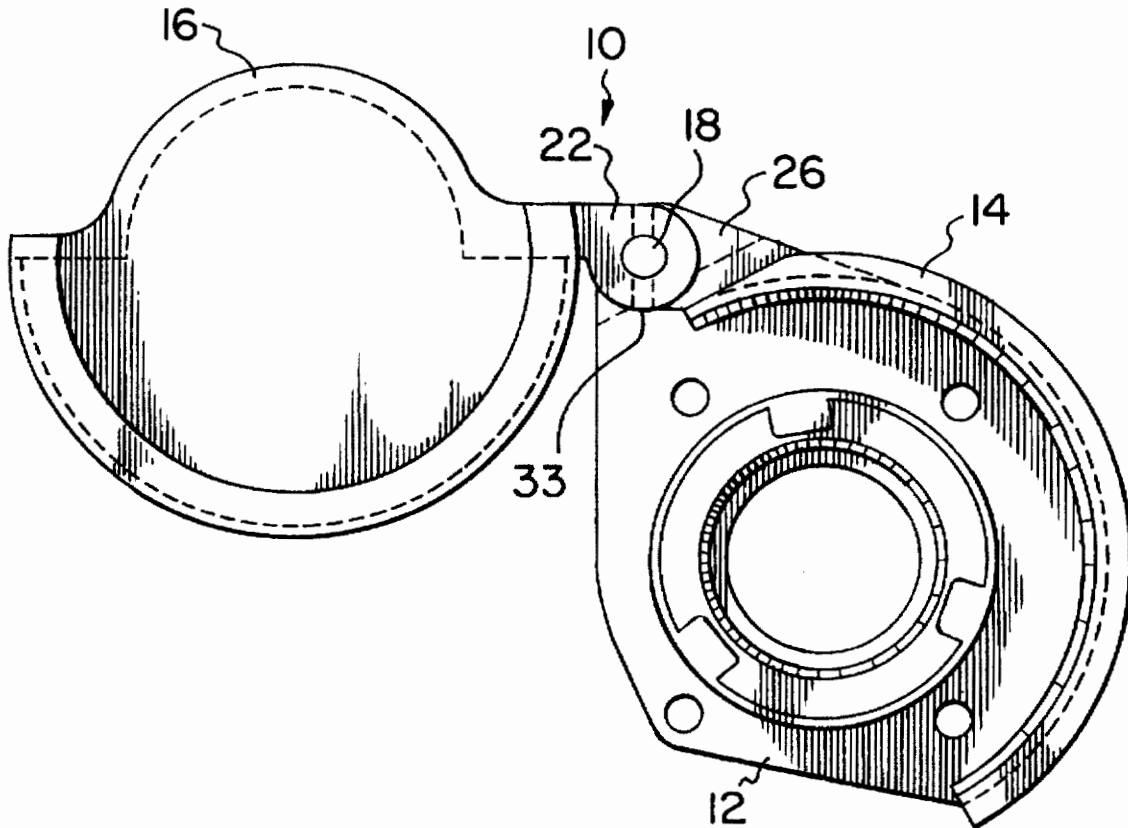
Attorney, Agent, or Firm—Evenson, McKeown, Edwards &
Lenahan P.L.L.C.

[57]

ABSTRACT

A cap and shield assembly for a fluid conduit coupler has a shield and a cap hingedly connected to the shield with a shaft having a cross-pin extending therethrough. A cam bushing in the bore of the shield has a cam surface which coacts with the cross-pin to provide a positive closed position for the cap relative to the shield. Preferably, the cam bushing also provides a positive open position. The cap and shield assembly is particularly advantageous for couplers having a dry-break interface because the cap is readily moved between open and closed positions and operators will be more inclined to use the cap after fluid transfer. Shrouds on the cap and the shield coact to protect the coupler interface when the cap is in the closed position thereby protecting the dry-break interface from contamination by road and environmental debris. This is particularly advantageous compared to the dust cap of the prior art which tends not to be used for its intended purpose of protecting the fluid conduit coupler.

25 Claims, 6 Drawing Sheets



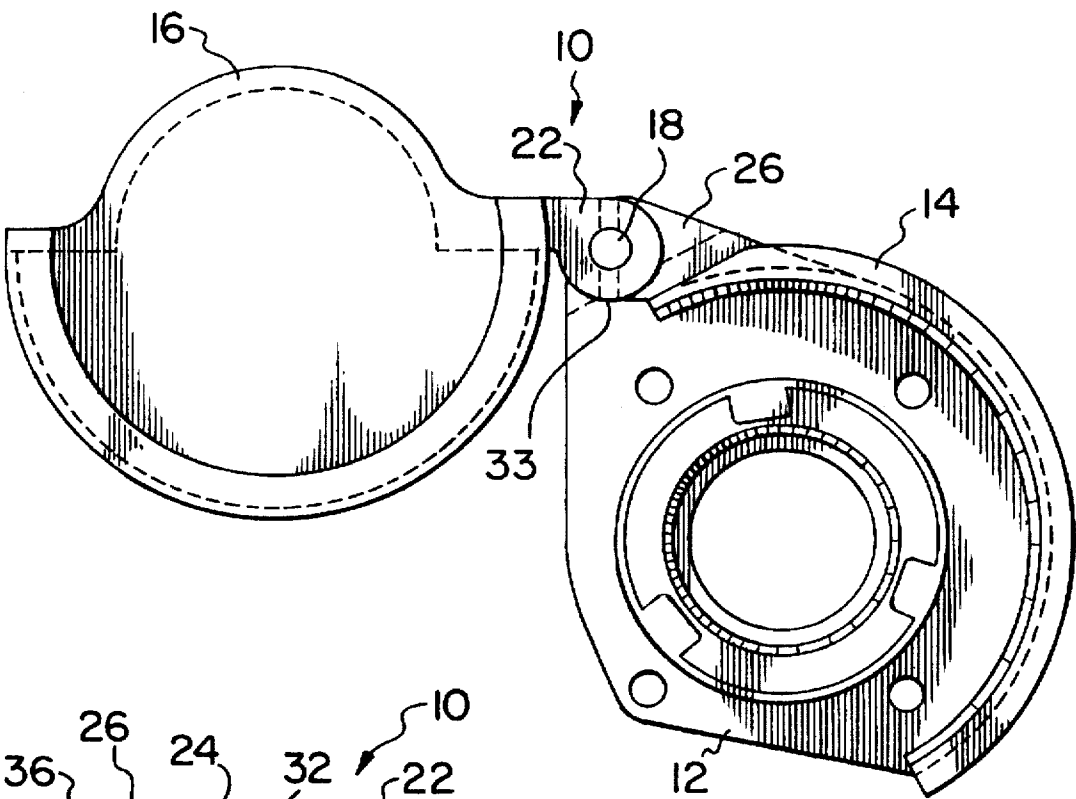


FIG. 1

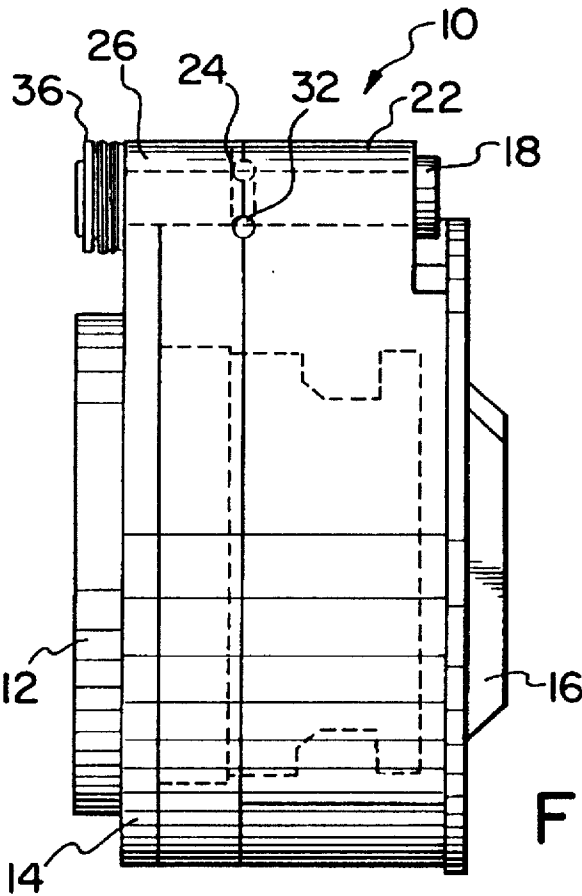


FIG. 2

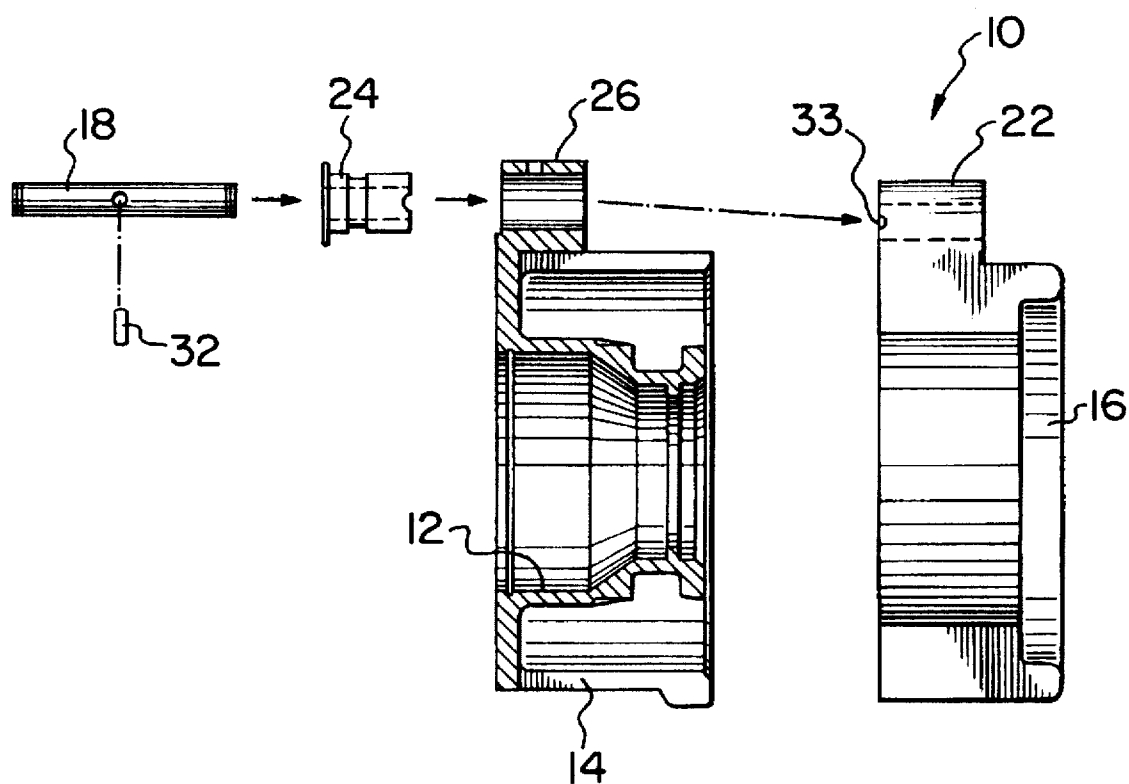


FIG. 3

FIG. 5

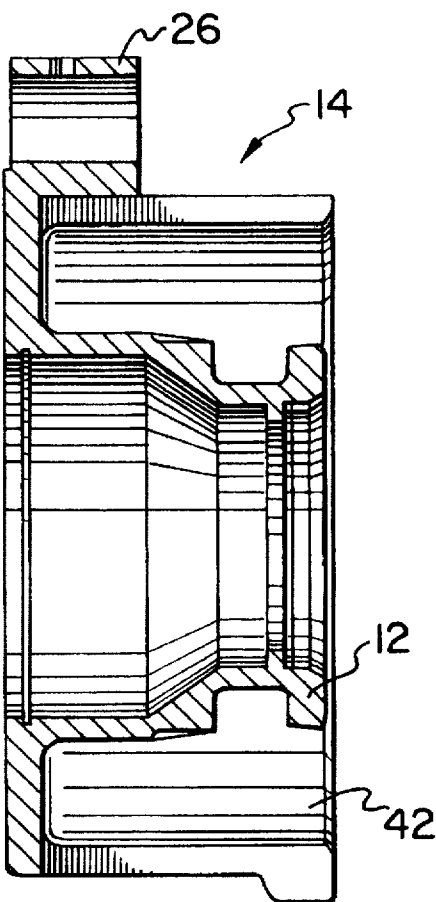
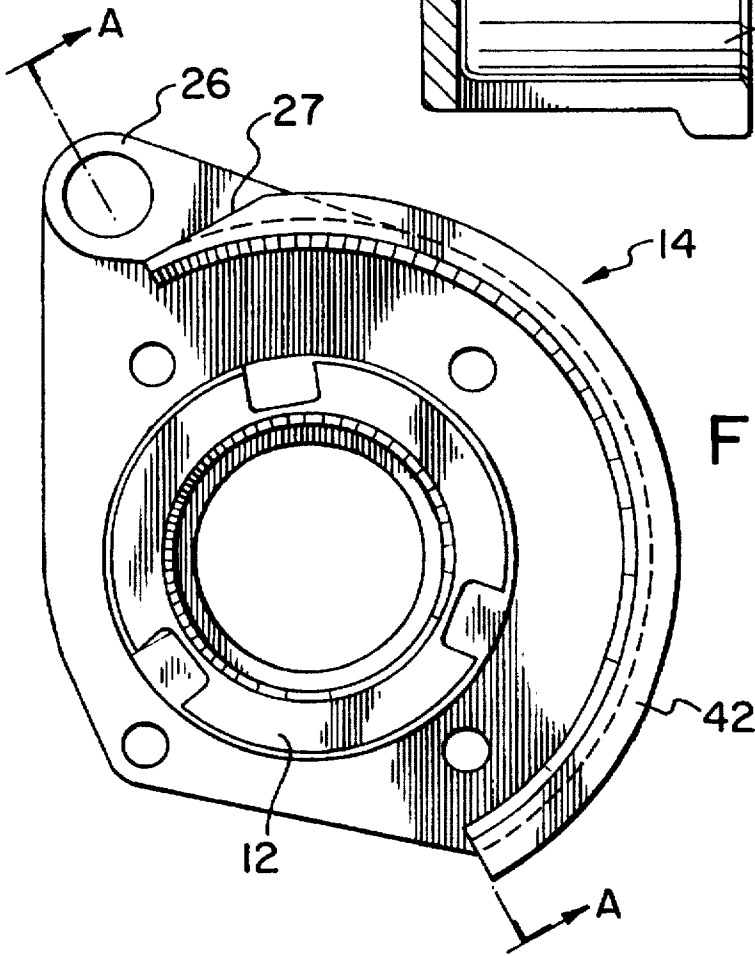


FIG. 4



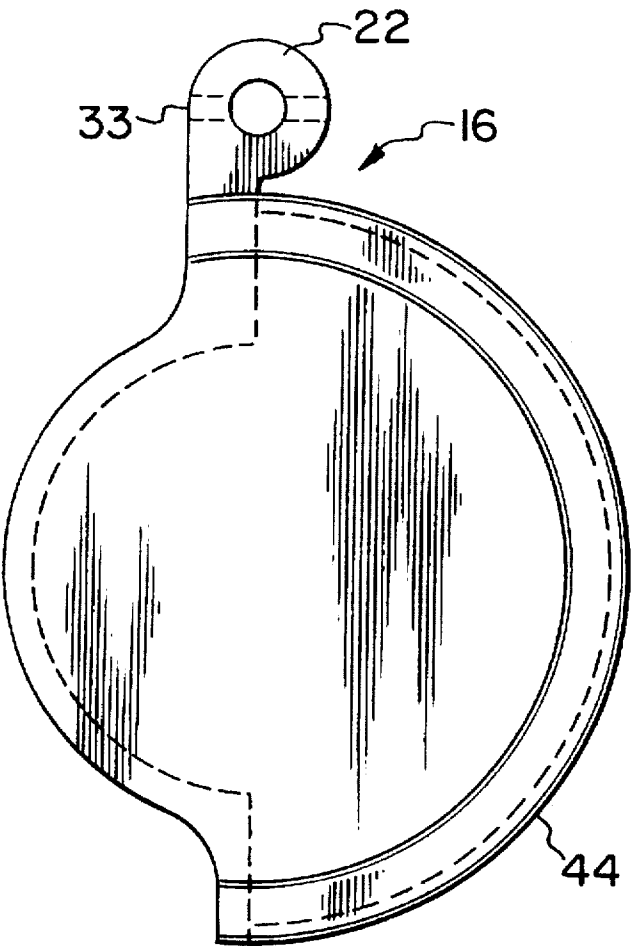
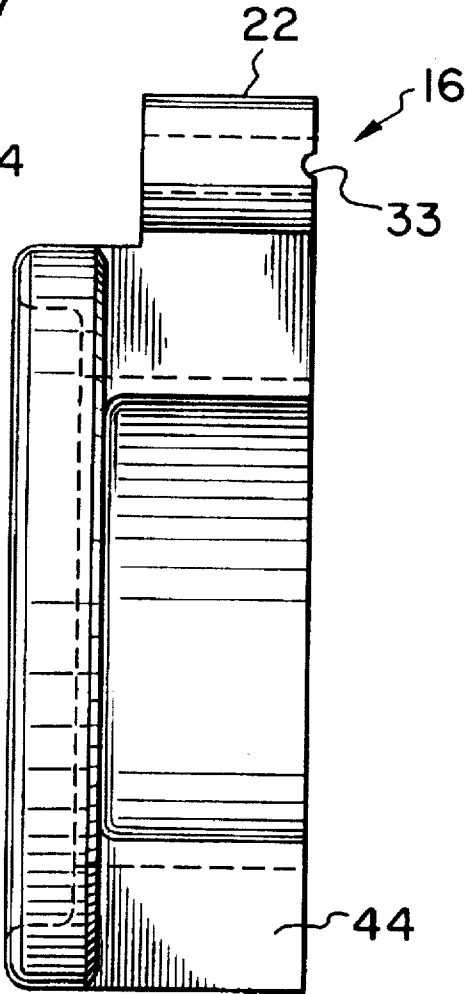


FIG. 6

FIG. 7



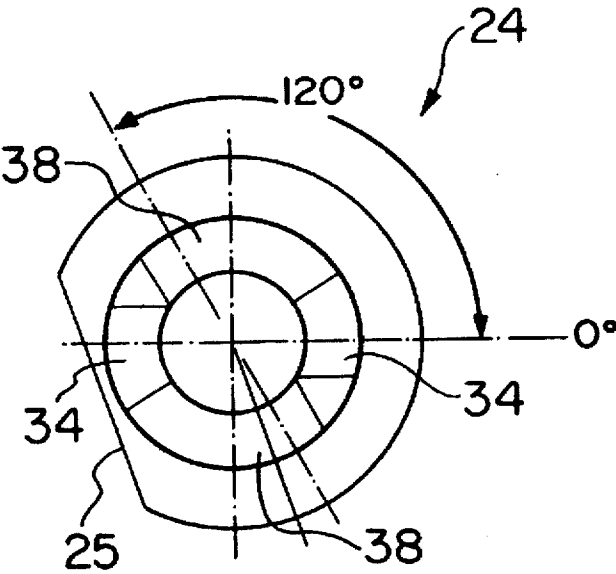


FIG. 8B

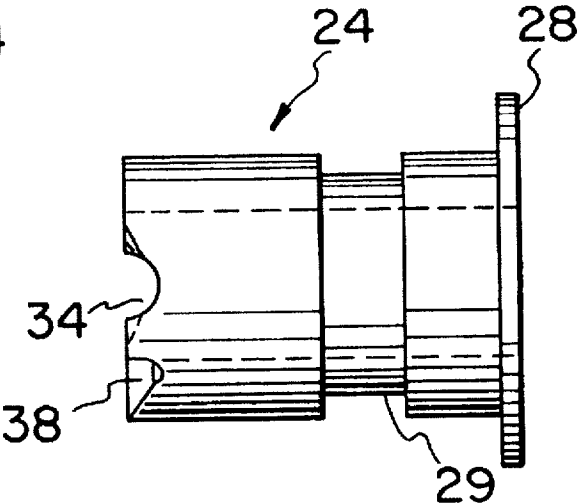


FIG. 8A

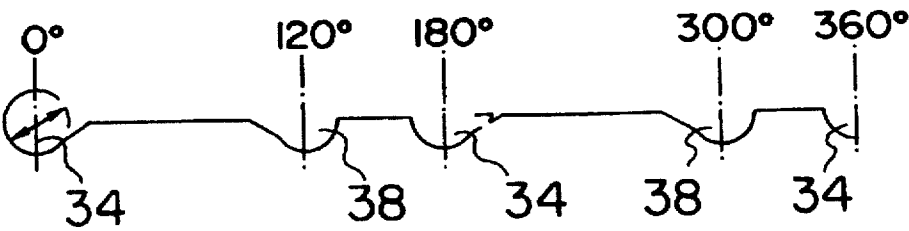
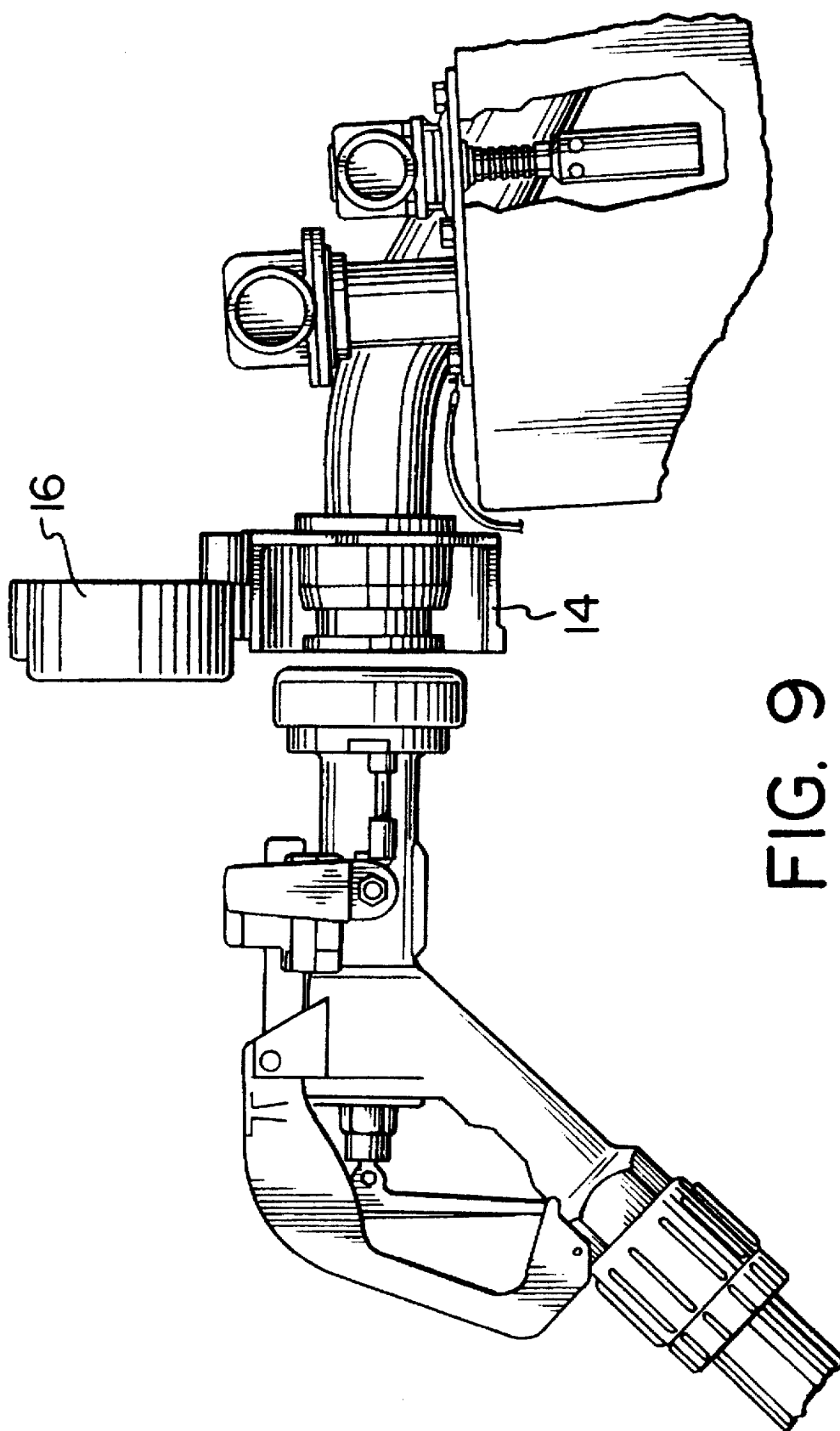


FIG. 8C



CAP AND SHIELD ASSEMBLY

FIELD OF THE INVENTION

The present invention relates to the field of fluid transfer systems and in particular to a cap and shield assembly for a fluid conduit coupler, and more particularly for a coupler having a dry-break interface.

BACKGROUND OF THE INVENTION

Certain fluid conduits and particularly those for transferring flammable or other hazardous fluids, such as fuel, pose potential safety and environmental hazards in the event of leakage from the fluid conduit. For example, in the refuelling of fleet vehicles, such as buses and trucks, it is desirable to deliver fuel at a high flow rate to reduce the time required for refuelling. However, there is a potential safety and environmental hazard if fuel spills from the fuel tank, for example by overflowing, or if fuel escapes from the fuel nozzle when it is not inserted into the fuel tank. There is also a danger that fuel may foam or splash out of the tank during refuelling, especially at high flow rates.

Accordingly, it is recognized that couplers between fluid conduit sections should be capable of coupling and uncoupling while preventing fluid leakage. Such couplers are frequently referred to as "dry-break couplers" and are provided with valves which must be closed before the couplers can be disconnected and which cannot be operated until the couplers are connected. In this way, dry-break couplers inhibit leakage of fluid, for example fuel, from a nozzle and/or a fluid reservoir.

U.S. Pat. No. 5,078,170 (Jan. 7, 1992, Emco Wheaton, Inc.) relates to a coupler for a fluid conduit. The coupler is a dry-break coupler and is specifically constructed so as to be locked in coupled relation when liquid and other fluids flow therethrough. A valve in the coupler must be closed to prevent leakage before uncoupling can be effected. The dry-break mechanism is described in detail in U.S. Pat. No. 5,078,170, the disclosure of which is incorporated herein by reference.

An example of a suitable positive nozzle connector is the POSI/LOCK-105® (Emco Wheaton, Toronto, Canada) automatic fuelling system. The POSI/LOCK-105® system has a nozzle with a bumper ring a popper valve and an interlock plate. In operation, the nozzle is connected to the coupler such that an interface in the coupler engages the interlock plate in the nozzle. The poppet valve of the nozzle is then actuated and a corresponding poppet valve in the dry-break coupler is thus opened. The fuel lever can then be operated and fuel can be transferred to the fuel tank. To disengage the nozzle, the popper lever is released and the dry-break seals in the nozzle and the coupler provide a spill-free disconnection.

It will be appreciated by those skilled in the art that the connection between couplers of the dry-break coupler system is dependent on a good connection between the interface plates of the couplers. It is therefore important that the interface in the coupler be kept free of debris. To this end, the prior art coupler has been provided with a dust cap which is attached by a chain to the coupler assembly, as shown in U.S. Pat. No. 5,078,170. It is not necessary that the dust cap provide a fluid-tight seal since the dry-break interface in the coupler already serves this function. Unfortunately, in the experience of the present applicant, operators find the dust cap inconvenient to use and the dust caps therefore tend not to be used. The applicant has also found that since the dry-break seal provides a liquid-tight seal, operators are not

concerned about fuel leaking from the tank or nozzle and tend not to be concerned with replacing the dust cap over the coupler after refuelling. Furthermore, the chain is prone to breakage so that the dust cap may be lost in transit. In either case, the coupler interface is exposed and is not protected from debris, especially when the vehicle is in transit.

It is an object of the present invention to provide a cap and shield assembly to protect a fluid conduit coupler from debris.

It is another object of the present invention to provide a cap and shield assembly for retrofit to an existing fluid conduit coupler.

SUMMARY OF THE INVENTION

According to one aspect of the present invention, there is provided a cap and shield assembly for a fluid conduit coupler, comprising a shield and a cap hingedly connected to the shield. The shield and the cap are arranged such that when the cap is in a closed position, the fluid conduit coupler is protectively disposed therebetween, and when the cap is rotated from a closed position to an open position, the coupler is exposed. The cap and shield assembly also comprise cam means for positively retaining the cap in the closed position and for moving the cap vertically away from the coupler and the shield when the cap is rotated from the positively closed position to the open position.

According to another aspect of the present invention, there is provided a kit for retrofit to a coupler for a fluid conduit, comprising a shield and a cap adapted to be hingedly connected to the shield. The retrofit fluid conduit coupler is protectively disposed between the shield and the cap when the cap is in a closed position and is exposed when the cap is rotated from a closed position to an open position. The kit also comprises cam means adapted for positively retaining the cap in the closed position and for moving the cap vertically away from the coupler and the shield when the cap is rotated from the positive closed position to the open position.

BRIEF DESCRIPTION OF THE DRAWINGS

In drawings which illustrate embodiments of the present invention,

FIG. 1 is a top plan view of one embodiment of a cap and shield assembly of the present invention wherein the cap and shield assembly is shown with a cap in the open position;

FIG. 2 is a side elevational view of the cap and shield assembly of FIG. 1 with the cap in the positive closed position;

FIG. 3 is an exploded view of the cap and shield assembly of FIG. 1;

FIG. 4 is a top plan view of a unitary structure of the coupler and shield of FIG. 1;

FIG. 5 is a cross-sectional view of the unitary structure of FIG. 4 along the A—A;

FIG. 6 is a top plan view of the cap of FIG. 1;

FIG. 7 is a side elevational view of the cap of FIG. 6;

FIG. 8A is a side elevational view of a cam bushing according to the present invention;

FIG. 8B is a bottom plan view of the cam bushing of FIG. 8A;

FIG. 8C is a cam profile of the cam bushing of FIG. 8A; and

FIG. 9 is an illustration of an existing coupler adapted with the cap and shield assembly of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in FIG. 1, a cap and shield assembly 10 for a fluid conduit coupler 12 has a shield 14 and a cap 16. The cap 16 is hingedly connected to the shield 14 so that the cap 16 can be moved between a positive closed position as shown in FIG. 2 and an open position as shown in FIG. 1. In accordance with the present invention, the cap 16 is readily movable from the closed position to the open position and back again so that operators will be inclined to use the cap 16 for its intended purpose of protecting the fluid conduit coupler 12. In the case of a dry-break coupler, the shield 14 and the cap 16 coact to protect the coupler interface (not shown) from debris.

As shown more clearly in FIG. 3, the cap 16 and the shield 14 are held in position relative to each other with a shaft 18 which extends through a bore in a boss 22 of the cap 16 and a cam bushing 24 which is disposed in a bore in a boss 26 of the shield 14.

The cam bushing 24 is illustrated in more detail in FIGS. 8A and 8B. One end of the cam bushing 24 has a flange 28 to abut against the shield 14. Preferably, the flange 28 has a flat region 25 to abut against a corresponding flat portion 27 (shown more clearly in FIG. 4) on the shield 14 to rotationally position the cam bushing 24 relative to the shield 14. The other end of the cam bushing 24 has a contoured cam surface. The cam profile of the cam bushing 24 of FIGS. 8A and 8B is illustrated more clearly in FIG. 8C. Preferably, the cam bushing 24 is held in position vertically relative to the shield 14 with a retaining screw (not shown) which extends through a radial bore in the boss 26 into an undercut 29. The shaft 18 is provided with a radial bore to receive a cross-pin 32 (shown more clearly in FIG. 3) which, when the cap 16 is in the closed position, is seated in the cam grooves 34. The facing end surface of the boss 22 of the cap 16 has a retaining groove 33 to engage the cross-pin 32. The shaft 18 is held in position at each end by a retaining device, such as a circlip, and is provided at least at one end with biasing means, such as one or more conical disc spring washers 36 (see FIG. 2) or a coil spring (not shown).

In the embodiment shown in the drawings, the cam bushing 24 is disposed in a bore in the boss 26 of the shield 14. However, it will be appreciated by those skilled in the art that the cam bushing 24 may also be disposed in a bore in the boss 22 of the cap 16.

Furthermore, it will be appreciated by those skilled in the art that the cam action could also be achieved by providing a cam surface on an end surface or in an intermediate groove of either the boss 22 of the cap 16 or the boss 26 of the shield 14. The advantage of using the present arrangement is that the pin 32 and bushing 24 can be made of hard material to reduce wear and to facilitate manufacture by machining, while the cap 16 and shield 14 may be made of less expensive softer materials.

With reference again to FIG. 8C, when the cap 16 is in the closed position (see FIG. 2), the cross-pin 32 is seated in opposing cam grooves 34. When the cap 16 is rotated away from the closed position, the cross-pin 32 follows the contour of the slope of the cam grooves 34 to a flat surface of the cam profile, moving the cap 16 vertically away from the coupler 12 and the shield 14. It will be understood by those skilled in the art that reference to vertical movement is relative to a horizontal plane defined by the base of the shield 14 and does not necessarily refer to the orientation of the cap and shield assembly 10.

Upon further rotation of the cap 16, the cross-pin 32 travels along the flat surface of the cam profile and is urged

into opposing cam grooves 38 by the spring washer 36. When the cross-pin 32 is seated in the cam grooves 38, the cap 16 is in a positive open position. Thus, in accordance with the present invention, the cam bushing 24 provides positive open and closed positions for the cap 16 by retaining the cross-pin 32 into the cam grooves 38 and the cam grooves 34, respectively.

In the embodiment shown in FIGS. 8A, 8B and 8C, the cam grooves 34, 38 are separated by an angle of 120° to provide a corresponding 120° angle opening of the cap 16 relative to the shield 14. The size of the angle is not important; however, a 120° angle has been found to provide sufficient room for an operator to manually engage the bumper ring of a nozzle, such as the POSI/LOCK-105®, described hereinbefore. The positive open position of the cap 16, relative to the positive closed position, is preferably at an angle in the range of from about 90° to 180° and more preferably in the range of from about 110° to 130°.

In the embodiment depicted in the drawings, the cam follower is a cross-pin 32 extending through the shaft 18. However, it will be appreciated by those skilled in the art that other cam follower arrangements are possible without departing from the scope of the present invention. For example, a cam pin may extend outwardly from the shaft on only one side thereof. In this case, only one cam groove would be required to lock the cap 16 in the positive closed position.

It will also be appreciated by those skilled in the art that the cam profile may also be changed without departing from the scope of the present invention. For example, there could be only two grooves separated by an angle of 180°. In this case, one end of the cross-pin 32 rests in a first of the two grooves in the positive closed position and sits in the second of the two grooves in the positive open position.

While it is preferable to have both positive open and closed positions for the cap 16, it is not necessary for the open position to be positive. In this case, the operator holds the cap 16 open during the coupling and uncoupling steps and the cap 16 rests against the coupled fluid conduits during fluid transfer. The biasing spring washer and the cam surface urge the cap 16 into a positive closed position once decoupled.

Referring now to FIGS. 4 and 5, the shield 14 has a shroud 42 which extends around a portion of the shield 14. The coupler 12 is of a known construction, for example as described in U.S. Pat. No. 5,078,170. The cap and shield assembly of the present invention is particularly suited for protecting a coupler which is provided with a dry-break seal and valve (not depicted in the drawings). In FIGS. 4 and 5, the coupler 12 and the shield 14 are formed as a unitary structure adapted for subsequent attachment to a fluid conduit flange (not shown).

However, it will be appreciated by those skilled in the art that the coupler 12 can be fastened to a separate shield 14 for subsequent attachment to a filler neck flange. It will therefore be appreciated by those skilled in the art that the cap and shield assembly 10 of the present invention could be supplied as a complete unit for new installations or as a kit for retrofit to an installed coupler, as illustrated in FIG. 9.

Referring now to FIGS. 6 and 7, the cap 16 is provided with a shroud 44 which extends around a portion of the cap 16. When the cap 16 is in the closed position, the shroud 42 of the shield 14 and the shroud 44 of the cap 16 coact to protect the coupler 12 and in particular the coupler interface (not shown) from contamination by road/environmental debris.

5

While it is not necessary to provide a fluid-tight seal between the cap 16 and the shield 14 or the cap 16 and the coupler 12, it may be advantageous to provide such a seal to further protect the coupler interface from the environment. Such a seal may be effected, for example, with a gasket.

It may also be desirable to have the capability to lock the cap into position relative to the shield to protect the coupler and/or the fluid conduit or reservoir from tampering. This can be readily effected in the cap and shield assembly of the present invention in a conventional manner.

The cap and shield assembly is particularly suitable for mounting on the fuel tanks of fleet vehicles, such as buses and trucks, off-road vehicles, construction equipment, locomotive and marine vehicles. The cap and shield assembly may also be used to protect the interface of a fuel nozzle.

It will be apparent from reading this description of preferred embodiments that many modifications or alterations may be made without departing from the spirit and scope of the invention as defined in the following claims, which are meant also to encompass all equivalent forms of the invention as would be apparent to a person skilled in the art.

We claim:

1. A cap and shield assembly for a fluid conduit coupler, comprising:

a shield and a cap hingedly connected to the shield, the shield and the cap being arranged such that when the cap is in a closed position, the fluid conduit coupler is protectively disposed therebetween, and when the cap is rotated from a closed position to an open position, the coupler is exposed; and

cam means for positively retaining the cap in the open and closed positions and for moving the cap vertically away from the coupler and the shield when the cap is rotated from the positive closed position to the open position.

2. A cap and shield assembly according to claim 1, wherein the coupler and the shield are formed as a unitary structure.

3. A cap and shield assembly according to claim 1, wherein the cam means has a cam profile which also provides a positive open position for the cap relative to the shield.

4. A cap and shield assembly according to claim 3, wherein the positive open position of the cap is at an angle in the range of from about 90° to 180° relative to the positive closed position.

5. A cap and shield assembly according to claim 3, wherein the positive open position of the cap is at an angle in the range of from about 110° to 130° relative to the positive closed position.

6. A cap and shield assembly according to claim 3, wherein the positive open position of the cap is at an angle of about 120° relative to the positive closed position.

7. A cap and shield assembly according to claim 1, wherein the cam means is a cam bushing which coacts with a cam follower on a hinge shaft.

8. A cap and shield assembly according to claim 7, wherein the cam bushing is disposed in the shield.

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9. A cap and shield assembly according to claim 7, wherein the cam bushing is disposed in the cap.

10. A cap and shield assembly according to claim 7, wherein the cam follower is a cross-pin which extends through the hinge shaft.

11. A cap and shield assembly according to claim 1, wherein the cap and the shield are provided with shrouds which coact in the closed position to protect the coupler.

12. A cap and shield assembly according to claim 1, further comprising means for providing a seal between the coupler and the cap.

13. A cap and shield assembly according to claim 1, further comprising means for providing a seal between the shield and the cap.

14. A kit for retrofit to a coupler for a fluid conduit, comprising:

a shield and means for mounting the shield around the coupler;

a cap hingedly connected to the shield, so as to arrange the shield and cap such that when the cap is in a closed position, the fluid conduit coupler is protectively disposed therebetween, and when the cap is rotated from a closed position to an open position, the coupler is exposed; and

cam means for positively retaining the cap in the closed position and for moving the cap vertically away from the coupler and the shield when the cap is rotated from the positive closed position to the open position.

15. A kit according to claim 14, wherein the cam means has a cam profile which provides a positive open position for the cap relative to the shield.

16. A kit according to claim 15, wherein the positive open position of the cap is at an angle in the range of from about 90° to 180° relative to the positive closed position.

17. A kit according to claim 15, wherein the positive open position of the cap is at an angle in the range of from about 110° to 130° relative to the positive closed position.

18. A kit according to claim 15, wherein the positive open position of the cap is at an angle of about 120° relative to the positive closed position.

19. A kit according to claim 14, wherein the cam means is a cam bushing for coacting with a cam follower on a hinge shaft.

20. A kit according to claim 19, wherein the cam bushing is disposed in the shield.

21. A kit according to claim 19, wherein the cam bushing is disposed in the cap.

22. A kit according to claim 19, wherein the cam follower is a cross-pin extending through the hinge shaft.

23. A kit according to claim 14, wherein the cap and the shield are provided with shrouds which coact in the closed position to protect the coupler.

24. A kit according to claim 14, further comprising means for providing a seal between the coupler and the cap.

25. A kit according to claim 14, further comprising means for providing a seal between the shield and the cap.

* * * * *

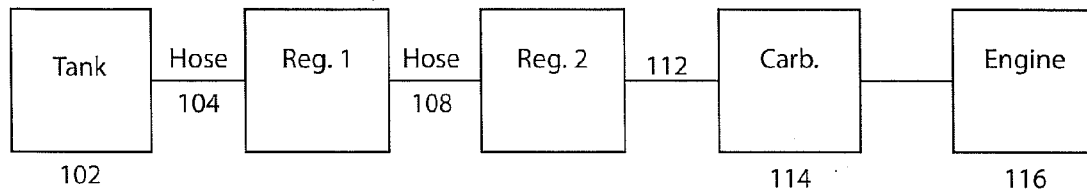
EXHIBIT 1013



US 20110100335A1

(19) **United States**(12) **Patent Application Publication**
Parlatore et al.(10) **Pub. No.: US 2011/0100335 A1**(43) **Pub. Date: May 5, 2011**(54) **FUEL DELIVERY SYSTEM****Publication Classification**(75) Inventors: **William R. Parlatore**, Annapolis,
MD (US); **Howard A. Brooks**,
Annapolis, MD (US)(51) **Int. Cl.**
F02M 37/00 (2006.01)
F02B 43/00 (2006.01)(52) **U.S. Cl.** **123/511; 123/527**(73) Assignee: **Marine Green, LLC**(57) **ABSTRACT**(21) Appl. No.: **12/612,776**

A method and system for fuel delivery. The method and system may include one or more fuel storage tanks housing propane, one or more regulators through which fuel may flow and one or more fuel metering devices or systems. The flow of fuel from a fuel storage tank to an engine may be such that the engine runs in a clean and efficient manner.

(22) Filed: **Nov. 5, 2009**

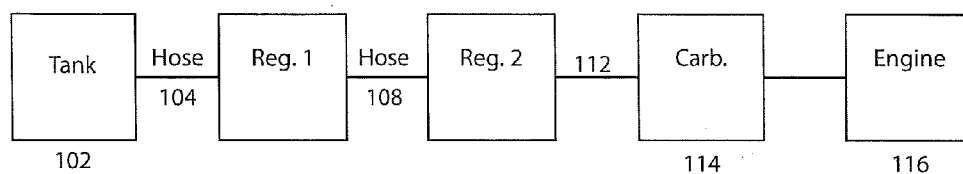


Fig. 1

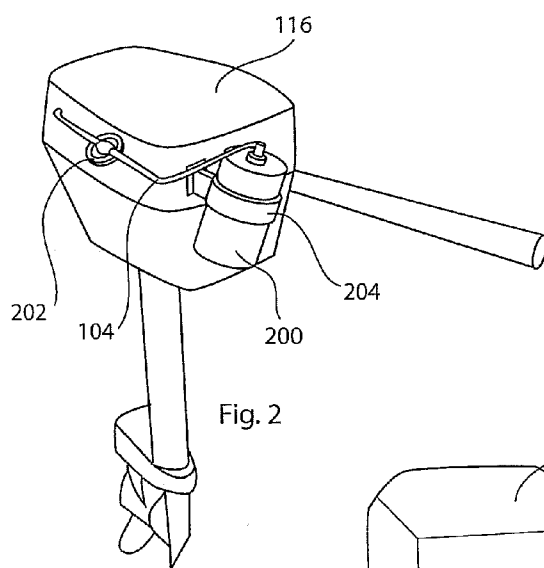


Fig. 2

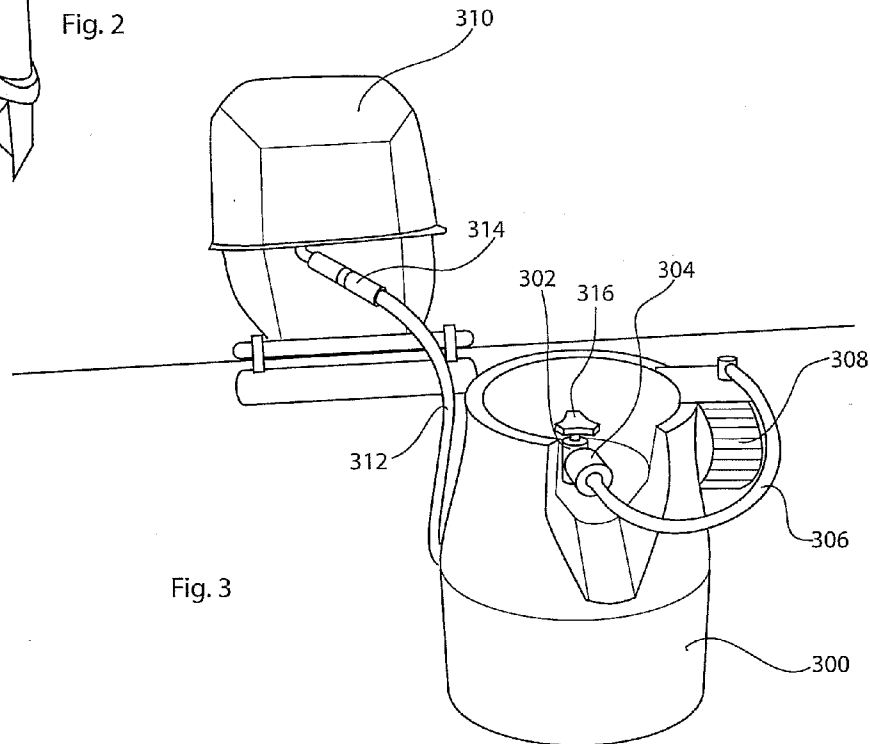


Fig. 3

FUEL DELIVERY SYSTEM

BACKGROUND

[0001] Engines used in any application are known to utilize fuel. In many applications, such as in two and four stroke marine outboard engines, fossil fuels have been used as the primary source of fuel. However, modern engines are typically criticized for their use of fossil fuels as they are claimed to not be environmentally friendly. Two stroke engines are further criticized due to their running and use characteristics. Thus, in many applications where two stroke engines are used to be prevalent, such as in marine outboard engines, designers and manufacturers are now switching to four stroke outboard engines.

[0002] However, as is well known and publicized, four stroke engines remain somewhat inefficient and suffer from a variety of potential drawbacks, specifically with regard to the environment. A number of solutions have been proposed to increase both the efficiency and environmental friendliness of such engines. For example, some marine outboard engines now utilize alternative fuels, such as ethanol-infused gasoline, or bio-gas. These alternatives cause a variety of problems in many applications, however. The use of ethanol in gasoline can absorb water which can cause onboard fuel supplies to eventually contain water as a result of condensation or other means, causing significant problems in engines that are used less frequently. Additionally, for users who wish to safeguard their outboard engines from these problems, fuel disposal is often viewed as a solution but environmentally-unfriendly manners of disposing of unused fuel are often implemented.

[0003] Additionally the decreased effective shelf life of alternative fuels, such as bio-gas can pose problems in engines that are used less frequently as the fuel may not properly combust if it is not used within a limited time period.

[0004] Other attempted solutions, for example the use of liquid propane delivery systems, have not proved successful. In such uses of propane, the vaporization of propane from its liquid state causes a significant amount of heat to be absorbed, ultimately freezing the regulator through which the propane flows from a tank to the engine and rendering the engine inoperable.

SUMMARY

[0005] One exemplary embodiment describes a fuel delivery system. The fuel delivery system may include a fuel tank that houses propane; a first regulator coupled to the fuel tank; a second regulator coupled to the first regulator; and a fuel metering system coupled to the second regulator and delivering propane to an engine.

[0006] Another exemplary embodiment can include a method for providing fuel to an engine. The method for providing fuel to an engine can include storing liquid propane in a tank; flowing the liquid propane to a first regulator; converting the liquid propane to a propane vapor by the first regulator; flowing the propane vapor to a second regulator; metering the flow of the propane vapor from the second regulator to an engine; and maintaining the temperature of the propane at about an ambient temperature.

BRIEF DESCRIPTION OF THE FIGURES

[0007] Advantages of embodiments of the present invention will be apparent from the following detailed description

of the exemplary embodiments thereof, which description should be considered in conjunction with the accompanying drawings in which:

[0008] FIG. 1 shows an exemplary block diagram of a fuel delivery system.

[0009] FIG. 2 shows an exemplary diagram of components of a fuel delivery system and engine.

[0010] FIG. 3 shows another exemplary diagram of components of a fuel delivery system and engine.

DETAILED DESCRIPTION

[0011] Aspects of the invention are disclosed in the following description and related drawings directed to specific embodiments of the invention. Alternate embodiments may be devised without departing from the spirit or the scope of the invention. Additionally, well-known elements of exemplary embodiments of the invention will not be described in detail or will be omitted so as not to obscure the relevant details of the invention. Further, to facilitate an understanding of the description discussion of several terms used herein follows.

[0012] The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any embodiment described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other embodiments. Likewise, the term “embodiments of the invention” does not require that all embodiments of the invention include the discussed feature, advantage or mode of operation.

[0013] Generally referring to FIGS. 1-3, a propane vapor delivery system may be described and shown. The fuel vapor delivery system may be such that clean, economical use of an engine may be achieved with minimal complexity.

[0014] In one exemplary embodiment and as shown in the exemplary diagram in FIG. 1, a gas, such as liquefied petroleum gas or propane, may be supplied to an engine as fuel. The gas may be stored in a bottle or tank, such as LPG tank 102. In a further exemplary embodiment, the gaseous form of liquefied propane may be used as a fuel for marine outboard four-stroke propulsion engines, as well as two stroke engines or any other type of engine with a pressurized lubricating injection system. An exemplary fuel system may use liquefied petroleum gas (LPG or propane) which may be stored in a vapor gaseous state in LPG tank 102 and which may not utilize engine coolant to keep regulators from freezing or otherwise malfunctioning.

[0015] LPG, as implemented or utilized in the exemplary embodiments described herein, may provide any of a number of advantages over other fuels. For example, LPG may act as a higher octane fuel source as well as decrease potentially harmful emissions while also offering substantially the same or better performance over other known fuels. An increase in fuel economy and a decrease in potentially harmful emissions may be up to 20% or more. Additionally, LPG may reduce wear on an engine and some components, for example extending the life of spark plugs, reducing varnish build-up on a carburetor and increasing the amount of time needed between oil changes. Further, LPG may be stored in any number of environments without the use of additives or unique storage conditions without affecting its usefulness or performance.

[0016] In a further exemplary embodiment, the LPG tank 102 may be connected to a regulator, such as a primary regulator 106, converter or vaporizer. This connection may be made using a hose 104, such as a high pressure hose, or any

form of pipe, for example a rigid pipe. The primary regulator **106** may step down the pressure of any stored propane vapor energy in tank **102**, and may further output this lowered pressure to a secondary regulator **110**. For example, the primary regulator **106** may be such that it reduces pressure of the propane from a high pressure state while the propane is in the LPG tank **102**, which may be approximately 180-250 psi, to a sub-atmospheric pressure, approximately 10 psi. The secondary regulator **110** can act as a vacuum-controlled flow rate regulator. Further, the secondary regulator **110** can meter propane gas to an engine **116**, for example, through a negative pressure signal, such as a vacuum signal, from the air-fuel mixer on a carburetor **114** designed or modified to use propane as a fuel source.

[0017] Still to exemplary FIG. 1, and in a further example, the carburetor **114** may include both an air-fuel mixer and a throttle body. When the engine **116** is being cranked or otherwise running, a partial vacuum may be generated in the throttle body of carburetor **114**. This partial vacuum may be passed on from the throttle body to the fuel vapor hose to the secondary regulator **110**. The secondary regulator **110** may sense the vacuum and open, letting fuel vapor flow into the carburetor **114**. As the throttle is opened, a butterfly valve inside the carburetor **114** may open further, thus allowing for more fuel to be drawn in and allowing the engine **116** to accelerate or increase revolutions. Further, the air-valve implementation of the carburetor **114** may allow for a safe and accurate method of supplying propane gas from LPG tank **102** while also allowing for the fuel metering in the mixer to be self-contained. Additionally, it may be envisioned that a mechanical or electrical fuel injection system could be used in lieu of carburetor **114** while achieving similar results.

[0018] In further exemplary embodiments, and referring to FIG. 2, the regulator arrangement of the primary regulator **106** and the secondary regulator **110** may be such that they are combined as a single, two-stage, regulator **202**. In this exemplary embodiment the combined regulator **202** would then feed the vaporized propane into carburetor **114** through hose **112**. Additionally, as shown in exemplary FIG. 2, LPG tank **200**, in some examples, may be coupled directly to engine **116**, using any desired coupling, such as mounting bracket **204**.

[0019] The exemplary embodiment shown in FIG. 2 may be utilized in any desired situation, such on a small or single-cylinder outboard engine. The mounting of LPG tank **200** on the engine may provide many advantages. For example, this embodiment may be beneficial in some desired situations, for example when utilizing compact fuel supplies on a general yacht tender service or for any other similar-sized application, such as generators or personal watercraft where storage space or space of a fuel tank may be limited.

[0020] In still further exemplary embodiments, and referring to FIG. 3, the LPG tank **300** may be located separate, but coupled to, an engine **310**. The LPG tank **300** may be connected to the primary regulator **304** as described previously, for example by connector **302**. Additionally, a low pressure output of the secondary regulator **308** may be attached to a propane carburetor (not pictured) on the engine **310** in any of a variety of manners, for example through hose **312** and coupling **314**. Further, a low pressure output of the secondary regulator **308** may be attached to the propane carburetor either permanently or releasably.

[0021] Still referring to exemplary FIG. 3, the primary regulator **304** and the secondary regulator **308** may be two

separate regulators that can be based on the design and size of an engine. The primary regulator **304** in this exemplary embodiment may be connected to LPG tank **300** as described above. Additionally, the primary regulator **304** may be connected to the secondary regulator **308** by a hose **306**, pipe, tube or the like, such as that described above.

[0022] In each of the exemplary embodiments described herein the arrangement of the regulators **106** and **110**, **202** and **304** and **308**, as shown in FIGS. 1-3, respectively, can maintain about an ambient temperature from the surrounding air temperature rather than utilizing an interface with a cooling circuit of the engine **116** or other heat source to function as desired. In some other exemplary embodiments, the temperature maintained by any regulators described herein may be such that the flow of propane is allowed as desired. This may be accomplished as a result of the vapor delivery nature of the system as well as a design match of the system to fit specific air-fuel requirements of an engine size, for example for a marine engine. The maintenance of the regulator at about an ambient temperature may be facilitated by both the design of the regulator or regulators which may be sized to a specific engine, for example a marine engine having a known or desired horsepower rating. Additionally, the maintenance of the about ambient temperature may be such that the regulator or regulators are not affected, for example, by freezing as a result of the conversion of the LPG from tank **102** to a gaseous state and the flow of the fuel is not negatively affected or impacted.

[0023] In still further examples, any of the embodiments described herein may include a fuel shut-off valve, such as a safety fuel shut-off valve **316** or switch. For example, a standard propane tank shut-off valve may be utilized in some embodiments. Additionally, in other embodiments, such as embodiments where a larger, electrically actuated engine is utilized, an electric solenoid shut-off valve may be used.

[0024] In still other exemplary embodiments, for example engines as shown in FIG. 3, which may be large or powerful engines, or any situation where more fuel may be desired, an LPG tank may be mounted or located in any desired position or location. Whereas the LPG tank shown in exemplary FIG. 2 may be mounted on the side of an engine, here other locations for mounting an LPG tank may be used as desired. As shown in FIG. 3, a mounting bracket (not pictured) may be secured to LPG tank **300** and any other desired member of a vessel or craft associated with engine **310**. Also the LPG tank **300** may be formed out of any desired material, for example aluminum or a composite construction. Additionally, the LPG tank **300** may be coupled with any conduit described herein, such as a high pressure hoses, rigid tubes, pipes and the like in any desired manner, such as a screw fitting. Additionally, should it be desired, any number of fuel tanks may be coupled together to provide any desired amount of available fuel. Any coupling of additional tanks may be done in a manner known in the art.

[0025] Further, as described herein, the LPG applications may be used on any desired form of engine, such as marine outboard engines, and may further operate independently of an engine's cooling circuit. This may be accomplished through the use of vapor fuel delivery rather than the delivery of liquid propane gas. Additionally, on some engine types, such as engines of smaller displacement, smaller amounts of propane may be utilized to achieve a desired operation, thus

further issues pertaining to cooling and freezing, such as those known to affect the conversion of propane from liquid to gas, may be avoided.

[0026] The foregoing description and accompanying drawings illustrate the principles, preferred embodiments and modes of operation of the invention. However, the invention should not be construed as being limited to the particular embodiments discussed above. Additional variations of the embodiments discussed above will be appreciated by those skilled in the art.

[0027] Therefore, the above-described embodiments should be regarded as illustrative rather than restrictive. Accordingly, it should be appreciated that variations to those embodiments can be made by those skilled in the art without departing from the scope of the invention as defined by the following claims.

1. A fuel delivery system, comprising:
a fuel tank that houses propane;
a first regulator coupled to the fuel tank;
a second regulator coupled to the first regulator; and
a fuel metering system coupled to the second regulator to deliver propane vapor to an engine.
2. The fuel delivery system of claim 1, wherein the engine is a marine outboard engine.
3. The fuel delivery system of claim 1, wherein the fuel is reduced in pressure by the first regulator.
4. The fuel delivery system of claim 1, wherein the second regulator receives a signal from the fuel metering system and delivers fuel to the fuel metering system.
5. The fuel delivery system of claim 4, wherein the signal is a vacuum signal.
6. The fuel delivery system of claim 1, wherein the fuel metering system is a carburetor.
7. The fuel delivery system of claim 1, wherein the fuel is propane.
8. The fuel delivery system of claim 1, wherein the first regulator and the second regulator are combined as a two stage regulator.
9. The fuel delivery system of claim 1, wherein the coupling of the first regulator with the second regulator is such

that fuel flowing between the first regulator and the second regulator is kept at an about ambient temperature.

10. The fuel delivery system of claim 1, wherein the second regulator is coupled to the fuel metering system with a releasable coupling.

11. The fuel delivery system of claim 1, further comprising at least one shut-off valve.

12. A method for providing fuel to an engine, comprising:
storing liquid propane in a tank;
flowing propane to a first regulator;
decreasing the pressure of the propane by the first regulator;
flowing the propane to a second regulator;
metering the flow of the propane from the second regulator to an engine; and
maintaining the temperature of the propane at an about ambient temperature.

13. The method of claim 12, wherein the flow of the propane vapor from the second regulator to the engine is metered by a carburetor.

14. The method of claim 12, further comprising reducing the pressure of the liquid propane in the tank from about 180-250 psi to about 4-12 psi by the first regulator.

15. The method of claim 12, further comprising one of releasably coupling the second regulator to the engine and releasably coupling the first regulator to the second regulator.

16. The method of claim 12, wherein the flow of the propane vapor from the second regulator to the engine is metered by a vacuum signal.

17. The method of claim 12, wherein the flow of the propane vapor from the second regulator to the engine is metered by a carburetor.

18. The method of claim 12, wherein the flow of the propane vapor from the second regulator to the engine is metered by a fuel injection system.

19. The method of claim 12, further comprising securing the tank to the engine.

20. The method of claim 12, wherein the engine is a marine outboard engine.

* * * * *

EXHIBIT 1014

[54] DUAL FUEL SYSTEM

[75] Inventor: John E. Hallberg, Peachtree City, Ga.

[73] Assignee: PetroSystems International, Inc., Nashville, Tenn.

[21] Appl. No.: 239,005

[22] Filed: Feb. 27, 1981

[51] Int. Cl.³ F02B 43/00; F02M 21/04

[52] U.S. Cl. 123/527; 123/577; 48/180 C; 261/16; 261/44 C

[58] Field of Search 123/525, 527, 577; 48/180 C, 180 R, 184; 261/16, 41, 44 C

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Primary Examiner—Charles J. Myhre

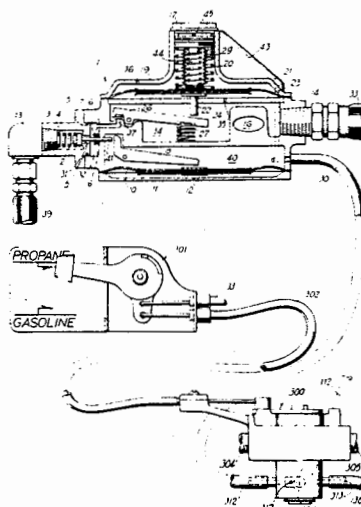
Assistant Examiner—E. Rollins Cross

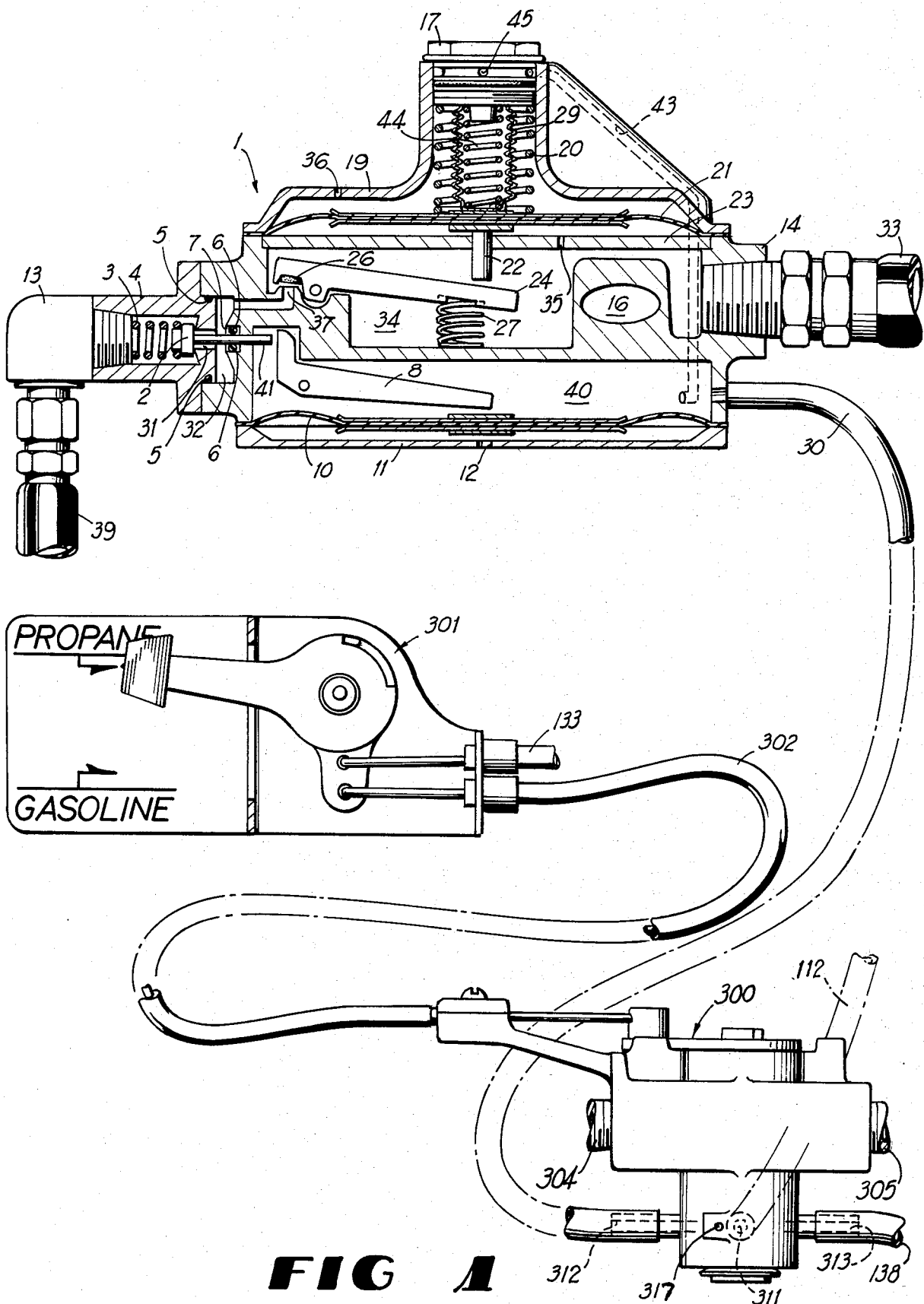
Attorney, Agent, or Firm—L. Lawton Rogers, III

[57] ABSTRACT

A dual fuel system for use with internal combustion engines comprising a manually actuated dual fluid valve which alternatively supplies gasoline to the engine's carburetor or engine intake manifold vacuum to a single-stage liquified gas to gaseous fuel converter having a liquified fuel inlet valve actuated in response to intake manifold vacuum by a diaphragm of substantially the same diameter as a second diaphragm which actuates a valve to a converter gaseous expansion chamber where desired gaseous pressure is maintained and is automatically reduced during cruise conditions by compression of a bellows which acts on the second diaphragm in response to reduced engine intake manifold pressure during such cruise conditions, and a pressurized gaseous fuel and air mixer having a plunger structure responsive to venturi vacuum which meters air flow and actuates a valve needle to meter fuel flow. One alternative preferred embodiment of the mixer employs a relatively large piston which travels a relatively short distance within a cylinder and meters flow of air between the lower surface of the piston and a coaxial annular surface defining a passage into which air flows between such surface and the piston together with fuel, which fuel flows into the fuel and air passage through the piston and through a fuel transfer tube that acts as a piston guide. A second alternative preferred embodiment of the mixer utilizes a smaller diameter piston which travels a relatively long distance and a substantially oval plunger which projects into a substantially rectangular air passage to meter air flow.

25 Claims, 14 Drawing Figures





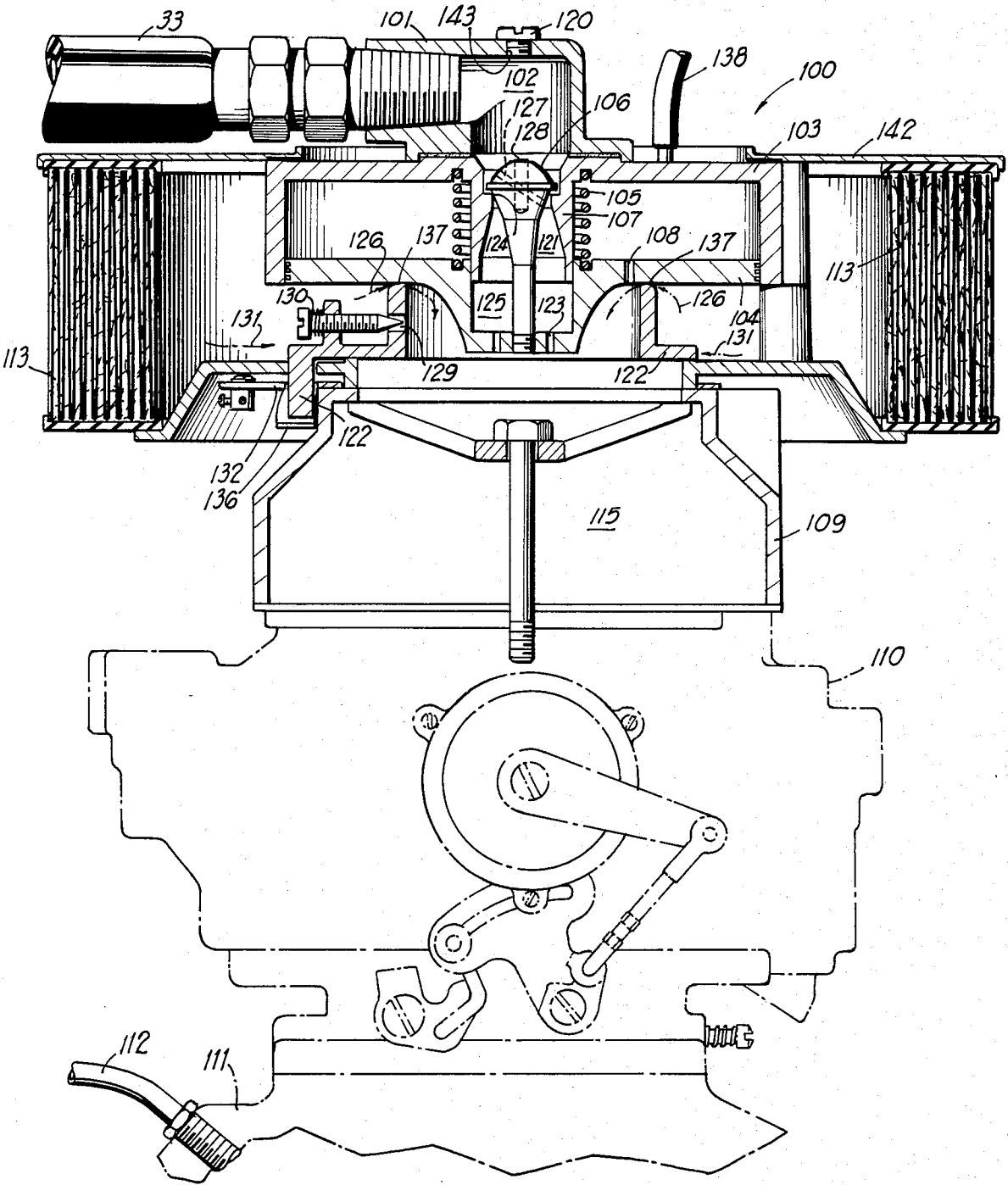


FIG 2

MATCH LINE TO FIG. 3B

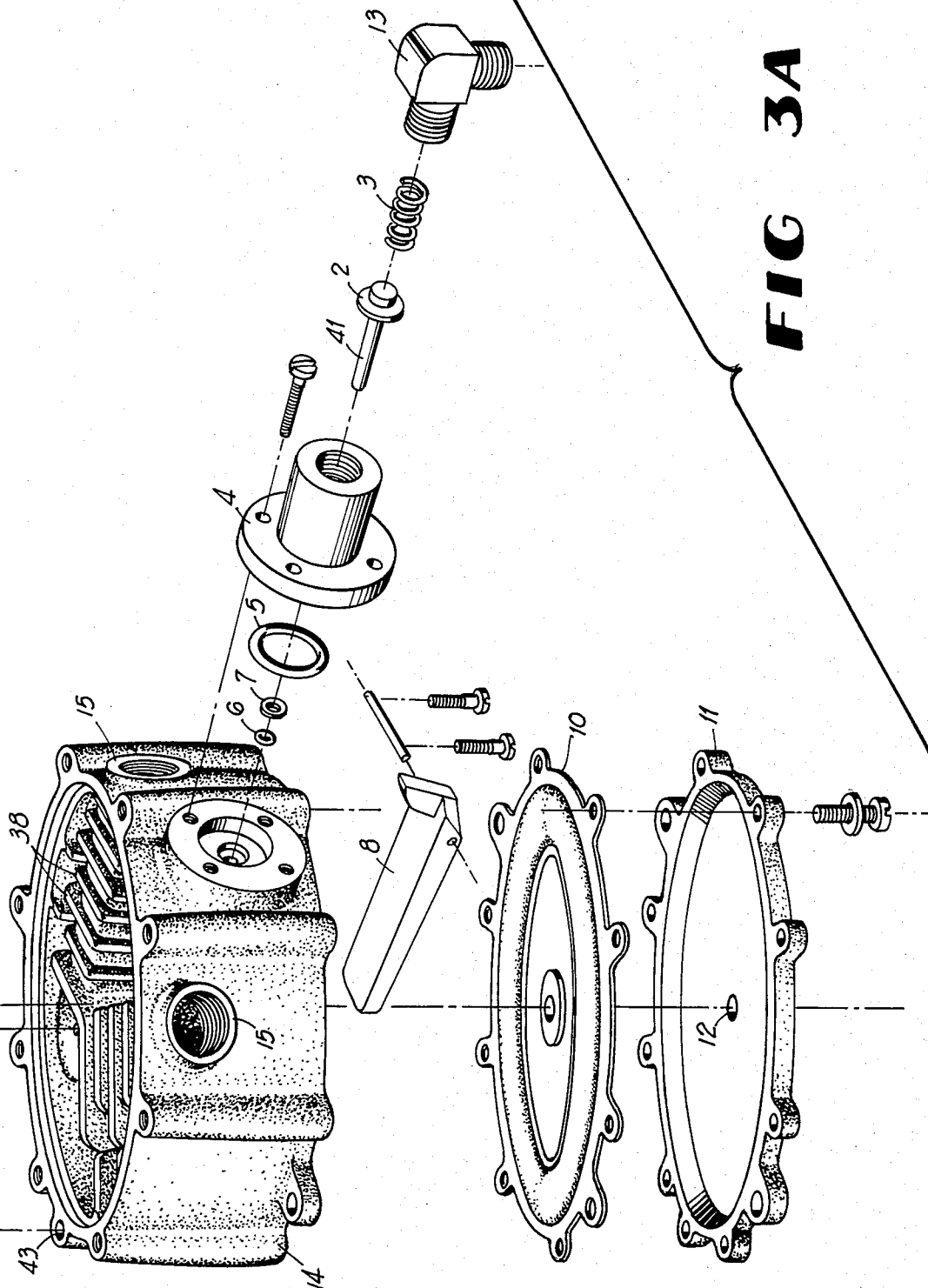
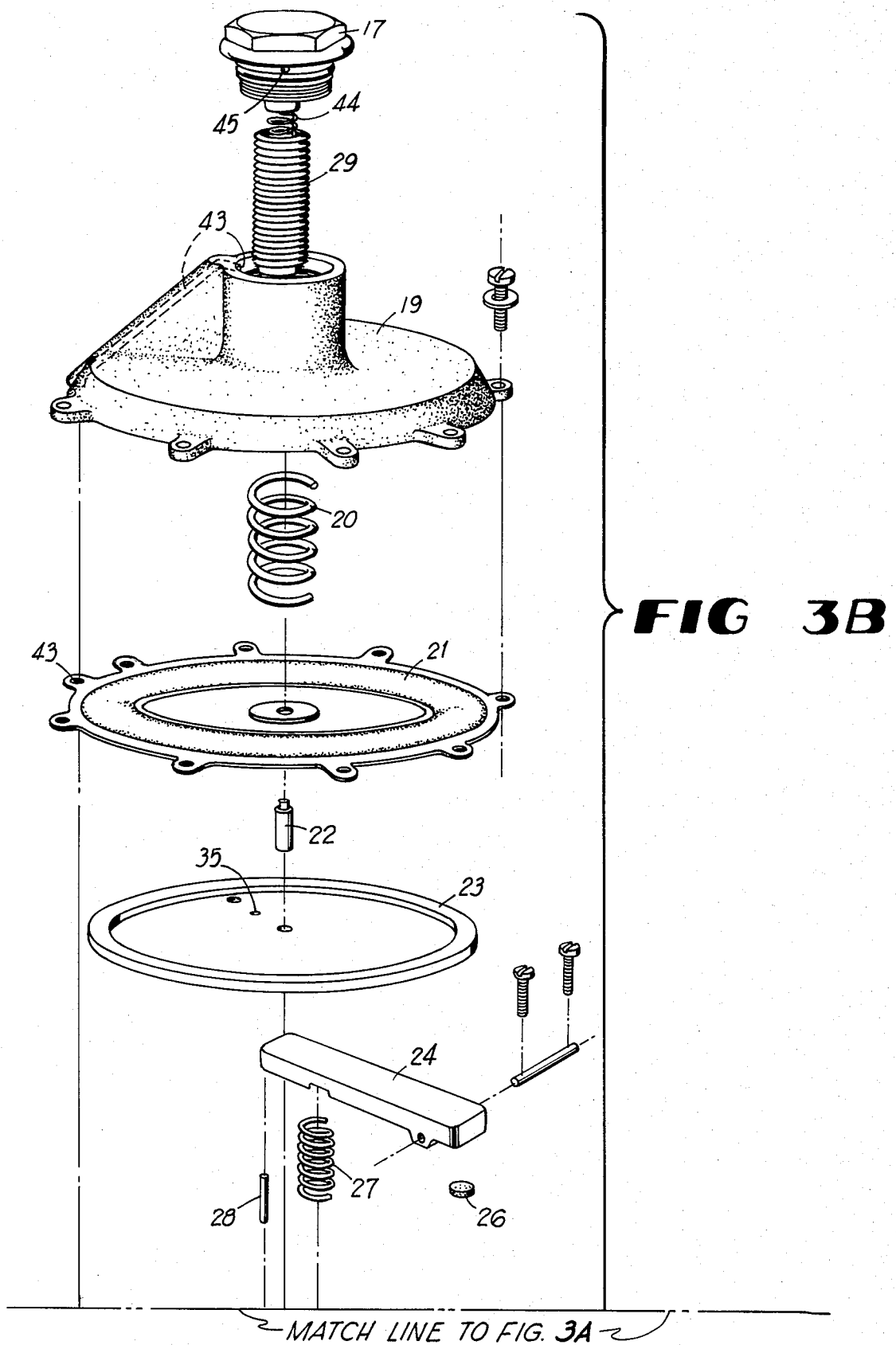


FIG 3A



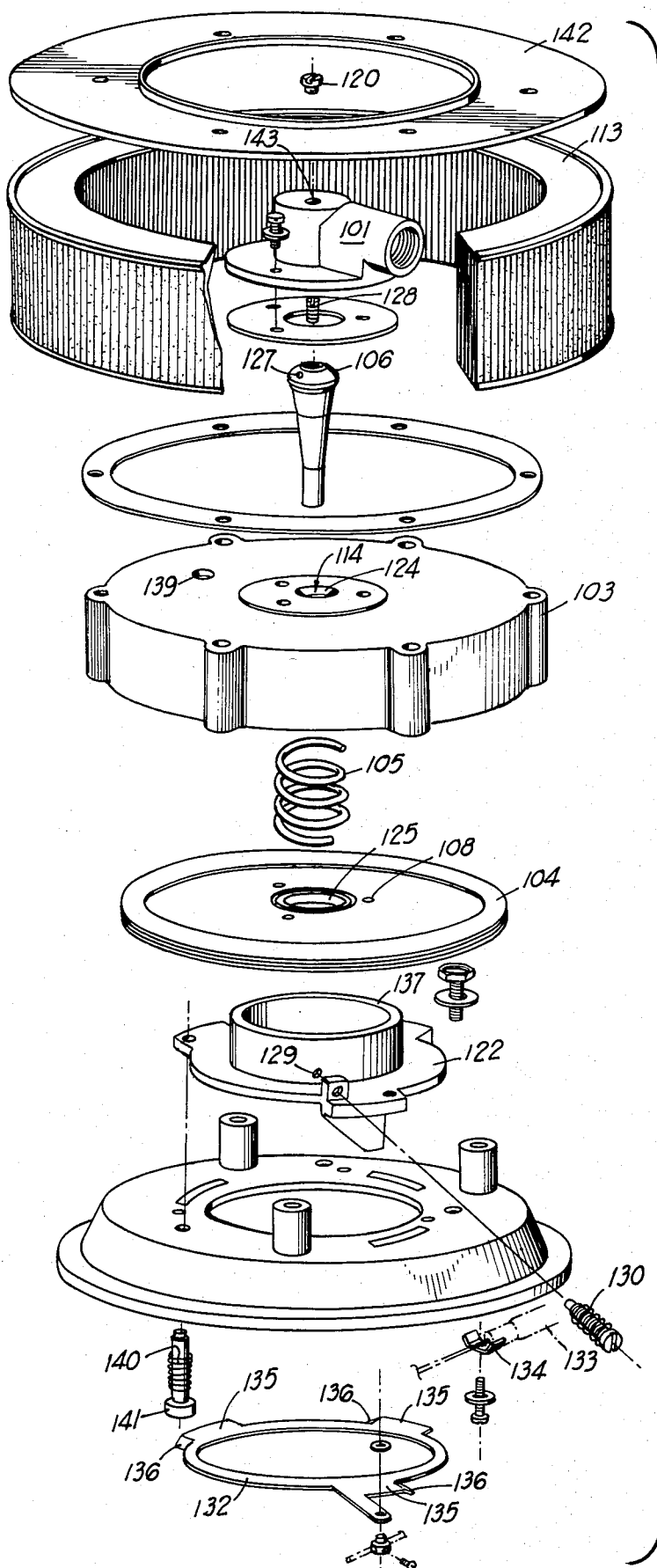


FIG 4

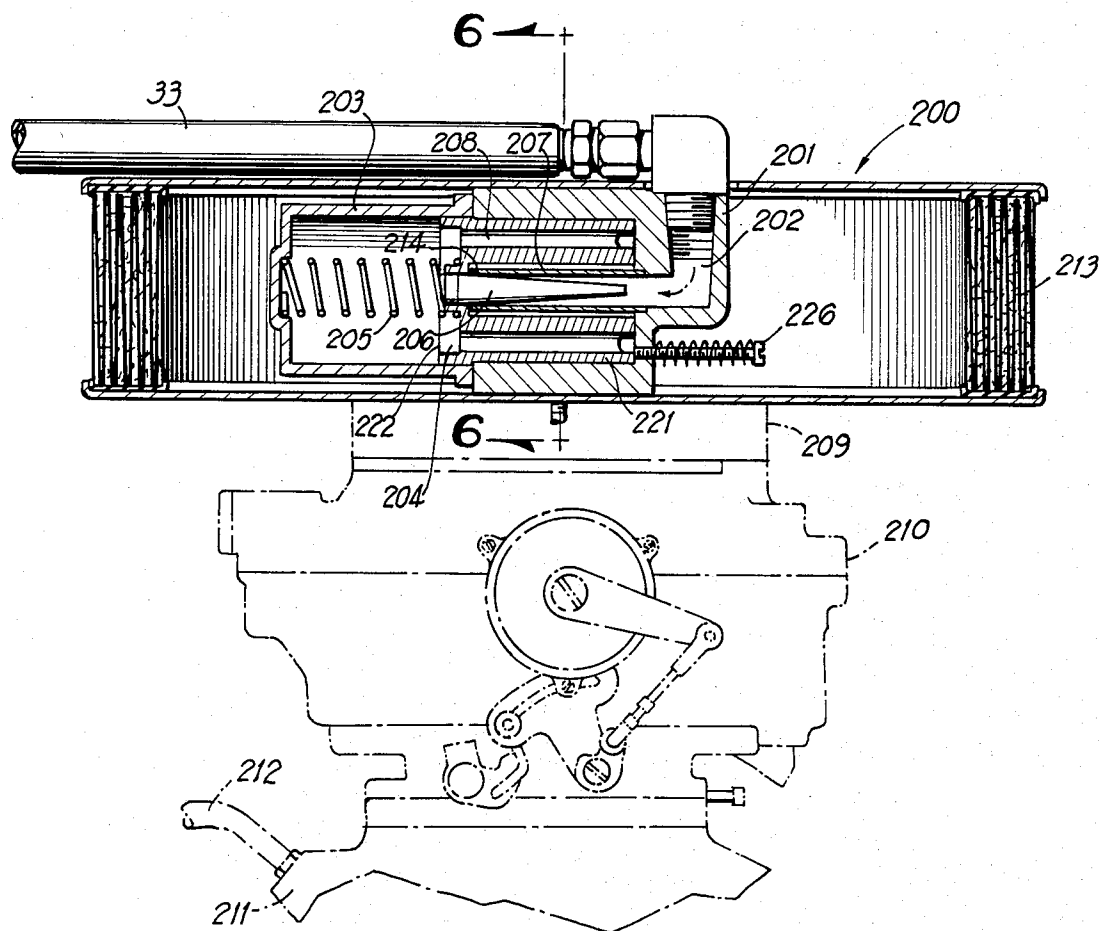


FIG 5

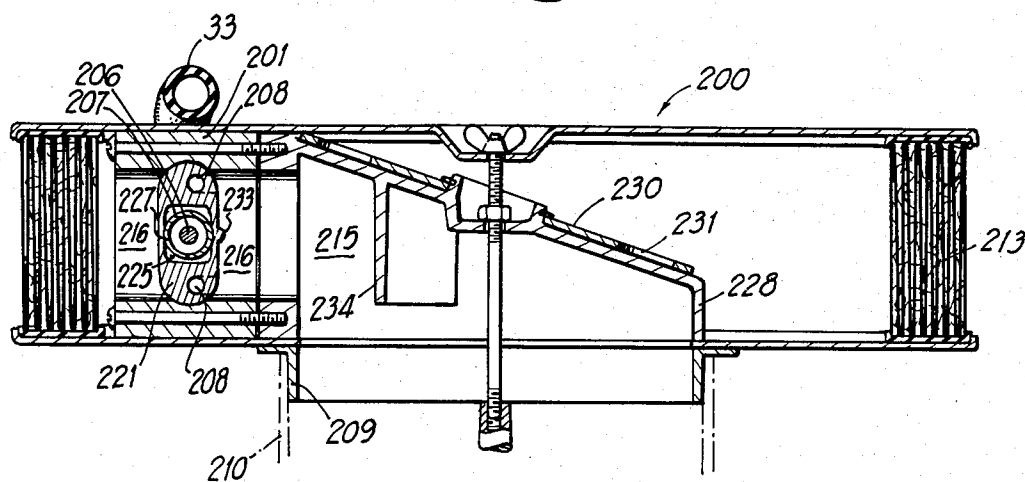


FIG 6

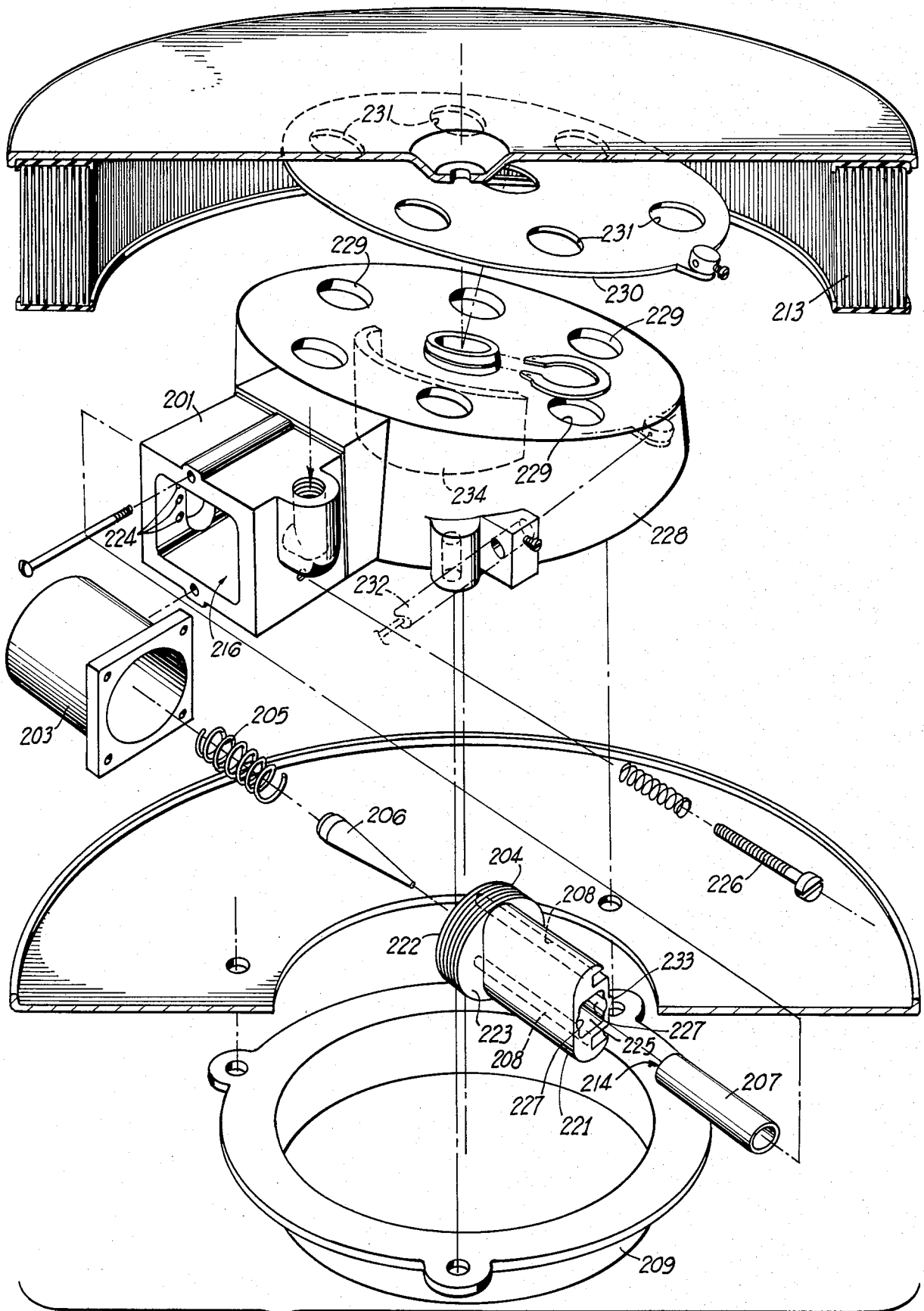


FIG 7

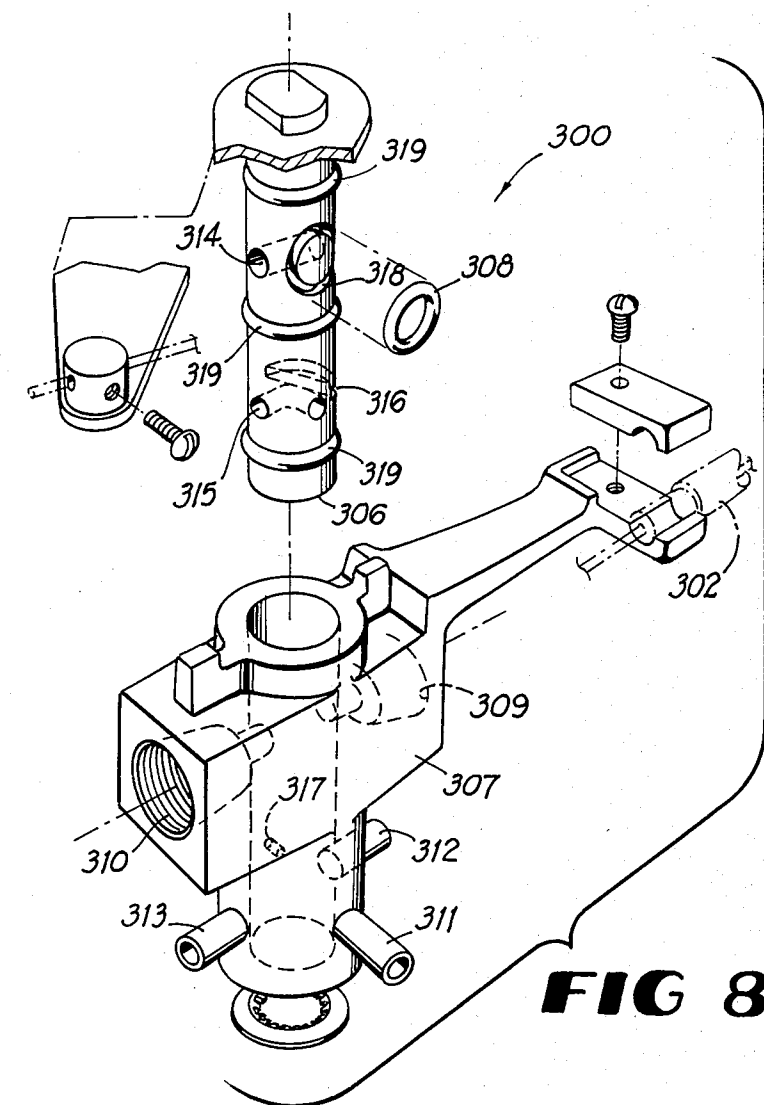


FIG 8

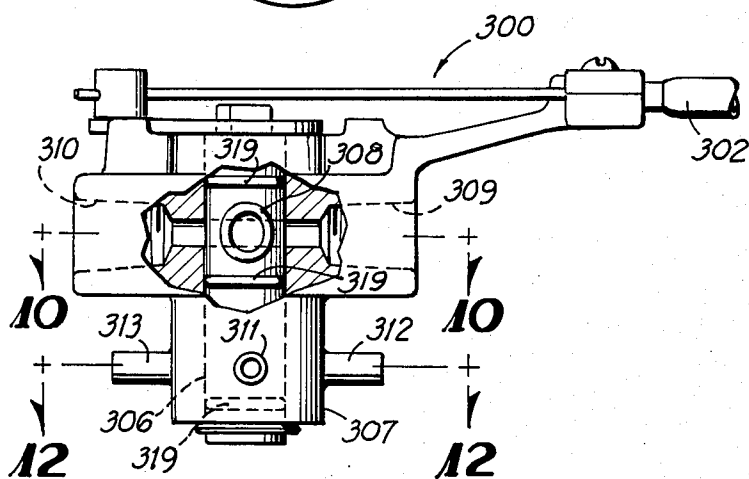


FIG 9

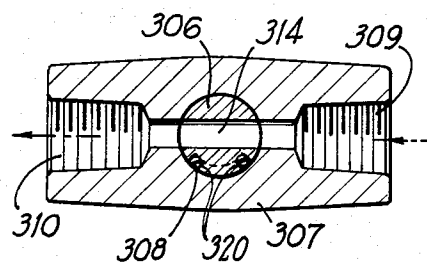


FIG 10

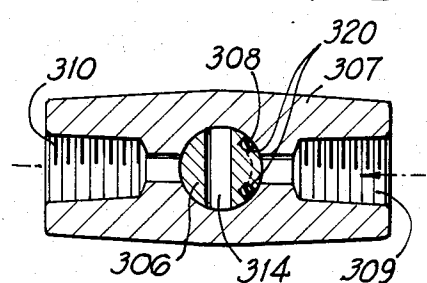


FIG 11

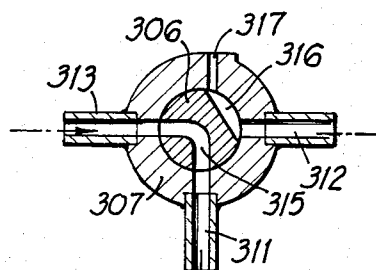


FIG 12

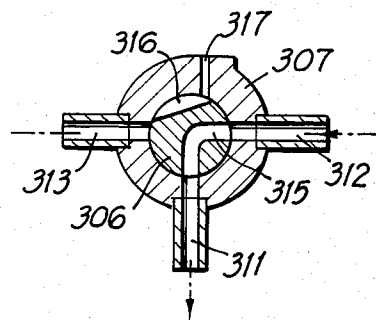


FIG 13

DUAL FUEL SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a system for use with a conventional internal combustion engine, such as an automobile engine, to permit alternative utilization of a liquified gas fuel such as liquified petroleum gas, natural gas, hydrogen or propane and a liquid fuel such as gasoline, alternatively selectable by a manually operated control.

2. Description of the Prior Art

Dual fuel systems having manually actuated selection means are well known in the prior art. Illustrative of early dual fuel systems are the following U.S. Pat. Nos.

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Such systems for use with a liquid fuel and a liquified gas fuel typically consist of three principal elements: (a) a means for selecting the fuel to be utilized, (b) a liquified-to-gaseous fuel converter or vaporizer and (c) a gaseous fuel and air mixer or carburetor. Each of these principal elements will be addressed seriatim.

a. Fuel Selection Means

Most conventional modern propane carburetion equipment utilizes electrically operated solenoid valves for alternative selection of fuels. One valve is normally in the liquid propane line running from the propane storage tank of the vehicle adjacent to the inlet to the propane converter or vaporizer, and another is in the gasoline line supplying the carburetor. Such solenoid valves are typically activated by a single pole double throw switch mounted where it may be conveniently operated by the driver to permit alternative selection of propane or gasoline. Such electrically operated solenoid valves are typically the weakest link in conventional dual fuel carburetion systems. They frequently do not work well in the environment of the engine, and it is difficult to locate a reliable voltage source in the vehicle's electrical system which is the right voltage, is available during engine starting and does not affect the ignition system.

At least one prior art dual fuel system utilizes a vacuum operated solenoid valve in the propane portion of the system but retains an electrically operated solenoid valve in the gasoline portion of the system.

b. Converters

Liquified petroleum gas, propane and the other "gaseous" fuels with which the present invention is intended to be used are normally held for use in a reservoir or tank under sufficient pressure and at a temperature such that the fuels are in a liquid state. Thus, such fuels are referred to as "liquified gas" fuels. Conversion of such liquified fuel to a gaseous state at a pressure and temperature usable by conventional internal combustion engines must be accomplished in a converter structure which is accordingly denominated a "liquified gas to gaseous fuel converter" or a "liquified-to-gaseous fuel converter."

Most conventional liquified gas to gaseous fuel converters are of the two stage variety comprising a relatively small diameter first stage, or primary, diaphragm

within a chamber warmed by hot engine coolant liquid, which primary diaphragm controls a normally open inlet valve, and a large diameter second diaphragm which controls a normally closed valve.

U.S. Pat. No. 3,528,787, for "Fuel Carburation Apparatus," assigned to the same assignee as the instant application, disclosed a liquified-to-gaseous fuel converter structure comprising a single diaphragm responsive to engine venturi vacuum which actuates an inlet valve. The present invention improves upon the converter element of that patent and conventional converter structures.

c. Mixers

Early propane mixers consisted simply of a tube affixed in the existing gasoline carburetor at a point where the venturi narrows. These so called "spud ins" were acceptable during a period when gasoline and propane were very inexpensive. Subsequent development was directed toward design of a separate propane venturi, and designs for a separate venturi and separate idling system were developed. However, as one skilled in the art will appreciate, a venturi is not very effective as a metering device when air flow is low and slow. Furthermore, a venturi typically has a narrow control range such that it is difficult to design a venturi which will satisfy both low speed and high speed conditions. Accordingly, an ideal system would incorporate a separately engineered venturi for each speed of air flow.

Several mixer designs have been directed to a variable venturi which used a tapered plug device in the opening of the carburetor, with the plug moving up and down in response to variations in air flow. Inherent limitations in such "variable venturi" or "air valve" carburetors are present due to the weight of the plug and short distance of travel. Typically all engine operation conditions must be accommodated within approximately five-eighths of an inch (15.9 millimeters) of plug travel. Additionally, such designs exhibit hysteresis problems and relatively poor fuel economy characteristics. Thus, such problems weigh against the utilization of the variable venturi.

The mixer structures disclosed in U.S. Pat. No. 3,528,787 and utilized in similar "SU" type carburetors employ a plunger structure comprising a round piston acted on by venturi vacuum and atmospheric pressure and a smaller round piston or plunger which variably obstructs air flow through an air passage and from which extends a needle positionable in a fuel orifice on the side of the air passage opposite the plunger structure. Such projection of the needle from the plunger results in a relative large mixer structure.

Another prior art mixer utilizes a relatively large diaphragm to regulate air flow and to move a valve needle to cooperate with an orifice in a mixer structure somewhat similar to one embodiment of the mixer of the present invention.

It is therefore an object of the present invention to overcome the problems associated with prior art dual fuel systems.

It is yet another object of the present invention to provide a dual fuel system adaptable for use with original equipment or for addition to existing equipment, which system fills a need for alternatively selectable fuel provision means.

It is a further object of the present invention to provide a dual fuel system having a mixer which can ac-

commodate relatively large variations in the manufacturing tolerances of its parts.

It is a further object of the present invention to provide a dual fuel system which assists in compliance with strict emission control standards for internal combustion engines by providing for utilization of inherently clean burning propane in conventional vehicles.

It is a further object of the present invention to provide a dual fuel system having a gaseous fuel mixer and to provide a mixer having positive fuel control while minimizing hysteresis.

It is a further object of the present invention to provide a dual fuel system having a liquified gas to gaseous fuel converter in which the converter has a valving structure on which undue pressure is not exerted by the valve actuator when the valve is in the closed position.

It is a further object of the present invention to provide a dual fuel system having a liquified gas to gaseous fuel converter with the converter adapted to operate at very low manifold vacuum pressures such as those experienced during engine starting in cold climates.

It is a further object of the present invention to provide a dual fuel system having a liquified gas to gaseous fuel converter which automatically self adjusts to provide an "economy" fuel mixture during cruise conditions.

It is a further object of the present invention to provide a dual fuel system having a liquified gas to gaseous fuel converter which has an inlet valve which positively locks off incoming fuel even if the inlet valve actuator diaphragm breaks.

It is a further object of the present invention to provide, in a dual fuel system, a positive acting means for selecting fuel which functions without the use of electricity.

It is a further object of the present invention to provide a dual fuel system having a gaseous fuel and air mixer which is easily adaptable to use with a variety of fuels, including liquified petroleum gas, propane, natural gas and hydrogen as well as other gases usable for combustion in internal combustion engines.

It is a further object of the present invention to provide a dual fuel system utilizing a mixer which is sufficiently compact to occupy substantially only the space within the air cleaner element on conventional engines.

SUMMARY OF THE INVENTION

The present invention achieves these and other objectives in a system which may be used with conventional internal combustion engines, such as automobile engines, to permit alternative utilization of a liquified gas fuel, such as liquified petroleum gas, propane, natural gas, hydrogen or other gases usable for combustion in internal combustion engines, and a liquid fuel, such as gasoline, alternatively selectable by a manually operated control. While other fuels may advantageously be utilized with the instant invention, for the purposes of the following description, it will be assumed that the fuels to be utilized are propane and gasoline unless otherwise indicated.

The system comprises generally: (a) a fuel selection means generally including a fluid dual valve which may be controlled by a remote control mounted, for instance, on the dashboard of an automobile, (b) a converter for converting the pressurized, liquified fuel, such as propane, to a gaseous state at desired pressures and temperatures and (c) a mixer for combining the pressurized gaseous fuel with air and delivery to the

conventional gasoline carburetor. Alternative embodiments of the mixer are disclosed. Operation of the dual fuel system is as follows.

Positioning of the fuel selection control in the "gasoline" mode results in opening the vacuum line connected to the converter to the atmosphere and a consequent absence of pressure differential between the two sides of the converter liquid inlet diaphragm and positive lock-off of the converter liquid inlet valve. With the control in such position, a valve in the gasoline line between the gasoline pump and conventional gasoline carburetor is "on," and the conventional carburetor functions in the normal fashion with air passing through the air filter and mixer and into the carburetor. Additionally, there may be optional provision in the "gasoline" mode for opening of the air passage within the mixer or an air bypass around the mixer to facilitate passage of air into the conventional carburetor.

When the "propane" mode is selected, the gasoline valve portion of the fuel selection means is "off," thereby preventing supply of gasoline to the carburetor, and the connection of a vacuum line between the intake manifold of the engine and the converter is completed. When the engine is started, engine intake manifold vacuum reduces the pressure on one side of the converter liquid inlet valve diaphragm, resulting in movement of the diaphragm against a liquid inlet valve lever as a result of atmospheric pressure on the opposite side of the inlet valve diaphragm. Movement of the inlet valve lever urges the liquid inlet valve open, thereby permitting liquid propane to enter a fuel passage in the converter. Propane is admitted through a second valve in the converter structure into a gaseous fuel chamber where it expands to a gas with the resulting gas pressure normally being regulated to 11 inches w.c. Such regulation is achieved by a second, or main, diaphragm which is spring biased on one side to actuate the gas valve and is urged by increased pressure within the chamber on the other side of the second diaphragm to allow the gas valve to close.

In the preferred embodiment, the liquified fuel inlet valve diaphragm is substantially the same size as the second, or main, diaphragm. Utilization of such a large inlet valve diaphragm results in very quick starting capability because relatively little drop in intake manifold pressure is required to activate the inlet valve. Such a small drop in manifold pressure at starting is common with the low engine starting speeds normally experienced during cold weather conditions.

Elevation of the temperature of the propane to encourage vaporization is achieved in a portion of the gaseous fuel chamber where fins are warmed by heat from engine coolant piped through the body of the converter. Such vaporization of the propane and elevation of its temperature is achieved primarily during cruise and medium speed operation of the engine. At higher speed operation, propane is elevated in temperature less, which is desirable since it is beneficial for an engine to run with cooler propane at higher speeds because the volumetric efficiency of the engine is thereby improved. Accordingly, the engine will run slightly richer at the wide open throttle position.

Conversely, during cruise conditions, engine coolant elevates the temperature of the propane, thereby increasing its volume and resulting in a leaner fuel mixture. Additionally, a duct from the engine manifold pressure chamber of the converter communicates with a bellows and bellows spring structure which is located

inside the second diaphragm spring such that the second diaphragm is biased by the bellows and bellows spring structure toward the gaseous fuel chamber. During cruise conditions, the engine intake manifold vacuum, which is between 7 inches h.g. and 20 inches h.g., causes the bellows to contract, thereby decreasing pressure on the second diaphragm, which in turn reduces the pressure in the gaseous fuel chamber from approximately 11 inches w.c. to approximately 8 inches w.c. This further reduces fuel flow during cruise conditions, thereby insuring a lean fuel mixture which is desirable for fuel economy during cruise conditions.

The mixer of the instant invention, which is shown and described in alternative embodiments, utilizes a plunger structure and tapered member or needle to meter fuel and air flow in response to engine demand. The plunger structure in the first embodiment is a relatively large round piston which provides a larger effective surface area than a diaphragm of the same diameter, thereby resulting in more effective fuel and air control because the ratio of piston surface areas subjected to pressure differentials is greater than the same ratio on similar diaphragm type mixers. In the second embodiment, the plunger structure is a smaller round piston with a projecting portion having a cross section which is substantially oval (e.g., of elongated cross section having two parallel sides and half-circular ends). In both embodiments the piston is actuated by atmospheric pressure and engine vacuum. Engine vacuum is communicated to the side of the piston away from the air passage while atmospheric pressure is maintained on the opposite side of the piston. Attached to the plunger structure is a needle which extends into an orifice thereby forming a needle valve fuel meter. Engine vacuum actuates the piston, which opens the needle valve and supplies a fuel and air mixture to the engine (through the conventional carburetor), thereby tending to increase pressure within the mixer, which results in stable piston positions and uniform fuel flow at various engine speeds.

In the first embodiment of the mixer of the present invention air flow is regulated by the distance between one face of a large round piston and an annular surface coaxial with the piston. Since the area of the "cross section" of the air passage in this embodiment is effectively the product of the diameter of the annular surface multiplied by the distance of the piston from that surface, a relatively large volume of air is admitted for a given increment of piston travel, and total piston travel can be relatively short, permitting design of a compact mixer. In the second embodiment of the present invention control of air flow is achieved, in part, by using an oval plunger which affords a greater ratio of air control surface area to surface area of the piston covered by the plunger than the ratio achieved in round plunger mixers. Thus the ratio of the area of the cross section of the air passage to piston diameter is relatively large, permitting a compact mixer.

In the second embodiment of the mixer of the present invention, unlike the structure disclosed in U.S. Pat. No. 3,528,787 and similar "SU" type carburetors, the valve needle is mounted entirely within a cavity in the plunger which controls air flow, and the needle projects into an orifice located at the end of a gaseous fuel passage formed by a fuel transfer tube also entirely within the plunger cavity (when the plunger fully occludes the air passage). Such structure provides a compact mixer while utilizing a very long needle to allow accurate

control of fuel flow, and the fuel transfer tube may be utilized as a guide for the plunger/piston structure, obviating the need for such a separate guide within the cylinder in which the piston travels or elsewhere. Such relatively long piston travel also substantially lessens any effect of hysteresis because the effect of any hysteresis which may be experienced is negligible by comparison to the total piston and needle travel.

The needle may also be mounted partially within a cavity in the piston in the second embodiment of the mixer of the present invention, and a fuel transfer tube acts as a piston guide, but there are certain structural differences between the two mixer preferred embodiments which will become apparent by reference to the drawings and detailed description which follows.

The foregoing and other objects and advantages of the present invention, as well as the details of an illustrative embodiment and alternatives thereto will be more fully understood from the following description of the drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational partial cross-section of the converter assembly with schematized fluid dual valve and valve control means.

FIG. 2 is a side elevational cross section of a first embodiment of the mixer assembly shown mounted on a conventional carburetor.

FIG. 3A is an exploded perspective view of the body and lower portions of the converter assembly.

FIG. 3B is an exploded perspective view of the top and upper portions of the converter assembly with a portion of a duct 43 shown in dotted lines.

FIG. 4 is an exploded perspective view of the first embodiment of the mixer assembly.

FIG. 5 is a side elevational partial cross-section of the second embodiment of the mixer assembly shown mounted on a conventional carburetor.

FIG. 6 is an elevational cross-section taken along the lines 6—6 in FIG. 5 of the second embodiment of the mixer assembly.

FIG. 7 is an exploded perspective view of the second embodiment of the mixer assembly.

FIG. 8 is an exploded perspective view of the fluid dual valve assembly.

FIG. 9 is a side elevational view of the valve assembly shown in FIG. 8 with a portion of the valve body cut away to show a portion of the internal construction of the fluid dual valve.

FIG. 10 is a cross sectional view taken along lines 10—10 of FIG. 9 when the dual fluid valve is in a first, "gasoline on," position.

FIG. 11 is a cross sectional view similar to FIG. 10 with the valve spool rotated 90 degrees to a second, "propane on," position.

FIG. 12 is a cross sectional view taken along lines 12—12 of FIG. 9 when the dual fluid valve is in the first, "gasoline on," position.

FIG. 13 is a cross sectional view similar to FIG. 12 with the valve spool rotated 90 degrees to the second, "propane on," position.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The converter and fuel selection means of the invention are shown in FIG. 1 and two alternative embodiments of the mixer portion of the invention are shown in partial section in FIG. 2 and in FIGS. 5 and 6. An ex-

ploded view of the converter assembly is shown in FIGS. 3A and 3B, an exploded view of the fluid dual valve is shown in FIG. 8 and exploded views of the alternative embodiments of the mixer portion of the invention are shown in FIGS. 4 and 7. In the figures, 1 is the liquified-to-gaseous fuel converter structure, 300 is the fluid dual valve structure and 100 and 200 are alternative embodiments of the mixer structure.

Operation of converter structure 1 and fluid dual valve structure 300 is the same, except as specifically indicated hereinafter, with mixer embodiment 100 and mixer embodiment 200, which are shown mounted on conventional carburetors 110 and 210 in FIGS. 2 and 5, respectively. Carburetors 110 and 210 are shown in FIGS. 2 and 5 mounted on engine intake manifolds 111 and 211, to which are connected intake manifold vacuum lines 112 and 212, respectively. Accordingly, mixer 100, carburetor 110, engine intake manifold 111, and intake manifold vacuum line 112 alone will hereafter be referred to in description of converter structure 1 and fluid dual valve structure 300, but it should be understood that such description is equally applicable to operation of converter structure 1 and fluid dual valve structure 300 with mixer 200, carburetor 210, engine intake manifold 211 and intake manifold vacuum line 212, respectively, unless otherwise specifically indicated.

Referring to FIGS. 1, 8 and 9, the fuel to be utilized is selected by positioning fluid dual valve control 301 in one of two positions, either "gasoline" or "propane." Positioning of control 301 in the "gasoline" mode acts through control cable 302 to rotate spool 306 within valve body 307 such that converter vacuum line 30 shown in FIG. 1 communicating with first vacuum outlet port 312 is open to the atmosphere through notch 316 in spool 306 communicating, as shown in FIG. 12, between first vacuum outlet port 312 and vent 317. The vent 317 communicates with the atmosphere when valve control 301 is in the "gasoline" mode. Simultaneously, gasoline from gasoline supply line 304 is supplied to the carburetor 110 through engine gasoline line 305, which lines communicate through tunnel 314 (see FIG. 10) connecting liquid inlet opening 309 and liquid outlet opening 310 in fluid dual valve 300. In this mode, the carburetor functions normally.

Liquid inlet diaphragm 10 in converter 1 is peripherally clamped between converter body 14 and converter base plate 11 such that the top side of diaphragm 10 is exposed to the pressure condition within converter vacuum line 30, which is atmospheric pressure during "gasoline" mode operation. The bottom side of liquid inlet diaphragm 10 is subjected to external atmospheric pressure at all times via converter base plate bleed 12.

Plunger-type liquified fuel inlet valve 2 is spring biased, as by liquid inlet spring 3, such that when pressure on opposite sides of liquid inlet diaphragm 10 is equal, liquid inlet lever 8 is not lifted, and the inlet valve 2 is closed.

Leakage of pressurized propane from supply 39 through inlet valve fitting 13 and into converter 1 is prevented by liquid inlet body O-ring 5 which creates a seal between liquid inlet body 4 and converter body 14. Sealing around liquified fuel inlet valve shaft 41 is provided by liquid inlet valve O-ring 6 which is held in place by liquid inlet valve O-ring retainer 7. Liquified fuel inlet valve 2 and the related structures of the present invention thus provide a "lock-off" of liquified gaseous fuel supplied to the converter 1 because the valve 2 will remain closed even if the integrity of converter

vacuum line 30 is broken or liquid inlet diaphragm 10 is ruptured.

When the "propane" mode of control 301 is selected, spool 306 is rotated within valve body 307 by control cable 302 such that O-ring 308 on the face of spool 306 forms a seal between spool 306 and valve body 307 around liquid inlet opening 309, as shown in FIG. 11, thereby prohibiting flow of gasoline to conventional carburetor 110 and preventing leakage of gasoline from gasoline supply line 304. Referring to FIG. 8, O-ring 308 is seated in a slot 318 milled into the face of spool 306. The walls of slot 318 are substantially parallel to the radius of the spool 306 at each incremental segment of the slot. Thus, as may be observed in FIGS. 10 and 11, opposing segments of the inner slot wall 320 proximate the greatest arc of the spool 306 oppose each other at an acute angle, as do the elements of the letter "V," and thereby capture the O-ring 308 and hold it in place in slot 318. Seal rings 319, which may be O-type rings, seated in circumferential slots (not shown) in spool 306, provide seals to the atmosphere and provide bearing surfaces which separate spool 306 from valve body 307.

Simultaneously, during "propane" mode operation, duct 315 within spool 306 is aligned to communicate with vacuum inlet port 311 and first vacuum outlet port 312, as is shown in FIG. 13, thereby connecting converter vacuum line 30 (shown in FIG. 1) through outlet port 312 and inlet port 311 to intake manifold line 112, which connects to engine intake manifold 111 shown in FIG. 2.

When the engine (not shown) is started, intake manifold starting vacuum, communicated to engine intake manifold pressure chamber 40 in converter 1 shown in FIG. 1 through lines 112 and 30 and fluid dual valve 300, creates a reduced pressure on the upper side of the liquid inlet diaphragm 10. Atmospheric pressure on the opposite (lower) side of diaphragm 10 urge diaphragm 10 upward against liquid inlet lever 8, the opposite end of which drives inlet valve shaft 41 against bias spring 3 and opens liquid inlet valve 2. Thus, liquified gaseous fuel flows through inlet valve orifice 31 into liquified fuel passage 32.

Pressure constantly exerted on the top side of main diaphragm 21 by a yieldable means, such as main diaphragm spring 20 and bellows 29 (more fully explained below) urges main diaphragm 21 against valve actuator stem 22, which in turn actuates fuel lever 24. Once actuated, fuel level 24 lifts fuel outlet cover 26, typically sponge, from fuel outlet 37, thereby permitting flow of fuel into gaseous fuel chamber 34. As pressure within gaseous fuel chamber 34 reaches that desired, the bias of spring 20 and bellows 29 is overcome and main diaphragm 21 moves upward, permitting fuel level 24 to seat fuel outlet cover 26 on outlet 37, thereby stopping flow of fuel into gaseous fuel chamber 34.

As the mixer 100 admits pressurized gaseous fuel to the engine, as will be more fully explained below, through gaseous fuel line 33 when the engine is being started or is running, the pressure within gaseous fuel chamber 34 of converter 1 is reduced. Such reduction of pressure is communicated to the lower side of main diaphragm 21 through opening 35 in guide plate 23. Consequently, main diaphragm 21 is urged downward by atmospheric pressure communicated to its top side through orifice 36 in converter top 19 and by the force exerted by main diaphragm spring 20 and optional bellows 29. Such downward movement again moves stem 22 against fuel lever 24, thereby lifting fuel outlet cover

26 from fuel outlet 37 and permitting additional flow of gaseous fuel into gaseous fuel chamber 34 to maintain the desired pressure. Stem 22, which acts as a valve actuator, is guided by guide plate 23 and contacts but is not connected to fuel lever 24 so that no force in addition to that exerted by fuel lever spring 27 is exerted on fuel lever 24 and fuel outlet cover 26 when main diaphragm 21 moves upward beyond the point at which fuel outlet cover 26 is fully seated. This prevents undesirable pressure on and compression of fuel outlet cover 26. Rotation of guide plate 23 within body 14 is prevented by guide plate pin 28 as shown in FIG. 3B.

The pressure of gaseous fuel within gaseous fuel chamber 34 is normally regulated to a pressure of approximately 11 inches w.c., achieved by selection of main diaphragm spring 20 and bellows 29 and bellows spring 44 to provide the desired pressure.

Fuel flowing into gaseous fuel chamber 34 is warmed by heat from a hot liquid, such as engine coolant, communicated to the fuel through fins 38 visible in FIG. 3A surrounding hot liquid coolant passage 16, through which engine coolant is circulated via hot liquid inlets 15, also shown in FIG. 3A. Such elevation of the temperature of the fuel is achieved primarily during cruise and medium speed operation of the engine. At higher engine speed operation, gaseous fuel passes through the converter so quickly that the temperature thereof is not significantly affected, which is desirable because it is beneficial for an engine to run with cooler gaseous fuel at higher speeds because secondary cooling by the fuel improves the volumetric efficiency of the engine. The engine thus runs slightly richer at wide open throttle since more fuel is contained in a given volume of fuel at lower gaseous fuel temperatures. Conversely, during cruise conditions, a lesser quantity of fuel is contained in a given volume of gaseous fuel as a result of elevation of the gaseous fuel temperature within converter 1, and a relatively leaner fuel mixture results.

Additionally, a duct 43 (shown in FIGS. 1 and 3B) communicating with engine manifold chamber 40, where engine manifold pressure is maintained, also communicates through passages 45 in converter cap 17 with a bellows 29, which is located inside the main diaphragm spring 20 and is biased against main diaphragm 21 by a means for yieldably forcing the bellows 29, such as bellows spring 44 inside of bellows 29. Thus, during cruise conditions, when the engine intake manifold pressure is between 7 inches h.g. and 20 inches h.g., bellows 29 contracts responsive to reduced intake manifold pressure, thereby decreasing the pressure on main diaphragm 21 and thus reducing the pressure level maintained in gaseous fuel chamber 34 from the normal level of approximately 11 inches w.c. Main diaphragm spring 20, bellows spring 44 and bellows 29 are selected to cooperate such that the pressure will be reduced in gaseous fuel chamber 34 during cruise conditions to approximately 8 inches w.c. This pressure reduction further reduces fuel flow to the mixer 100 during cruise conditions, thereby automatically providing for a lean fuel mixture (lower fuel-to-air mixture ratio) desirable for fuel economy during cruise conditions.

FIGS. 2 and 4 show section and exploded views, respectively, of a first alternative preferred embodiment of the mixer of the present invention, indicated by numeral 100 on FIG. 2. Mixer 100 includes, generally, (a) body structure including fuel inlet elbow 101, which forms a pressurized gaseous fuel passage 102, and cylinder 103 and (b) a plunger structure comprising piston

104 which moves within cylinder 103. Attached to piston 104 is needle 106 which cooperates with an orifice 114 above pressurized gaseous fuel passage 102 to form a needle valve-type structure which controls passage of pressurized gaseous fuel through valve passage 121 and into mixing chamber 115. Needle 106 may be removably attached to piston 104 by threading, press fitting or other conventional mounting means to permit interchangeable use of needles having different tapers appropriate for use with different gaseous fuels. Generally, a steeper needle taper is required for use with a fuel having a relatively smaller energy content and therefore requiring a higher fuel-to-air ratio for proper combustion.

Operation of mixer 100 may be understood by reference to FIGS. 2 and 4. At starting in the "propane" mode, engine starting venturi vacuum is communicated to mixing chamber 115 through conventional carburetor 110 and carburetor adapter 109. Such reduction of pressure within mixing chamber 115 is also communicated to the upper side of piston 104 via piston orifices 108. The lower side of piston 104 disposed radially outward of annular surface 137 on piston lifter 122 is subjected to outside atmospheric pressure communicated through air filter 113, which is held in place by air filter top plate 142. Such atmospheric pressure acting on the lower side of piston 104 urges the piston upward, overcoming the resistance of a yieldable bias means, such as spring 105, which urges piston 104 downward. Upward movement of piston 104, which is guided by sliding contact between the outside surface of fuel transfer tube 107 and the inner surface of piston cavity 125, lifts needle 106 from the annulus of contact 124 between the needle 106 and fuel transfer tube 107 at orifice 114, thereby permitting gaseous fuel within pressurized gaseous fuel passage 102 to flow through orifice 114 and valve passage 121 into piston cavity 125 and thence into mixing chamber 115 through fuel ports 123 (visible only in FIG. 2) in piston 104. Additionally, atmospheric air flows through the air filter 113 and as indicated by arrows 126 into mixing chamber 115 through the air passage which opens between piston 104 and piston lifter 122 when piston 104 moves upward, and such air continues to flow toward the engine through mixing chamber 115. Thus, gaseous fuel and atmospheric air mix within mixing chamber 115 and as both are drawn into conventional carburetor 110 through carburetor adapter 109.

The above-described flow of pressurized gaseous fuel and atmospheric air into mixing chamber 115 increases the pressure in the air passage within carburetor adapter 109, which increase in pressure is communicated to the top side of piston 104 via piston orifices 108. Resulting equalization of pressure on both sides of piston 104 permits spring 105 to urge piston 104 downward, thereby reducing the flow of gaseous fuel and atmospheric air into mixing chamber 115, which, in turn, results in a decrease in pressure in mixing chamber 115 as a consequence of venturi vacuum and repeat of the above-described sequence, which tends toward an equilibrium condition at each engine speed.

Provision is also made for separately controlled supply of atmospheric air and pressurized gaseous fuel to mixing chamber 115 at engine idle speeds while piston 104 remains in its downmost position. Gaseous fuel may pass through idle inlet tunnel 127 in needle 106, which inlet is variably partially obstructed by an adjustable valve means such as idle fuel adjustment screw 128. Idle

adjustment screw 128 is adjusted by insertion of a screwdriver through the access 143 in inlet elbow 101 created by removal of plug 120. Idle inlet tunnel 127 is positioned through the needle 106 surface above and below the annulus of contact 124 around orifice 114 to communicate with the needle 106 surface above and below the annulus of contact 124 so that fuel may pass from pressurized gaseous fuel passage 102 through idle inlet tunnel 127 and into valve passage 121. Air is admitted to mixing chamber 115 through idle air orifice 129 in piston lifter 122, and such air is metered by an adjustable valve means, such as by idle air adjustment screw 130. Such separate provision for supply at engine idle speeds permits improved control of air and fuel during idle without materially affecting fuel and air supply at higher engine speeds.

During "gasoline" mode operation of the dual fuel system, venturi vacuum communicated to the top side of piston 104 causes the piston 104 to be raised as described above, resulting in flow of air between the bottom side of piston 104 and annular surface 137 of piston lifter 122 as indicated by arrows 126 and into then functioning conventional carburetor 110 through mixing chamber 115.

More fuel efficient operation may be achieved by providing optional means for mechanically lifting piston 104 to permit flow of air as indicated by arrows 131 under piston lifter 122 when the "gasoline" mode is selected and mixer 100 is not functioning. Such lifting may be accomplished by addition of lifter actuator 132. In use, lifter actuator 132 is slightly rotated about its vertical axis by an actuation means, such as control cable 133 connected to control cable connector 134 and operated by a control means, which may conveniently be fluid dual valve control 301, shown in FIG. 1, which also actuates fluid dual valve 300. Such rotation results in sliding movement of lifter actuator arms 135 against camming surfaces 136 on piston lifter 122, thereby urging piston lifter 122 upward against the resistance of springs 140 surrounding pins 141 (one set of which pins and springs is shown in FIG. 4), thus permitting flow of air under piston lifter 122 and into conventional carburetor 110. Upon reverse rotation of lifter actuator 132 in response to movement of control 301, piston lifter 122 is pulled down to its normal, seated position by springs 140. Rotation of lifter actuator 132 in the desired direction with coupling to control 301 as shown in FIG. 1 requires that cable 133 pass through a bell crank (not shown) or other means to reverse cable movement or, alternatively, cable 133 may be coupled to lifter actuator 132 to rotate it in the opposite direction from that achieved by connection as shown in FIG. 4.

Alternatively, a second optional means for providing free air flow to the conventional carburetor 110 during "gasoline" operation of the dual fuel system may be achieved by providing communication between the top side of piston 104 and a vacuum source during "gasoline" operation, which thereby reduces the pressure on the top side of piston 104, resulting in movement of piston 104 upward responsive to atmospheric pressure on its lower side, thus permitting free flow of air between piston 104 and annular surface 137 on piston lifter 104. Provision for such communication is shown in FIGS. 1 and 2 by mixer vacuum line 138 which communicates with the top side of piston 104 through cylinder fitting 139, visible in FIG. 4, and connects to second vacuum outlet port 313 in fluid dual valve body 307. When fluid dual valve control 301 is positioned in the

"gasoline" mode, duct 315 in spool 306 communicates between vacuum inlet port 311 and second vacuum outlet port 313, as is shown in FIG. 13, thereby resulting in communication of engine intake manifold vacuum to the top side of piston 104 through mixer vacuum line 138.

FIGS. 5 and 6 show section views and FIG. 7 shows an exploded view of an alternative embodiment of the mixer assembly of the present invention, indicated by numeral 200. In this embodiment, mixer 200 includes, generally, (a) body structure comprising mixer body 201 and fuel transfer tube 207, which together form a pressurized gaseous fuel passage 202, and cylinder 203 and (b) a plunger structure comprising a piston 204, which moves within cylinder 203, and piston actuator 221 of substantially oval cross section. Mixer body 201 also forms an air passage 216 shown in FIGS. 6 and 7 into which piston actuator 221 projects with the greater oval axis of the cross section of piston actuator 221 oriented transverse to air passage 216 for movement therein to variably restrict air flow. Movement of the plunger structure (comprising piston actuator 221 and piston 204) is guided by sliding contact between a portion of the outside surface of fuel transfer tube 207 and arcuate sliding surfaces 227 in piston actuator cavity 225. Attached to piston 204 is a needle 206, which moves within orifice 214 of pressurized gaseous fuel passage 202 to form a needle valve-type structure which controls passage of the pressurized gaseous fuel into mixing chamber 215. Needle 206 may be removably mounted in the plunger structure by employing threading, press fitting or other conventional mounting means to permit interchangeable use of needles having different tapers appropriate for use with different gaseous fuels as described above in connection with mixer 100.

Operation of second embodiment of mixer 200, which is similar to operation of first embodiment of mixer 100, may be understood by reference to FIGS. 5, 6 and 7.

At starting in "propane" mode operation, engine starting venturi vacuum is communicated to mixing chamber 215 and the downstream side of air passage 216 through a conventional carburetor 210 and carburetor adaptor 209. Such venturi vacuum is also communicated to the back side 222 of piston 204 through piston orifices 208. The front side 223 of piston 204 is substantially subjected to outside atmospheric pressure communicated through air filter 213 and into cylinder 203 through mixer body 201 holes 224 (visible in FIG. 7). Such atmospheric pressure acting on the front side 223 of piston 204 urges piston 204 against the resistance of a yieldable bias means such as spring 205, and the reduced pressure on the back side 222 of piston 204 induced by venturi vacuum. Such movement of piston 204 moves piston actuator 221 and needle 206. Movement of needle 206 away from orifice 214 at the end of fuel transfer tube 207 permits gaseous propane within pressurized gaseous fuel passage 202 to flow into piston actuator cavity 225 and thence into air passage 216 in mixer body 201 and into mixing chamber 215. Venturi vacuum also draws atmospheric air through air filter 213 and air passage 216 past piston actuator 221 and into mixing chamber 215. Thus, gaseous fuel and atmospheric air mix within mixing chamber 215 as both are drawn into conventional carburetor 210 through carburetor adaptor 209. Baffle 234 attached to housing 228 serves to break up air and fuel flow and induce turbulence so that such flow will not stratify and limit flow into the engine.

The above-described flow of pressurized gaseous fuel and atmospheric air into mixer body 201 increases the gaseous pressure within the mixer body, which increase in pressure is communicated to the back side 222 of piston 204 through piston actuator 221 orifices 208. 5 Resulting equalization in pressure on both sides of piston 204 permits spring 205 to urge piston 204 and the structures attached thereto toward mixer body 201, thereby reducing the flow of gaseous propane between orifice 214 and needle 206 into piston actuator cavity 10 225 and thence into mixer body 201, and movement of piston actuator 221 projecting into mixer body 201 reduces the flow of atmospheric air through mixer body 201. Such reduction in air and fuel flow, in turn, results in a decrease in pressure on the downstream side of air 15 passage 216 as a consequence of venturi vacuum and repeat of the above-described sequence, which tends toward an equilibrium condition at each engine speed.

Provision is made for controlled supply of atmospheric air and pressurized gaseous fuel to the engine by 20 second mixer embodiment 200 at engine idle speeds by providing a means for adjustably inhibiting projection of piston actuator 221 into mixer body 201 such as screw 226 which passes through mixer body 201 and contacts the end of piston actuator 221, thereby limiting 25 travel of piston actuator 221 and piston 204 and needle 206 rigidly connected thereto. Such limitation of travel provides a minimum passage for atmospheric air through air passage 216 and maintains a passage for gaseous propane between orifice 214 and needle 206. 30

During "gasoline" mode operation of the dual fuel system, as with first mixer embodiment 100, venturi vacuum communicated to the back side 222 of piston 204 against spring 205 as described above results in withdrawal of piston actuator 221 from air passage 216, 35 thereby permitting flow of air through air passage 216. More fuel efficient operation may be achieved by provision of an optional air valve providing a passage for air bypassing air passage 216. Such an optional air valve, best shown in FIG. 7, is provided in mixer 200 by openings 229 in housing 228 which align with air valve plate 40 openings 231 in air valve plate 230 which is rotated by a control cable 232, which may conveniently be actuated by control 301 by coupling to control 301 in place of cable 133 shown in FIG. 1. 45

Inadvertent incorrect orientation of the plunger structure of second mixer embodiment 200 to mixer body 201 during assembly or reassembly after servicing may be prevented by providing piston actuator 221 with an irregular cross sectional shape, as for instance, by the 50 provision of ridge 233 so that piston actuator 221 will be received in mixer body 201 only in the correct orientation.

Although the present invention is described and illustrated above with detailed reference to the preferred 55 embodiments, the invention is not intended to be limited to the details of such embodiments but includes numerous modifications and changes thereto while still falling within the intent and spirit hereof.

I claim:

1. A dual fuel system for an internal combustion engine comprising:

- (a) a fluid dual valve actuated by a manual control to permit flow of liquid fuel to the engine's carburetor when the control is in a first position and to prevent 60 such flow when the control is in a second position;
- (b) a liquified gas to gaseous fuel converter actuated by a decrease in engine manifold pressure commu-

nicated from the engine to the converter through the fluid dual valve when the control is in the second position; and

- (c) a mixer which mixes gaseous fuel supplied by the converter with air and supplies the mixture to the engine when the control is in the second position and which permits flow of air to the engine's carburetor when the control is in the first position.

2. A dual fuel system for an internal combustion engine comprising:

- (a) a converter body forming a liquified fuel passage and a gaseous fuel chamber;
- (b) a liquid fuel inlet valve yieldably biased toward a closed position and a first actuator responsive to a drop in engine manifold pressure to actuate the liquid fuel inlet valve for permitting fuel to flow into the liquified fuel passage;
- (c) a gaseous fuel inlet valve between the liquified fuel passage and the gaseous fuel chamber which valve is yieldably biased toward a closed position and a second actuator responsive to a pressure drop in the gaseous fuel chamber to actuate the gaseous fuel valve for permitting fuel flow into the gaseous fuel chamber;
- (d) a mixer body forming an air passage and a pressurized gaseous fuel passage communicating with the gaseous fuel chamber and having an orifice communicating with the air passage;
- (e) a plunger proximate the air passage for movement to variably restrict air flow through the air passage;
- (f) a means for yieldably biasing the plunger in one direction of movement, the plunger having a surface communicating with the air passage at the downstream side of the plunger to receive application of vacuum tending to move the plunger in the opposite direction against resistance imposed by the yieldable bias means;
- (g) a needle positionable within the orifice, one of the orifice and needle being movable relative to the other by the plunger to control the flow of gaseous fuel through the orifice;
- (h) a valve body having a liquid inlet opening, a vacuum outlet opening, a vacuum inlet port, a vacuum outlet port communicating with the first actuator, and a vent; and
- (i) a spool rotatable within the valve body in response to a control, said spool having a tunnel communicating between the liquid inlet opening and the liquid outlet opening when the control is in a first position, a duct communicating between the vacuum inlet port and the vacuum outlet port when the control is in a second position, and a notch communicating between the vacuum outlet port and the vent when the control is in the first position.

3. A dual fuel system according to claim 2, wherein the first actuator comprises a first diaphragm having one side communicating with the vacuum outlet port and the opposite side communicating with the external atmosphere and a valve linkage communicating between the first diaphragm and the liquified fuel inlet valve; and wherein the second actuator comprises a second diaphragm of substantially the same size as the first diaphragm having one side exposed to the gaseous pressure within the gaseous fuel chamber and the opposite side communicating with the external atmosphere, a valve actuator communicating between the gaseous fuel inlet valve and the second diaphragm and a yieldable

means for resisting diaphragm deflection induced by increased pressure in the gaseous fuel chamber and for urging the second diaphragm against the valve actuator.

4. A dual fuel system according to claim 3, further comprising means for automatically providing a lean fuel mixture of gas and air to the engine during cruise conditions by reducing the pressure of fuel in the gaseous fuel chamber, comprising:

- (a) a bellows and a means for yieldably forcing the bellows against the external atmosphere side of the second diaphragm, and
- (b) a means for contracting the bellows in response to a drop in engine manifold pressure to reduce the force exerted by the yieldable forcing means and bellows on the second diaphragm.

5. A dual fuel system according to claim 4, wherein:

- (a) the bellows contracting means comprises a second duct within the converter body structure communicating between the bellows and an engine manifold pressure chamber formed by the body structure and one side of the first diaphragm, and
- (b) the converter body is provided with a means for circulating liquid in heat transfer relation with the gaseous fuel chamber.

6. A dual fuel system according to claim 2, wherein the plunger includes a piston defining said surface, the piston having an oppositely facing surface communicating with the air passage at the upstream side of the plunger, the mixer body includes a cylinder receiving the piston and the yieldable bias means comprises a spring urging the plunger toward the orifice.

7. A dual fuel system according to claim 6, wherein a portion of the plunger projects within the air passage for movement therein to variably restrict air flow through the passage and has a substantially oval cross section with the greater oval axis transverse to the air passage.

8. A dual fuel system according to claim 6, wherein the plunger has a cavity, and the orifice and a portion of the gaseous fuel passage is within the cavity, the needle being mounted to the plunger within the cavity and being carried by the plunger to project within the orifice.

9. A dual fuel system according to claim 2, wherein the needle is provided with a tunnel positioned through the needle surface above and below an annulus of contact between the valve needle and the orifice and a screw to variably obstruct the tunnel for providing limited flow of fuel during engine idle conditions while the needle is fully closed.

10. A dual fuel system according to claim 2, further comprising means to variably inhibit travel of the plunger to a minimum air flow restricting position for permitting flow of air and fuel during engine idle conditions.

11. A dual fuel system according to claim 2, further comprising means for urging the plunger against the yieldable bias means to permit free flow of air through the air passage, said urging means comprising a mechanical linkage between the control and a third actuator, which actuator moves the plunger, when the control is moved to the first position, against the yieldable bias means.

12. A dual fuel system according to claim 2, further comprising means for urging the plunger against the yieldable bias means to permit free flow of air through the air passage, said urging means comprising a second vacuum outlet port in the valve body communicating

with the plunger surface and, when the control is in the first position, communicating with the vacuum inlet port via the duct.

13. A dual fuel system according to claim 2, further comprising a mechanical linkage between the control and an air supply valve to open the air supply valve when the control is in the first position to permit flow of air to the engine's carburetor bypassing the air passage.

14. A dual fuel system according to claim 2, wherein an O-ring seated on the surface of the spool forms a seal between the spool and the valve body around the liquid inlet opening when the spool is in the second position.

15. A dual fuel system according to claim 2, wherein the needle is removably affixed to the plunger so that needles having various tapers may be interchangeably used with fuels having different properties.

16. A dual fuel system for an internal combustion engine comprising:

- (a) a first body forming a liquified fuel passage, a gaseous fuel chamber, a manifold pressure chamber, and a liquid passage for circulating liquid in heat transfer relation with the gaseous fuel chamber;
- (b) a plunger-type liquified fuel inlet valve yieldably biased toward a closed position by a first spring and actuated to permit liquified fuel to flow into the liquified fuel passage by a first diaphragm acting on a lever, said diaphragm having one side exposed to pressure in the manifold pressure chamber and the other side exposed to the external atmosphere;
- (c) a lever-type gaseous fuel inlet valve between the liquified fuel passage and the gaseous fuel chamber yieldably biased toward a closed position by a second spring and actuated to permit fuel to flow into the gaseous fuel chamber by a second diaphragm of substantially the same diameter as the first diaphragm acting on a valve actuator removably contacting the gaseous fuel inlet valve, said second diaphragm having one side communicating with the external atmosphere and the other side communicating with the gaseous fuel chamber;
- (d) a diaphragm spring and a bellows and a bellows spring resisting second diaphragm deflection induced by increased pressure in the gaseous fuel chamber and urging the second diaphragm against the valve actuator, said bellows communicating with the duct to contract in response to a pressure reduction in the manifold pressure chamber to reduce resistance to deflection of the second diaphragm induced by increased pressure in the gaseous fuel chamber;
- (e) a second body forming an air passage, a pressurized gaseous fuel tube communicating with the gaseous fuel chamber and with the air passage via an orifice, and a cylinder;
- (f) a plunger having a portion of substantially oval cross section projecting within the air passage for movement therein to variably restrict air flow through the passage and a piston for movement within the cylinder, said piston having a surface communicating with the air passage at the downstream side of the plunger to move the plunger in a direction opposite resistance imposed by a piston spring and an oppositely facing surface communicating with the air passage at the upstream side of the plunger, said oval portion having a cavity, a portion of the wall of which contacts the tube to guide the plunger;

- (g) a needle removably affixed to the plunger within the cavity and positionable within the orifice to control the flow of gaseous fuel through the orifice;
- (h) an adjustable stop to variably inhibit travel of the plunger structure to its fully projecting position to permit flow of air and gas during engine idle conditions;
- (i) a third body having a liquid inlet opening, a liquid outlet opening, a vacuum inlet port for communication with the engine's intake manifold, a vacuum outlet port communicating with the manifold pressure chamber, and a vent;
- (j) a spool manually rotatable within the third body in response to a control, said spool having a tunnel communicating between the liquid inlet opening and the liquid outlet opening when the spool is in a first position; a second duct communicating between the vacuum inlet port and the vacuum outlet port when the spool is in a second position, a notch communicating between the vacuum outlet port and the vent when the spool is in the first position, and an O-ring seated on the surface of the spool to form a seal between the spool and the third body around the liquid inlet opening when the spool is in the second position; and
- (k) a mechanical linkage between the control and an air supply valve to open the air supply valve when the control is in the first position to permit flow of air to the engine's carburetor bypassing the air passage.
17. A dual fuel system for an internal combustion engine comprising:
- a converter for converting liquified fuel to a gaseous fuel, said converter having a gaseous fuel chamber with a liquified fuel inlet aperture, an engine vacuum inlet aperture and an outlet aperture adapted for communication with the carburetor of an internal combustion engine, said converter being operable responsively to engine manifold vacuum and to the pressure within said fuel chamber to pass gaseous fuel from said inlet aperture to said outlet aperture under a positive pressure;
 - a mixer for mixing air with a gaseous fuel for application to a combustion chamber, said mixer having a mixing chamber with an air inlet passageway adapted for fluid communication with a source of air, a gaseous fuel inlet aperture in fluid communication with the outlet aperture of said converter, an outlet aperture adapted for fluid communication with the carburetor of an internal combustion engine, air valve means for restricting the passage of air from said air inlet aperture to said outlet aperture responsively to engine venturi vacuum, and fuel valve means for restricting the passage of gaseous fuel from said fuel inlet aperture to said outlet aperture responsively to movement of said air valve means; and
 - a manually operable valve adapted for fluid communication with a source of liquified gas, a source of gasoline, atmospheric pressure and engine manifold vacuum, said valve being operative in a first position to pass gasoline to the carburetor of the internal combustion engine and being operative in a second position to pass liquified gas to the inlet aperture of said converter, and to apply engine vacuum to the engine vacuum inlet aperture of said converter.

18. The system of claim 17 wherein the response of said second valve means to the pressure within said fuel chamber is modulated as a direct function of engine manifold vacuum.

19. The system of claim 17 including means for adjusting the idle position of said mixer without adjusting the response characteristics thereof to engine demand.

20. The system of claim 17 wherein said fuel valve means is located within an axial passage in said air valve means.

21. The system of claim 17 wherein said air valve means includes a cylinder having a flat bladed extension, said extension apertured to receive a portion of said fuel valve means.

22. The system of claim 17 wherein said mixer includes:

- a mixing chamber having a generally rectangular air inlet passageway in fluid communication with a source of air, a fuel inlet tube adapted for fluid communication with a source of a gaseous fuel, and an outlet passageway adapted for fluid communication with a combustion chamber; and

- valve means for restricting the passage of air through said air inlet passageway to said outlet passageway and for restricting the passage of gaseous fuel from said fuel inlet tube to said outlet aperture,

- said valve means including a piston slidable within a chamber and having a generally flat bladed projection, the axis of said cylinder being normal to said air inlet passageway and said chamber being disposed relative to said air inlet passageway so that said flat bladed projection variably restricts the flow of air through said air inlet passageway responsively to the position of said piston in said cylinder,
- said fuel inlet tube supporting said piston within said cylinder.

23. The system of claim 22 wherein said converter comprises:

- a gaseous fuel chamber having an inlet aperture adapted for communications with a source of liquified gas, an outlet aperture adapted for communications with the carburetor of an internal combustion engine, and a plurality of internal partitions defining a convoluted passageway between said inlet and outlet apertures;

- first valve means being operable responsively to engine manifold vacuum to pass liquified gas from said inlet aperture to said second valve means, and
- second valve means being operable responsively to the pressure within said fuel chamber to pass liquified gas to said fuel chamber, said second valve means includes a diaphragm the movement of which is responsive to the pressure differential between atmospheric pressure and the pressure within said fuel chamber of less than about one third pounds per square inch;

- means for modifying the response of said second valve means to the pressure in said fuel chamber in response to engine vacuum, the effects of an increase into engine manifold vacuum being opposed to the effects of an increase in the pressure within said fuel chamber;

- a passageway adapted for fluid communication with a source of engine coolant, the walls of said passageway being in a heat transfer relationship to the partitions in said fuel chamber,

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whereby liquified gas may be passed from said inlet aperture through the heated and convoluted passageway in said fuel chamber for conversion to a gaseous fuel and for subsequent passage through said outlet aperture under a positive pressure to the carburetor of an internal combustion engine.

24. The system of claim 17 wherein said converter comprises:

a gaseous fuel chamber having an inlet aperture adapted for communications with a source of liquified gas, an outlet aperture adapted for communications with the carburetor of an internal combustion engine, and a plurality of internal partitions defining a convoluted passageway between said inlet and outlet apertures;

first valve means being operable responsively to engine manifold vacuum to pass liquified gas from said inlet aperture to said second valve means, and second valve means being operable responsively to the pressure within said fuel chamber to pass liquified gas to said fuel chamber, said second valve means includes a diaphragm the movement of which is responsive to the pressure differential between atmospheric pressure and the pressure within said fuel chamber of less than about one third pounds per square inch;

means for modifying the response of said second valve means to the pressure in said fuel chamber in

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response to engine vacuum, the effects of an increase into engine manifold vacuum being opposed to the effects of an increase in the pressure within said fuel chamber;

a passageway adapted for fluid communication with a source of engine coolant, the walls of said passageway being in a heat transfer relationship to the partitions in said fuel chamber,

whereby liquified gas may be passed from said inlet aperture through the heated and convoluted passageway in said fuel chamber for conversion to a gaseous fuel and for subsequent passage through said outlet aperture under a positive pressure to the carburetor of an internal combustion engine.

25. A method of operating an internal combustion engine on a liquified fuel comprising the steps of:

- (a) manually positioning a fuel selector switch;
- (b) converting a liquified fuel to a gaseous fuel responsively to the position of the fuel selector switch, to engine manifold vacuum, and to the pressure of the converted fuel;
- (c) metering air to the carburetor of the internal combustion engine responsively to carburetor venturi vacuum; and
- (d) metering gaseous fuel to the carburetor of the internal combustion engine responsively to the metered flow of air.

* * * * *

EXHIBIT 1017

Internal Combustion Engines

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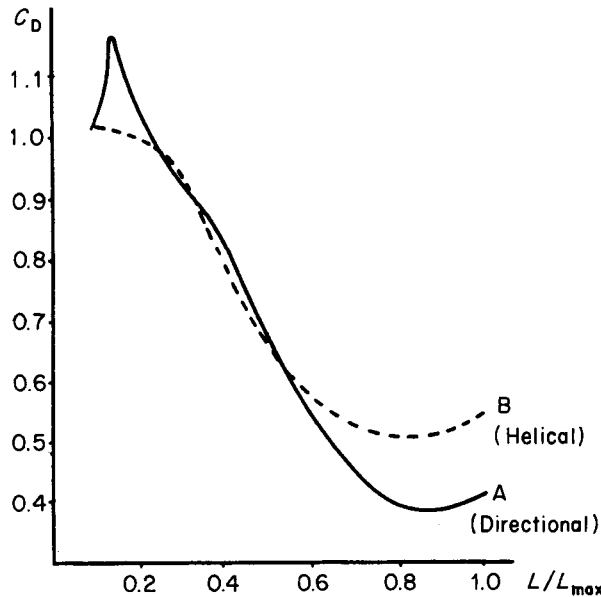


Figure 11 Variation of flow coefficient with valve lift for directed and helical inlet ports (Tindal and Williams, 1977). Reprinted with permission © 1977 Society of Automotive Engineers, Inc.

2. Steady flow testing of inlet ports

Before proceeding to discuss the development of the air motion produced by helical and directed ports during the induction and compression strokes, it will be useful to consider steady flow testing in more detail. This well-established technique is still widely used in the development of inlet ports. The cylinder head itself, or a prototype model which may be made of wood or other easily worked material, is mounted on a rig which supplies a steady flow of air through the port and valve. The cylinder is simulated by a long tube of equivalent diameter; this is usually made of transparent plastic in order to allow visualization of the flow. The rate of swirl of the air within the tube is measured over a range of fixed valve lifts, the pressure drop across valve and port being maintained at the same value (commonly 25 cm of water) for all lifts. Figure 12 (Watts and Scott, 1970) shows a typical rig. The swirl rate is measured at a fixed distance from the head (typically one cylinder diameter) by means of a vane anemometer or an impulse momentum meter (Figure 13). The vane anemometer employs a rotor supported on low friction bearings, mounted coaxial with the plastic tube; the speed of rotation may be determined by means of a stroboscope or by an electronic counter coupled to a sensor in the tube wall. It has the disadvantage that it will only respond

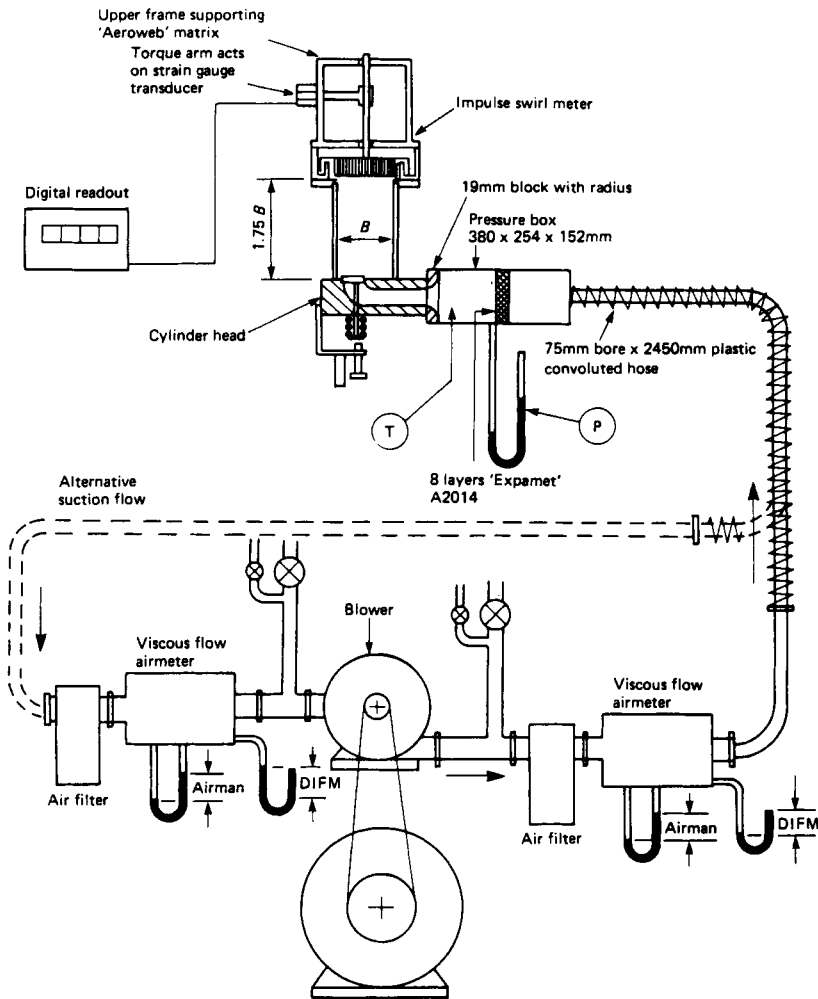


Figure 12 Steady flow rig for testing inlet ports (Watts and Scott, 1970). Reprinted by permission of the Council of the Institution of Mechanical Engineers from Symposium on Diesel Engine Combustion, 1970.

correctly to a swirl which is coaxial with the cylinder; it will give little or no reaction to a motion such as that illustrated in Figure 9(a), even though the air velocities may be quite high. The impulse momentum meter (Tippleman, 1977), on the other hand, responds directly to the angular momentum of the air in the tube. It embodies a circular element of honeycomb structure which is a clearance fit inside the tube and acts as a flow rectifier, turning the air into the axial direction. The torque acting on the flow rectifier can easily be measured and is equal to the angular momentum flux.

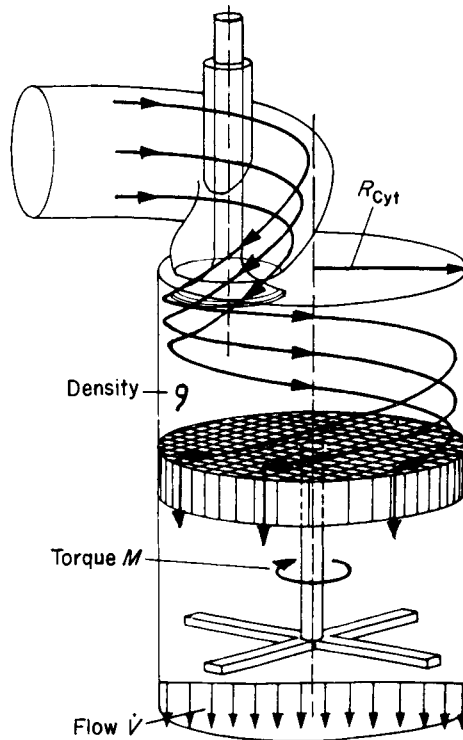


Figure 13 Impulse momentum meter (Tippelman, 1977). Reprinted with permission © 1977 Society of Automotive Engineers, Inc.

Thus the device provides an accurate measurement of angular momentum, irrespective of the velocity distribution. The steady flow test is performed under conditions which differ in a number of respects from those which exist in an engine. In particular the air flow into an engine cylinder is unsteady and must be influenced to some extent by the presence of the piston. Nevertheless the procedure is a valuable means of comparing the characteristics of different port shapes.

3. Cylinder air flow measurements in motored engines

To obtain accurate and detailed information about the air motion in the cylinder during the induction and compression strokes, it is necessary to make measurements inside a motored engine; the techniques most commonly employed are laser-Doppler anemometry and hot wire anemometry (Witze, 1980; Durst *et al.*, 1981; Monaghan *et al.*, 1981; Tindal *et al.*, 1982; Dyer, 1985). The former has a number of advantages — for example it causes no

fer. Consequently the rate of increase of temperature of the surface of the droplet slows down, the temperature gradient within the liquid becomes less steep, and a point is reached where all the heat received by the droplet goes to vaporize the fuel, the temperature becoming constant at a value which is often referred to as the “wet-bulb temperature” by analogy with psychometrics.

Godsave (1953) found that the burning rate of a fuel was less dependent on its volatility, as represented by the vapour pressure, than on the rate of heat transfer. He concluded that the critical property of the fuel was the enthalpy of evaporation. From the results of experiments, Godsave and others have found that the droplet size decreases in such a way that the square of the diameter is a linear function of time. More precisely,

$$D^2 = D_0^2 - \lambda t$$

where D_0 = diameter at $t = 0$ and λ is called the evaporative constant.

If the droplet is assumed to be spherical, its volume at time t is given by $\frac{\pi D^3}{6}$. It may easily be shown that

$$\frac{d}{dt} \left(\frac{\pi D^3}{6} \right) = - \frac{\pi \lambda}{4} D$$

and if a constant mean density, ρ_m , is assumed for the droplet liquid, the rate of change of mass is given by

$$- \frac{\rho_m \pi \lambda}{4} D.$$

In other words, the instantaneous rate of change of mass of the droplet is directly proportional to the diameter. Figure 26 shows the results of measurements by Nishiwaki (1955) of the way in which the size of water droplets of various initial diameters decreased after they were suddenly introduced into a furnace where the temperature was 620°C. For almost the whole of the evaporation period, D^2 is directly proportional to time, the temperature of the droplet being constant at the “wet-bulb” value. During the first half second or so, the diameter is decreasing at a much slower rate; this is because the droplet temperature is still rising to its final value.

In another experiment Nishiwaki built an apparatus in which a droplet of fuel, suspended on a thin filament of silica, could suddenly be plunged into an environment of high temperature air. The change in size of the droplet was monitored by cine-photography. Figure 27 shows D^2 plotted against time for a droplet of α -methyl naphthalene; the air temperature was 713°C. The diagram may conveniently be divided into several phases. Initially the droplet temperature is rising and vaporization is negligible; D^2 increases slightly as

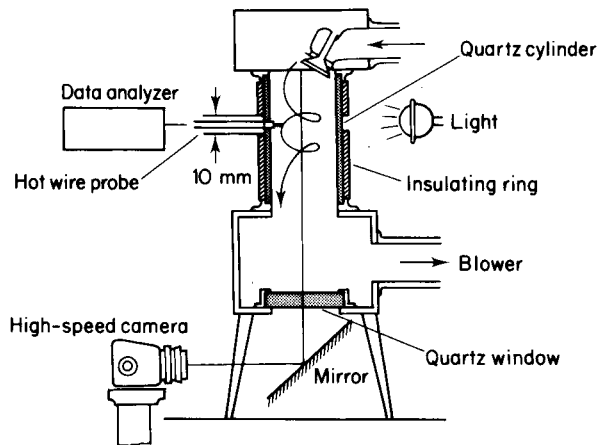


Figure 27 Experimental apparatus for gas flow study in cylinder by high speed photography and hot wire anemometry (Matsushita *et al.*, 1985).

hot wire anemometry was used in the engine development process for both diesel and spark-ignition engines. Although it is hard to find good examples of the actual application of LDA to engine design it is quite reasonable to expect that LDA could replace hot wire anemometry in most development tasks. For example, the development of the Toyota lean-burn system, which was previously discussed with respect to the use of flow visualization in engine design, also benefited from quantitative measures of the swirl velocity profiles using hot wire anemometry (see Figures 27 and 28). Today, the measurement of swirl could be performed both with more ease and accuracy through the use of LDA. In the previous section we discussed how the Toyota researchers used visualization techniques to develop their system. However, they supplemented the visualization results with quantitative measures of swirl in the cylinder to aid them in their decision process. In addition to the swirl profiles in the cylinder, the Toyota engine developers were also interested in more detailed measurements of velocity profiles around the intake valve to characterize the intake port flows. A similar measurement, coupled with three-dimensional modelling, is being performed using LDA to study the effects of port shape on in-cylinder flows by the AVL researchers Brandstatter *et al.* (1985). Since engine flows are particularly complicated, engine developers, such as Toyota and AVL, use all possible techniques to insure a successful design.

The effect of combustion chamber shape on the flow field is of particular interest to diesel engine developers and hot wire anemometry has been used extensively to characterize the flows produced by various geometries of

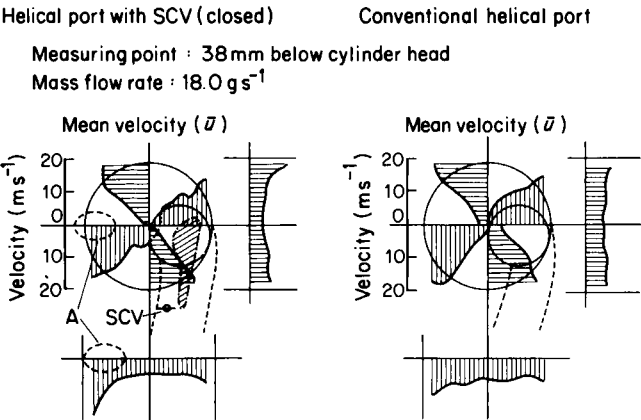


Figure 28 Flow velocity pattern for conventional helical port and SCV valve closed (Matsushita *et al.*, 1985).

the piston bowl. One study compares the flow fields produced by a toroidal design to those of a re-entrant design (Figure 29). By using shielded hot wires, it was determined that the re-entrant design held the swirl in the bowl longer during expansion process, thus explaining the better performance of this chamber at retarded injection timings. An LDA system would have yielded similar information with more confidence in the accuracy of the measured flow velocities and it is expected that LDA will replace the hot wire for most in-cylinder engine applications.

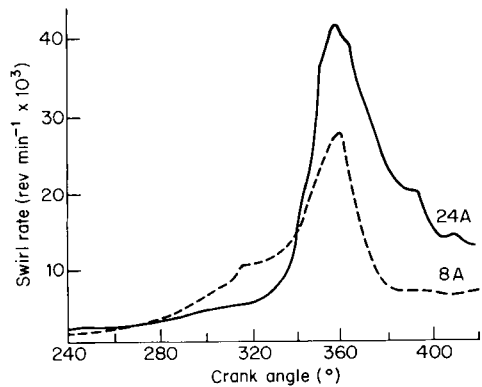


Figure 29 Comparison of swirl rates in toroidal and re-entrant chambers. Case 24a denotes the re-entrant chamber (Williams and Tindal, 1980).

EXHIBIT 1018

Alternative Transportation FUELS

Utilisation in Combustion Engines



M. K. Gajendra Babu
K. A. Subramanian



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Petitioner MWE Investments, LLC, et al.
Exhibit 1003, Page 1079

Alternative Transportation FUELS

Utilisation in Combustion Engines

**M. K. Gajendra Babu
K. A. Subramanian**



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Generally two types of viscometers are used to measure the viscosity of a fuel:

1. Redwood viscometer
2. Saybolt viscometer

6.3.2.1 Redwood Viscometer

A redwood viscometer consists of a cylindrical oil cup furnished with a gauge point, a metallic orifice jet at the bottom having a concave depression from inside to facilitate a ball with stiff wire to act as a valve to start or stop oil flow as shown in Figure 6.2. The outer side of the orifice jet is convex, so that the oil under test does not creep over the lower face of the oil cup. The oil cup is surrounded by a water bath with a circular electrical immersion heater and a stirring device. Two thermometers are provided to measure the water bath

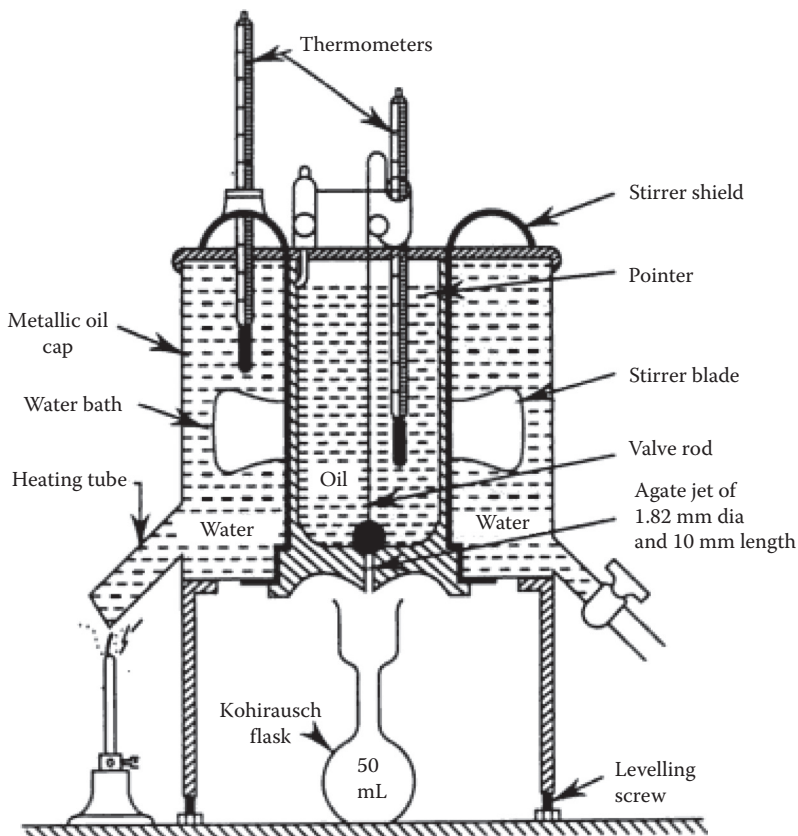


FIGURE 6.2
Redwood viscometer.

temperature and oil temperature under test. A round flat-bottomed flask of 50 mL marking is used to measure 50 mL of oil flow against time. The water bath with oil cup is supported on a tripod stand with levelling screws.

6.3.2.1.1 Procedure

The oil cup is cleaned with a solvent, preferably carbon tetrachloride (CTC), and it is wiped dry thoroughly with a paper napkin or a soft cloth (do not use cotton waste) and the orifice jet is wiped with a fine thread. The water bath is kept with the oil cup on the tripod stand and is levelled. Water is poured into the water bath up to 15–20 mm below the top portion. The ball (valve) is kept in position and clean filtered oil is poured as the sample (use a strainer not coarser than BS 100 mesh) to be tested into the oil cup up to the gauge point and it is covered with the lid. A 50-mL flask with clean dry is placed under the orifice jet of the oil cup. The ball (valve) is lifted and a stopwatch is simultaneously started and the oil is allowed into the receiving flask. The receiving flask (50 mL) is adjusted in such a way that the oil string coming out of the jet strikes the neck of the flask to avoid foaming (formation of air bubbles) on the oil surface. One has to wait till the oil level touches the 50-mL mark. The stopwatch is stopped and the time is recorded. The experiment is repeated at different temperatures above ambient.

6.3.2.2 Saybolt Viscometer

This apparatus mainly consists of a standard cylindrical oil cup surrounded with a water bath with an immersion heater and a stirring device (Figure 6.3). The apparatus is supplied with two stainless steel orifice jets, namely a universal jet and Furol jet, which can be fitted at the bottom of the oil cup as per our requirement. A rubber cork stopper arrangement is also provided at the bottom to facilitate the start and stop of the oil flow from the viscometer. Two thermometers are provided to measure the water bath temperature and oil temperature under test. A round flat-bottomed flask with a 60-mL marking on the neck is provided to measure 60 mL of oil flow against time. The oil cup with the water bath is supported on a stand with levelling screws.

6.3.2.2.1 Procedure

The oil cup is cleaned with a solvent, preferably CTC, and it is wiped dry thoroughly with a paper napkin or a soft cloth (cotton waste is not used) and the orifice jet is wiped with a fine thread. The water bath is kept with the oil cup on the tripod stand and is levelled. Water is poured into the water bath up to 15–20 mm below the top portion. The orifice opening is closed from the bottom with the rubber cork provided. The oil to be tested is poured into the strainer by keeping the strainer on the oil cup until the oil fills the cup as well as in the side well. The excess oil is withdrawn in the side well and the thermometers are positioned in the water bath and in the oil cup. A clean dry 60-mL flask is taken and placed under the orifice jet of the oil cup that centres

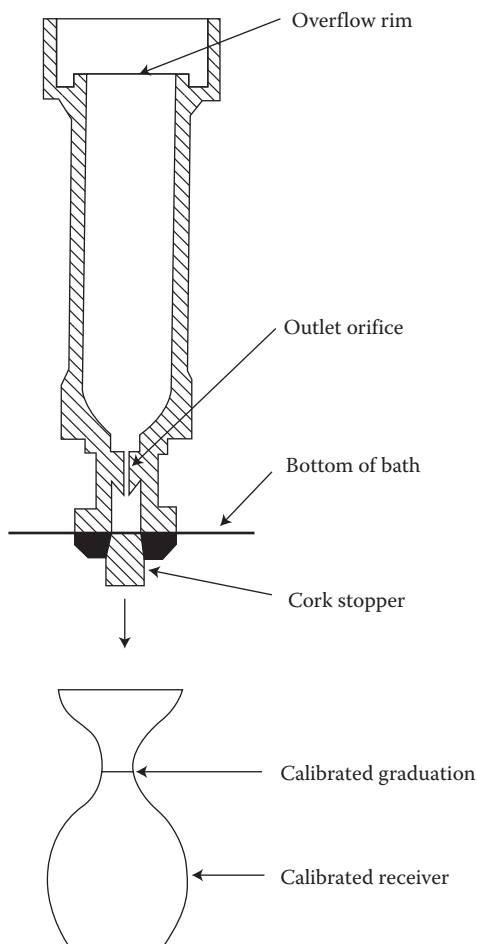


FIGURE 6.3
Saybolt viscometer.

it. The rubber cork is pulled open and a stop watch is simultaneously started and the oil is allowed into the receiving flask. The receiving flask (60 mL) is adjusted in such a way that the oil string coming out of the jet strikes the neck of the flask to avoid foaming (formation of air bubbles) on the oil surface. When the oil level reaches the 60-mL mark, the watch is stopped and the time is recorded in seconds. Repeat the experiment at different temperatures above ambient. Use a specific nozzle suitable for the lubricant or the oil.

6.3.2.2.2 Calculation

$$\text{Kinematic viscosity } (\nu) = (A \times t - (B/t)) \times 10^{-6} \text{ in m}^2/\text{s} \quad (6.8)$$

where

$A = 0.264$, $B = 190$, when $t = 40\text{--}85$ s

$A = 0.247$, $B = 65$, when $t = 85\text{--}2000$ s

The *density* of the given oil is

$$\rho = (w_2 - w_1) \times (10^3/50) \text{ in kg/m}^3 \quad (6.9)$$

where

w_1 = weight of the measuring jar in grams

w_2 = weight of 50 cc of oil in grams

$$\text{Absolute viscosity } (\mu) = \rho \times v \text{ in Pa s or N s/m}^2 \quad (6.10)$$

6.3.3 Flash Point

The flash point is the lowest temperature corrected to a barometric pressure of 101.3 kPa (760 mm Hg), at which the application of an ignition source causes the vapours of a specimen of the sample to ignite under specified conditions of the test. The flash point temperature is one measure of the tendency of the test specimen to form a flammable mixture with air under controlled laboratory conditions. It is only one of a number of properties that must be considered when assessing the overall flammability hazard of a material. It is used in shipping and safety regulations to define *flammable* and *combustible* materials. An Ables apparatus is used to determine the flash point that is shown in Figure 6.4.

6.3.3.1 Description of Apparatus

In the Pensky–Martens closed cup flash point test, a brass test cup is filled with a test specimen and is fitted with a cover. The sample is heated and stirred at specified rates depending on what is being tested. An ignition source is directed into the cup at regular intervals with simultaneous interruption of stirring until a flash that spreads throughout the inside of the cup is seen. The corresponding temperature is its flash point. The Pensky–Martens closed cup is sealed with a lid through which the ignition source can be introduced periodically. The vapour above the liquid is assumed to be in reasonable equilibrium with the liquid. Closed cup testers give lower values for the flash point (typically 5–10 K) and are a better approximation of the temperature at which the vapour pressure reaches the lower flammable limit (LFL).

6.3.3.2 Procedure

The apparatus is installed on a table near a 230-V, 50-Hz, 5-A single-phase power source. The electrical heater is kept on the table. The oil cup holder is

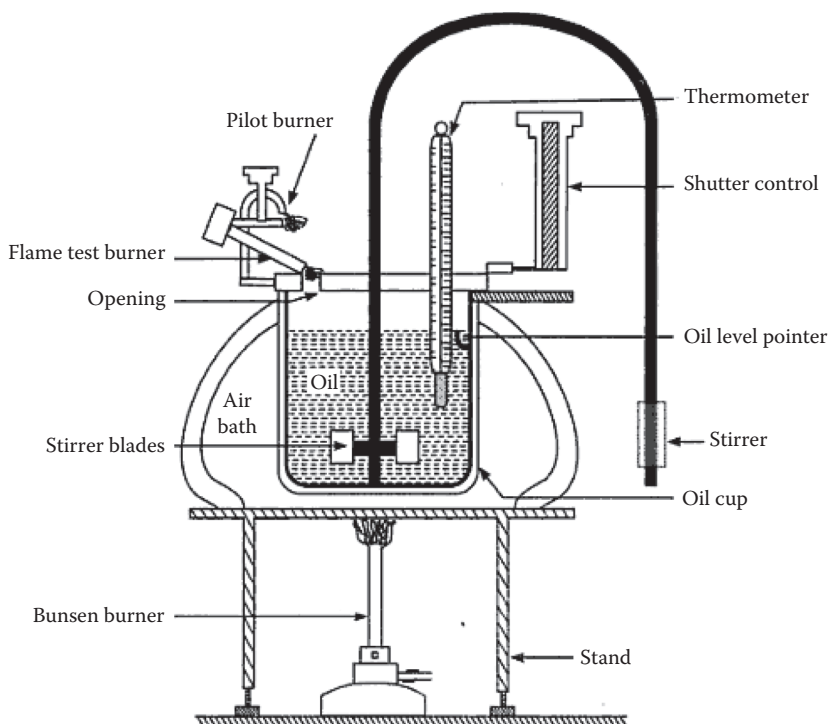


FIGURE 6.4
Ables apparatus.

positioned (air bath) on the heater. The oil cup is inserted into the bath and positioned in it. The oil to be tested is poured into the oil cup up to the mark. The lid is closed, the heater is connected to the electrical power source and the oil is heated at a slow and steady rate of $2^{\circ}\text{C}/\text{min}$ with the help of the regulator. By stirring the oil with the stirring mechanism, a small flame is maintained on the wick. The flame is introduced to the oil surface by operating the circular handle, which makes the maintained flame that dips into the oil cup by opening the shutter. This is done at every $1/2$ min, only after the sample oil reaches $15\text{--}17^{\circ}\text{C}$ before the expected flash point. Record the temperature at which the first flash is recorded and that is reported as the flash point of the sample oil. To stop the experiment, switch off the heater and allow it to cool.

6.3.4 Cloud Point and Pour Point

The *cloud point* is the temperature of a liquid specimen when the smallest observable cluster of hydrocarbon (HC) crystals first occurs upon cooling under prescribed conditions. The purpose of the cloud point method is to detect the presence of wax crystals in the specimen; however, trace amounts

of water and inorganic compounds may also be present. The intent of the cloud point method is to capture the temperature at which the liquids in the specimen begin to change from a single liquid phase to a two-phase system containing a solid and a liquid. The specimen is cooled at a specified rate and is examined periodically. The temperature at which a cloud is first observed at the bottom of the test jar is recorded as the cloud point. The cluster of wax crystals looks like a patch of whitish or milky cloud, hence the name of the test method. The cloud appears when the temperature of the specimen is low enough to cause wax crystals to form.

The *pour point* is the lowest temperature at which movement of the test specimen is observed under the prescribed conditions of the test. The pour point of a petroleum specimen is an index of the lowest temperature of its utility for certain applications.

6.3.4.1 Description of Apparatus

The apparatus for measuring cloud and pour points is shown in Figure 6.5, which consists of a cylindrical glass test jar with a 33.2–34.8 mm outside diameter and 115 and 125 mm height. The inside diameter of the jar may range

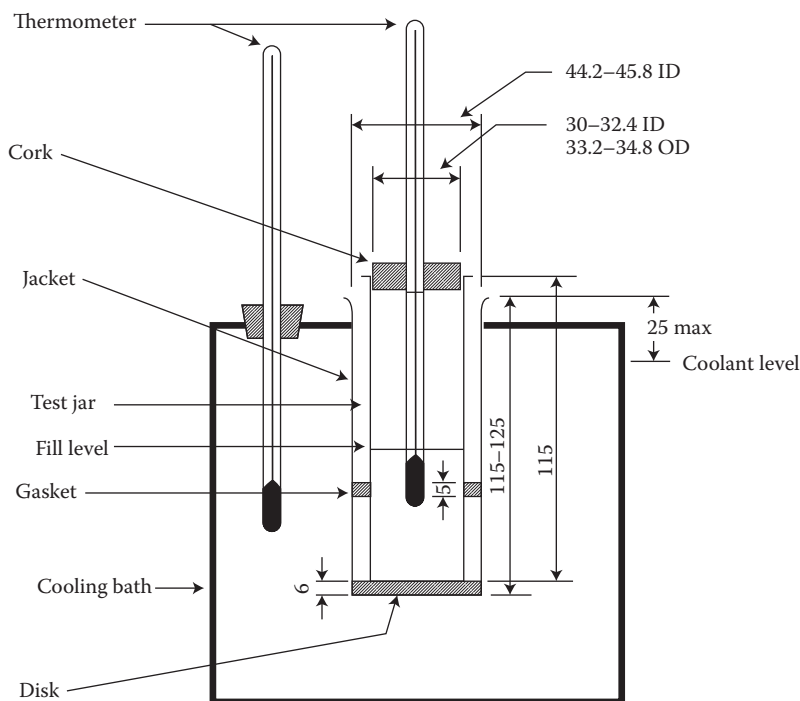


FIGURE 6.5

Apparatus for measuring cloud point and pour point.

from 30 to 32.4 mm within the constraint that the wall thickness must not be greater than 1.6 mm. The jar should be marked with a line to indicate the sample height 54 ± 3 mm above the inside bottom. This test jar is to be inserted in a metal or a glass jacket, watertight, cylindrical, flat bottom, about 115 mm in depth, with an inside diameter of 44.2–45.8 mm. It shall be supported free of excessive vibration and firmly in a vertical position in the cooling bath of 6.7 so that not more than 25 mm projects out of the cooling medium. Thermometers should be placed inside the apparatus as shown in Figure 6.5.

6.3.4.2 Procedure

6.3.4.2.1 Cloud Point

The sample to be tested is brought to a temperature at least 14°C above the expected cloud point. Any moisture that may be present is removed by a method such as filtration through dry lintels filter paper until the oil is perfectly clear, but makes such filtration at a temperature of at least 14°C above the approximate cloud point. The sample is poured into the test jar to the level mark. The test jar is tightly closed by the cork carrying the test thermometer. High cloud and pour thermometers are used if the expected cloud point is above -36°C and a low cloud and pour thermometers are used if the expected cloud point is below -36°C . The position of the cork and the thermometer is so adjusted that the cork fits tightly, the thermometers and the jar are coaxial and the thermometer bulb is resting on the bottom of the jar. See that the disk, gasket and the inside of the jacket are kept clean and dry. The disk is placed in the bottom of the jacket. The disk and jacket shall have been placed in the cooling medium for a minimum of 10 min before the test jar is inserted. A jacket cover may be used while the empty jacket is cooling. The gasket is placed around the test jar, 25 mm from the bottom. The test jar is inserted in the jacket. The jar should not be placed directly into the cooling medium. The temperature of the cooling bath is maintained at $0 \pm 1.5^{\circ}\text{C}$.

At each test thermometer reading that is a multiple of 1°C , the test jar is removed from the jacket quickly but without disturbing the specimen; after inspecting the cloud, it is replaced in the jacket. This complete operation shall require not more than 3 s. If the oil does not show a cloud when it has been cooled to 9°C , the test jar is to be transferred to a jacket in a second bath maintained at a temperature of $-186 \pm 1.5^{\circ}\text{C}$ (see Table 6.2). The jacket should not be transferred. If the specimen does not show a cloud when it has been cooled to -6°C , the test jar is transferred to a jacket in a third bath maintained at a temperature of $-336 \pm 1.5^{\circ}\text{C}$. For the determination of very low cloud points, additional baths are required; each bath needs to be maintained in accordance with Table 6.2. In each case, the jar is transferred to the next bath, if the specimen does not exhibit the cloud point and the temperature of the specimen reaches the lowest specimen temperature in the range identified for the current bath in use, based on the ranges stated in Table 6.2. The cloud

EXHIBIT 1019

PREFACE

MECHANICAL ENGINEER'S REFERENCE BOOK

Edited by

A. PARRISH, M.B.E., C.Eng., M.I.Mech.E.

With specialist contributors

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PREFACE

The introduction of SI Metric Units has necessitated to British Standards and other National Standards technical literature should reflect or anticipate the principal objective of the eleventh edition of Reference Book which has been completely revised and given in SI units only, even though in some instances information are in the inch or MKSA systems.

It is hoped that this book will meet the needs of management personnel in the Mechanical, Chemical and Engineering disciplines. It should also prove valuable to Engineers and College Lecturers and Students.

The contributors who are drawn from Industrial Associations and Educational bodies have done so with sufficient depth to give a thorough coverage of the subject readily understood by the reader. Further information is given in numerous tables and illustrations. An extensive bibliography is given in each section which gives reference to national and international literature and standards covering the subject matter.

Much of the technology is common to many of the work of the International Standards Bodies and for the removal of barriers to trade. Many of the terms referred to in the text may therefore be compared with National bodies.

Absolute units at first present difficulty to those used in inch and metric systems and it takes use to become used to a newton or a pascal as a force or pressure, because the gravitational systems do not differ from the loads (mass) and forces. The expressions, however, are the same when the units are in the coherent (SI) system. Many special names used in the older systems. No attempt is made to convert empirical data to another system of units, but to do this unilaterally. A case in point is gearing, which are not yet fully converted to SI. Some of the problems on the former unit systems as, for example, pipe sizes, the inch nominal sizes in the metric standards and which are based on the material stresses in kgf/cm² prevent the use of SI units for expressing the properties.

This book describes a wide variety of engineering practices and technology in metric units at the International level so far as it is at present practicable.

Extracts from British Standard publications are taken from the British Standards Institution, 2 Park Street, London. Copies of the complete publication may be obtained from the Institution.

13 POWER TRANSMISSION

STANLEY W. JONES

A full consideration of power transmission elements involves reference to numerous British Standards which have not yet been issued in SI units. Many such standards contain empirical formulae which are not valid in a consistent system of units and in these special cases the original form has been quoted. It is undesirable to anticipate action by the British Standards Institution and where Imperial units are currently the major source of reference, a metric conversion has been added.

ENERGY TRANSFER

This section, which deals with methods of energy transfer, outlines the principles which define the range of operation of various shaft mounted elements concerned with the transmission of power. The basis of shaft design for various operating criteria will also be examined.

The diversity of requirements for power transmission connections between prime mover and driven machine has led to the development of a wide range of clutches and couplings.

Couplings

Some manufacturers market more than six different types of coupling, several in combination with clutch and braking capability. Although certain applications are not critical as to the type of connection used, it is wise to compare alternative designs on a feasibility basis.

In the simplest type of *rigid* coupling the shafts rotate as one and any initial errors are transmitted to the driven member. Conventionally one half has a concentric spigot on its flange which fits into a recess in the other half flange; the fit being arranged to prevent lateral loads being taken by the connecting bolts. End thrust cannot be accommodated, neither is rapid disconnection possible.

Oldham couplings are rigid types intended to connect parallel shafts. The flanged ends on each shaft, which have a central grooved face, are connected by a central member having a tenon on each face, offset by 90°.

Hooke's joint or coupling has a star-like configuration made up of four equidistant arms, the pairs of which are pin-jointed into forks carried by the two shafts. Relative angular displacement of the shafts about the perpendicular centres of the pins is thus provided. If there is an appreciable difference between centre lines of parallel shafts, a cardan shaft with a joint at each end can be provided and this reduces the variation in velocity ratio.

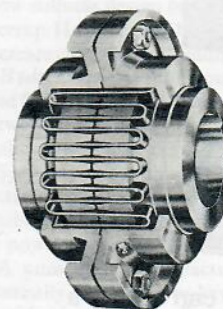
A *flexible* coupling specification should differentiate between the ability to tolerate misalignment and the inherent torsional flexibility. The specification should also clearly define the degree of flexibility required, whether this be radial (torsional) or in respect of an axial or end float motion. Data to be assembled should list the nature of torque

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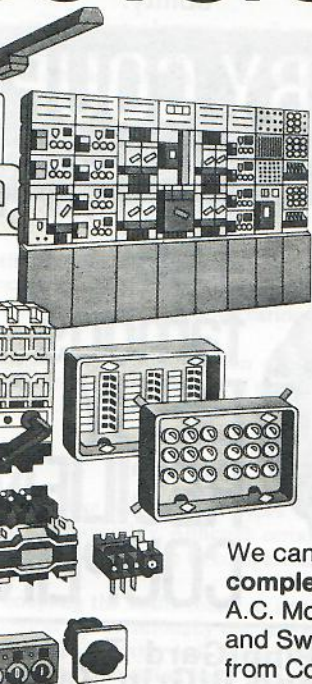
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fluctuation at particular speeds, the lack of concentricity between the shafts to be connected and any limitations in terms of space availability or environment. Manufacturer's recommendations should be sought in respect of peak loadings and the degree of misalignment that can be permitted.

Coupling characteristics exert considerable influence on the vibratory response of a shaft system and the type chosen should help in controlling response when the system is subjected to various stimuli. Lateral vibrations may be transmitted from adjacent machinery or arise within the system itself due to unbalanced masses. Torsional vibration will be minimised if operating ranges avoid critical speed areas. The degree of response in a 'soft' coupling will permit smooth running at speeds much above critical, alternatively a 'stiff' coupling will place certain orders of frequency outside the operating speed range.

The simplest *spider* type of flexible coupling takes its name from the rubber star or cruciform which engages with the metal jaws of each half coupling. Maximum capacity is 4 hp (3 kW) at 100 rev/min or its equivalent. In *Disc* couplings the half body flanges are fitted with steel drive pins which engage with a rubberised fabric centre disc. Torsional flexibility is small but compensated for by good capacity under impulsive loading and powers up to 700 hp (520 kW) at 1800 rev/min can be accommodated.

In *pin* type couplings, one half body has pins mounted on flexible buffers which engage in holes bored in the other half body. Some variations of this type provide a brake drum facility and incorporate shear pin overload protection. Powers up to 3500 hp (2610 kW) at 100 rev/min are typical.

Couplings which rely upon the power transmitting capability of rubber-like materials usually involve the element in shear or compression loading. Rubber in shear will permit a low stiffness design but is not capable of sustaining a large stress because of its tendency to creep. However, the high bulk modulus of rubber can be utilised by arranging mountings to create compression loading and a progressive increase in stiffness may thus be provided.

Hydrokinetic or fluid couplings transmit power due to the kinetic energy transfer in a fluid filling operation. Essentially, the torque developed depends upon the speed difference between the two halves and the parameter characteristics of the fluid. A variable speed facility is available if a convenient reservoir can be tapped.

Spring type couplings are grooved in the periphery of each half body to permit connection by flat springs which are intended to flex in the process of providing radial flexibility and absorbing shock loads. A totally enclosed lubricated container is typical for powers up to 650 hp (485 kW) at 100 rev/min.

A number of manufacturers have developed *toothed gear* couplings which utilise externally toothed hubs keyed to driving and driven shafts. Connection between them is provided by an internally toothed sleeve and the assembly is enclosed to ensure adequate lubrication between mating teeth. These types have a high power/size ratio and are readily available for capacities up to 500 hp (375 kW) at 100 rev/min.

A simple way of connecting two shafts is by the use of *chain* couplings. This involves mounting single row chain wheels on the end of each shaft and fitting a duplex chain for inter-connection. The assembly is enclosed and grease lubricated. Although misalignment flexibility is small, the simplicity of disconnection is attractive for many applications and powers up to 2500 hp (1865 kW) at 750 rev/min are typical. Effective coupling design depends on the type of fit contemplated for the bolts or other connecting media, since this determines how the load is shared. Methods which depend on an equation of the torsional capacity of shaft with bolt resistance are unlikely to yield accurate results for dynamic situations, although equality of shearing might be used for a preliminary assessment of non-critical dimensions.

Clutches

Clutches are used when a connection to an intermittently rotating member is required. A positive connection involves engagement between projecting jaws with provision

EXHIBIT 1020

Carsten Baumgarten

Mixture Formation in Internal Combustion Engines

With 180 Figures and 9 Tables

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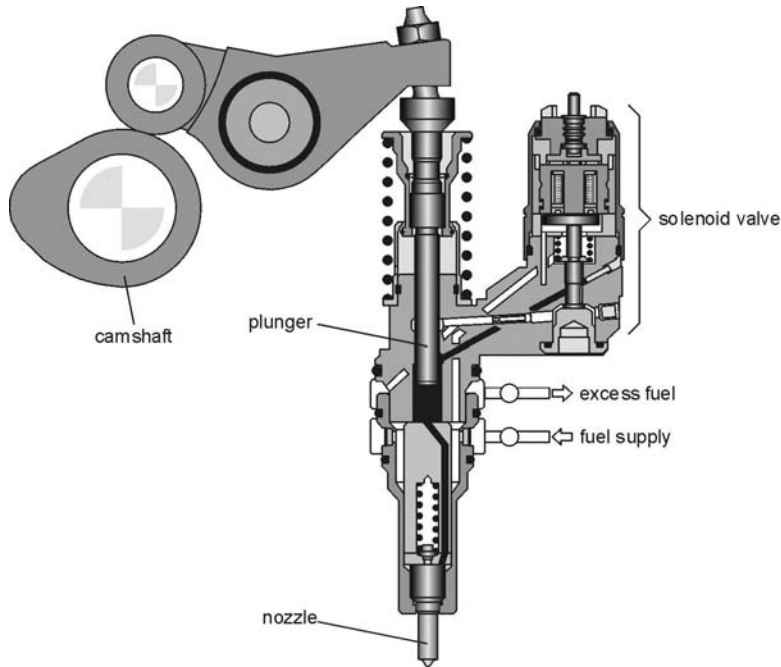


Fig. 2.27. Unit Injector [46]

The second main group of high-pressure injection systems are those in which the generation of injection pressure and the injection itself occur synchronously. These systems are driven by a camshaft, which is mechanically coupled with the engine. A basic characteristic of these systems is the intermittent pressure generation: high pressure is only available during a small crank angle interval.

In the case of the so-called unit injector system (UIS), the pump and the injection nozzle are combined into a single unit, see Fig. 2.27. Each cylinder of the engine is equipped with such a unit, which is driven by the cam via a rocker arm for example. The omission of the high-pressure pipes between the pump and the injector allows significantly higher peak injection pressures (about 200 MPa and more) than in the case of the unit pump system, see below. The shape of the cam determines the motion of the plunger and thus the generation of pressure as a function of crank angle. The spring at the upper part of the injector presses the plunger against the rocker arm and the rocker arm against the cam, and guaranteeing force closure during operation.

Fig. 2.28a shows a simplified picture of the unit injector with a closed needle. The solenoid valve is opened, and as soon as the plunger is pushed down, excess fuel is carried into the scavenge line. According to the desired start of injection, the control unit of the engine closes the solenoid valve, and the plunger compresses the fuel. As soon as the pressure is large enough to lift the spring-loaded needle, injection begins, Fig. 2.28b. Due to the large feed rate of the plunger, the

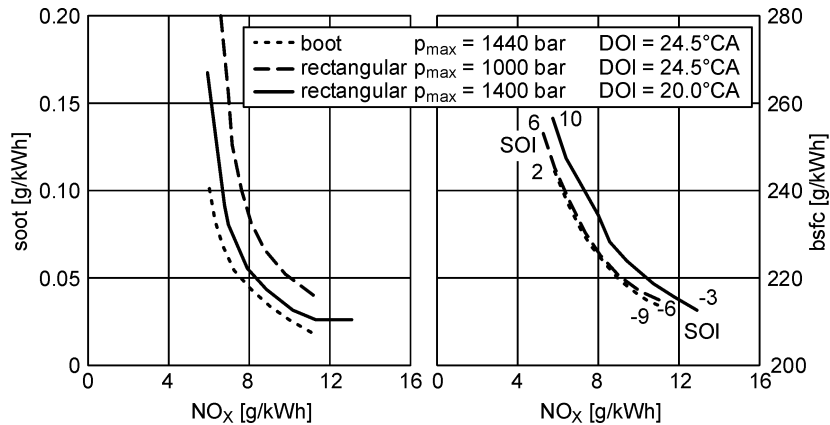


Fig. 6.7. Comparison of rectangular and boot-type injection, single cylinder engine, displacement: 1 liter, 1400 rpm, 100% load, no EGR [52]. SOI and DOI: start and duration of injection

specific power and decreasing the soot emissions, which are known to increase when applying EGR. In all cases, a very fast needle closing is advantageous in order to avoid the formation of soot due to a deteriorated mixture preparation.

Post-Injection

There are two kinds of post-injections, the late one and the early one. Late post-injection is applied in order to provide the exhaust gases with a well-defined quantity of evaporated but unburned fuel, which is then used in the catalytic reactions inside the exhaust gas after-treatment system. Injection pressure, amount of fuel, and injection timing must be carefully adjusted in order to prevent oil dilution. In the case of EGR, the late post-injection can alter the ignition delay, because some of the injected and unburned fuel is transported back into the cylinder.

The early post-injection directly follows the main injection and is a very effective measure to reduce soot emissions. Small amounts of fuel are injected with high pressure. Due to the small dwell time between main and post-injection, the injection is cut, and air is entrained in the near nozzle region and in the partial oxidation zone of the main combustion. It is very important to achieve a fast and complete closing of the injector needle in order to realize this additional entrainment of air and to avoid an unintended post-injection of low-speed large fuel drops which would significantly increase the emissions of soot and unburned hydrocarbons. The high-pressure post-injection contains enough kinetic energy to achieve an effective mixture formation and to entrain further oxygen into the partial oxidation zone. The combustion of this mixture increases the temperature during the late combustion phase and thus enhances the reduction of soot Fig. 6.8. The heat released by the post-injection is not sufficient to increase the NO_x emissions. Altogether, this kind of post-injection can result in a significant reduction of

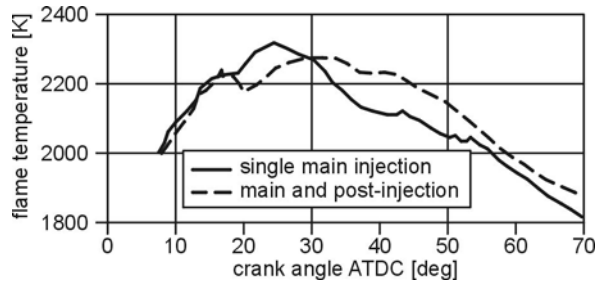


Fig. 6.8. Increase of temperature due to an early post-injection [12]

soot emissions (up to 70% reduction), while the fuel consumption is not affected (e.g. [21, 52]). The more soot produced by the main combustion, the more effective the post-injection.

6.2.3 Piezo Injectors

It has been shown in the previous sections that modern and future injection systems must be capable of performing multiple injections with variable injection timing and dwell times between two subsequent injections as well as variable injection pressures and extremely small pilot masses in order to reduce both, engine-out raw emissions and fuel consumption. The more flexible the injection system, the more accurate the optimization of the injection at each single operating point of the engine map can be. In addition to this, an extremely high reproducibility of injection timing and injected masses is necessary, especially in the case of short injection pulses. High needle speeds and a precise and complete needle closing are necessary in order to improve mixture formation and to avoid a deteriorated mixture formation and unintended post-injections at the end of each injection. Most of these demands can be fulfilled if piezo actuators instead of the slower and less precise solenoid valves are used in order to control the motion of the needle. The basic approach of the piezo technique is to use the elongation of a piezo quartz, which is proportional to the voltage impressed between two opposing surfaces, as the actuator. Piezo quartzes are extremely stiff, and the elongation is also extremely precise and fast. If the voltage is kept constant, a constant elongation can be realized. Because the elongation is proportional to the voltage, any elongation between zero and a maximum value can be precisely adjusted. Usually, a number of piezo quartzes are mechanically arranged in line (so-called piezo stack) in order to increase the resulting amplitude. In general, two main concepts are possible, the indirect and the direct needle control.

Fig. 6.9 shows the piezo-inline-injector from Bosch, where an indirect needle control is realized. The assembly consists of a piezo stack, a hydraulic coupling device, a control valve, and the nozzle module. The hydraulic coupling device amplifies the elongation of the piezo stack and transfers it to the control valve. In order to start the injection event, the needle of the control valve moves downwards and the pressure on top of the injection needle decreases because more fuel leaves

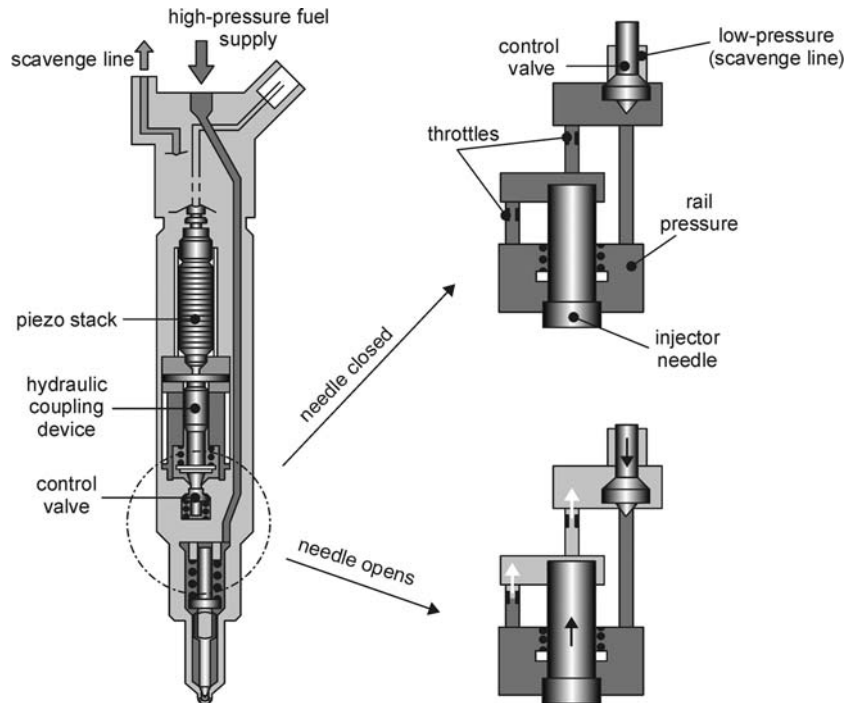


Fig. 6.9. Piezo in-line injector from Bosch [70]

the volume above this needle (larger cross-sectional area of the throttle) than enters from the high-pressure side (smaller throttle). At the end of injection the control valve closes and the increasing pressure above the injection needle pushes it downward again. Altogether, the stiff and close arrangement of the piezo actuator and needle, combined with small moving masses, allows the realization of an extremely reproducible, precise, and fast needle movement. Up to five injections per cycle with variable timings and extremely small injected fuel quantities can be performed [70].

The direct needle control offers even more flexibility, because well-defined partial needle lifts can be easily realized. Such a concept is shown in Fig. 6.10. The piezo stack is directly connected to the needle. This concept allows realizing any partial needle lift between zero and a maximum value, which is given by the maximum elongation of the stack. Because the needle lift is directly proportional to the voltage, it is possible to realize any kind of injection rate shape if the voltage can be controlled accordingly. This system has been designed as a research tool by the Institute of Technical Combustion at the University of Hanover in order to investigate the effect of different injection rate shapes on the combustion process of DI diesel engines (e.g. [54, 78, 75, 81]). The direct needle control has also turned out to be very effective in the case of pulsed injection in HCCI applications [66] (Sect. 6.4). In the case of ramp- or boot-type injections, the rate is controlled by needle seat throttling.