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Charboneau et al.

[11] **3,911,896**

[45] **Oct. 14, 1975**

[54] **CATALYTIC HEATER**

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[73] Assignee: **Walbro Corporation,** Cass City, Mich.

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[52] **U.S. Cl.** .... **126/350 A;** 431/170; 431/208

[51] **Int. Cl.²** **F24H 1/00**

[58] **Field of Search** .... 431/170, 7, 208; 126/350 A, 92 RC

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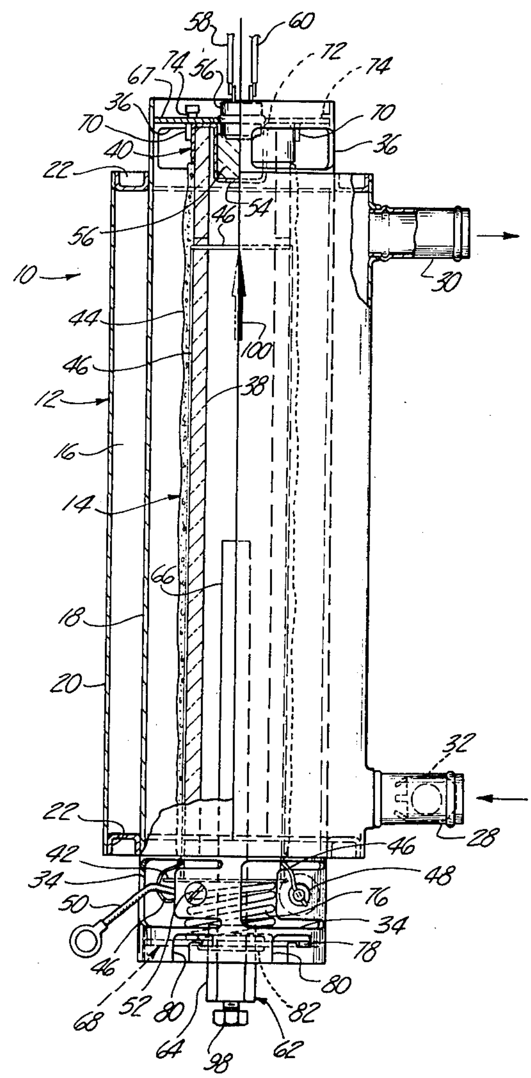
Primary Examiner—Edward G. Favors
Attorney, Agent, or Firm—Barnes, Kisselle, Raisch & Choate

[57] **ABSTRACT**

A heater device for preheating liquid coolant of an internal combustion engine having an elongate cylindrical heat exchanger with an elongate catalytic heater assembly releasably mounted generally coaxially therein. The heater assembly has a catalytic impregnated fibrous material wrapped around an elongate porous ceramic tube with closed ends and an injector which discharges vaporized fuel into the interior of the ceramic tube.

22 Claims, 11 Drawing Figures



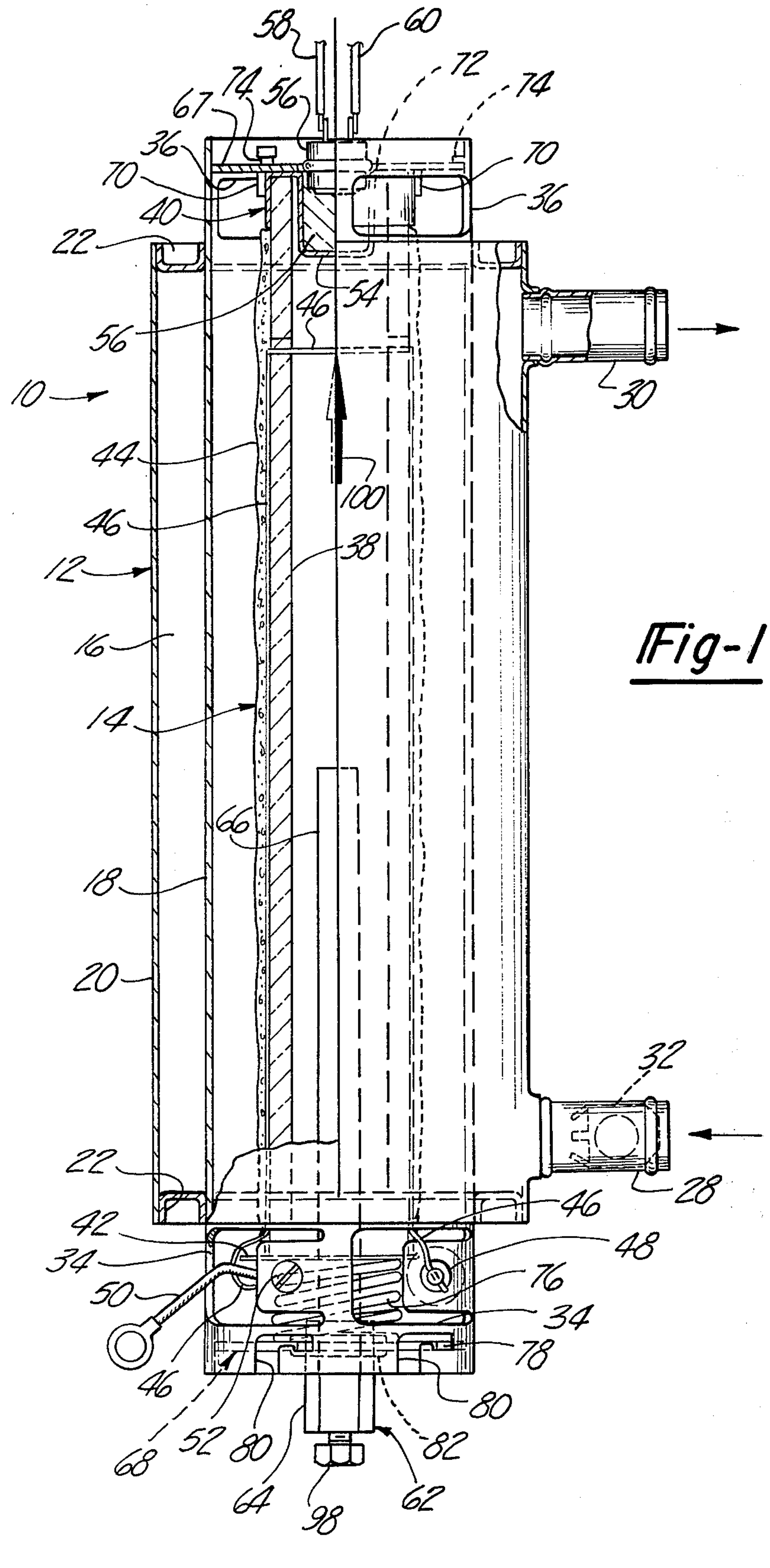

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Fig-1

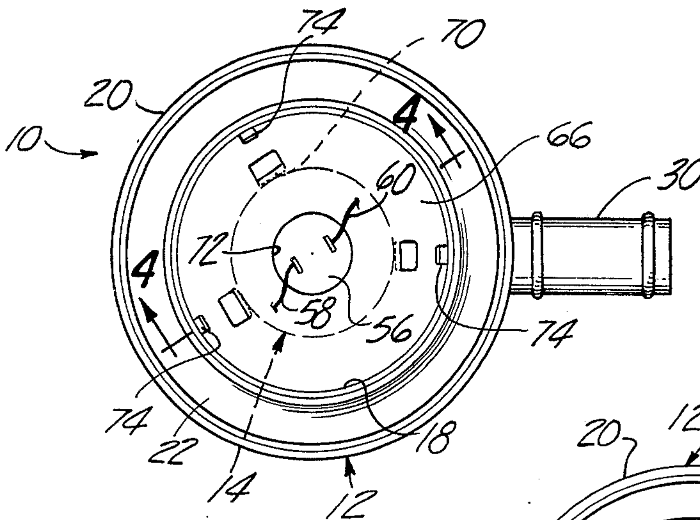

Fig-2

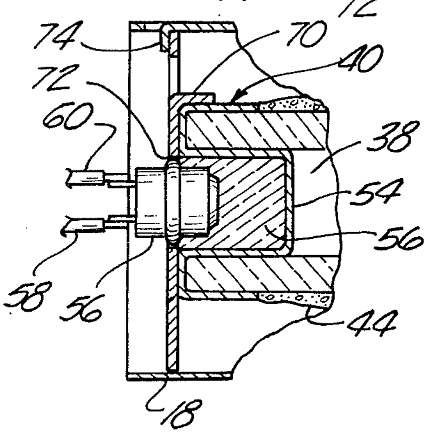

Fig-4

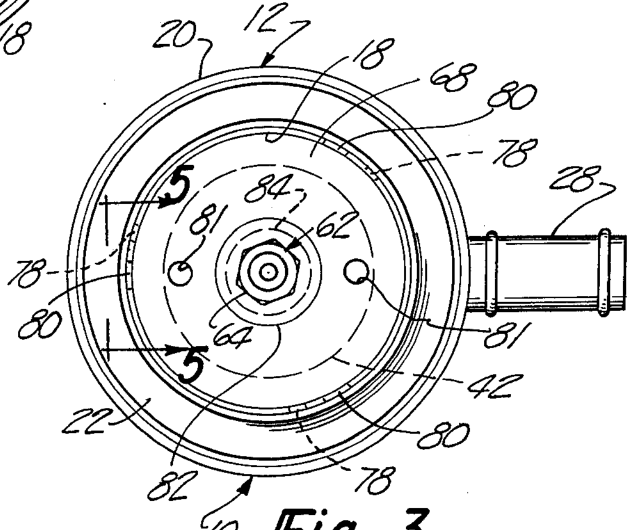

Fig-3

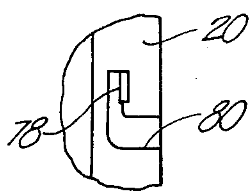

Fig-5

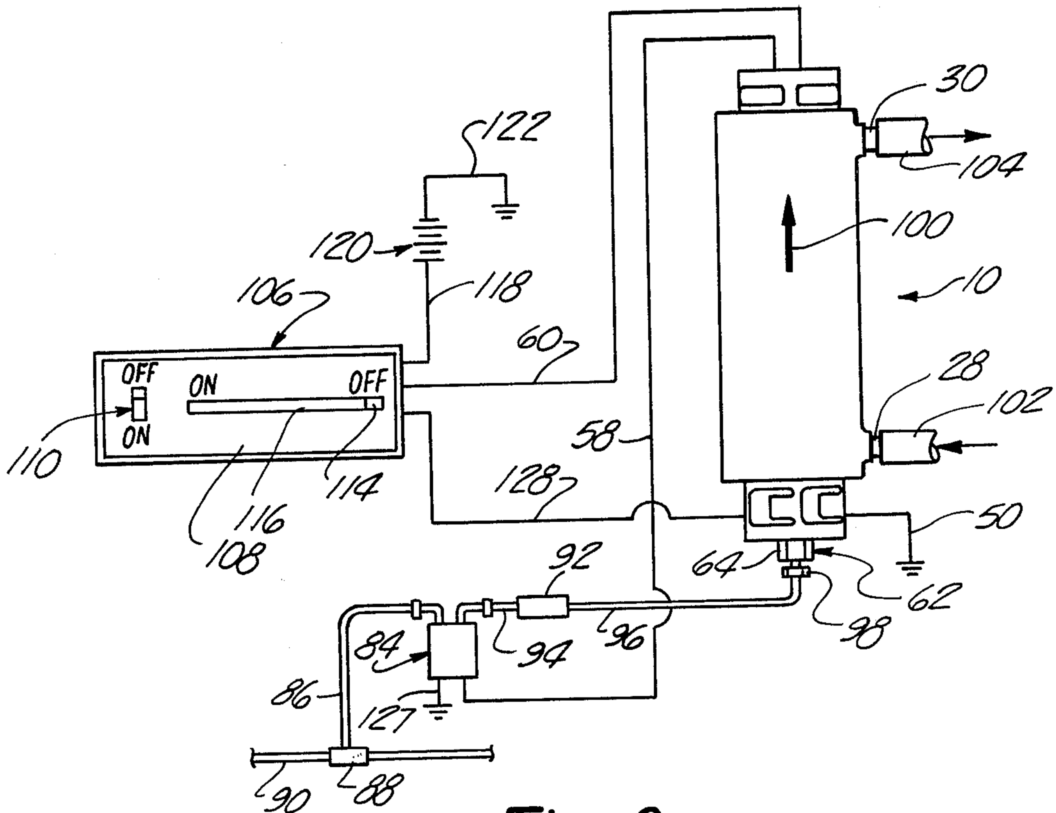
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Fig-6

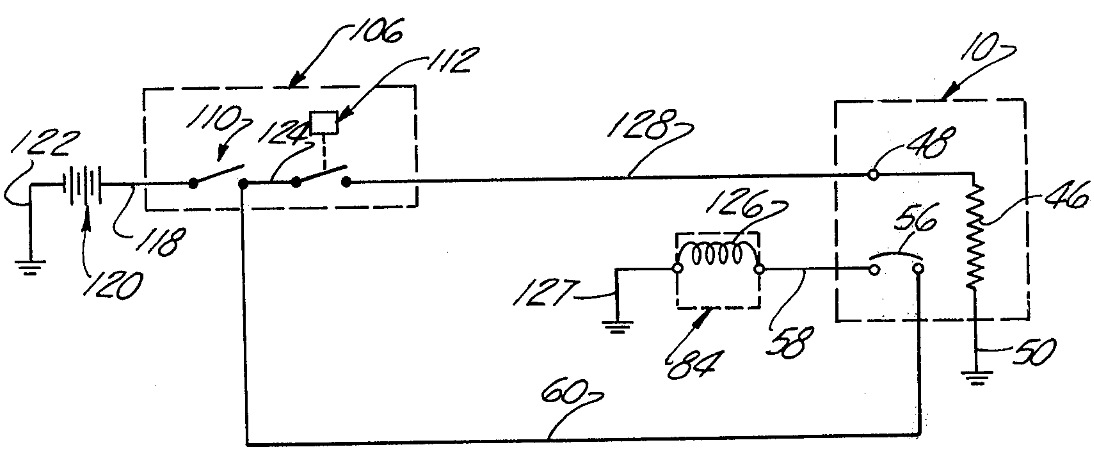
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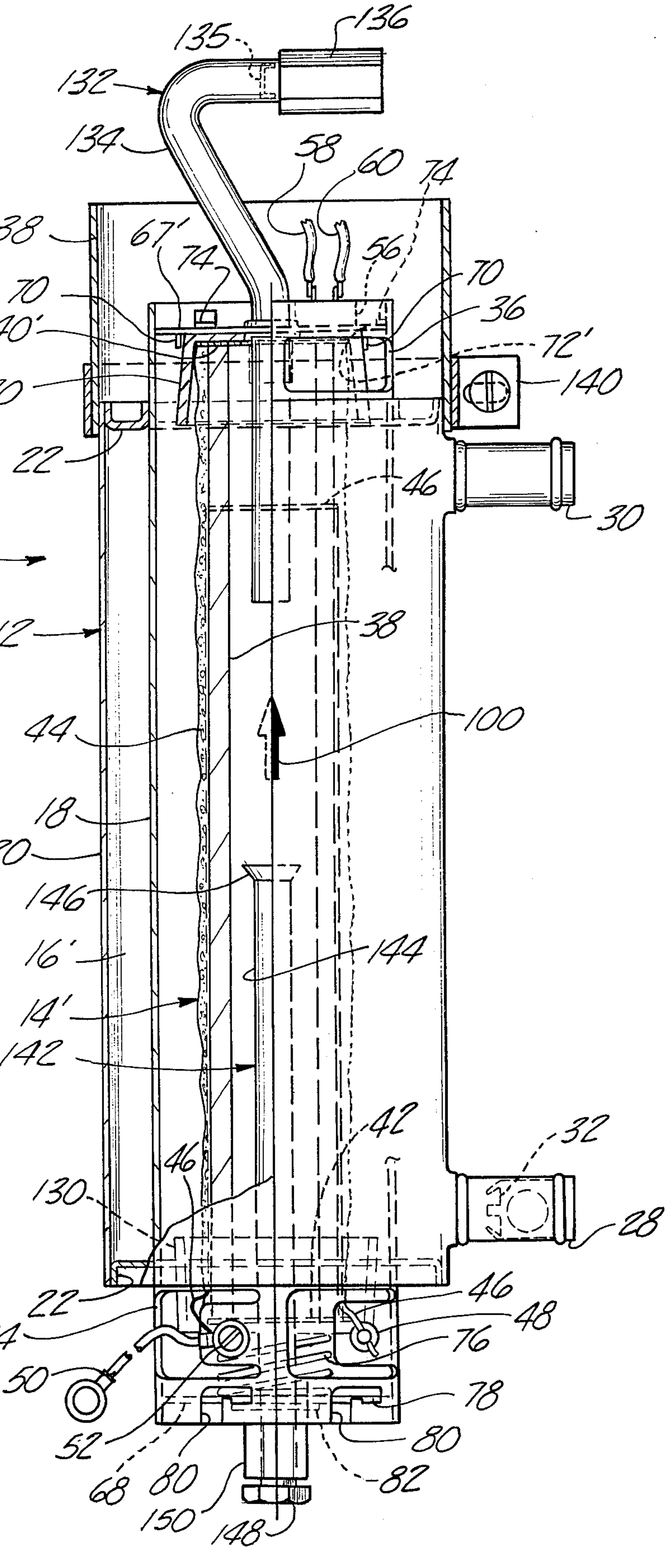
Fig-7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142
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32
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76
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68
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150
148

Fig-8

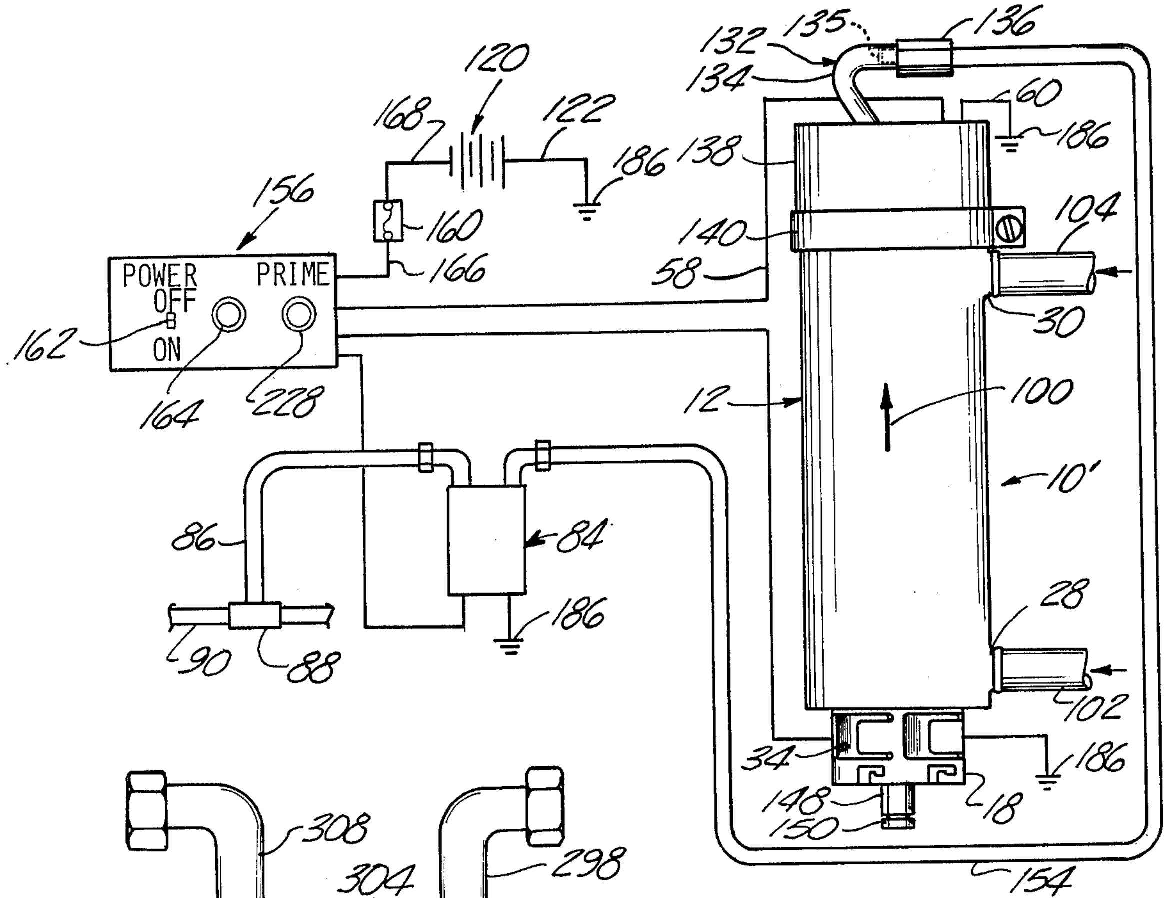
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Fig-9

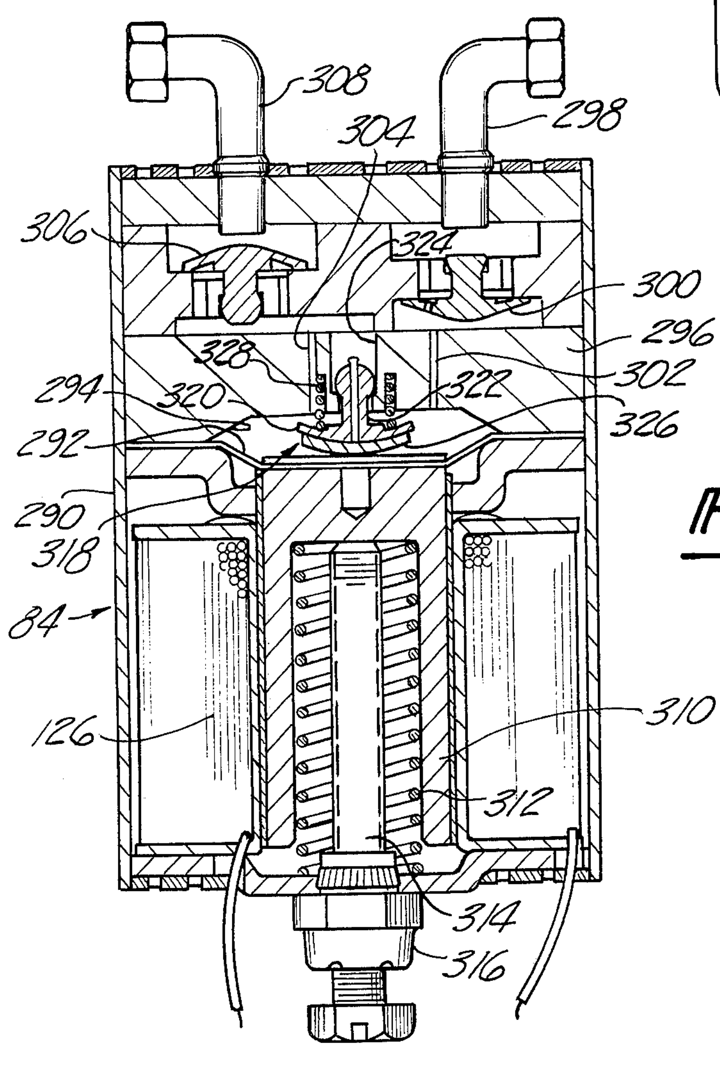
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Fig-11

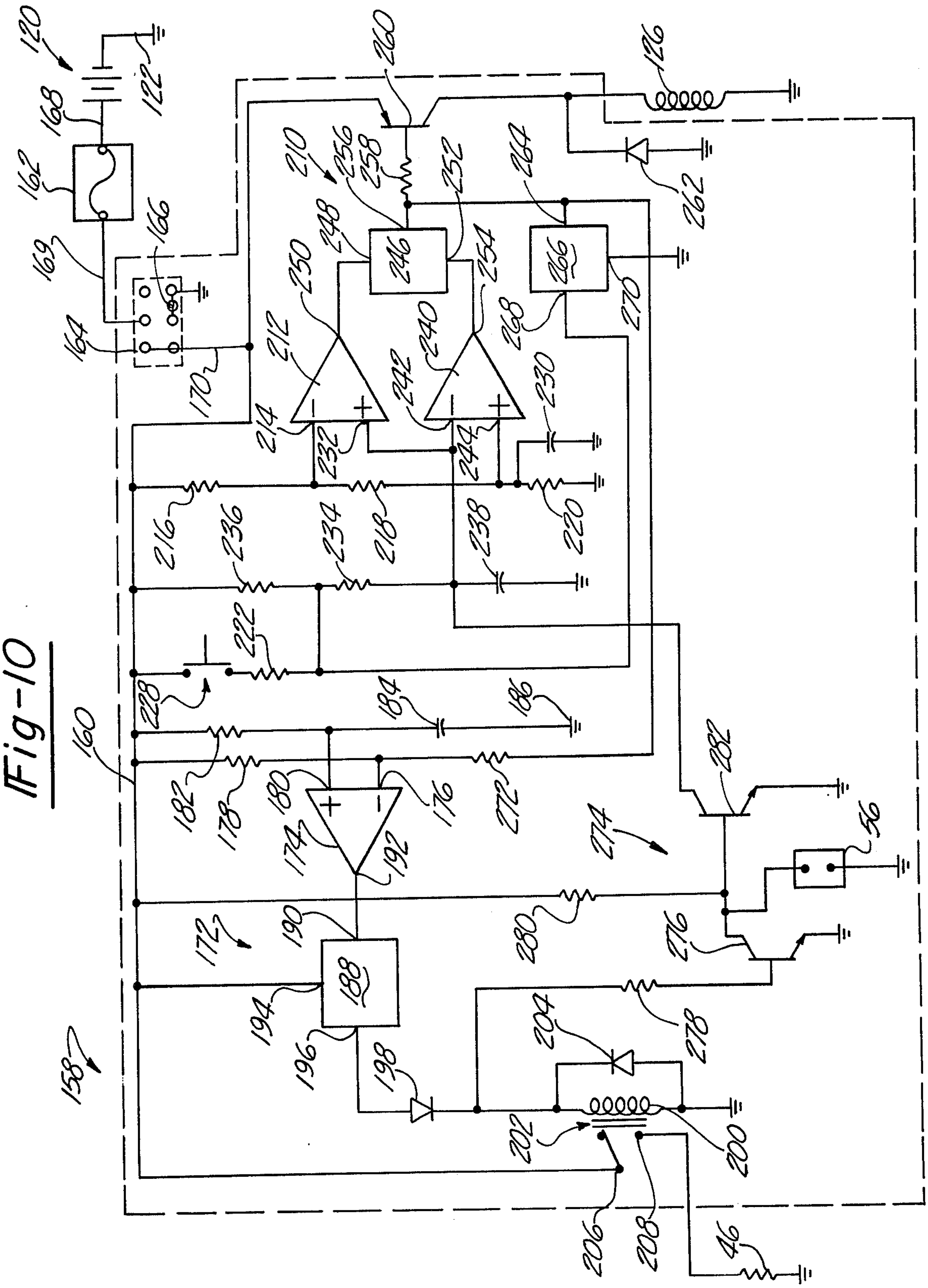

Fig-10

CATALYTIC HEATER

This invention relates to a device for preheating the liquid coolant of an internal combustion engine and more particularly to such a device with a flameless catalytic heater.

Objects of this invention are to provide a catalytic heater device which is safe, compact, of economical manufacture and assembly, and has a long maintenance-free service life.

These and other objects, features, and advantages of this invention will be apparent from the following description, appended claims, and accompanying drawings in which:

FIG. **1** is a side view partially in section of a catalytic heater embodying this invention;

FIG. **2** is a top view of the catalytic heater of FIG. **1**;

FIG. **3** is a bottom view of the catalytic heater of FIG. **1**;

FIG. **4** is a fragmentary sectional view on line **4—4** of FIG. **2**;

FIG. **5** is a fragmentary view on line **5—5** of FIG. **3**;

FIG. **6** is a semi-diagrammatic view of the catalytic heater of FIG. **1** connected to both a control box and a fuel pump connected to the gasoline line of a moter vehicle;

FIG. **7** is a schematic diagram of the electric control circuit for both the catalytic heater and fuel pump of FIG. **6**;

FIG. **8** is a side view partially in section of a modified catalytic heater embodying this invention;

FIG. **9** is a semi-diagrammatic view of the catalytic heater of FIG. **8** connected to both a control box and a fuel pump connected to the gasoline line of a motor vehicle;

FIG. **10** is a schematic diagram of an electronic control circuit for the catalytic heater and fuel pump of FIG. **8**; and

FIG. **11** is a sectional view of the fuel pump of FIGS. **6** and **9**.

Referring in more detail to the drawings, FIG. **1** illustrates a catalytic heater **10** embodying this invention having a heat exchanger jacket **12** encircling a catalytic heater assembly **14**. Heat exchanger **12** has a cylindrical chamber **16** defined by an inner metallic tube **18**, an outer metallic tube **20** encircling the inner tube, and metallic end rings **22** interposed between the tubes and fixed thereto, such as by brazing. Engine liquid coolant enters chamber **16** through an inlet conduit **28** fixed to outer tube **20** adjacent the lower end of chamber **16** and flows from chamber **16** through an outlet conduit **30** fixed to outer tube **20** adjacent the upper end of chamber **16**. A check valve **32** in inlet conduit **28** prevents liquid coolant from flowing out of chamber **16** through the inlet conduit. A plurality of slots or windows **34** and **36** adjacent opposed ends of inner tube **18** allows atmospheric air to flow through the tube adjacent the outer periphery of heater assembly **14**.

As shown in FIGS. **1** and **4**, heater assembly **14** has a porous ceramic tube **38** with upper and lower end caps **40** and **42** fixed thereto. A layer of a fibrous material **44** is wrapped around ceramic tube **38** and impregnated with a catalytic agent, such as platinum. A suitable fibrous material is the ceramic felt T-3 fiber produced by Refractory Products Company of Carentersville, Ill. A nichrome wire **46** extends axially along the outside of tube **38** beneath the layer of fibrous material

44 to provide an electrical resistance heating element for preheating the catalytic heater assembly. One end of nichrome wire **46** is connected to an insulated binding post **48** mounted on tube **18** and the other end of wire **46** is connected to tube **18** and a ground lead wire **50** by a machine screw **52.**

Upper end cap **40** of heater assembly **14** has a central depression or cup **54** therein which extends into the interior of the upper end of ceramic tube **38.** A temperature responsive or thermostatic switch **56** with insulated lead wires **58** and **60** connected thereto is potted in the cup **54** of end cap **40** by a suitable potting material **56,** such as Acid-Alk Mortar No. 33 available from Sauereisen Cements Company of Pittsburgh, Pa. A fuel injector **62** with a union **64** on the lower end of an evaporator tube **66** extends through and is fixed to lower end cap **42** of heater assembly **14** to discharge vaporized fuel into the interior of ceramic tube **38** adjacent the longitudinal mid portion thereof.

Heater assembly **14** is mounted substantially coaxially in inner metallic tube **18** by an upper locator disc **67** and a lower locator disc **68.** As shown in FIGS. **1** and **2,** upper locator disc **67** bears on the upper end of heater assembly **14** and has three circumferentially spaced, inwardly and downwardly struck tabs **70,** which engage the outer periphery of upper end cap **40,** and a central aperture **72** providing clearance for thermostatic switch **56.** Locator disc **67** abuts on three circumferentially spaced, inwardly struck tabs **74** in the upper end of inner tube **18.** As shown in FIG. **1,** heater assembly **14** is yieldably urged into engagement with upper locator disc **67** by a spring **76** interposed between and bearing on lower locator disc **68** and lower end cap **42** of the heater assembly. As shown in FIGS. **1, 3** and **5,** lower locator disc **68** is releasably retained in tube **18** by three circumferentially spaced tabs **78** on the disc **68** which are received in three circumferentially spaced reentrant slots **80** in the lower end of tube **18.** Rotating of lower disc **68** for installation in and removal from tube **18** is facilitated by a pair of holes **81** in the disc **68.** A rubber grommet **82** encircles injector **62** and is received in an aperture **84** in locator disc **68** to coaxially position the lower end of heater assembly **14** in tube **18.**

When catalytic heater **10** is installed to preheat the liquid coolant of an internal combustion engine, fuel injector **62** is connected to a source of pressurized hydrocarbon fuel, such as gasoline or liquified petroleum gas. As shown in FIG. **6,** when device **10** is installed in a motor vehicle, gasoline may be supplied to injector **62** under pressure by a separate electric fuel pump **84** with an inlet connected by a line **86** through a tee **88** to the fuel line **90** of the vehicle (not shown) between the gasoline tank and the fuel pump of the internal combustion engine. The outlet of pump **84** is connected to injector **62** through a fuel metering orifice **92,** lines **94** and **96,** and male coupling **98.** As indicated by arrow **100** (FIGS. **1** and **6**), catalytic heater **10** should be mounted so that the longitudinal axis of heater assembly **14** extends generally vertically with fuel injector **62** at the lower end thereof. The catalytic heater **10** is mounted at a vertical height between the vertically highest and lowest points in the cooling system of the engine and preferably closer to the highest point thereof so that the liquid coolant will be circulated through the heater and engine when the heater is operating. The inlet conduit **28** of heat exchanger **12** is connected by a hose **102** to the engine cooling system at a low point thereof such as the engine drain opening or through a core plug in the side of the block of the engine. The outlet conduit **30** of heat exchanger **12** is connected by a hose **104** to the engine cooling system at a higher point than the inlet **28** such as at the connection at the heater inlet hose to the cooling system of the vehicle.

As shown in FIGS. **6** and **7**, control box **106** is electrically connected to catalytic heater **10** to control the functioning thereof. Control box **106** has a front panel **108** with a master power switch **110** mounted thereon and a timer switch **112** mounted therein with a manually movable actuator lever **114** which projects through a slot **116** in control panel **108**. One contact of power switch **110** is connected through a lead line **118** to the positive pole of a battery **120** and the negative pole of the battery is connected to ground of the vehicle frame by a lead line **122**. The other contact of switch **110** is connected to both one contact of switch **112** by a lead line **124** and to one contact of temperature responsive switch **56** by lead line **60**. The other contact of temperature responsive switch **56** is connected by lead line **58** to the solenoid actuating coil **126** of electric fuel pump **84** which is grounded by a lead line **127**. The other contact of timer switch **112** is connected by a lead line **128** to one end of nichrome wire resistance heating element **46** through binding post **48** and the other end of the nichrome wire **46** is grounded through lead line **50**.

In using catalytic heater **10** to preheat the engine coolant of an internal combustion engine, master power switch **110** and timer switch **112** are both closed to supply current through lead line **128** to the nichrome wire electrical resistance heating element **46**. Heating element **46** preheats at least portions of the catalytic agent of heater assembly **14** to an operating temperature which would produce a catalytic heat reaction with fuel discharged into the heater assembly. Timer switch **112** controls the length of time current is supplied to heating element **46** and turns the heating element off after sufficient time has elapsed for the catalytic agent to be heated to an operating temperature. Temperature responsive switch **56** closes in response to the preheating of the catalytic agent to its operating temperature to supply current through lead lines **60** and **58** to energize electric fuel pump **84**. When fuel pump **84** is energized, it supplies gasoline under pressure to fuel injector **62**. The gasoline is metered into injector **62** by orifices **92**, becomes vaporized as it passes upwardly through evaporator tube **66**, and is discharged into the interior of ceramic tube **38**. Under the influence of the catalytic agent of the heater assembly, the vaporized fuel undergoes a catalytic reaction producing heat which warms liquid coolant in heat exchanger **12**. Heating of the liquid coolant in chamber **16** of heat exchanger **12** produces a thermosiphon action which causes warmer liquid to flow out of the heat exchanger through outlet conduit **30** and into the cooling system of the engine, and cooler liquid from the engine cooling system enters the bottom of the heat exchanger through inlet conduit **28**. This preheats the liquid coolant of the internal combustion engine, and hence, the engine itself which greatly facilitates starting of the engine in cold weather conditions.

FIG. **8** illustrates a modified catalytic heater **10'** embodying this invention in which like numerals designate component parts which are the same as the corresponding component parts of catalytic heater **10**. The catalytic heater assembly **14'** of heater **10'** has a pair of ceramic end caps **130** received on opposed ends of heater assembly **14'** and is centered in heat exchanger jacket **12** by discs **67'** and **68**. Thermostatic switch **56** is secured to the upper end cup **130** by a suitable potting material, such as the Leepoxy Epoxy System No. 16–149 available from Leepoxy Plastics, Inc. of Fort Wayne, Ind. Liquid hydrocarbon fuels, such as gasoline, are at least partially vaporized and discharged within catalytic heater assembly **14'** by a fuel injector **132** which has an evaporator tube **134** with a tube screen **135** and a union **136** at the upper end thereof. Evaporator tube **134** is fixed to disc **67'** with the lower portion thereof extending coaxially into heater assembly **14'** through apertures in upper end plate **40'** and cup **130**. To prevent high winds from extinguishing the catalytic reaction of fuel with heater element **14'**, a tubular shield **138** on the upper end of heat exchanger **12** extends substantially above exhaust or outlet ports **36**. Shield **138** is received over the upper end of outer tube **20** of heat exchanger **12** and retained thereon by a band or hose clamp **140**. If desired, tubular shield **138** could be simply an extension of outer tube **20** of heat exchanger **12**.

To receive and vaporize any liquid fuel discharged from fuel injector **132**, a secondary evaporator assembly **142** is coaxially received in the lower end of heater assembly **14'**. Evaporator assembly **142** has an evaporator tube **144** into which droplets of fuel discharged from tube **134** are funneled by a flared upper end **146**. Evaporator tube **144** is fixed to lower end cap **42** of heater assembly **14'**, extends through lower end cup **130**, and is closed at the lower end thereof by a plug **148** received in a union **150** fixed thereto.

Catalytic heater **10'** is supplied with a pressurized hydrocarbon fuel in gaseous or liquid form, such as liquified petroleum gas or gasoline. Gaseous fuels are supplied to catalytic heater **10'** through secondary evaporator assembly **142** by connecting a suitable conduit to union **150** thereof with the injector **132** being sealed by inserting plug **148** in union **136** thereof. Liquid fuels are supplied to catalytic heater **10'** through injector **132** by a suitable conduit connected to union **136** thereof and the lower end of the secondary evaporator is sealed by inserting plug **148** in union **150** thereof.

As shown in FIG. **9**, when catalytic heater **10'** is installed in an automotive vehicle, gasoline may be supplied under pressure to injector **132** by a separate electric fuel pump **84** with an inlet connected by line **86** through tee **88** to fuel line **90** of the vehicle (not shown) between the gasoline tank and the fuel pump of the internal combustion engine of the vehicle. The outlet of pump **84** is connected to injector **132** through a line **154** and union **136**. As indicated by arrow **100**, catalytic heater **10'** is mounted so that the longitudinal axis of the heater assembly **14'** extends generally vertically with fuel injector **132** at the upper end thereof. Catalytic heater **10'** is connected by hoses **102** and **104** to the cooling system of the engine and mounted at a vertical height in relation thereto in the same manner as catalytic heater **10** to produce a thermosiphon action to circulate coolant to the catalytic heater and the cooling system.

A control box **156** with an electronic circuit **158** shown schematically in FIG. **10** cycles catalytic heater **10'** and fuel pump **84**. Power is supplied to a DC power bus **160** of control circuit **158** from battery **120** through a fuse **162** and a master power switch **164** with an indicator light **166** connected by lead lines **168, 169** and **170.**

Circuit **158** has a preheat control section **172** which is responsive to application of battery power to bus **160** to apply power to heating element **46** for a predetermined time interval to preheat the catalyst of heater assembly **14'**. Control section **172** comprises a comparator **174** having a reference input **176** connected through a resistor **178** to bus **160**, and having a threshold input **180** connected through a resistor **182** to bus **160** and through a capacitor **184** to ground **186** of the vehicle frame. A latch **188** receives a first input **190** from the output **192** of comparator **174**, and a second input **194** from bus **160** directly. Latch **188** has an output **196** connected through the anode-cathode junction of a silicon diode **198** and thence through a coil **200** of a relay **202** to ground **186.** A second diode **204** is connected in reverse polarity across coil **200** to suppress inductive ringing in the coil when relay **202** turns off. Relay **202** also has a pair of normally open contacts **206, 208** connected to bus **160** and preheat element **46**, and responsive to energization of coil **200** to apply battery power directly to heating element **46.**

In the operation of preheat control section **172**, the output of latch **188** is initially set to a high voltage state by application of battery power to bus **160.** This relatively high voltage forward biases diode **198** so that relay **202** is energized and preheat current is supplied to element **46.** At the same time current flows through resistor **182** and into capacitor **184** so that a charge is gradually built up thereupon. After an interval of time determined by the values of resistor **182** and capacitor **184**, the voltage on the capacitor at threshold input **180** of comparator **174** exceeds the reference voltage at input **176** so that the comparator provides a reset signal at input **190** of latch **188.** The latch is thus reset so that the output thereof goes low and relay **202** is deenergized until master switch **164** is turned off and then on again to reset latch **188** to a high voltage state. The preheat time interval determined by resistor **182** and capacitor **184** is preferably in the range of twelve to fourteen minutes.

Control circuit **158** further comprises a pump control section **210** which includes a first comparator **212** having its reference input **214** connected through a resistor **216** to bus **160**, and through series connected resistors **218, 220** to ground **186** of the vehicle frame. A filter capacitor **230** is connected across resistor **220.** The threshold input **232** of comparator **212** is connected through series connected resistors **232, 236** to bus **160**, and through a capacitor **238** to ground **186.** A second comparator **240** has its threshold input **242** connected to threshold input **232** of comparator **212**, and has its reference input **244** connected to the junction of resistors **218, 220.** Resistors **216, 218** and **220** thus form a voltage divider which places a first reference voltage at reference input **214** of comparator **212**, and a second lower reference voltage at the reference input **244** of comparator **240.** A resistor **222** and a normally open pushbutton switch **228** are connected in series across resistor **236.** Switch **228** is mounted on control box **156** and may be manually activated to prime pump **84** as explained in detail hereinafter.

A latch **246** has a first input **248** connected to the output **250** of comparator **212**, and has a second input **252** connected to the output **254** of comparator **240.** The output **256** of latch **246** is connected through a resistor **258** to the base of a PNP transistor **260** which has its emitter connected to bus **160** and its collector connected through the solenoid coil **126** of pump **84** to ground **186.** A diode **262** is connected in reverse polarity across coil **126** to suppress inductive ringing in the coil when transistor **260** turns off. Output **256** of latch **246** is also connected through a resistor **272** to input **176** of comparator **174**, and to a first input **264** of a discharge switch **266** which has a second input **268** connected to the junction of resistors **234, 246** and an output **270** connected to ground **186.**

In the operation of pump control section **210**, output **256** of latch **246** is set high when battery power is initially applied to bus **160** so that the emitter-base junction of transistor **260** is reverse biased and current is blocked from coil **126** of pump **84.** In the meantime current passes through resistors **236, 234** into capacitor **238** so that the voltage at threshold input **232** of comparator **212** gradually rises. When this rising voltage exceeds the reference voltage supplied at input **214** by voltage divider **216, 218, 220**, comparator **212** supplies a reset input to latch **246** so that output **256** goes low, transistor **260** conducts and current is supplied to coil **126** of pump **84.** At the same time, input **264** of discharge switch **266** goes low so that switch **266** discharges capacitor **238** through resistor **234** and discharge switch input **268** to ground **186.** When the decreasing voltage on capacitor **238** at threshold input **242** of comparator **240** drops below the level of the second lower reference voltage supplied at reference input **244** by voltage divider **216, 218, 220**, comparator **240** provides a set signal at input **252** of latch **246** so that the output thereof goes high thus turning off transistor **260** and blocking current flow to coil **126** of pump **84.** Discharge switch **266** is also turned off at this time so that capacitor **238** may recharge. Thus, pump control circuit **210** operates as an oscillator which has a period and duty cycle dependent upon the relative values of resistors **216, 218, 220, 234, 236** and capacitor **238.** In the preferred embodiment of catalytic heater **10'** the charge time of capacitor **238** through resistors **236, 234** may be in the range of **5** to **15** seconds and preferably is about **10** seconds while the discharge time thereof through resistor **234** and switch **266** may be in the range of **30** to **80** milliseconds and preferably is about **50** to **60** milliseconds. Thus, current is supplied to coil **126** of pump **84** preferably for 50 to 60 milliseconds at 10-second intervals.

To prime fuel pump **84** a switch **228** is closed to place resistor **222** in parallel with resistor **236**, thereby decreasing the charge time for capacitor **238** and increasing the rate at which pump **84** is cycled. The decreased charge time for capacitor **238** when control section **210** is operating in the pump-priming mode may be in the range of within **200** to 700 milliseconds and is preferably about 400 to 500 milliseconds.

Control circuit **158** also includes a pump inhibit circuit **274** which is responsive to the temperature of catalytic heater assembly **14'** to selectively inhibit activation of pump control section **210** if heater device **10'** is not functioning properly. Circuit **274** includes a first NPN transistor **276** which has its base connected through a resistor **278** to the cathode of diode **198**, and its emitter connected directly to ground **186.** The collector of transistor **276** is connected through a resistor

280 to bus 160, and to the base of a second NPN transistor 282. The base of transistor 282 is also connected to ground 186 through normally open thermal switch 56 which is mounted on heater assembly 14' and responsive to the temperature thereof to connect the base of transistor 282 directly to ground. The emitter of transistor 282 is connected to ground and the collector thereof is connected to the junction of resistor 234 and capacitor 238. Thus, when latch 188 supplies preheat current to element 46, transistor 276 is turned on and transistor 282 is turned off so that capacitor 238 is allowed to alternately charge and discharge as described above. If heater 10' is operating properly, catalytic heater assembly 14' will be preheated to a temperature at which thermal switch 56 closes and the base of transistor 282 is connected to ground independently of preheat section 172 before the preheat section 172 turns off. However, if the temperature of heater assembly 14' is below the temperature at which switch 56 closes when preheat section 172 turns off, or if the heater assembly temperature should thereafter fall below such predetermined temperature, switch 56 will open and current will be supplied to the base emitter junction of transistor 282 through resistor 280. Transistor 282 will then be turned on to drain substantially all of the charge from capacitor 238, and to thereby inhibit further operation of pump control section 210 and hence pump 84.

In using catalytic heater 10' to preheat the engine coolant of an internal combustion engine, master switch 162 is manually actuated to energize control circuit 158 to supply current to resistance heating element 46. Heating element 46 preheats at least portions of the catalytic agent of heater assembly 14' to an operating temperature which would produce a catalytic heat reaction with fuel discharged into the heater assembly. The preheat control section 172 of circuit 158 controls the length of time current is supplied to heating element 46 and turns the heating element off after sufficient time has elapsed for at least portions of the catalytic agent to be heated to an operating temperature. Prior to the heating element being turned off by control section 172, fuel pump 84 is energized to discharge fuel through injector 132 into heating element 14' by the pump control section 210 of control circuit 158 and, if catalytic heater 10' is functioning properly, temperature responsive switch 56 closes to assure continued cycling of pump 84 to supply fuel to the catalytic heater. The cyclic or pulsating flow of liquid fuel supplied by pump 84 to injector 132 is smoothed or evened out by fuel screen 135, at least partially vaporized by evaporator tube 134 and discharged therefrom into heater assembly 14'. The vaporized portion of the fuel under the influence of the catalytic agent of heater assembly 14' undergoes a catalytic reaction producing heat which warms liquid coolant in heat exchanger 12. If the fuel is not completely vaporized by evaporator tube 134, the liquid portion thereof will drop by gravity into secondary evaporator assembly 142 into which it will be subsequently vaporized and discharged into the interior of heater assembly 14' to undergo a catalytic reaction producing heat to warm the liquid coolant in heat exchanger 12. Liquid fuel is vaporized in secondary evaporator assembly 142 because evaporator tube 144 is maintained at an elevated temperature by the heat produced by the catalytic reaction. Heating of the liquid coolant in heat exchanger 12 produces a thermosiphon action to circulate the liquid coolant of the engine and thus preheat the engine in the same manner as catalytic heater 10.

The useful life of the catalytic agent of the catalytic heaters is belived to be substantially decreased by contact of the catalytic agent with liquid fuel, and hence, no fuel should be supplied to the catalytic heaters when they are not being operated. However, it has been discovered that the main fuel pump of at leat some internal combustion engines creates sufficient pressure surges or pulses in fuel line 90 to force fuel through conventional electric fuel pumps utilized with the catalytic heaters and thence into the catalytic heaters when they are not operating, thereby decreasing the useful life of the catalytic agent thereof. This may be prevented from happening by using conventional valves with a conventional electric pump supplying fuel to the catalytic heaters by arranging the valves to prevent fuel from flowing through the conventional pump when the catalytic heater is not operating. However, it is preferred to use a specially designed pump, such as pump 84, with a suitable valve arrangement incorporated directly therein.

As shown in FIG. 11, pump 84 has a housing 290 with a flexible diaphragm 292 received therein and underlying a pump chamber 294 in a carrier plate 296 fixed in the housing. Gasoline is admitted to pump chamber 294 through inlet conduit 298, inlet valve assembly 300, and passageway 302 through carrier plate 296 and discharged from the pump chamber through outlet passageway 304 in carrier plate 296, output valve assembly 306 and outlet conduit 308. The gasoline is moved through pump chamber 294 by the flexing of diaphragm 292 which is actuated by an armature 310 connected thereto, yieldably biased in one direction by a spring 312, and moved in the opposite direction by energization of solenoid coil 126. The length of the stroke of armature 310 and hence the quantity of fuel delivered on each discharge stroke of pump 84 is controlled by adjustment of a threaded stop screw 314 received in a nut 316 fixed to housing 290.

Gasoline is prevented from flowing through pump 84 when solenoid coil 126 is de-energized by a valve assembly 318 mounted on carrier plate 296 and shown in FIG. 11 in the open position with coil 126 energized. Valve assembly 318 has a valve 320 with a bulbous stem 322 received for reciprocation in a counterbore 324 in carrier plate 296 to close and open (as shown in FIG. 11) fuel outlet passage 304. Valve 318 has a metallic wear cap 326 on the lower surface thereof and is yieldably biased by a spring 328 into engagement with armature 310 for reciprocation therewith.

In operation of pump 84 energization of coil 126 moves armature 310 to the position shown in FIG. 11, thereby opening valve 316 and flexing diaphragm 292 to pull gasoline into pump chamber 294 through inlet conduit 298, inlet valve 300 and passageway 302. When coil 126 is de-energized, spring 312 moves armature 310 upwardly from the position shown in FIG. 11, thereby moving diaphragm 292 to discharge fuel from pump chamber 294 through passageway 304, outlet valve 306 and outlet conduit 308, and, upon completion of the discharge stroke of diaphragm 292, closing valve 320 against the bias of spring 324. Thus, valve 320 remains closed so long as coil 126 is de-energized, thereby preventing gasoline from being forced through pump 84 when the pump is not operating by pressure surges or pulses in the fuel line **90** to which inlet conduit **298** is connected.

Since the useful life of the catalytic agent is decreased by contact with liquid fuel, the quantity of liquid fuel supplied to catalytic heaters **10** and **10'** during operation thereof should be controlled within close tolerances to assure that an excess quantity of liquid fuel is not supplied to the catalytic heaters. The quantity of liquid fuel supplied to heater **10** is controlled by adjustment of stop screw **314** of pump **84** and metering orifice **92** and the quantity of liquid fuel supplied to catalytic heater **10'** is controlled by adjustment of stop screw **314** of pump **84** and the rate of cycling of fuel pump **84** by pump control section **210** of control circuit **158.** Preferably, catalytic heater **10'**, rather than heater **10,** is used with liquid fuels since the secondary evaporator assembly thereof prevents liquid fuel from coming in contact with the catalytic agent.

A heater assembly embodying this invention in which vaporized fuel is discharged into a closed elongate porous chamber extending generally vertically with a catalytic agent distributed about the outer periphery thereof provides a flameless catalytic heater for an internal combustion engine which will operate safely and efficiently, has a long service life and requires little or no maintenance. The useful life of the catalytic agent of the heater device is prolonged when used with liquid fuels by an evaporator received in the lower end of the closed chamber with the fuel injector overlying the evaporator. The arrangement of an elongate catalytic heater assembly within a cylindrical heat exchanger provides a compact heater device embodying this invention. The releasable mounting of the heater assembly within an elongate tube which is a wall of the heat exchanger provides a catalytic heater of economical manufacture and assembly and facilitates removal of the heater assembly for inspection, repair, or replacement after the catalytic heater has been installed for use with an internal combustion engine.

We claim:

1. A flameless heater using a combustible hydrocarbon fuel for preheating liquid coolant of an internal combustion engine comprising; an elongate, cylindrically shaped heat exchanger having an inlet and an outlet for liquid coolant of an engine, said heat exchanger being adapted to be mounted with its axis extending generally vertically, an elongate catalytic heater assembly received in said cylindrically shaped heat exchanger, said catalytic heater assembly comprising an elongate porous tube, end caps closing both ends of said porous tube, a layer of fibrous material overlying said porous tube and being impregnated with a catalytic material, an electric resistance heater element carried by said porous tube for preheating said catalytic material, and a fuel injector extending into said porous tube for discharging at least partially vaporized hydrocarbon fuel into the interior of said porous tube, whereby when a vaporized hydrocarbon fuel is discharged by said injector into said catalytic heater assembly when preheated by said electric resistance element, the fuel is oxidized by a flameless catalytic reaction to heat liquid coolant of the engine in the heat exchanger.

2. The flameless heater of claim **1** which also comprises a temperature responsive switch mounted on one of said end caps.

3. The flameless heater of claim **1** wherein said injector extends through one of said end caps and comprises an evaporator tube adapted to discharge at least partially vaporized hydrocarbon fuel into the interior of said tube adjacent the mid portion of the longitude of said porous tube.

4. The flameless heater of claim **2** wherein said injector extends through one of said end caps and comprises an evaporator tube adapted to discharge at least partially vaporized hydrocarbon fuel into the interior of said porous tube adjacent the mid portion of the longitude of said porous tube.

5. The flameless heater of claim **1** which comprises an elongate metallic tube having an axial length exceeding the axial length of said porous tube of said heater assembly and an inside diameter exceeding the outside diameter of said heater assembly, locators received in said metallic tube adjacent opposed ends of said heater assembly to position said heater assembly generally coaxially with metallic tube.

6. The flameless heater of claim **5** wherein said metallic tube is a wall of said heat exchanger which is in contact with liquid coolant in said heat exchanger.

7. The flameless heater of claim **5** wherein said locators comprise discs and which also comprises abutments on said metallic tube engageable with one of said discs to limit movement of said one disc generally axially through said metallic tube in at least one direction, said one disc bearing on said heater assembly adjacent one end thereof, and a spring interposed between said other disc and said heater assembly to urge said one disc into engagement with both said abutment and said heater assembly.

8. The flameless heater of claim **5** wherein at least one of said locators is releasably retained in said metallic tube to releasably retain said heater assembly therein.

9. The flameless heater of claim **5** wherein said metallic tube has circumferentially spaced re-entrant slots in one end thereof and at least one of said locators has tabs thereon engageable in said re-entrant slots to releasably retain said one locator and said heater assembly in said metallic tube.

10. The flameless heater of claim **7** wherein said metallic tube has circumferentially spaced re-entrant slots in one end thereof and said other disc has tabs thereon engageable in said re-entrant slots to releasably retain said other disc and said heater assembly in said metallic tube.

11. The flameless heater of claim **5** wherein at least one of said locators comprises a disc releasably received in said metallic tube to releasably retain said heater assembly therein.

12. The flameless heater of claim **5** wherein said metallic tube communicates with the atmosphere adjacent both ends of said porous tube of said heater assembly whereby atmospheric air may pass upwardly through said metallic tube adjacent the outer peripheral surface of said heater assembly.

13. The flameless heater of claim **1** wherein said injector comprises a tube extending into said porous tube adjacent the lower end thereof.

14. The flameless heater of claim **1** wherein said injector comprises a first metallic tube adjacent one end of said porous tube and the flameless heater also comprises a second metallic tube closed adjacent one end and at least in part received in said porous tube adjacent the other end thereof, said first and second tubes each having an open end within said porous tube with said open ends being in spaced-apart generally opposed and generally coaxial relation to each other.

15. The flameless heater of claim **1** wherein said injector is adjacent the upper end of said porous tube and the flameless heater also comprises an evaporator received in said porous tube adjacent the lower end thereof and underlying said injector to receive liquid fuel discharged from said injector and subsequently vaporize such liquid fuel and discharge the vaporized fuel into said porous tube.

16. The flameless heater of claim **15** wherein said evaporator comprises a metallic tube with a closed lower end and a flared upper end adapted to funnel liquid fuel discharged from said injector into the interior of said metallic tube.

17. A flameless heater using a combustible hydrocarbon fuel in liquid state for preheating liquid coolant of an internal combustion engine comprising; an elongate heat exchanger having an inlet and an outlet for liquid coolant of an engine, said heat exchanger being adapted to be mounted with its axis extending generally vertically, an elongate catalytic heater assembly received in said heat exchanger, said catalytic heater assembly comprising an elongate porous hollow tubular carrier impregnated with a catalytic material, both ends of said hollow tubular carrier being closed, an electric resistance heater element carried by said tubular carrier for preheating said catalytic material, a fuel injector at least in part received in said hollow tubular carrier adjacent the upper end thereof for discharging at least partially vaporized hydrocarbon fuel into the interior of said hollow tubular carrier, and a fuel evaporator at least in part received in said hollow tubular carrier adjacent the lower end thereof and underlying said injector to receive liquid fuel discharged from said injector and subsequently vaporize such liquid fuel and discharge the vaporized fuel into said hollow tubular carrier, whereby when vaporized hydrocarbon fuel is discharged into said catalytic heater assembly when preheated by said electric resistance element, the fuel is oxidized by a flameless catalytic reaction to heat liquid coolant of the engine in the heat exchanger.

18. The flameless heater of claim **17** wherein said hollow tubular carrier comprises an elongate rigid porous tube, end caps closing both ends of said porous tube, and a fibrous material overlying said porous tube and impregnated with said catalytic material.

19. The flameless heater of claim **17** wherein said fuel injector and said fuel evaporator each comprise a metallic tube extending at least in part into said hollow tubular carrier in generally coaxial alignment with each other and each having an open end with said open ends being in spaced-apart generally opposed relation within said tubular carrier.

20. The flameless heater of claim **17** wherein said heat exchanger has a generally cylindrically shaped metallic tubular wall having an axial length exceeding the axial length of said hollow tubular carrier and an inside diameter exceeding the outside diameter of said hollow tubular carrier, said metallic tubular wall of said heat exchanger being in contact with liquid coolant in said heat exchanger and lying adjacent to said catalytic heater assembly, and locators carried by said metallic tubular wall of said heat exchanger adjacent opposed ends of said catalytic heater assembly to position said catalytic heater assembly generally coaxially within said metallic tubular wall of said heat exchanger.

21. The flameless heater of claim **17** wherein said evaporator comprises a metallic tube with a closed lower end adapted to receive liquid fuel discharged from said injector into the interior of said metallic tube of said evaporator.

22. A flameless heater using a combustible hydrocarbon fuel for preheating liquid coolant of an internal combustion engine comprising; an elongate heat exchanger having an inlet and an outlet for liquid coolant of an engine, said heat exchanger being adapted to be mounted with its axis extending generally vertically, an elongate catalytic heater assembly received in said heat exchanger, said catalytic heater assembly comprising an elongate porous hollow tubular carrier impregnated with a catalytic material, both ends of said hollow tubular carrier being closed, an electric resistance heater element carried by said tubular carrier for preheating said catalytic material, a first fuel injector tube at least in part received within said tubular carrier adjacent one end thereof for discharging at least partially vaporized hydrocarbon fuel into the interior of said hollow carrier, and a second tube sealed adjacent one end and at least in part received within said tubular carrier adjacent the other end thereof, said first and second tubes each having an opening within said tubular carrier and being at least in part generally coaxially aligned with said openings in spaced-apart generally opposed relation to each other, whereby when a vaporized hydrocarbon fuel is discharged by said injector into said catalytic heater assembly when preheated by said electric resistance element, the fuel is oxidized by a flameless catalytic reaction to heat liquid coolant of the engine in the heat exchanger.

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