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(54) **COMBUSTION APPARATUS WITH FUEL PRE-HEATING**

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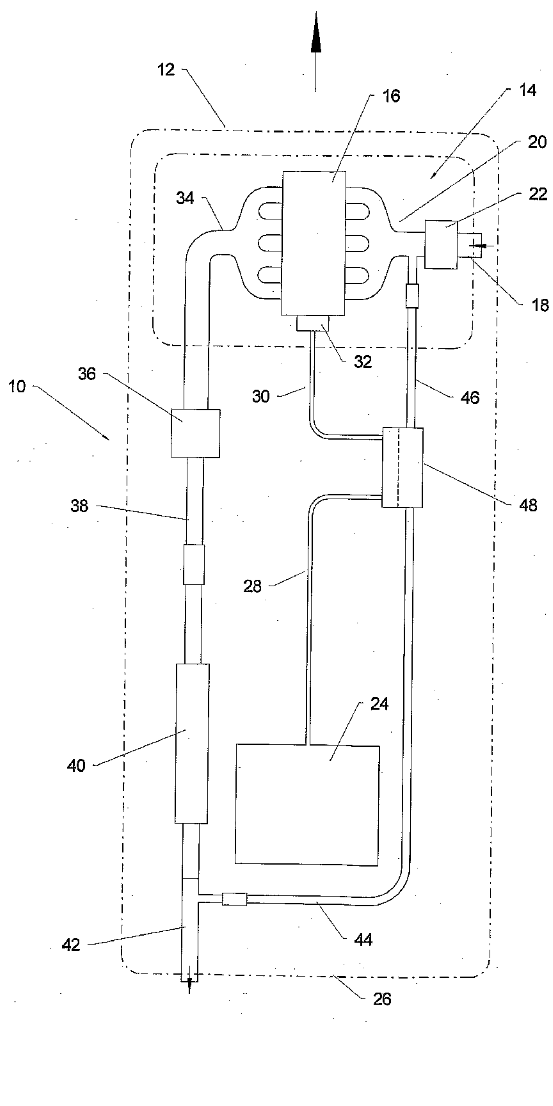
(57) **ABSTRACT**

A combustion apparatus such as a Diesel engine (**16**) in a motor vehicle (**1**) has an air inlet system (**20**,**22**) through which air can be drawn air from the atmosphere to the engine, a fuel supply system (**28**, **30**, **32**) for supplying fuel to the engine, and an exhaust system (**34**, **36**, **38**, **40**, **42**) for exhausting combustion gas from the engine to the atmosphere. A heat exchanger (**48**) is provided between the exhaust system and the fuel supply system so that heat is transferred from the exhaust gas to the fuel so as to warm the fuel and thus improve the combustion efficiency of the engine. When applied to a conventional layout of motor vehicle the heat exchanger can conveniently be disposed beneath the vehicle away from the engine compartment so as not to cause overcrowding thereof. The heat exchanger may form part of an EGR system (**44**,**46**) for feeding a proportion of the exhaust gas from the exhaust system to the air inlet system so as to cool the recirculating exhaust gas and thus enhance the reduction of NO and NO_2 emissions.



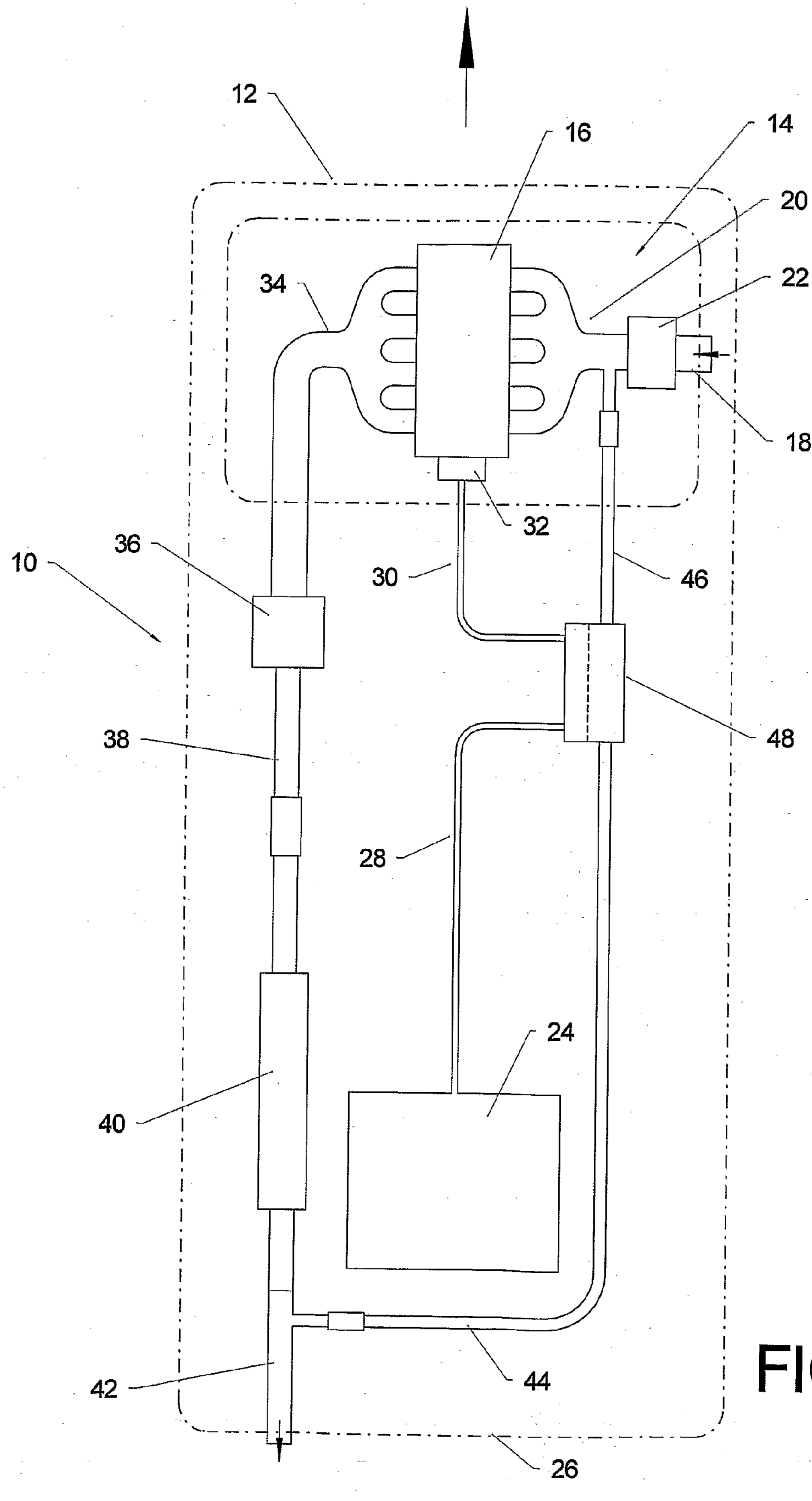


FIG. 1

FIG. 2

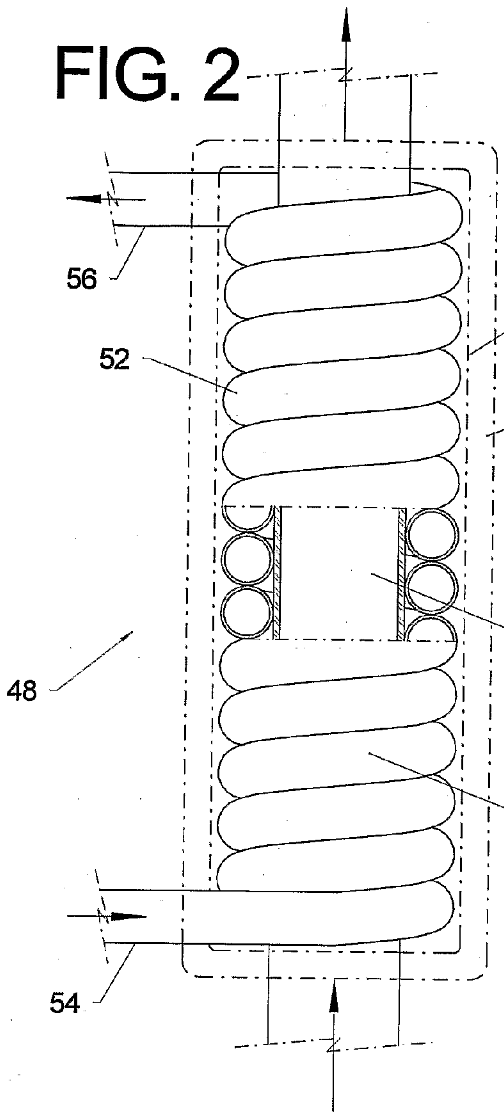
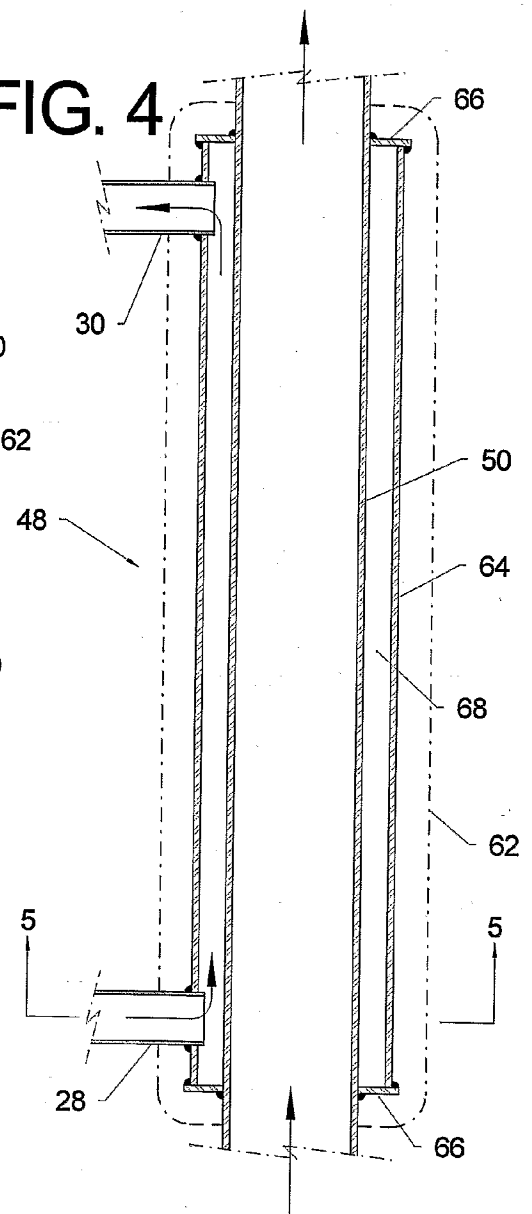


FIG. 4



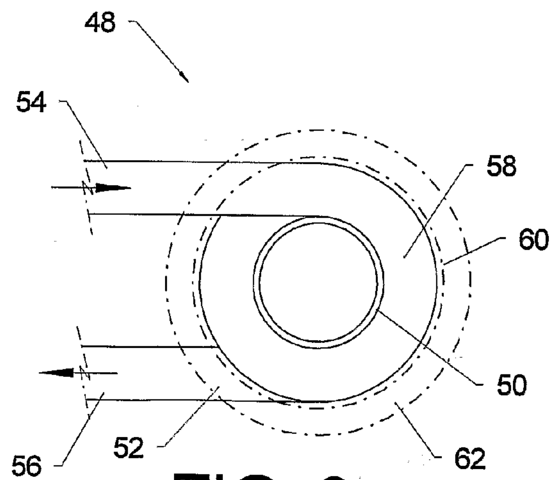


FIG. 3

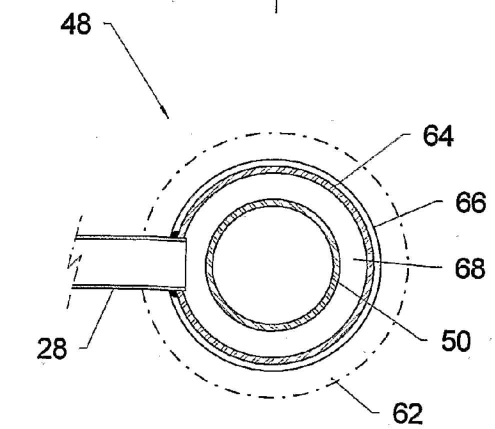


FIG. 5

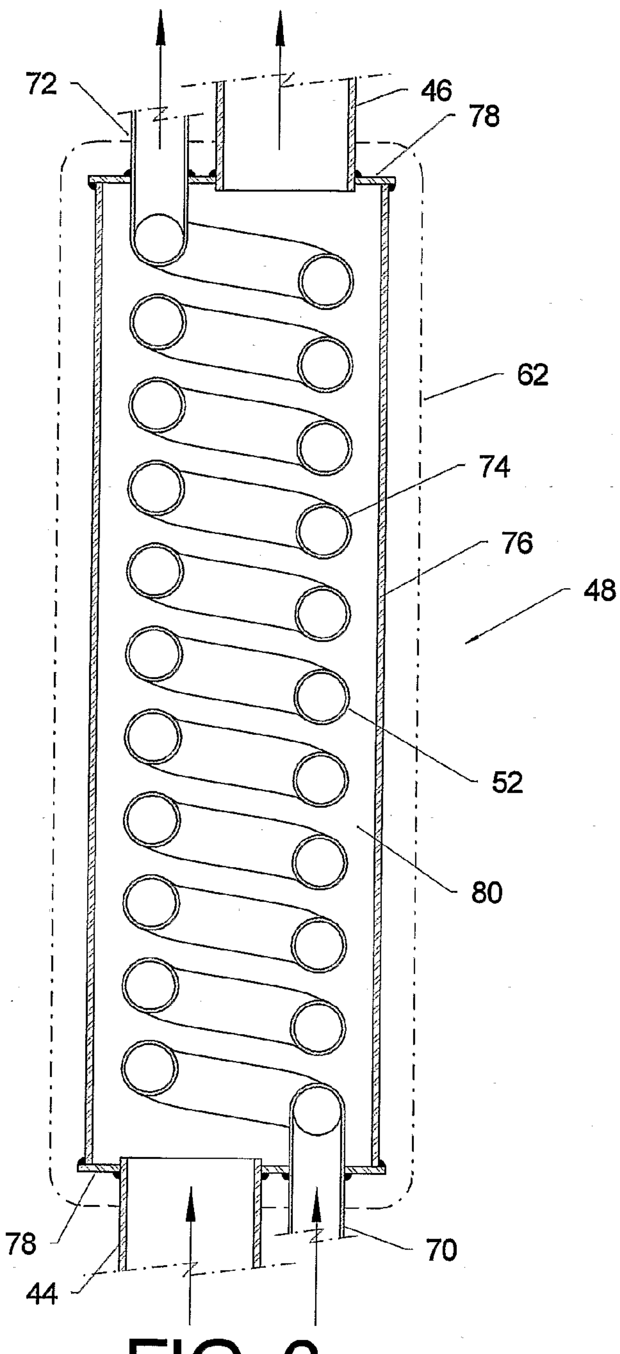


FIG. 6

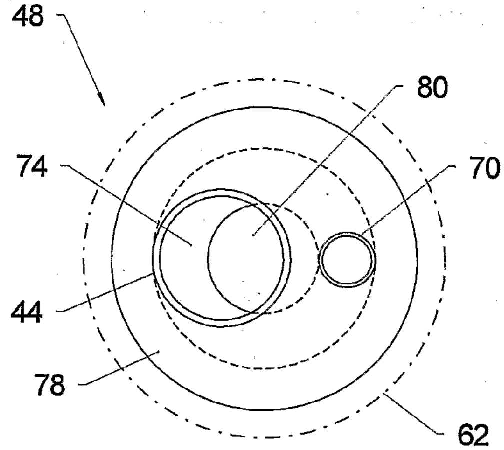


FIG. 7

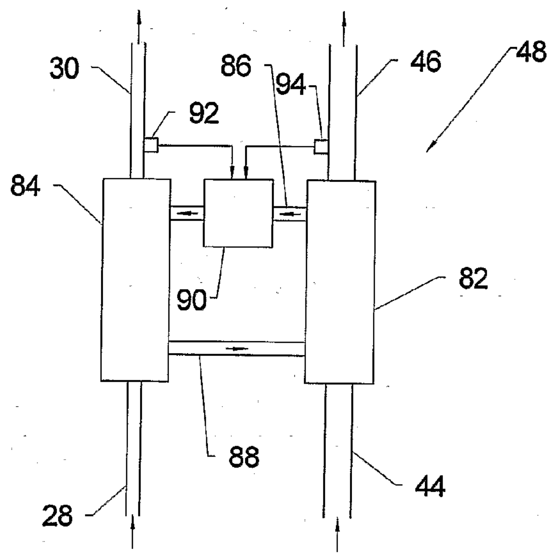

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FIG. 8

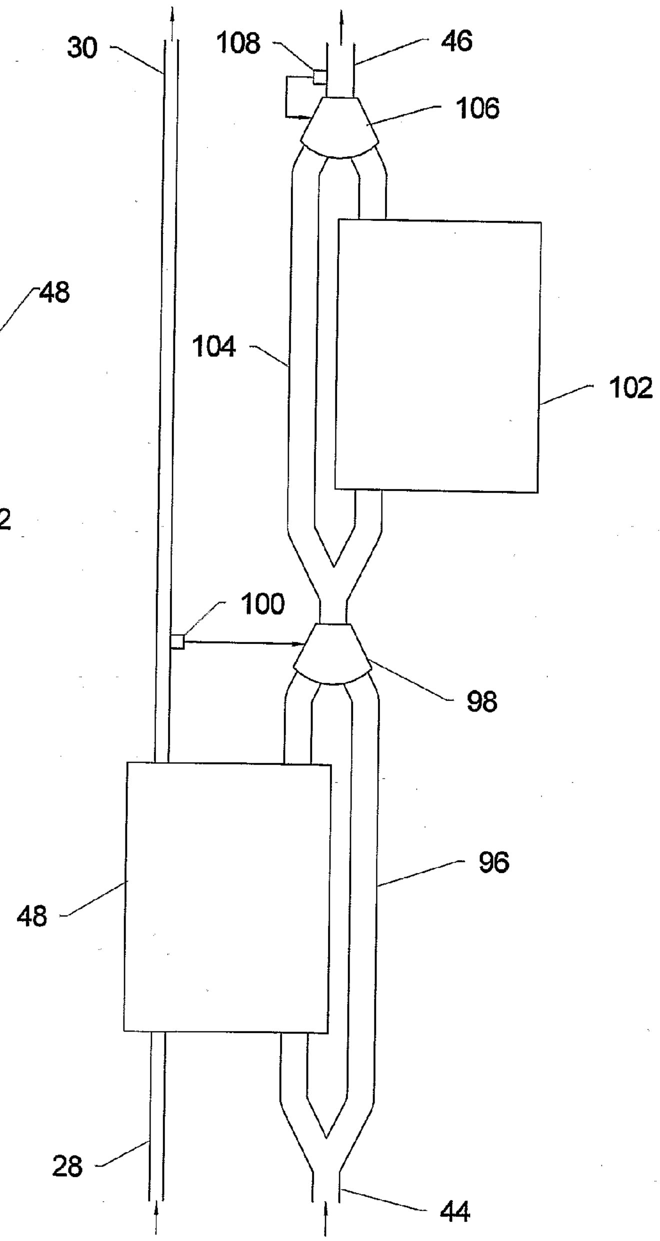
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FIG. 9

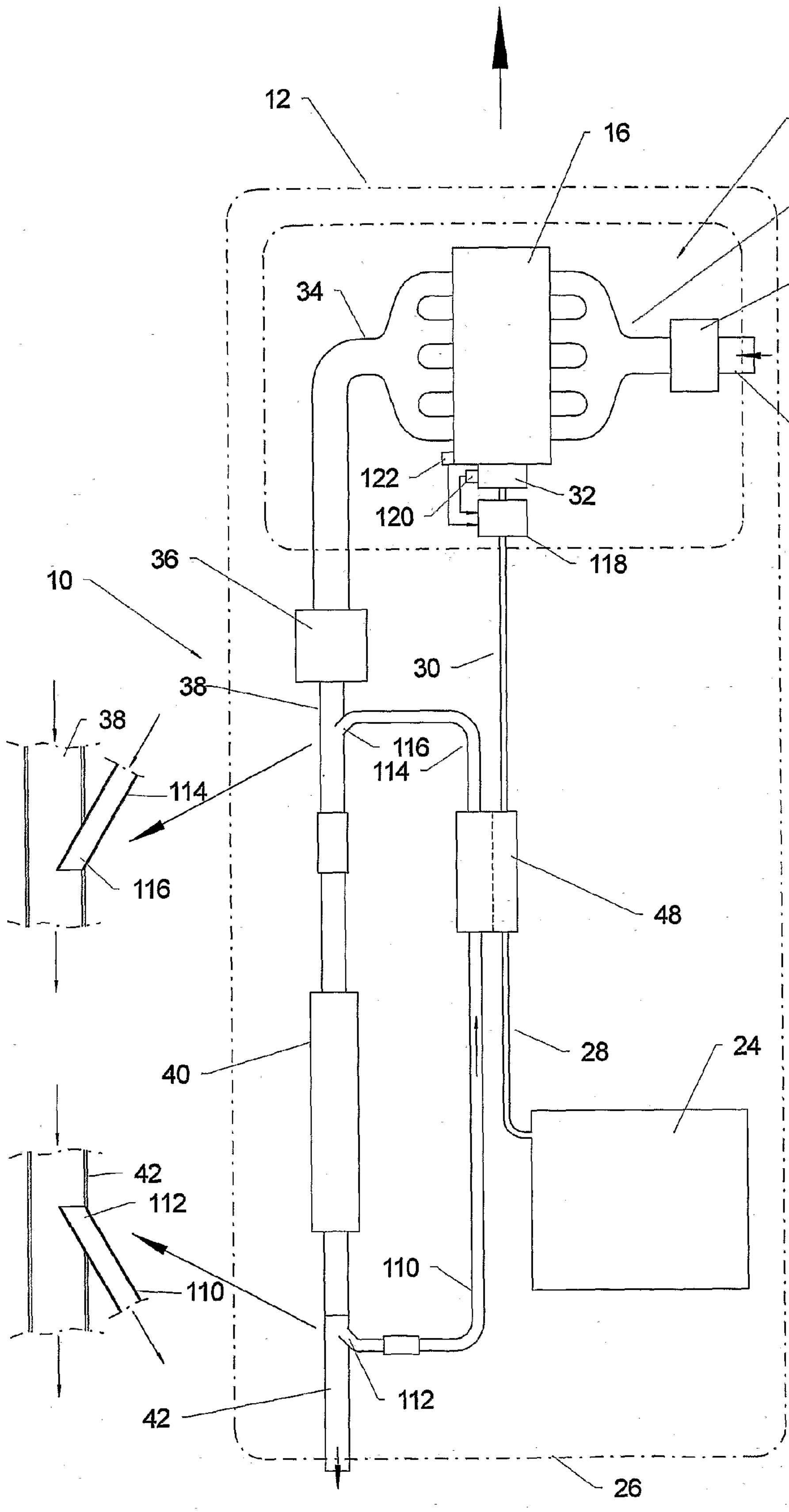
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FIG. 10

COMBUSTION APPARATUS WITH FUEL PRE-HEATING

[0001] This invention relates to a combustion apparatus with fuel pre-heating. The invention was originally conceived in connection with diesel-engines for motor vehicles, but it also has other applications, such as in connection with stationery engines, marine engines and engines for other purposes, engines that burn other fuel oils, and boilers.

[0002] Nearly every conventional diesel engine has an air inlet system through which air is drawn from the atmosphere into the engine, a fuel supply system for supplying fuel from a fuel tank to the engine and an exhaust system for exhausting combustion gas from the engine to the atmosphere.

[0003] In the art of diesel engine combustion efficiency, it is known that the combustion efficiency, and therefore fuel economy, of a diesel engine can be improved if the fuel is warmed before it is injected into the engine. In order to achieve this, it is known to provide a heat exchanger between the fuel supply system and the engine's coolant system. However, the engine compartments of most designs of motor vehicle are already overcrowded, and the addition of such a heat exchanger, between the fuel supply system and the cooling system, adds to the overcrowding in the engine compartment and consequent difficulty in servicing the vehicle.

[0004] A primary aim of the present invention, or at least of specific embodiments of it, to provide a combustion apparatus with improved efficiency that alleviates the problem discussed above.

[0005] In accordance with a first aspect of the present invention, there is provided a combustion apparatus comprising a combustor having an air inlet system through which air can be drawn air from the atmosphere to the combustor, a fuel supply system for supplying fuel to the combustor, and an exhaust system for exhausting combustion gas from the combustor to the atmosphere, wherein a heat exchanger is provided between the exhaust system and the fuel supply system so that, in use, heat is transferred from the exhaust gas to the fuel so as to warm the fuel and thus improve the combustion efficiency of the engine. When applied to a conventional layout of motor vehicle with a fuel tank disposed towards the rear of the vehicle, with the engine disposed in an engine compartment towards the front of the vehicle, and with the exhaust system leading from the engine towards the rear of the vehicle, the heat exchanger can therefore conveniently be disposed beneath the vehicle away from the engine compartment so as not to cause overcrowding of the engine compartment.

[0006] In one arrangement of the first aspect of the invention, the exhaust system includes a loop portion for feeding a proportion of the exhaust gas from a first point in the exhaust system to a second point in the exhaust system upstream of the first point relative to the main flow of exhaust gas in the exhaust system, and the heat exchanger is provided between the loop portion and the fuel supply system so that, in use, heat is transferred from the exhaust gas in the loop portion to the fuel so as to warm the fuel.

[0007] Turning to a previously unrelated topic, in the art of diesel engine emissions, it is known that the emissions (particularly of nitrogen oxide and nitrogen dioxide) of a diesel engine can be reduced if some of the exhaust gas is cooled and recirculated through the engine. It is therefore known to provide an exhaust gas recirculation system for feeding a proportion of the exhaust gas from the exhaust system to the air inlet system.

[0008] In one relatively simple example of exhaust gas recirculation, gas to be recirculated is branched from the exhaust system near its open end, passed through a cooling pipe and then fed into the intake system immediately before the engine's inlet manifold. Air is drawn along the cooling pipe on the outside of the pipe by a venturi fitted near the open end of the exhaust system, and so heat is transferred to the air from the exhaust gas that is drawn through the pipe to cool the recirculating exhaust gas. The heat that is extracted from the recirculating exhaust gas is therefore completely wasted.

[0009] In another more complex example of exhaust gas recirculation, gas to be recirculated is branched from the exhaust system immediately after the engine's exhaust manifold and passed through an intercooler and control valve before being fed into the intake system immediately before the engine's inlet manifold. The valve is controlled by an electronic box of tricks that receives signals from various sensors around the engine. In the intercooler, heat is transferred from the recirculating exhaust gas to the coolant of the engine's cooling system which, although well above ambient temperature, is well below the temperature of the recirculating exhaust gas. Again, the heat that is extracted from the recirculating exhaust gas is completely wasted. Furthermore, the addition of an intercooler between the exhaust gas recirculation system and the cooling system adds to the overcrowding of the engine compartment and consequent difficulty in servicing the vehicle. Moreover, the size and/or efficiency of the cooling system may need to be increased to cope with the additional demand placed on it by the intercooler.

[0010] A subsidiary aim at least of specific embodiments of the present invention is to provide a combustion apparatus not only with improved efficiency but also with improved emissions and that alleviates at least some of the problems discussed above.

[0011] In another arrangement of the first aspect of the invention, the exhaust system includes an exhaust gas recirculation system for feeding a proportion of the exhaust gas to the air inlet system, and the heat exchanger is provided between the exhaust gas recirculation system and the fuel supply system so that, in use, heat is transferred from the recirculating exhaust gas to the fuel so as to cool the recirculating exhaust gas and warm the fuel. A single heat exchanger can therefore be used for the purposes of both improving emissions and improving fuel efficiency.

[0012] In one embodiment in which the exhaust system includes an exhaust return pipe and the fuel supply system includes a fuel feed pipe, a portion of the fuel feed pipe may simply be coiled around a portion of the exhaust return pipe so as to form the heat exchanger.

[0013] In another embodiment in which the exhaust system includes an exhaust return pipe, the fuel supply system may simply include a sleeve disposed around a portion of the exhaust return pipe so that, in use, fuel passes between the sleeve and the portion of the exhaust return pipe and heat is exchanged.

[0014] In the case where the exhaust system includes a catalytic converter, the exhaust return pipe preferably branches from the exhaust system downstream of the catalytic converter. In the case where the exhaust system includes a silencer, the exhaust return pipe preferably branches from the exhaust system downstream of the silencer. The exhaust gas is therefore subjected to cooling in the catalytic converter and/or the silencer before a proportion of the exhaust gas is recirculated. In the case where the exhaust system has a loop portion as discussed above, the exhaust return pipe preferably rejoins the exhaust system upstream of the silencer.

[0015] The heat exchanger may employ a heat exchange fluid that, in use, flows between a portion of the exhaust system and a portion of the fuel supply system. In this case, means may be provided for controlling the flow of the heat exchange fluid in dependence upon the temperature of the fuel and/or the temperature of the exhaust gas.

[0016] A gas bypass system may be provided for controlling the proportion of the exhaust gas that passes through the heat exchanger. The bypass system may be arranged to control the proportion in dependence upon the temperature of the fuel and/or the temperature of the exhaust gas.

[0017] The control of the heat exchange fluid flow and/or of the proportion of exhaust gas and/or fuel that passes through the heat exchanger can be used to ensure that appropriate cooling of the recirculating exhaust gas and warming of the fuel is achieved but without overheating of the fuel.

[0018] The combustion apparatus may further include means for conditioning liquid fuel in the fuel supply system between the heat exchanger and the combustor. Ultrasonic conditioning is known per se from patent documents U.S. Pat. No. 3,865,350 and DE10250483A1 so as to break down long chain molecules in and homogenise the liquid fuel and thus improve the fuel efficiency and/or reduce the emissions of the combustion apparatus. However, by ultrasonically conditioning the liquid fuel after it has been heated, it is believed that a synergistic effect is achieved. As an alternative to, or addition to, ultrasonically conditioning the fuel, it may also be conditioned by microwave energy, by other electromagnetic radiation, or by electromagnets.

[0019] This combination of heating and conditioning of the fuel may be used in combustion apparatus where the fuel is heated other than by the exhaust system. Therefore, in accordance with a second aspect of the invention, there is provided a combustion apparatus having a system for supplying liquid fuel to the combustor, the fuel supply system including means for heating the liquid fuel, and means for conditioning the liquid fuel after it has been heated by the heating means.

[0020] Means may be provided for varying the ultrasonic, microwave, electromagnetic radiation or magnetic field that is applied to the liquid fuel. The field varying means may be manually adjustable, for example to take account of different fuels that may be used in the combustion apparatus, and/or automatically in response to sensors of the state of operation of the combustion apparatus, for example to take account of varying fuel flow rates.

[0021] The combustion apparatus may take the form of a diesel engine.

[0022] A third aspect of the invention relates to a motor vehicle having a diesel engine system and a fuel tank, the fuel tank being disposed towards the rear of the vehicle, the engine being disposed in an engine compartment towards the front of the vehicle, and the exhaust system leading from the engine towards the rear of the vehicle. This is a conventional layout for a motor vehicle.

[0023] In accordance with the third aspect of the invention, the engine is in accordance with the first aspect of the invention, and the heat exchanger is disposed beneath the vehicle away from the engine compartment. This therefore makes use of the conventional vehicle layout, and the heat exchanger does not cause any overcrowding of the engine compartment.

[0024] In accordance with a fourth aspect of the present invention, there is provided an exhaust and fuel supply component or assembly for a combustion apparatus of the first aspect of the invention or for a motor vehicle of the third aspect of the invention, the component or assembly comprising a heat exchanger that is adapted to provide, or to form part of, the exhaust system and that is adapted to provide, or to form part of, the fuel supply system.

[0025] Specific embodiments of the present invention will now be described, purely by way of example, with reference to the accompanying drawings, in which:

[0026] FIG. **1** is a schematic plan view of a motor car with one version of the invention;

[0027] FIG. **2** is a plan view, partially sectioned, of a first form of heat exchanger that may be used in the motor car;

[0028] FIG. **3** is an end view of the heat exchanger of FIG. **2**;

[0029] FIG. **4** is a sectioned plan view of a second form of heat exchanger that may be used in the motor car;

[0030] FIG. **5** is an end view of the heat exchanger of FIG. **4**, section along the section plane **5-5** shown in FIG. **4**;

[0031] FIG. **6** is a sectioned plan view of a third form of heat exchanger that may be used in the motor car;

[0032] FIG. **7** is an end view of the heat exchanger of FIG. **6**;

[0033] FIG. **8** is a schematic plan view of a fourth form of heat exchanger that may be used in the motor car;

[0034] FIG. **9** is a schematic plan view to illustrate a modification that may be made to the heat exchangers of FIGS. **2** to **8**; and

[0035] FIG. **10** is a schematic plan view of a motor car with another version of the invention.

[0036] Referring to FIG. **1**, a first arrangement of motor car indicated generally by the dot-dash line **10** has, at the front **12** of the car **10**, an engine compartment indicated generally by the dot-dash line **14** containing a diesel engine **16**. Air enters the engine **16** via an air intake **18** and inlet manifold **20**. The air may be filtered and its temperature and flow rate may be sensed by sensors, all as represented by the box **22**. The car **10** has a fuel tank **24** disposed near the rear **26** of the car **10**, and diesel fuel is drawn through a fuel pipe **28**,**30** to an engine-driven injector pump **32**, from which fuel is injected into the engine **10** and combusts with the air. Exhaust gases from the engine **16** are exhausted via an exhaust manifold **34**, catalytic converter **36**, intermediate pipe **38**, silencer **40** and tailpipe **42** to the atmosphere.

[0037] The car **10** has an exhaust gas recirculation (EGR) system provided by a pipe **44**,**46** which is branched from the tailpipe **42** at the rear **26** of the car **10**, extends forwardly beneath the car and is branched into the inlet manifold **20** of the engine **16**. In use, the pressure differential of the exhaust gas in the tailpipe **42** above the air in the inlet manifold **20** causes some of the exhaust gas to flow from the tailpipe **42** along the EGR pipe **44**,**46** to the inlet manifold **20** and re-enter the engine **16**.

[0038] The EGR system causes the NO and NO_2 emissions of the engine **16** to be reduced, and the reduction is enhanced if recirculating exhaust gas is cooled between the tailpipe **42** and the inlet manifold **20**. Also, the combustion efficiency of the engine **16** is increased if fuel is warmed before it is injected into the engine **16**. In order to provide cooling of the recirculating exhaust gas and warming of the fuel, a heat exchanger **48** is fitted beneath the car away from the engine compartment. Fuel passes from the fuel pipe **28** through the heat exchanger **48** to the fuel pipe **30**, and recirculating exhaust gas passes from the EGR pipe **44** through the heat exchanger **48** to the EGR pipe **46**. During normal operating conditions of the engine **16**, the recirculating exhaust gas entering the heat exchanger **48** via the EGR pipe **44** is hotter than the fuel entering the heat exchanger **48** via the fuel pipe **28**. Heat is transferred in the heat exchanger **48** from the exhaust gas to the fuel. Accordingly, the fuel leaving the heat exchanger **48** in the fuel pipe **30** is warmer than the fuel entering the heat exchanger **48** in the fuel pipe **30**, and the exhaust gas leaving the heat exchanger **48** in the EGR pipe **46** is cooler than the exhaust gas entering the heat exchanger **48** in the fuel pipe **44**. The heat exchanger **48** therefore has the double effect of enhancing the reduction of NO and NO_2 emissions of the engine **16** and increasing the combustion efficiency of the engine **16**.

[0039] Any suitable form of heat exchanger **48** may be employed. For example, FIGS. **2** and **3** show a simple form of heat exchanger **48** in which the EGR pipes **44**,**46** are provided by a single tube **50** and the fuel pipes **28**,**30** are formed by a single tube **52**. The fuel tube **52** winds, between an inlet portion **54** and an outlet portion **56**, as a coil-bound helical portion **58** around and in contact with the EGR tube **50**. In order to increase the thermal conductivity between the helical portion **58** and the EGR tube **50**, the helical portion **58** may be encapsulated by a medium (indicated by dash-dot lines **60**), having a high thermal conductivity, that also fills the interstices between the helical portion **58** and the EGR tube **50**, and the encapsulating medium **60** may be covered by a material **62** having a low thermal conductivity and emissivity.

[0040] A second form of heat exchanger **48** is shown in FIGS. **4** and **5**. The EGR pipes **44**,**46** are provided by a single tube **50**. The tube **50** passes through a sleeve **64** having end caps **66** welded to the sleeve **64** and the tube **50**. The fuel pipe **28** passes through and is welded to the wall of the sleeve **64** adjacent one end of the sleeve **64**, and the fuel pipe **30** passes through and is welded to the wall of the sleeve **64** adjacent the other end of the sleeve **64**. The EGR gas therefore flows through the tube **50** and transfers heat through the wall of the tube **50** to the fuel flowing from the fuel pipe **28** to the fuel pipe **30** through the annular chamber **68** formed between the tube **50** and the sleeve **64**. The sleeve **64** may be covered by a material **62** having a low thermal conductivity and emissivity.

[0041] A third form of heat exchanger **48** is shown in FIGS. **6** and **7**. The fuel pipes **28**,**30** are provided by a single tube **52** that winds, between an inlet portion **70** and an outlet portion **72**, as a loosely-wound helical portion **74**. The helical portion **74** is contained in a sleeve **76** having end caps **78** through which the inlet and outlet portions **70**,**72** pass. The EGR pipes **44**,**46** also pass through the end caps **78**, which are welded to the sleeve **76**, the EGR pipes **44**,**46** and the fuel inlet and outlet portions **70**,**72**. The fuel therefore flows through the helical portion **74** and receives heat through the wall of the helical portion **74** from the EGR gas flowing from the EGR pipe **44** to the EGR pipe **46** through the chamber **80** formed between the helical portion **74** and the sleeve **76**. Again, the sleeve **76** may be covered by a material **62** having a low thermal conductivity and emissivity.

[0042] The various forms of heat exchanger **48** described with reference to FIGS. **2** to **7** may be designed by trial and error or by theoretical calculation so that they provide an appropriate amount of heat exchange from the EGR gas to the fuel under normal operating conditions and so that they do not result in overheating of the fuel, without there being any control over the amount of heat exchange. However, control may be provided, if desired, to enhance the effect of the heat exchanger **48** over a range of operating conditions of the engine.

[0043] For example, referring to FIG. **8**, the heat exchanger **48** may comprise a first section **82** in which heat is transferred from the EGR gas flowing in the EGR pipes **44**,**46** to a heat exchange fluid and a second section **84** in which heat is transferred from the heat exchange fluid to the fuel flowing in the fuel pipes **28**,**30**. The heat exchange fluid flows from the first section **82** to the second section **84** via a flow path **86** and returns via a return path **88**. One of the paths **86**,**88** includes a controllable valve **90** that is used to control the rate of flow of the heat exchange fluid, and therefore the rate of heat transfer between the first and second sections **82**,**84**. A sensor **92** is provided for sensing the temperature of the fuel leaving the second section **84** of the heat exchanger **48**, and the valve **90** is responsive to the sensor **92** so that the valve **90** begins to open when the temperature of the fuel entering the fuel pipe **30** increases above a predetermined temperature. The valve **90** and sensor **92** therefore act as a thermostat to maintain the fuel entering the fuel pipe **30** at a generally constant temperature. The valve **90** and sensor **92** may be provided by a thermo-mechanical device employing similar technology to that used for automotive cooling system thermostats, or electrical control may be employed. Additionally or alternatively, the valve **90** may be responsive to a sensor **94** that senses the temperature of the exhaust gas leaving the first section **82** of the heat exchanger **48**.

[0044] It will be appreciated that, in the arrangement shown in FIG. **8**, the position of the valve **90** affects both the heating of the fuel and the cooling of the recirculating exhaust gas. FIG. **9** shows an alternative arrangement in which the outlet temperatures of the fuel and the recirculating exhaust gas can, to some extent, be controlled independently. The inlet EGR pipe **44** branches between the EGR side of the heat exchanger **48** and a heat exchanger bypass pipe **96**. The heat exchanger bypass pipe **96** is recombined with the outlet from the EGR side of the heat exchanger **48** by a controllable two-way valve **98** which is responsive to a temperature sensor **100** on the fuel pipe **30** immediately after the fuel side of the heat exchanger **48**. The outlet of the valve **98** is branched between an air-cooled radiator or cooler **102** and a radiator bypass pipe **104**. The radiator bypass pipe **104** is recombined with the outlet of the radiator **102** by a further controllable two-way valve **106**. The outlet of the valve **106** feeds the EGR pipe **46**, and the valve **106** is responsive to a temperature sensor on the EGR pipe **46** immediately after the valve **106**. The valves **98**,**106** and sensors **100**,**108** may be provided by a thermo-mechanical devices employing similar technology to that used for automotive cooling system thermostats, or electrical control may be employed. The valve **98** and sensor **100** serve to control the proportions of exhaust gas that pass through the heat exchanger **48** and its bypass pipe **96** so that, insofar as is possible, the fuel is heated to a generally constant temperature. The valve **106** and sensor **108** serve to control the proportions of exhaust gas that pass through the radiator **102** and its bypass pipe **104** so that, insofar as is possible, the recirculating exhaust gas is cooled to a generally constant temperature.

[0045] Referring to FIG. **10**, a second arrangement of motor car **10** is generally similar to that described with reference to FIG. **1**, except that it does not have an EGR system that loops from the exhaust system back to the air inlet system. Instead, the exhaust system has a loop portion which branches from the exhaust tail-pipe **42** at a joint **112** into a pipe **110** leading to the exhaust-side of the heat-exchanger **48**, and from the exhaust-side of the heat-exchanger **48** a pipe **114** connects to a joint **116** in the intermediate pipe **38**. The joints **112**,**116** are arranged so that a proportion of the exhaust flowing through the tail-pipe **42** is diverted into the pipe **110**, through the heat exchanger **48** and pipe **114**, and re-joins the intermediate pipe **38** at the joint **116**, upstream of the joint **112**.

[0046] The forms of heat exchanger **48** and control described above with reference to FIGS. **2** to **9** may be applied not only to the arrangement of FIG. **1**, but also to the arrangement of FIG. **10**.

[0047] In FIG. **10**, an ultrasonic conditioning unit **118** is provided in the fuel pipe **30** between the heat exchanger **48** and the injector pump **32**. The unit **118** may, for example, be of the type described in patent document U.S. Pat. No. 3,865,350 or DE10250483A1. By acting on the liquid fuel in the pipe **30** after it has been heated by the heat exchanger **48**, a synergistic effect is achieved with regard to the homogenisation and breaking down of the molecular structure of the fuel so as to improve further the fuel efficiency and/or reduce further the emissions of the engine **16**. The ultrasonic conditioning unit **118** may be responsive to sensors **120**,**122** of, for example, the fuel flow rate, fuel temperature and engine temperature to vary the ultrasonic field that is produced in dependence upon those parameters to as to maximise the benefit provided by the fuel conditioning units **118**.

[0048] In addition to, or instead of conditioning the fuel ultrasonically, the unit **118** may be operable to condition the fuel using microwave or other electromagnetic radiation and/or a magnetic field produced by an electromagnet, again with the electromagnetic or magnetic field varied in dependence upon the various parameters.

[0049] It should be noted that the embodiments of the invention have been described above purely by way of example and that many modifications and developments may be made thereto within the scope of the present invention.

1. A combustion apparatus comprising a combustor (**16**) having an air inlet system (**20**,**22**) through which air can be drawn a from the atmosphere to the combustor, a fuel supply system (**28**, **30**, **32**) for supplying fuel to the combustor, and an exhaust system (**34**, **36**, **38**, **40**, **42**) for exhausting combustion gas from the combustor to the atmosphere, wherein a heat exchanger (**48**) is provided between the exhaust system and the fuel supply system so that, in use, heat is transferred from the exhaust gas to the fuel so as to cool the exhaust gas and warm the fuel.

2. An apparatus as claimed in claim **1**, wherein the exhaust system includes a loop portion (**110**,**114**) for feeding a proportion of the exhaust gas from a first point (**112**) in the exhaust system to a second point (**116**) in the exhaust system upstream of the first point relative to the main flow of exhaust has in the exhaust system, and the heat exchanger is provided between the loop portion and the fuel supply system so that, in use, heat is transferred from the exhaust gas in the loop portion to the fuel so as to warm the fuel.

3. An apparatus as claimed in claim **1**, wherein the exhaust system includes an exhaust gas recirculation system (**44**,**46**) for feeding a proportion of the exhaust gas to the air inlet system, and the heat exchanger is provided between the exhaust gas recirculation system and the fuel supply system so that, in use, heat is transferred from the recirculating exhaust gas to the fuel so as to cool the recirculating exhaust gas and warm the fuel.

4. An apparatus as claimed in claim **1**, wherein the exhaust system includes an exhaust return pipe (**44**,**46**; **110**,**114**) and the fuel supply system includes a fuel feed pipe (**28**,**30**), a portion (**58**) of the fuel feed pipe being coiled around a portion (**50**) of the exhaust return pipe so as to form the heat exchanger.

5. An apparatus as claimed in claim **1** wherein the exhaust system includes an exhaust return pipe (**44**,**46**; **110**,**114**) and the fuel supply system includes a sleeve (**64**) disposed around a portion (**50**) of the exhaust return pipe so that, in use, fuel passes between the sleeve and the portion of the exhaust return pipe and heat is exchanged.

6. An apparatus as claimed in claim **1**, wherein the exhaust system includes a catalytic converter (**36**) and is arranged such that the exhaust gas passes through the catalytic converter before passing through the heat exchanger.

7. An apparatus as claimed in claim **1**, wherein the exhaust system includes a silencer (**40**) and is arranged such that the exhaust gas passes through the silencer before passing through the heat exchanger.

8. An apparatus as claimed in claim **2**, wherein the wherein the exhaust system includes a silencer (**40**) disposed between said first and second points in the exhaust system and arranged such that the main flow of exhaust passes through the silencer.

9. An apparatus as claimed in claim **1**, wherein the heat exchanger employs a heat exchange fluid that, in use, flows between a portion (**82**) of the exhaust system and a portion (**84**) of the fuel supply system.

10. An apparatus as claimed in claim **9**, further including means (**90**,**92**) for controlling the flow of the heat exchange fluid in dependence upon the temperature of the fuel and/or the temperature of the exhaust gas.

11. An apparatus as claimed in claim **1**, further including a gas bypass (**96**,**98**) system for controlling the proportion of the exhaust gas that passes through the heat exchanger in dependence upon the temperature of the fuel and/or the temperature of the exhaust gas.

12. (canceled)

13. An apparatus as claimed in claim **1**, further including means (**118**) for conditioning liquid fuel in the fuel supply system between the heat exchanger and the combustor.

14. (canceled)

15. A combustion apparatus as claimed in claim **13**, wherein the conditioning means is operable to condition the fuel ultrasonically, using microwave energy, by other electromagnetic radiation and/or by electromagnets.

16. A combustion apparatus as claimed in claim **15**, further including means for varying the ultrasonic, microwave, electromagnetic radiation and/or magnetic field that is applied to the liquid fuel.

17. (canceled)

18. A combustion apparatus as claimed in claim **1**, wherein the combustor comprises a diesel engine (**16**).

19. A combustion apparatus as claimed in claim **1** fitted to a motor vehicle (**10**), the motor vehicle having a fuel tank (**24**) disposed towards the rear (**26**) of the vehicle and an engine compartment (**14**) disposed towards the front (**12**) of the vehicle, the combustor being disposed in the engine compartment, the exhaust system (**34**, **36**, **38**, **40**, **42**) leading from the engine towards the rear of the vehicle, and the heat exchanger (**48**) being disposed beneath the vehicle away from the engine compartment.

20-22. (canceled)

23. A combustion apparatus as claimed in claim **1**, wherein the heat exchanger is remote from the combustor.

24. A combustion apparatus as claimed in claim **1**, wherein the heat exchanger is arranged to transfer heat from the exhaust system to the fuel supply system independently of any cooling system of the combustor.

25. An engine system comprising:

an engine (**16**) having an air inlet system (**20**,**22**) through which air can be drawn from the atmosphere into the engine;

a fuel supply system (**28**, **30**, **32**) for supplying fuel to the engine; and

an exhaust system (**34**, **36**, **38**, **40**, **42**) for exhausting combustion gas from the engine to the atmosphere,

wherein:

the exhaust system includes an exhaust gas recirculation system (**44**,**46**) for feeding a proportion of the exhaust gas to the air inlet system; and

a heat exchanger (**48**) is provided between the exhaust gas recirculation system and the fuel supply system so that, in use, heat is transferred from the recirculating exhaust gas to the fuel so as to cool the recirculating exhaust gas and warm the fuel.

26. A motor vehicle (**10**) having:

an engine compartment (**14**) disposed towards the front (**12**) of the vehicle;

an engine (**16**) disposed in the engine compartment;

a fuel tank (**24**) disposed towards the rear (**26**) of the vehicle;

a fuel supply system (**28**, **30**, **32**) for supplying fuel from the fuel tank to the engine;

an air inlet system (**20**,**22**) through which air can be drawn from the atmosphere into the engine; and

an exhaust system (**34**, **36**, **38**, **40**, **42**) for exhausting combustion gas from the engine to the atmosphere,

wherein:

the exhaust system includes an exhaust gas recirculation system (**44**,**46**) for feeding a proportion of the exhaust gas to the air inlet system;

a heat exchanger (**48**) is provided between the exhaust gas recirculation system and the fuel supply system so that, in use, heat is transferred from the recirculating exhaust gas to the fuel so as to cool the recirculating exhaust gas and warm the fuel; and

the heat exchanger (**48**) is disposed beneath the vehicle away from the engine compartment.

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