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Csicsery

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[45] **Dec. 16, 1975**

[54] **SINGLE STAGE COLD START AND EVAPORATIVE CONTROL SYSTEM USING A BIMODAL ADSORBENT BED**

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[21] Appl. No.: **448,773**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 295,028, Oct. 4, 1972, Pat. No. 3,831,572.

[52] **U.S. Cl.** .... **123/180 R;** 123/3; 123/187.5 R; 123/127

[51] **Int. Cl.**[2] **F02M 1/16**

[58] **Field of Search**...123/179 G, 3, 180 R, 187.5 R, 123/119 E, 127

[56] **References Cited**

UNITED STATES PATENTS

1,490,192	4/1924	Anderson	123/127
3,221,724	12/1965	Wentworth	123/136
3,635,200	1/1972	Rundell et al.	123/3
3,831,572	8/1974	Csicsery	123/3 X
3,838,673	10/1974	Csicsery et al.	123/3 X

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Assistant Examiner—David D. Reynolds
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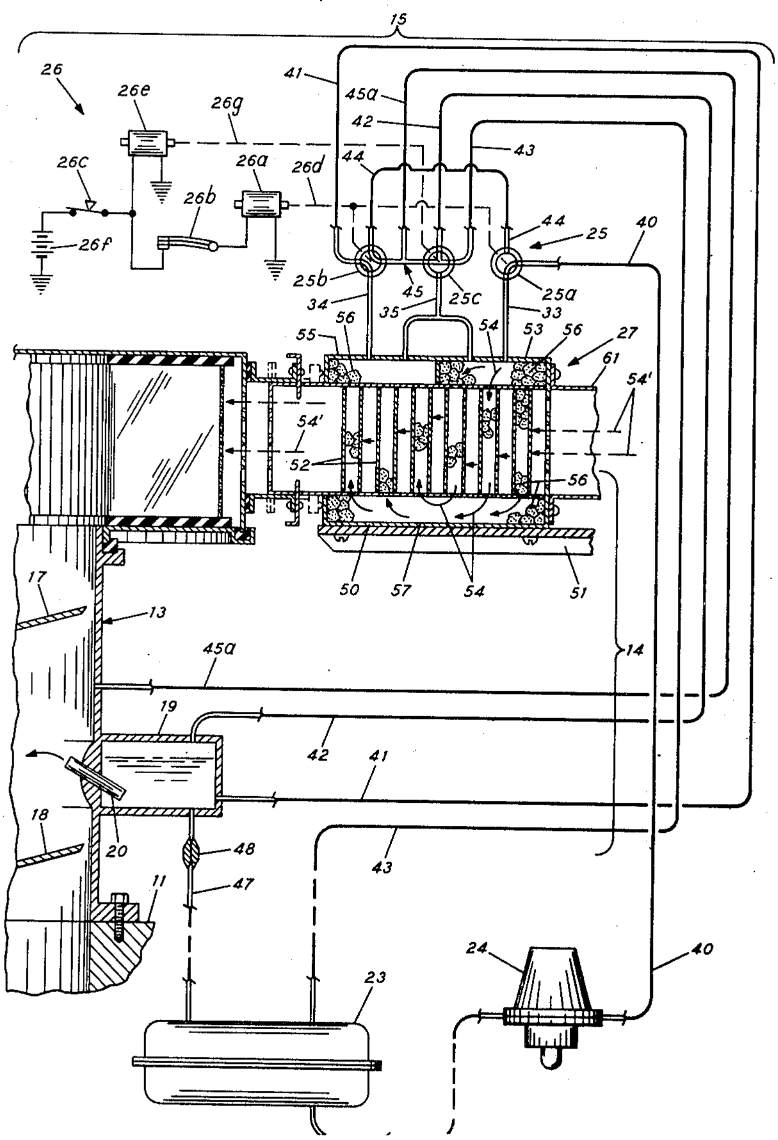
[57] **ABSTRACT**

As cold start is initiated in a spark-ignition internal combustion engine, lower molecular weight constituents of a full-range gasoline are selectively eluted by an elution system including an adsorbent bed of adsorbent material (cold start cycle). Under such circumstances, the adsorbent bed forms an elution zone within a cannister assembly. Furthermore, when the engine is in an inoperative state (vapor capture cycle) the same adsorbent bed is also capable of performing a second function: it adsorbes evaporative emissions originating from within the gasoline tank and carburetor bowl.

8 Claims, 8 Drawing Figures



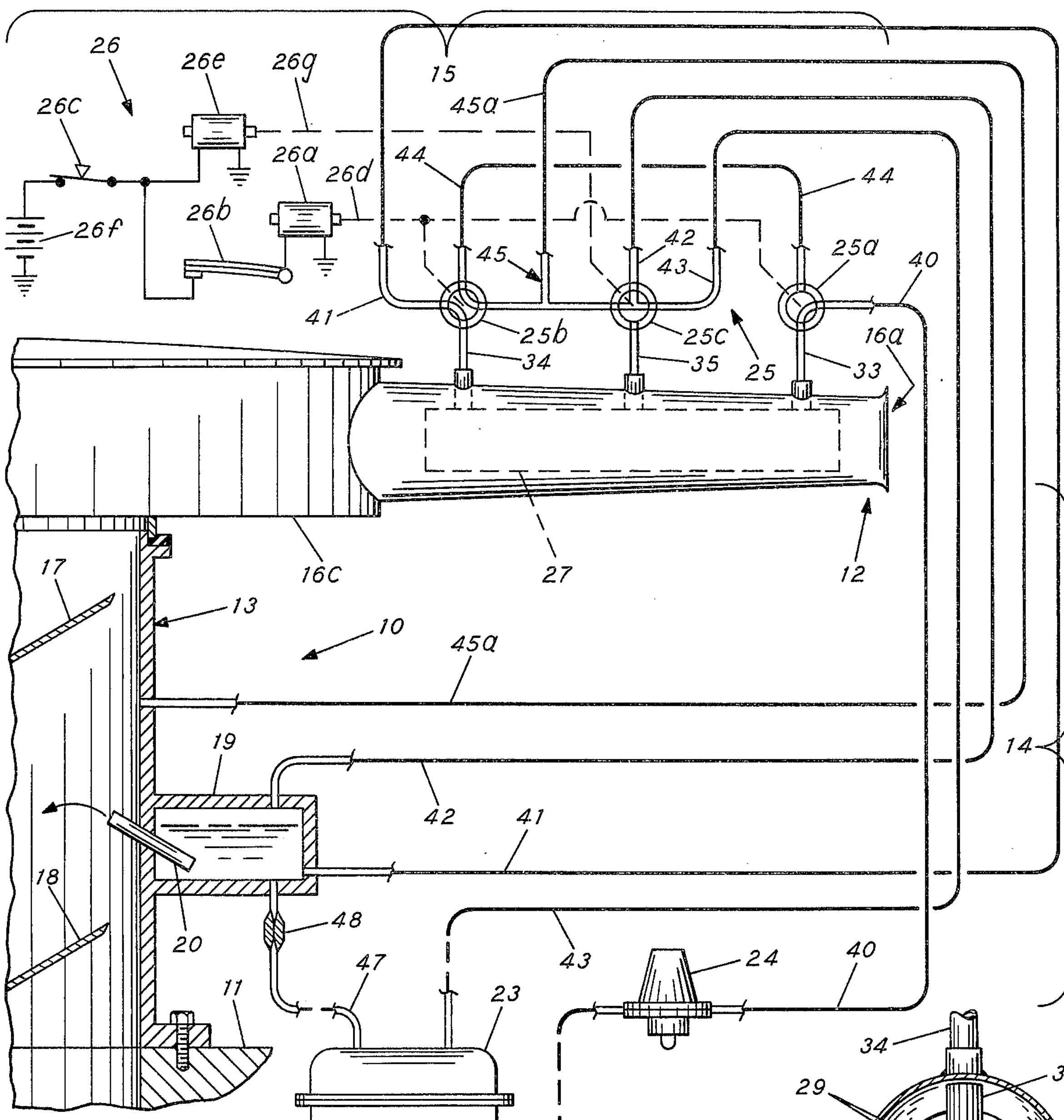


FIG.1

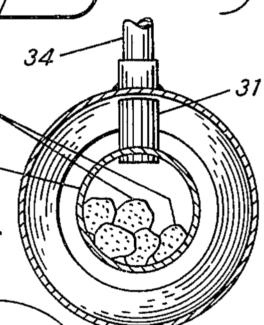


FIG.3

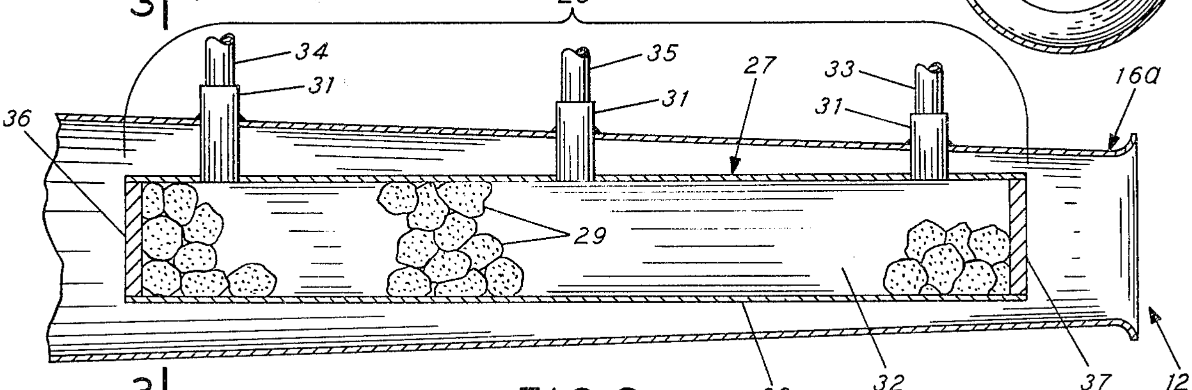


FIG.2

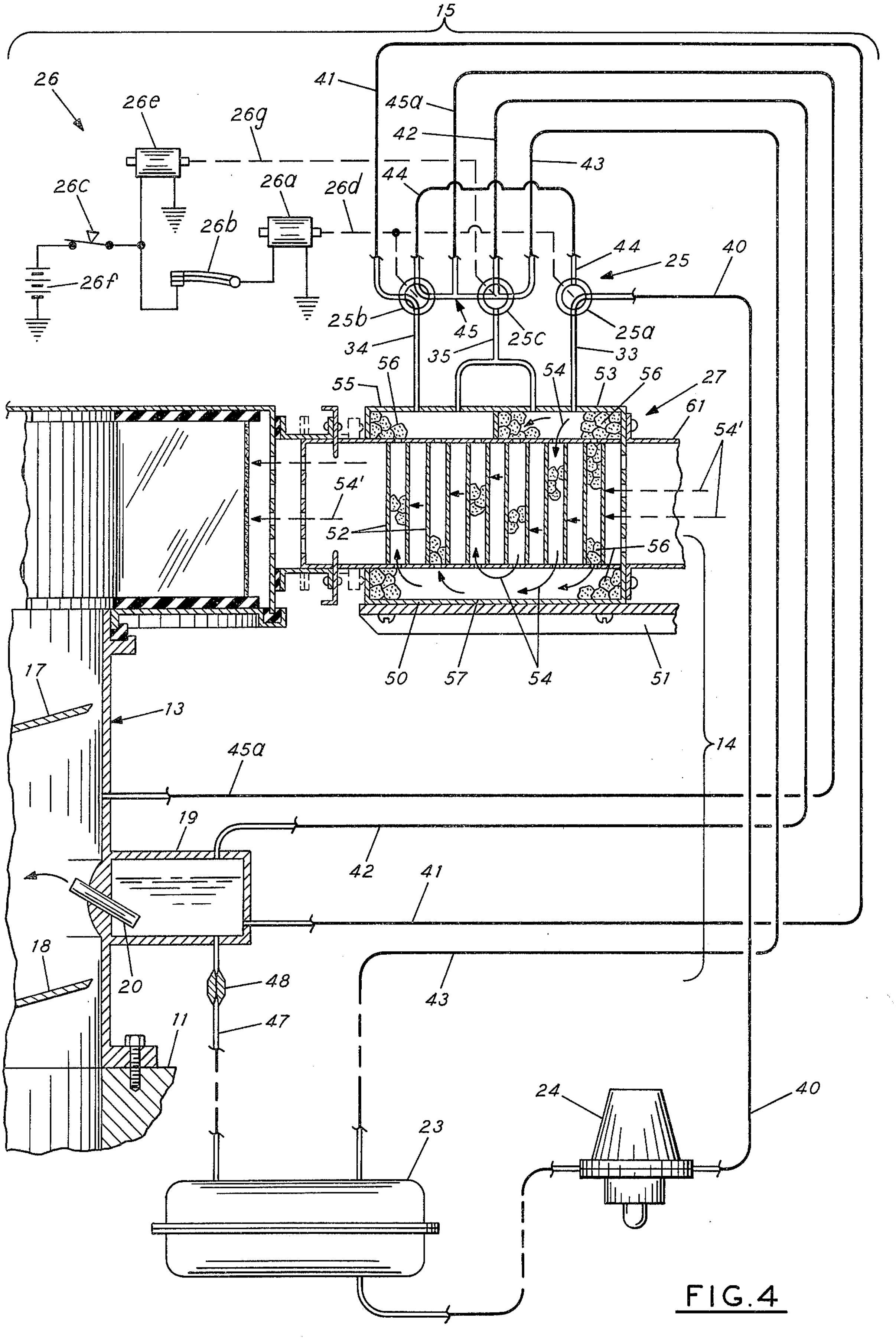

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FIG. 4

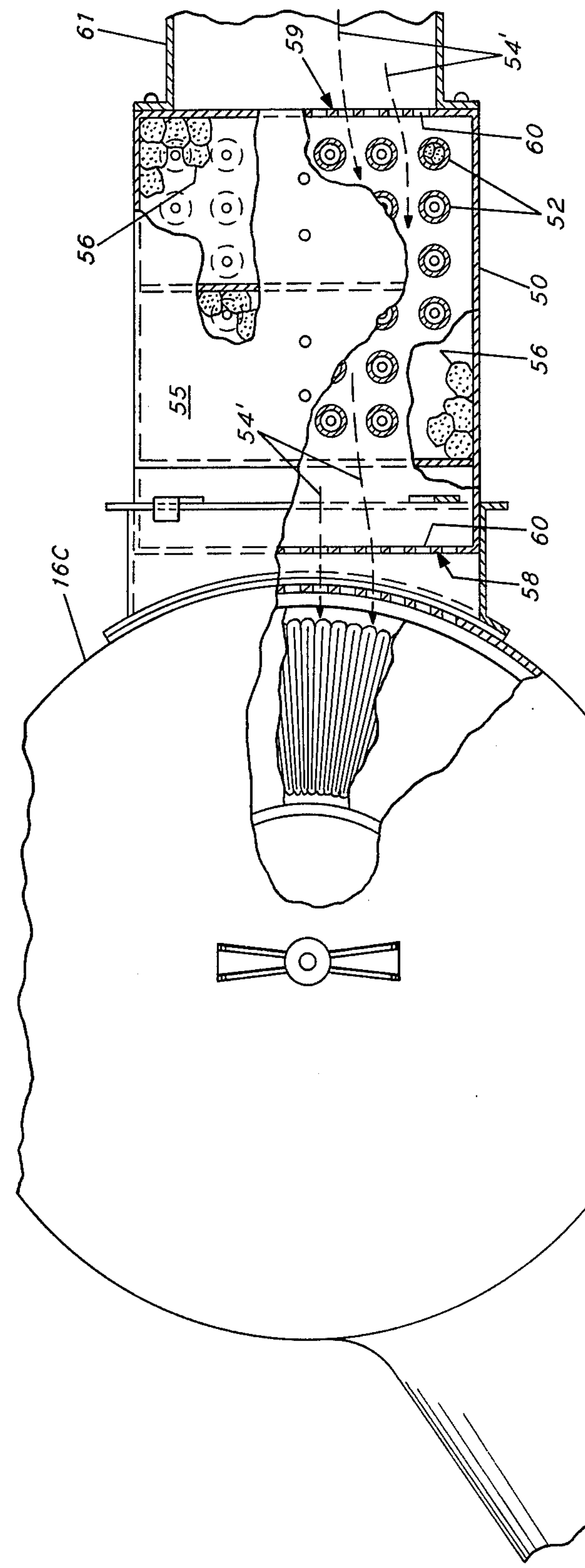

FIG.5

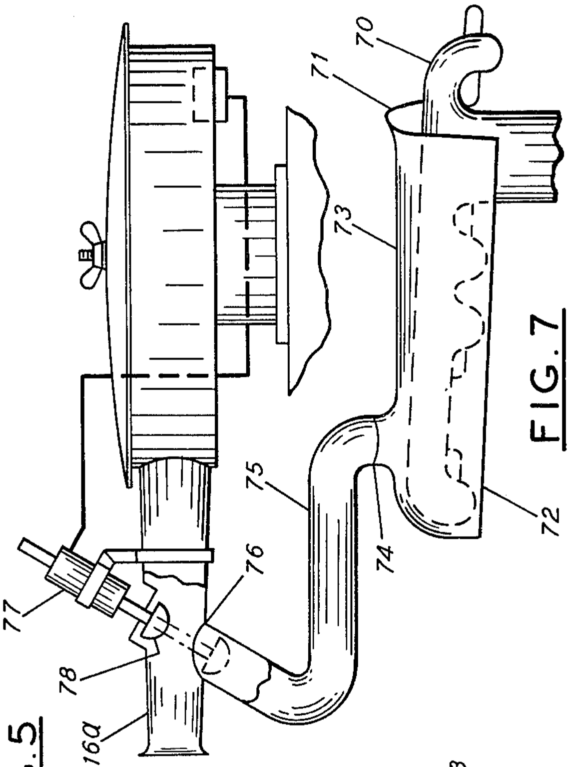

FIG.7

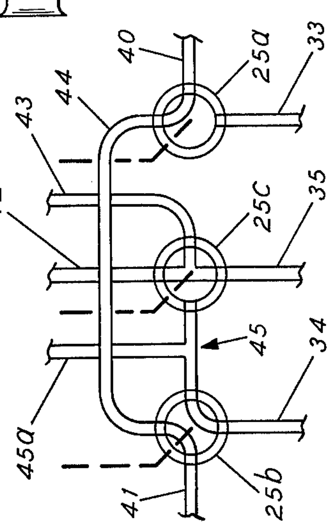

FIG.8

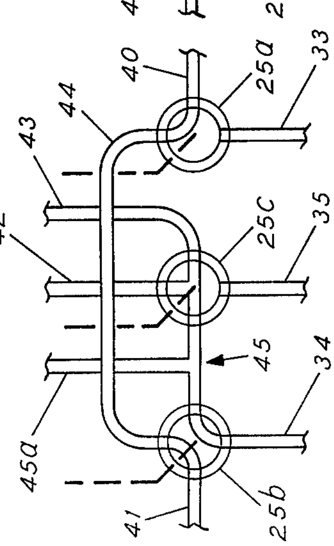

FIG.6

SINGLE STAGE COLD START AND EVAPORATIVE CONTROL SYSTEM USING A BIMODAL ADSORBENT BED

RELATED APPLICATIONS

The subject application is a continuation-in-part of Ser. No. 295,028 for "Single-Stage Cold Start and Evaporative Control Method and Apparatus for Carrying Out Same" filed Oct. 4, 1972, now U.S. Pat. No. 3,831,572, issued Aug. 27, 1974.

Other applications assigned to the assignee of the subject application containing common subject matter incorporated herein by reference, include:

Title		Serial No.
Two-Stage Cold Start and Evaporative Control System and Apparatus for Carrying Out Same	Sigmund M. Csicsery and Bernard F. Mulaskey	295,029 Filed 10-4-72 now U.S. Pat. No. 3,838,673
Cold Start Method and Apparatus for Carrying Out Same	John F. Senger	295,041 Filed 10-4-72 now abandoned
Fuel Injection Cold Start Evaporative Control Method and Apparatus for Carrying Out Same	Sigmund M. Csicsery	295,040 Filed 10-4-72 now U.S. Pat. No. 3,838,667
Two-Stage Fuel Injection Cold Start Method and Apparatus for Carrying Out Same	Sigmund M. Csicsery and Bernard F. Mulaskey	295,030 Filed 10-4-72 now U.S. Pat. No. 3,826,237
Fuel Injection Cold Start and Evaporative Control Method Using a Bimodal Adsorbent Bed	Sigmund M. Csicsery	448,775 Filed 3-6-74

BACKGROUND OF THE INVENTION

The present invention relates to cold starting and evaporative emission control of a spark-ignition internal combustion engine and has for an object the provision of a simple and effective cold start and evaporative control system for use in such engine

i. for selectively eluting from a full range fuel flowing to the engine, only the lower molecular weight constituents at cold start so to allow quick starting of the engine without excessive amounts of unburned hydrocarbons appearing at the exhaust (cold start cycle) as well as

ii. for adsorbing evaporative emissions from the gasoline tank and carburetor bowl when the engine is not operating (vapor capture cycle), without mileage loss.

Higher molecular weight constituents adsorbed during the cold start cycle and/or light, evaporative emissions adsorbed during the vapor capture cycle of the engine are subsequently purged from the engine, by consumption interior thereof, but only after the engine has warmed and full range fuel is being utilized.

In my parent application cited above, I taught how cold starting of a spark-ignition, internal combustion engine could be enhanced, such enhancement occurring without generating unburned hydrocarbons at the engine's exhaust. Specifically, as cold start conditions occur (cold start operating mode), just enough lower molecular weight constituents of a full-range fuel can be dynamically eluted for cold starting of the engine. The described elution system includes an adsorbent bed of adsorbent material packed within a cannister assembly. Fuel flow control from a fuel reservoir is by means of a controller circuit acting through a valve and conduit network. Initiation of the cold start cycle is straight-forward, as by means of a change in state of the ignition switch. In addition to the aforementioned cold start capabilities, my system also has the added feature of being able to adsorb evaporative emissions originating from within the carburetor bowl and the gasoline tank when the engine is inoperative, such emission capture occurring not within the above-identified adsorbent bed, but within a second adsorbent bed located coextensively with, but coaxially exterior thereof. However, since the cannister assembly supporting both first and second beds had to include an internal separation wall, experience has shown that the resulting cannister assembly could be rather costly and time-consuming to fabricate.

In accordance with the present invention, rather than requiring complex, double-wall construction, my cannister assembly now requires only a single adsorbent bed for performing the aforementioned dual functions. Thus in one embodiment, the cannister assembly uses only a single unitary sidewall to form the annular support space at its interior. Into the unitary space adsorbent materials are packed capable of interchangeably functioning as either an elution or emission capture adsorbent bed. Inasmuch as the two separate functions are interchangeable, it is essential that the adsorbent material (constituting the aforementioned adsorbent bed) be properly classified for these functions, viz, either polar or nonpolar or a combination thereof.

In many applications, a composite mixture of polar and nonpolar adsorbent materials is preferred. The range of the mix ratio, by volume, can be varied depending upon the nature of conditions encountered in the field. That is, in geographically humid zones of the world, such as found in the southern part of the United States, there may be a requirement for the use of greater amounts, by volume, of the nonpolar adsorbent contituent material for the purpose of increasing capture area of the cannister assembly. Results: increased probability of total adsorption of vapor emissions generated within the fuel system. Similarly, in colder climatic zones where start conditions are more severe, there may be some advantage to provide greater amounts of polar adsorbent material during the cold start cycle of the engine. The key requirement in both cases, of course, remans to provide polar and nonpolar adsorbent contituent materials in a combination that assures both efficient elution and capture modes of operation within the cannister assembly of the present invention.

Construction of the improved cannister assembly in accordance with present invention can vary. For example, in one embodiment a simple cylinder can be plugged at both ends with solid, annular pole pieces. Entry and egress of the engine fuel is by means of radially extending fitting conduits connected through the valve and conduit network to the fuel reservoir.

All operating cycles are automatically controlled through a controller circuit similar to one I previously proposed and described in the above-identified parent application. The control circuit, in turn, acts in conjunction with the valve and conduit network to allow (or prevent) fluid flow depending on the operating cycle.

In more detail, during the cold start cycle, the valve and conduit network is arranged to allow free passage of the full-range fuel into contact with the adsorbent bed say through a radial inlet fitting and thence by percolation thereover. Selective retardation of the higher molecular weight compounds, vis-a-vis the lower components then occurs. Thereafter, the latter constituents pass from a second radial outlet fitting conduit to the fuel well of the carburetor, and thence are mixed with air in a preselected air-fuel ratio. Results: the engine starts even under the most severe climatic conditions. Since the starting cycle is usually quite short, say from 1 to 15 seonds, the residence time for the high molecular weight compounds within the elution zone is preferably 1 to 2 orders longer say from 1 to 3 minutes. Thus, the heavier compounds remain selectively adsorbed with the adsorbent bed during starting of the engine. Thereafter, the adsorbent bed is disconnected from direct fuel flow by the controller. The full-range fuel from the reservoir, then is forced to flow in a direct path to the carburetor. As the full-range fuel is used and the cannister is disabled, it should be noted that the latter undergoes depressurization. Result: as the engine warms and hot air is passed adjacent to the cannister, adsorbed materials (adsorbates) within the adsorbent bed, are easily purged from the system. The resulting purged emissions flow from the bed through the valve and conduit network and thence to the intake of the carburetor for consumption within the engine.

In still more detail, during the inoperative state of the engine, (the vapor capture cycle), the same adsorbent bed interior of the cannister assembly is automatically placed in fluid contact with the carburetor fuel well and the gasoline tank through operation of the same controller and network system. Thus, the evaporative emissions are free to pass into, and be captured by the aforementioned adsorbent bed. Since studies indicate that up to 15 percent by volume of the total vapors admitted into the atmosphere during inoperativeness of I.C. engines are traceable to evaporative emissions originating from fuel sources of such engines, the present invention provides a useful solution to a serious environmental problem.

Since the function of the associated valve and conduit network and the controller circuit is to place the adsorbent bed of the cannister assembly in fluid flow relationship with relevant elements of the fuel system as required, it is apparent that after the engine has been started and adequately warmed, adsorbates within the adsorbent bed (due to the elution and capture cycles) can be automatically purged from the cannister: gases (either full or partial engine air or manifold exhaust gases) can be passed adjacent to the cannister assembly, as required.

Although the prior art has suggested both polar and nonpolar adsorbent materials for use in enhancing operation of I.C. fuel systems, there has been no suggestion of using commonly housed adsorbent materials in an unitary elution system to serve two functions: (i) selectively eluting from a full-range gasoline, only light, low molecular weight components thereof, to assure a smooth pollution-free start of a spark-ignition internal combustion engine while alternatively (ii) providing for capture of evaporative emission originating from the associated fuel system when the engine is in an inoperative state.

Further objects, features and attributes of the present invention will become apparent from a detailed description of several embodiments thereof, to be taken in conjunction with the following drawings in which:

DESCRIPTION OF THE FIGURES

FIG. **1** is a schematic view of a portion of an engine fuel system incorporating the present invention illustrating a typical carburetor and air cleaner assembly interconnected between a cold start - evaporative emission system of the present invention, said cold start evaporative control emission system including a cannister assembly housed within the air intake line of the air cleaner assembly under regulation of a valve and conduit network controlled by a controller circuit;

FIG. **2** is a partial cutaway of the cannister assembly of FIG. **1;**

FIG. **3** is an end view taken along line **3—3** of the cannister assembly of FIG. **2;**

FIG. **4** is another embodiment of the present invention illustrating in side elevation a dual flow cannister assembly mounted, as by a platform to the firewall of the engine compartment;

FIG. **5** is a top elevational view, partially cutaway, of the modified cannister assembly of FIG. **4;**

FIGS. **6** and **8** are fragmentary views of the valve and conduit network of FIG. **1** illustrating the position of the valve network in two positions: (i) after cold start has been achieved and the engine is at running temperature so that the cannister assembly can be desorbed by passing gases in heat transfer contact therewith; and (ii) after the engine has been placed in an inoperative state so that the cannister assembly is connected to the vapor zones of the fuel system (vapor capture cycle), respectively; and

FIG. **7** is a partially schematic view illustrating an alternate embodiment by which air can be heated to an elevated temperature to better desorb the cannister assembly of FIG. **1;**

DESCRIPTION OF A SPECIFIC EMBODIMENT

Referring now to FIG. **1,** there is illustrated an engine fuel system **10** connected to an engine intake manifold **11** of a spark-ignition internal combustion engine (not shown). Fuel system **10** of the present invention includes an air intake system **12,** a carburetor **13,** a fuel intake system **14,** that includes cold start-evaporative control system **15** of the present invention.

To form a combustible air-fuel mixture, air enters by way of air intake system **12,** say by way of air inlet line **16***a*, and is filtered at an air filter interior of an air filter housing **16***c*, before entry into carburetor **13.**

Carburetor **13** includes choke and throttle valves **17** and **18,** respectively, a fuel well **19,** and a discharge nozzle **20.** Fuel well **19** contains a metered quantity of gasoline to be mixed with air passing discharge nozzle

20. The resulting fuel-air mixture passes through intake manifold 11 into the engine combustion chambers (not shown) where combustion occurs. Supplying fuel well 19 with a metered quantity of gasoline is by means of the previously mentioned fuel intake system 14.

The fuel intake system 14 includes a gas tank 23 containing a reservoir of full-range fuel (i.e., a fullboiling gasoline), a fuel pump 24 and the cold startevaporative control system 15 of the present invention. Briefly, the cold start-evaporative control system 15 includes a valve and conduit network 25 in fluid contact with the discharge side of fuel pump 24 but under operative control of controller circuit 26 to provide selective flow relative to cannister assembly 27. As shown in FIG. 1, the cannister assembly 27 is mounted adjacent to the air intake system 12, say within air inlet line 16a. Fuel flow relative to the cannister assembly 27 is selectively controlled, as explained below, by the valve and conduit network 25 through controller circuit 26.

The valve and conduit network 25 is seen in FIG. 1 to include cold start inlet and exist valves 25a and 25b, respectively, controlled as follows: (i) mechanically by relay means 26a of the controller circuit 26 through transducer 26d and (ii) electrically through bimetal temperature switch 26b, ignition swtich 26c and battery 26f. A second relay 26e of controller circuit 26 is seen to control operation of evaporative emissions control valve 25c through mechanical transducer 26g. During the cold start cycle, the control valve 25c is placed in an inoperative condition as shown in FIG. 1; but, during the vapor capture cycle, it is activated to assume the position depicted in FIG. 8. During such operations, the transducers 26d and 26g are made to convert rectilinear travel of the relay means 26a and 26e to rotational motion of the control valves as explained below.

Cold-Start Evaporative Control System 15

With reference to FIG. 1, during cold start of a spark-ignition, I.C. engine, a full-range fuel, i.e., a full-boiling gasoline, having high and low molecular weight constituents, is conveyed from gas tank 23 through fuel pump 24 into the valve and conduit network 25 to cannister assembly 27 and thence from the cannister assembly 27 to fuel well 19 of the carburetor 13. Since a key in providing efficient cold starting conditions lies in the selective elution of light, lower molecular weight components, a brief discussion cannister assembly 27 seems to be in order and is presented below.

Cannister Assembly 27

Construction of the cannister assembly 27 can vary. In FIG. 2, the cannister assembly 27 is mounted within the intake air line 16a of the air intake system 12. It is preferably cylindrical. Its overall diameter must be kept to a minimum so as to allow sufficient air to bypass into the carburetor. Within its interior, a bed of adsorbment material indicated at 28 is provided. To accommodate the required volume of the afore-constituted adsorbment material, the length of cylindrical housing 30 may have to be about as long as the housing of air line 16a. Support of the housing 30 can be brought about by welding anchors 31 to side wall 32 of the housing 30 as well as to the air line 16a. The anchors 31 are provided with bores through which cold start inlet and outlet fitting conduits 33 and 34 as well as evaporative fitting conduit 35 are attached. End pole pieces 36 and 37 are welded at their edges to the side wall 32 of the housing 30. Each pole piece 36, 37 is a solid annulus having no openings therethrough. Accordingly, intake air exterior of the housing 30 is not allowed to directly mix with fuel continuously flowing through the fitting conduits 33 and 34 of the cannister assembly 27.

During operations related to the cold starting of the engine, controlled separation of the fuel components within the cannister assembly 27 occurs in a straightforward fashion. That is, as shown in FIG. 1, full-range fuel is seen to flow from the gas tank 23 and fuel pump 24 through conduit 40 to the inlet cold start valve 25a and thence through inlet fitting conduit 33 to the interior of cannister assembly 27. Within the assembly 27 controlled separation of the fuel components occurs. Result: light molecular weight liquid constituents forming a cold start effluent appear at outlet fitting conduit 34. The effluent then is quickly conveyed through outlet valve 25b and conduit 41 to the carburetor 13. At the carburetor 13, the light, lower molecular weight effluent mixed with air to form a efficient cold start air-fuel mixture for the engine.

Since separation of the heavy molecular weight vis-a-vis light groups with the cannister assembly 27 is based on the functional characteristics of the adsorbent material within the cannister assembly 27, a brief discussion of adsorption systems in general seems to be in order and is presented below. However, recall that such adsorbent materials also function as a vapor emission capture zone when the engine is placed in an inoperative state. For example, when evaporative control valve 25c is in an active condition, as depicted in FIG. 8, the vapor zones of the fuel well 19 and gas tank 23 are seen in FIG. 1 to connect to the interior of the cannister assembly 27 as follows: (i) for fuel well 29 via conduit 42, evaporative control valve 25c and conduit 35, and (ii) for gas tank 23 via conduit 43, control valve 25c and the conduit 35. Thus, the didactic discussion which follows has been divided along similar lines.

During the cold start cycle, the side wall 32 of the cylindrical shell housing 30 of FIG. 1, forms essentially a column of a solution adsorption, frontal analysis chromatography as classified in accordance with *Kirk-Othmer Encyclopedia of Chemical Technology*, 2nd Ed., Volume 5, page 418. In accordance with *Kirk-Othmer* op. cit., such classification is essentially based on the nature of the mobile phase of the system percolating through an adsorbent material generally indicated at 29 in FIG. 2.

Initially full-boiling gasoline enters by way of inlet fitting conduit 33. Thereafter, it percolates through and about the adsorbent bed 28. At the outlet fitting conduit 34, the order of elution is a function of the order of polarity of the constituents of the full range constituents since the individual molecules of the heavier components move at a slower rate (between the mobile and secondary phases) than do the lighter constituents.

Intermediate evaporative fitting conduit 35 is not free to pass constituents from the adsorbent bed 28 during the cold start cycle. As seen in FIG. 1, the evaporative control valve 25c is in an inoperative state, and thus prevents flow of the gasoline constituents therethrough, as previously mentioned. Within the interior of the adsorbent bed 28, the causes for separation of the constituents can be for a multiplicity of reasons, inter alia, the polarity (or nonpolarity) characteristics of the constituents seem to be a relevant criterion for separation classifications in that different relative velocities are thought to be imparted to the individual molecules of the groupings so that the least strongly adsorbed low molecular weight components elute as a group at the outlet fitting conduit **34** first, followed by a second grouping containing say both the light and heavy molecular weight constituents and so forth until all constituents have appeared.

Residence time of the lighter components within the adsorbent bed **28** is also a function of rather conventional engineering factors including the length of the cylindrical housing **30** as well as the pressure drop of the former during percolation of the fluids through the adsorbent material **29.** The flow rate of the mobile phase must be slow enough to allow maximum transfer of the molecules of the heavier constituents into and from the stationary and mobile phases yet fast enough to provide ample amounts of lighter components for quick starting of the engine. However, care ought be exercised in regard to the residence time of the heavier components. Since selective retardation of the heavier constituents due to relative polar-nonpolar interaction between the heavier components and adsorptive material **29,** can be quite long, say 1–3 minutes, while the typical starting cycle of a modern engine can be quite short, say from 1 second up to 15 seconds (except when problems of starting occurs), the heavier constituents usually remain adsorbed during starting. The aforementioned conclusion assumes, of course, that the composite adsorbent material **29** constituting the adsorbent bed **28** is of a compatible classification to perform both elution and vapor capture functions as discussed below.

Classification of Adsorbent Material 29

As previously mentioned, during elution of low molecular weight liquid fuel contituents, competition for the heavier molecular weight groupings of the full-range fuel is believed to be, more or less, dependent on its selective polar interaction with the adsorptive material **29** constituting the adsorbent bed **28.** The degree of interaction, in most, but not all cases, is believed to be directly related to the magnitude of the polarity of the material. A general rule seems to be: the greater the polarity, the greater the interaction. Thus, in accordance with the present invention, the adsorptive material **29** should have (preferably in addition to a nonpolar constituent, for reasons explained below) a polar element, say one selected from the following non-exclusive listing of popular polar adsorptive materials for proper operation as a cold start fuel effluent generator:

Polar Adsorptive Materials	Remarks
Silica gel	
Alumina	Activated Preferred
Alumina gel	
Barium sulfate	
Fuller's earth	
Calcium carbonate	
Bentonite	
Glass	
Diatomaceous earth, forisil, attupulgus	
Resins and plastics	Ion-exchange only
Glass	
Quartz	
Titania gel	
Titanium dioxide	
Metallic oxides	
Zeolites (sieves)	
Zirconia gel	
Sil X	
Solid Support Materials Coated with Liquid adsorbers, preferably chemically bonded (e.g., Durapak, Solids Coated with Octadecyl Silane, Fluoro-ethers)	Commonly used in liquid-liquid partition chromatography

However, during operations as an adsorber of evaporative emissions, as when the evaporative control valve **25***c* assumes the position depicted in FIG. **8,** the preferred polar classification of the material **29** is reversed. This assumption implies that the system requirements are such that the bed **28** must employ materials which possess the most effective capture surface per unit volume of material. Accordingly, the adsorptive material **29** should also contain, say as a second element thereof, a nonpolar component, say one selected from the following non-exclusive listing of nonpolar adsorbent materials in order to most effectively carry out the vapor capture aspect of the present invention.

Nonpolar Adsorbent Material	Remarks
Charcoal	
Charcoal blacks	
Graphite	
Resins and Plastics	Organic only
Paraffins	
Stibnite	
Sulfides	Metallic only
Talc	

In forming the composite bed **28,** the ratio, by volume, of polar to nonpolar material is preferably about **1:1.** In some cases, however, the ratio can be varied to accommodate changed conditions, e.g., where the system of the present invention is used in the more humid climates of the world, there may be a need to use greater amounts of the nonpolar constituent to provide a larger emission capture area within the bed **28.** Also, in other areas of the world as whre cold start conditions are more severe, it may be advantageous to use greater amounts, by volume, of the polar material as the chief adsorbent component. However, since there can be a large overlap of both functions within certain known adsorbent materials the adsorbent material **29** constituting adsorbent bed **28** need not be a dual component mixture but can utilize a single component system, provided it can perform in both the cold start and vapor capture functions, as outlined above.

Of course, the adsorbent material **29** can be formulated in a variety of ways for use within the cannister assembly **27.** For example, the adsorbent material **29** can be arranged in granular, pelletized or powdered form. Preparation is straight-forward: the adsorbent material should be calcined, acid and base washed, neutralized, and size graded prior to insertion within the housing **30,** say along lines set forth in *Kirk-Othmer*, op. cit., Volume 1, page 460. Since as previously mentioned, during elution the flow rate of the full range gasoline within the bed must be slow enough to allow maximum transfer of the molecules of the heavier compounds into and from the stationary and mobile phases, the size of the polar component of the adsorbent material **29,** if used, should be such as to minimize the pressure drop across a cannister assembly **27** without adversely affecting its ability to adsorb the heavier constituents. In this regard, an adsorbent bed **28** having about a 1-liter capacity can be filled with activated alumina (8 by 14 mesh) and such a bed has been found to adsorb from 200–300 ml of heavier constituents while yielding about 400 to 500 ml of light molecular weight constituents for use in the first initial minutes of the cold starting operation.

MODIFICATION

In FIG. **4**, the support of the cannister assembly **27** differs markedly from that shown in FIG. **1.** The cannister assembly **27** of FIG. **4** is seen to be mounted by shell housing **50** to a platform **51** which in turn is attached to a firewall (not shown) of the engine compartment. Additional space afforded by the platform **51** allows for a more complex constructural design of the cannister assembly **27.**

As shown, a series of upright tubular means **52** is constructed to carry the gasoline entering inlet chamber **53** along a series of sinusoidal passes through the interior of the cannister assembly **27** to exhaust chamber **55,** such passageways resembling those provided in a conventional tube-and-shell heat exchanger. The series of sinusoidal passes made by the gasoline are indicated by solid arrows **54** while the dotted arrows **54'** (see FIG. **5**) indicate the direction of the air phase flow. In the depicted arrangement, tube-side gasoline is conveyed—during cold starting—through the tubular members **52** between the inlet and exhaust chambers **53** and **55** respectively (multipass percolation) through adsorbent material **56** packed within the tubular members **52** as well as within the chamber **53** and **55.** Due to increased total length of the tubular members **52,** the resulting adsorbent bed is likewise greatly enlarged over that depicted in FIGS. **1** and **2.** The absolute length of the cannister assembly **27** of FIG. **4** can be correspondingly reduced, if desired, or if kept at comparable absolute lengths greatly improves elution efficiency. Thus, not only does the effluent at the exhaust chamber **55** consist essentially of low molecular weight liquid constituents during the cold start cycle, as previously explained, but also the heavier constituents remain adsorbed within the adsorbent material **56** until long after the engine has warmed up. That is to say, because the heavier constituents are retarded during percolation through the adsorbent material **56** for a longer time than required to usually start the engine, the effluent within the carburetor per each starting cycle of the internal combustion engine is limited essentially to the lightweight, low molecular weight constituents.

Further constructural differences between the embodiments depicted in FIG. **1** and FIG. **4** are readily apparent. For example, in FIG. **5**, the shell housing **50** is seen to be rectangular in cross-section whereby the assembly forms a parallelepipedon. Also, the shell housing **50** is also seen to include end walls **58** and **59.** Each end wall **58** and **59** includes a series of ports **60** to allow selective entry of hot, exhaust gases adjacent to but generally exterior of tubular member means **52** within interior of shell housing **50.** End wall **58** is also seen to attach by way of fasteners to the air cleaner housing **16***c*. End wall **59** is seen to be connected to a conduit **61** having a remote end (not shown) connected to a source of exhaust gases, say the exhaust manifold of the engine.

Of course tubular members **52** need not be discontinuous so as require the use of intermediate chamber **57** (FIG. **4**) to reverse the flow of the mobile phase; e.g., the tubular members **52** can be U-shaped with remote ends in fluid contact with inlet and exhaust chambers **53, 55,** respectively.

Although the embodiment depicted in FIG. **1** utilizes intake air to the engine for purging of the cannister assembly, it should also be noted that it could also contemplate utilization of gases from the exhaust manifold for this purpose. In this regard, assume that the engine has been started and warmed using the full-range fuel, i.e., the inlet and outlet cold start valves **25***a* and **25***b* have been placed in the positions depicted in FIG. **6** so that the full-range fuel is free to directly enter the engine carburetor. That is, full-range fuel bypasses the cannister assembly via flow through conduit **40,** inlet valve **25***a*, U-shaped connector conduit **44,** outlet valve **25***b* and conduit **41** for entry into the fuel well **19** of the engine. Simultaneously with the utilization of the full-range gasoline, the interior of the cannister assembly is depressurized by the change in operating state of exhaust start valve **25***b*. With reference to FIGS. **1** and **6,** the interior of the cannister assembly is placed in fluid contact with the carburetor via outlet conduit **34,** outlet valve **25***a* and T-shaped conduits **45,** having a stem **45***a* which connects to the inlet of the carburetor **13.** In similar fashion the vapor zones within the fuel well **19** and gas tank **23** are placed in fluid contact with the carburetor **13** since evaporative control valve **25***c* remains in an inoperative state as depicted in FIG. **1:** (i) for fuel well **19** via conduit **45,** valve **25***c* and T-shaped conduit **45;** (ii) for gas tank **23,** via conduit **43,** valve **25***c* and the T-shaped conduit **48.** In that way, as desorption of the heavier compounds within the cannister assembly can occur, say as warmed air or gases are conveyed in heat transfer contact with the adsorbent bed. These compounds are thereafter swept into the carburetor **13,** along with any evaporative emissions from the fuel well **19** and gas tank **24.** It should also be pointed out that if evaporative vapors had been previously captured within the adsorptive bed of the cannister assembly, they would likewise be purged at this time.

Modification of the purging operation: in FIG. **4,** the conveyance of the hot exhaust gases from the exhaust manifold is under control of additional electrical circuitry (not shown) of the controller circuit **26.** When the temperature of the exhaust manifold reaches a selected temperature, a relay (not shown) is tripped to pass the purging gases through the cannister assembly **27** of FIGS. **4** and **5** via conduit **61.** The desorbed materials within the adsorption bed of the cannister assembly **27** are ultimately consumed within the combustion chambers of the engine using the appropriate valve and conduit positions as previously described with reference to FIG. **1.**

Where the heavier compounds within the adsorption bed of the cannister assembly have relatively high boiling points, too high in fact to be renewed by passing adjacent engine air in heat transfer contact with the elution zone, the embodiment depicted in FIG. **4** is especially useful. In this regard, the adsorbent material **56** of FIG. **4** can be renewed using the hot exhaust gases as the purging agent. If the temperature of such exhaust gases ranges from 700° to about 800°F, only a relatively short desorption time is required. Temperature of the adsorbent bed can be a range from 400°–500°F with about 450°F being a satisfactory operating temperature. Generally desorption time is quite short for such range setting, say being from about 2–12 minutes in duration. The resulting desorbed compounds then pass through the air intake system and carburetor **13** to the combustion chambers where they are consumed. Even though the cannister assembly **27** of FIG. **4** is larger than that depicted in FIG. 2, it provides better heat-transfer characteristics during desorption of the adsorption bed since the available heat transfer area (between the heat transferring media) is much larger. That is to say, the shell-side hot gases traveling through the cannister assembly 27 of FIG. 4 is in extremely good heat transfer contact with a multiplicity of the tubular member means. Also, since temperature of the gases is much higher, the total purge time can be reduced. However, the total flow rate of the hot purged gases at the air intake system should be carefully controlled so that the composite temperature of the inlet air to the carburetor is not too hot for efficient utilization of the resulting air fuel mixture within the combustion chamber of the engine.

FIG. 7 illustrates yet another mode for desorbing the adsorption bed of the cannister assembly of the present invention. In accordance with the illustrated embodiment, engine air is heated by passing the air adjacent to exhaust manifold 70 and thence through the cannister assembly where desorption occurs. The exhaust manifold 70 itself is provided with an exterior hood 71 having lower skirts 72 which snuggly fit adjacent to the exhaust manifold, yet are open to incoming air. A central register 73 is also provided with a nozzle 74. Nozzle 74 in turn is attached by flexible conduit 75 connected at a port 76 say at the air intake line 16*a* of the air intake system. At the air intake line 16*a*, a solenoid operator 77 is positioned so that damper 78 is in register with port 76. Opening the damper 78 allows warmed engine air to enter the cannister assembly (not shown).

Sequence of Operations

Reference should not be had to FIGS. 1, 2, 4–6, and 8 illustrating the method aspects of the present invention. In more detail, it should be apparent that the initiation of the cold start cycle automatically occurs when the driver closes ignition switch 26*c* of the controller circuit 26 of FIGS. 1 and 4. Before the driver engages the ignition switch 26*c*, however, the valve and conduit network 25 and particularly the evaporative control valve 25*c* is in the position illustrated in FIG. 8 to carry out the vapor adsorption control function of the present invention. That is to say, the evaporative 3-way control valve 25*c* is in a relaxed state so that the conduits 35, 42 and 43 are in fluid communication so that the interior of the cannister assembly is connected with the vapor zones of the carburetor and the gas tank. When the engine is in an inactive state and evaporation of the fuel occurs, the vapors then are free to pass through these conduits to the adsorption bed of the cannister assembly of FIGS. 2 and 4. Adsorption of the vapor prevents its escape into the atmosphere.

Prior to initiation of cold start, assume the fuel well 19 has been emptied of full-range fuel. In this regard, consider also the function of drain conduit 47 of FIGS. 1 and 4 connected between fuel well 19 and gas tank 23. When the engine is in an inactive state, fuel within the fuel well 19 (liquid phase) drains therefrom via conduit 47 to the gas tank 23. As shown, the conduit 47 is provided with an oriface 48 so as to control the rate of drainage of the fuel, say at a rate which will allow total removal of all fuel from the well within a 6–12 hour period. Thus, when the engine is parked overnight, the drain conduit 47 in cooperation with orifice 48 provide for total removal of full-range fuel from the fuel well 19. It should also be apparent that if the drainage conduit 47 is mounted at the sidewall of the fuel well (not at the bottom wall as shown) not all of the full-range fuel will be drained. Instead, a residual reservoir remains, the amount of which is a function of the connector position relative to the top wall of the fuel well, e.g., if the connector to the fuel well and conduit is at a location say about two-thirds of the way away from the top wall, the residual fuel would be one-third of the total fuel well capacity. During initial starting of the engine, the position of nozzle 20 of the carburetor 13 could be arranged, depthwise, so that a selected, compatible mixture of the residual and eluted fuel would enter the carburetor to effect cold start of the engine.

As the engine turns over, the fuel pump 24 conveys full-range fuel through inlet start valve 25*a* to the cannister assembly 27 of FIGS. 2 or 4. Within the cannister assembly 27, the full-range fuel percolates through the adsorption bed culminating in the elution of paraffinic components at fuel well 19. From the fuel well 19, a metered amount of the paraffinic components is conveyed via nozzle 20 into the carburetor 13 where the fuel and air are properly mixed and then convey for consumption within the combustion chambers of the engine. After selected rise in the engine temperature, as measured by bimetal switch 26*b* of the controller circuit 26, say positioned at the water jacket or exhaust manifold of the engine, control relay 26*a* becomes deactivated, resulting in the cold start inlet and exhaust valves 25*a* and 25*b* returning to relaxed positions as shown in FIG. 6.

After the cold start exhaust and inlet valves 25*a* and 25*b* return to relaxed positions depicted in FIG. 6, the fuel intake system switches over to full utilization of the full-range gasoline. That is to say, fuel conveyed from fuel pump 24 passes via conduit 40 to inlet valve 25*a* and thence through U-shaped conduit 44, exhaust cold start valve 25*b* and conduit 41 to the fuel well 19. As full-range fuel is used, the adsorption bed of the cannister assembly is depressurized by its placement in fluid contact with the carburetor inlet.

It should be pointed out that during the operation of the engine, the evaporative control valve 25*c* of the valve and conduit network 25 remains in an activated state as depicted in FIGS. 1, 4 and 6. However, when the driver opens the ignition switch 26*c* of the controller circuit 26, the evaporative control valve 25*c* is activated through relaxation of relay 26*e* which places it in the position depicted in FIG. 8 whereby the adsorption bed of the cannister assembly 27 is then in direct vapor contact with the fuel well 19 and gasoline tank 23. In that way, as evaporative emissions are formed within the fuel well 19 or the gasoline tank 23, they are conveyed to the interior of the cannister assembly.

While the certain preferred embodiments of the invention have been specifically disclosed above, it should be understood that the invention is not limited thereto as many variations will be readily apparent to those skilled in the art and thus the invention is to be given the broadest possible interpretation within the terms of the following claims.

I claim:

1. In a spark-ignition internal combustion engine of the type having an air intake system, a fuel system, and a mixing means interconnected therebetween for mixing of full-range fuel with air to form a combustible mixture for delivery to combustion chambers of said engine, the improvement for reducing exhaust pollutants of said engine by (i) dynamically varying the com-

position of said full-range fuel during cold starting of said engine (cold start cycle) and (ii) alternatively adsorbing evaporative emissions originating from vapor zones within said fuel system at least during an inoperative state of said engine, comprising:

i. cannister means selectively connectable between said mixing means and a reservoir of said full-range fuel and including an adsorption bed of adsorbent material,

ii. control means for controlling fluid flow including liquid fuel as well as vapor emission flow between said reservoir means, said cannister means and said mixing means as a function of selected operating parameters,

iii. said control means including at least first and second condition means for alternatively (i) initiating, during said cold start cycle, flow of said full-range fuel from said reservoir to said cannister means and hence over said adsorption bed so as to elute a cold start fuel effluent composed essentially of low molecular weight liquid constituents, said effluent being passed to said mixing means in sufficient amounts to assure starting of said engine, and (ii) permitting flow of evaporation vapors from said vapor zones of said fuel system to said same adsorption bed for capture thereon, at least during said inoperative state of said engine.

2. The improvement of claim **1** in which said first condition means is further characterized by first and second valve means operative after said engine has started and warmed, to place said reservoir of fuel-range fuel in direct liquid flow contact with said mixing means, at least one of said valve means being operative to cause depressurization of said cannister means so as to allow purging of adsorbents within said adsorbent bed of adsorbent material for ultimate consumption within said engine.

3. The improvement of claim **1** in which said adsorbent material is selected so as to provide dual functions of: (i) efficient retardation of high molecular weight constituents of said full-range fuel percolating therethrough whereby essentially only low molecular weight constituents are eluted from said cannister means during cold starting of said engine, and (ii) effective capture of evaporative emissions originating from said vapor zones of said fuel system during said inoperative state of said engine.

4. Apparatus for reducing exhaust and inoperative pollutants produced by a spark-ignition internal combustion engine of the type including an air intake system, a fuel intake system, and a mixing means interconnected therebetween for mixing fuel with air to form a combustible mixture for delivery to combustion chambers of said engine, comprising:

i. a cannister assembly containing an adsorbent bed of adsorbent material (a) capable of selectively adsorbing high molecular weight constituents of a full-range fuel at cold start while eluting substantially unimpeded a cold start fuel effluent composed essentially of only low molecular weight constituents as well as (b) capable of selectively absorbing vapor constituents of said full-range fuel during at least an inoperative state of said engine,

ii. valve and conduit network means attached between said cannister assembly a reservoir means of said fuel, and said mixing means for providing selective flow of said cold start fuel effluent between said cannister assembly, said reservoir means and said mixing means, said network means including a plurality of conduit and valve means including a multiplicity of valve means controlling flow relative to said cannister assembly so as to allow, (a) in a first operating state, flow of said full-range fuel from said reservoir means over said adsorbent bed so as to elute said cold start fuel effluent therefrom, and to pass said effluent thereafter to said mixing means to provide for rapid starting of said engine without producing excessive exhaust pollutants and, (b) in a second operating state, flow of full-range fuel directly from said reservoir means to said mixing means bypassing said adsorbent bed after said engine is in a normal running condition while simultaneously allowing for depressurization of said adsorbent bed,

iii. said plurality of conduit and valve means also including a separate valve means operatively connected between said adsorbent bed and vapor zones of said fuel reservoir means and said mixing means for selectively conveying vapor evaporative emissions originating therein to said same adsorbent bed when said engine is in said inoperative state,

iv. control means operatively connected to said valve means of said valve and conduit network for changing operation states so as to direct fuel flow relative to said adsorbent bed, said reservoir and mixing means as a function of one or more engine operating parameters.

5. Apparatus of claim **4** in which said cannister assembly includes an enlarged cylindrical shell housing terminating in first and second end pole pieces and including a plurality of radically extending couplings extending through said housing, said plurality of couplings being connected to said reservoir means, said mixing means, and said adsorbent bed, through said valve means, whereby (i) in a first state, to allow the selective delivery of fuel to said fuel well of said mixing means as a function of a selected engine parameter, and (ii) in a second state, to allow selective vapor contact therebetween whereby evaporative emissions from said reservoir means and said mixing means can be adsorbed within said same adsorbent bed and thereby not escape into said surrounding atmosphere.

6. Apparatus of claim **4** in which said cannister assembly includes a multiplicity of tubular conduits each arranged parallel to each other within a single tubular shell housing, each conduit supporting a segment of said bed of adsorbent material but all terminating at central inlet and outlet chambers in operative contact with said valve means so as to provide said dual functions of: (i) cold start elution of low molecular weight cold start constituents and (ii) capture of evaporative emissions originating from said fuel system along sinusoidal paths within said single enlarged housing.

7. Apparatus of claim **6** in which said pole pieces are perforated, one thereof being connected by air intake control means including conduit means to a source of heated gas, so as to allow selective flow of said heated gas through said cannister assembly for purging said adsorbent bed with adsorbed cold start constituents, and evaporative emissions, said purged constituents from said adsorbent bed being carried into and consumed within said combustion chambers of said engine during normal running operation thereof.

8. Process for reducing formation of exhaust pollutants during a cold start cycle of a spark-ignition internal combustion engine the type having an air intake system, a fuel system, including a reservoir means containing a full-range fuel and a mixing means interposed therebetween without affecting full-range engine performance of said engine after cold starting has been concluded, while simultaneously providing for effective capture of evaporative emissions originating from vapor zones of said fuel system at least during an inoperative state of said engine, comprising the steps of:

i. during said cold start cycle, dynamically eluting from said full-range fuel passing through an adsorbent bed of adsorbent material, a cold start fuel effluent composed essentially of low molecular weight constituents,

ii. mixing said low molecular weight effluent with air to form an enriched fuel air mixture for delivery to combustion chambers of said engine during said cold start cycle where consumption without undue formation of exhaust pollutants occurs,

iii. terminating elution of said cold start fuel effluent after said engine has started,

iv. switching flow of said full-range fuel directly to said mixing means by bypassing liquid fuel flow with respect to said adsorbent bed,

v. purging with heated fluid said adsorbent bed of adsorbates,

vi. conveying said purged constituents into said combustion chambers of said engine, and

vii. after said engine has been placed in an inoperative state, opening vapor conduit means between said same adsorbent bed, said mixing means and said reservoir means whereby vapor emissions originating from within said fuel system are captured within said same adsorbent bed and hereby prevented from escaping into the atmosphere surrounding said engine.

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