(12) UK Patent Application (19) GB (11) 2485927 (13) A

(43) Date of A Publication 30.05.2012

(21) Application No: 1203034.2

(22) Date of Filing: 29.10.2010

Date Lodged: 22.02.2012

(62) Divided from Application No
**1018319.2** under section 15(9) of the Patents Act 1977

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(51) INT CL:
***F24D 3/08*** (2006.01) ***F23J 11/00*** (2006.01)
***F24D 17/00*** (2006.01)

(56) Documents Cited:
**GB 2387641 A**
**EP 1191659 A2**
**EP 0952406 A2**
**WO 2008/001107 A1**
**WO 2004/101982 A1**
**WO 2004/015261 A1**
**DE 029605834 U**
**JP 020301651 A**
**JP 2007002688 A**
**JP 2000297963 A**
**US 20060213196 A1**

(58) Field of Search:
INT CL **F01B, F01K, F02C, F02G, F24D**
Other: **Online: EPODOC, WPI**

(54) Title of the Invention: **Micro combined heat and power unit**
Abstract Title: **Micro combined heat and power unit having multiple heat exchangers**

(57) Disclosed is a micro combined heat and power (mCHP) generation system 1 comprising a burner 4 and an internal combustion engine (ICE) 2 used to power a generator 3. The mCHP has a first heat exchanger, which may be in the form of a water conduit 11 passing through an oil sump 22, to exchange heat between the ICE and/or generator and a working fluid and a second heat exchanger 14 to exchange heat between the burner exhaust system and the working fluid. A heat exchanger is also provided to transfer heat from the engine exhaust system to the working fluid. The working fluid may be water in a central heating system 7.

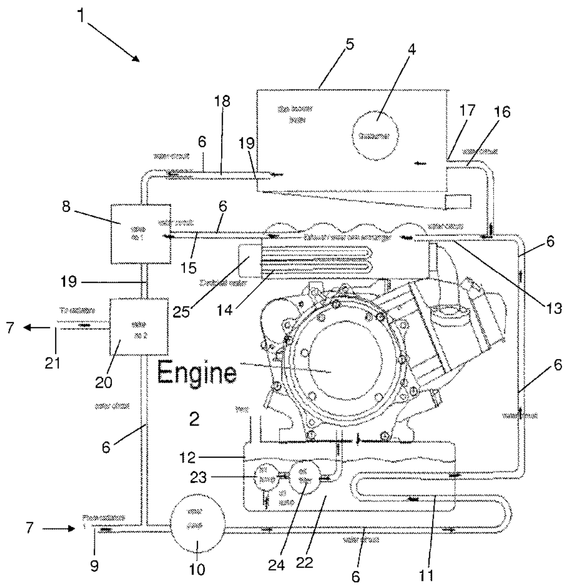


Figure 1

GB 2485927 A

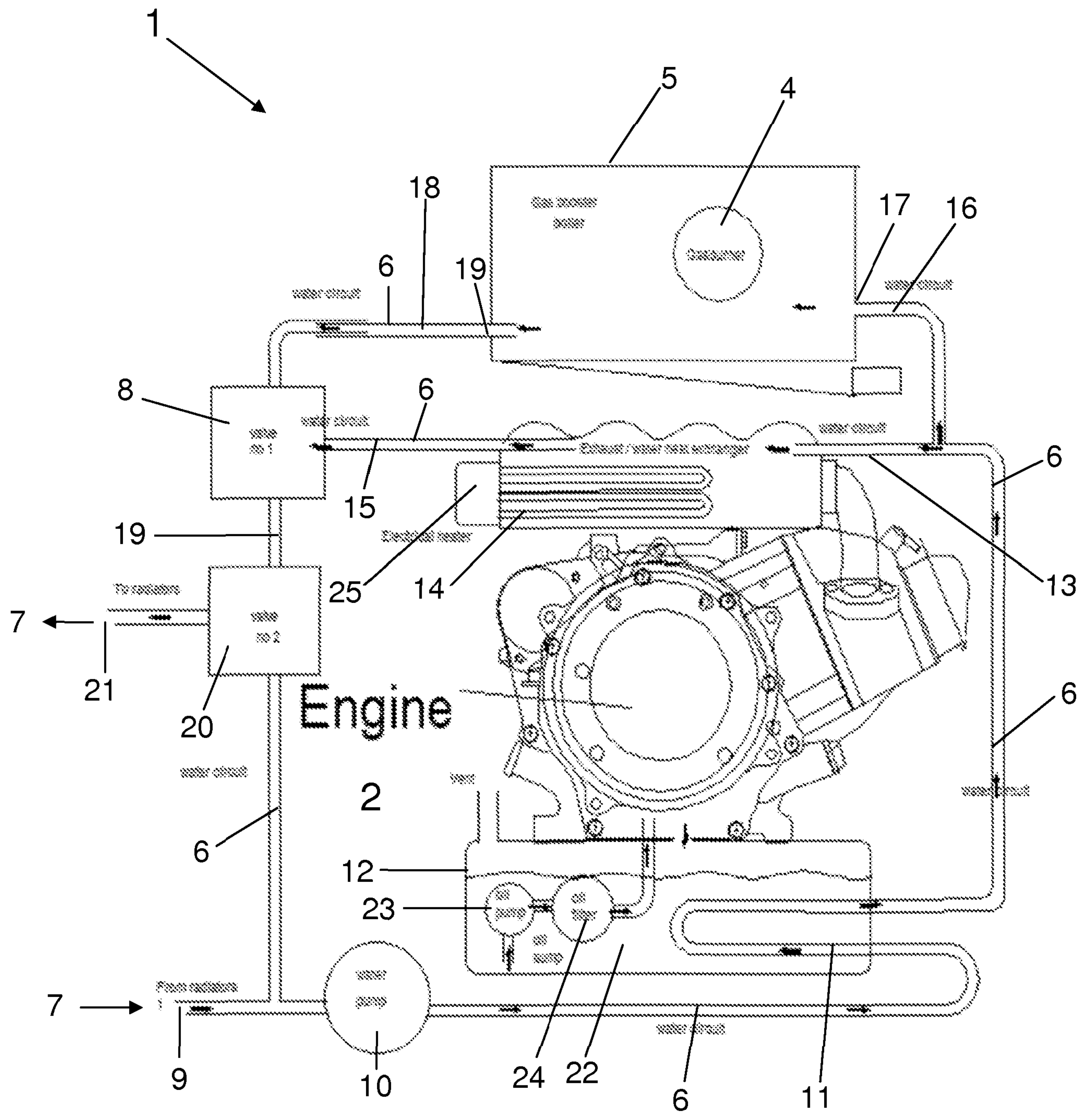
1
5
4
18
6
19
17
16
8
6
15
6
19
25
14
13
7
21
20
Engine
2
6
12
23
7
9
10
24
22
6
11

Figure 1

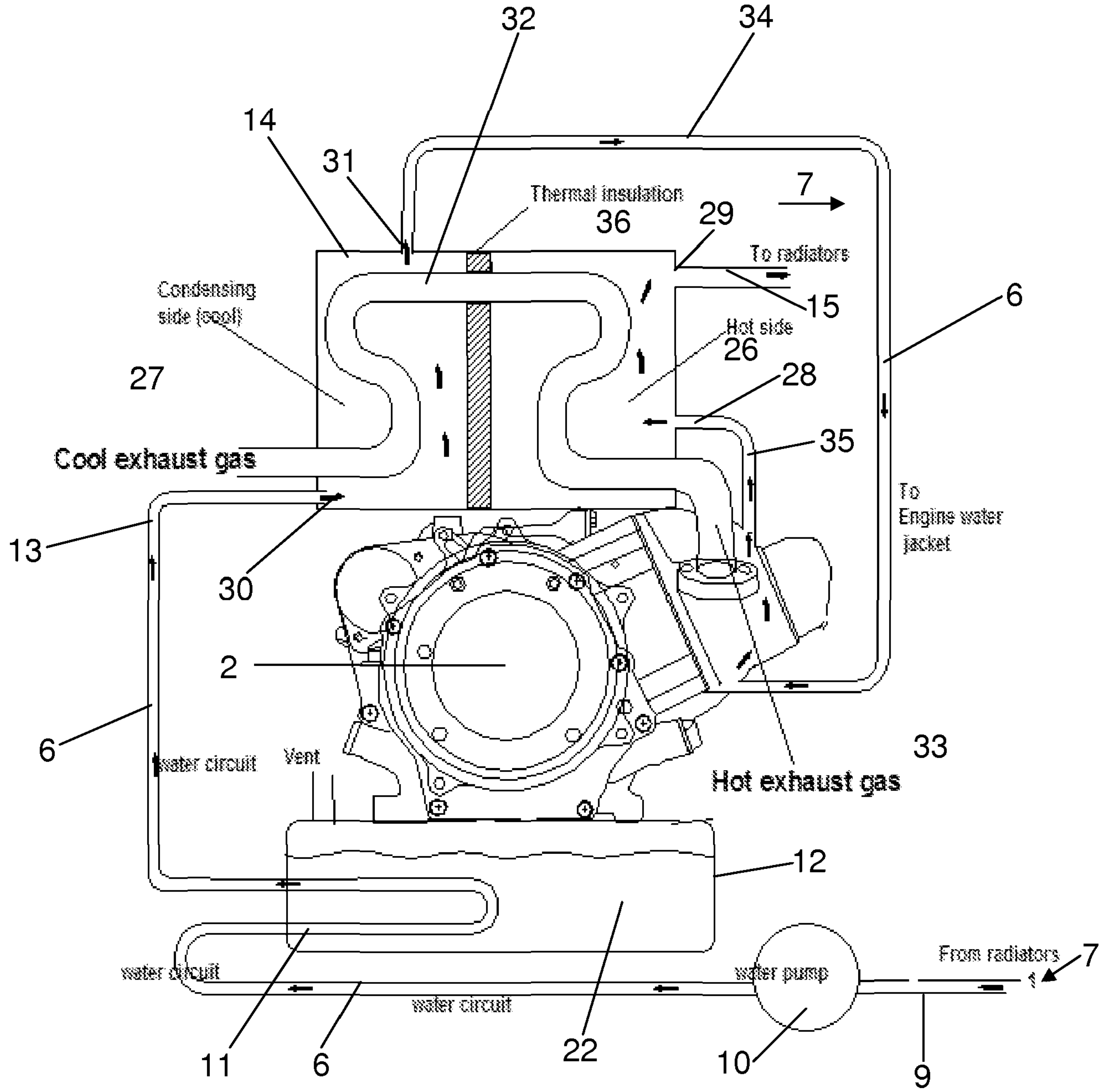
32
34
14
31
Thermal insulation
36
7
29
To radiators
15
6
Condensing
side (cool)
Hot side
26
27
28
Cool exhaust gas
35
To
Engine water
jacket
13
30
2
6
water circuit
Vent
33
Hot exhaust gas
12
From radiators
7
water circuit
water pump
water circuit
11
6
22
10
9

Figure 2

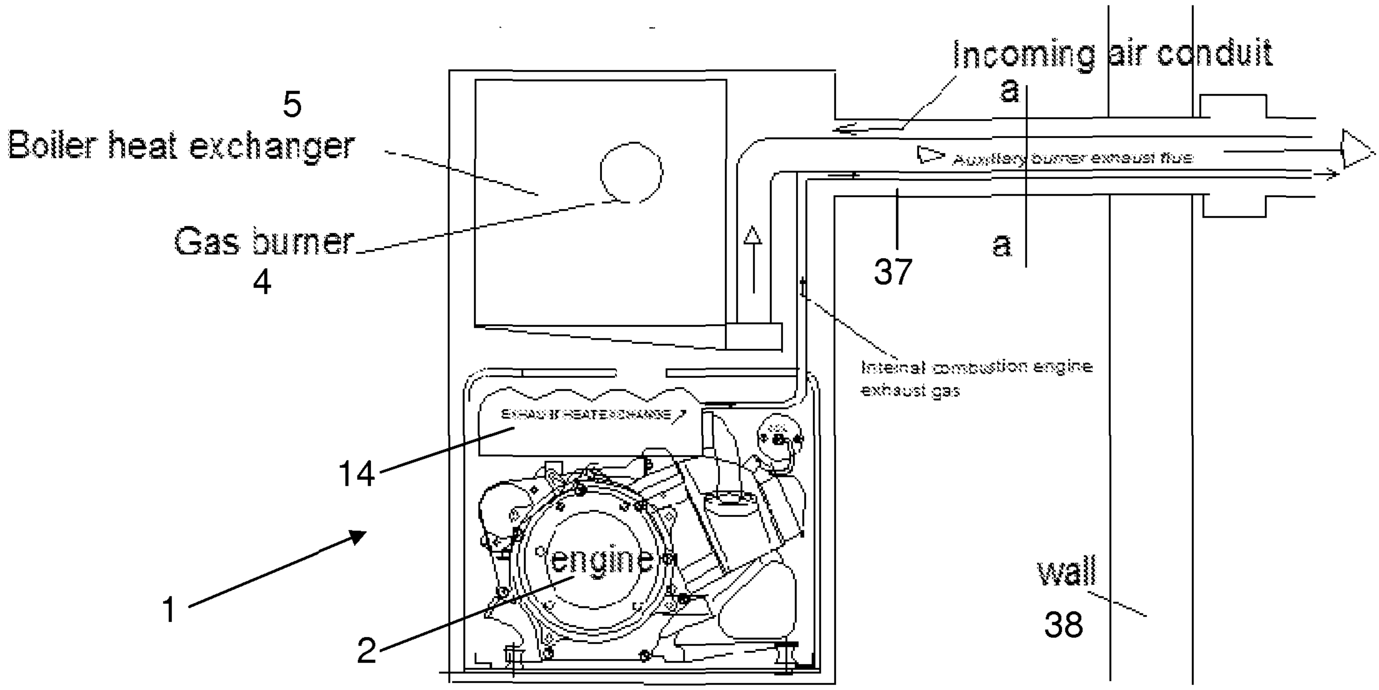


Figure 3

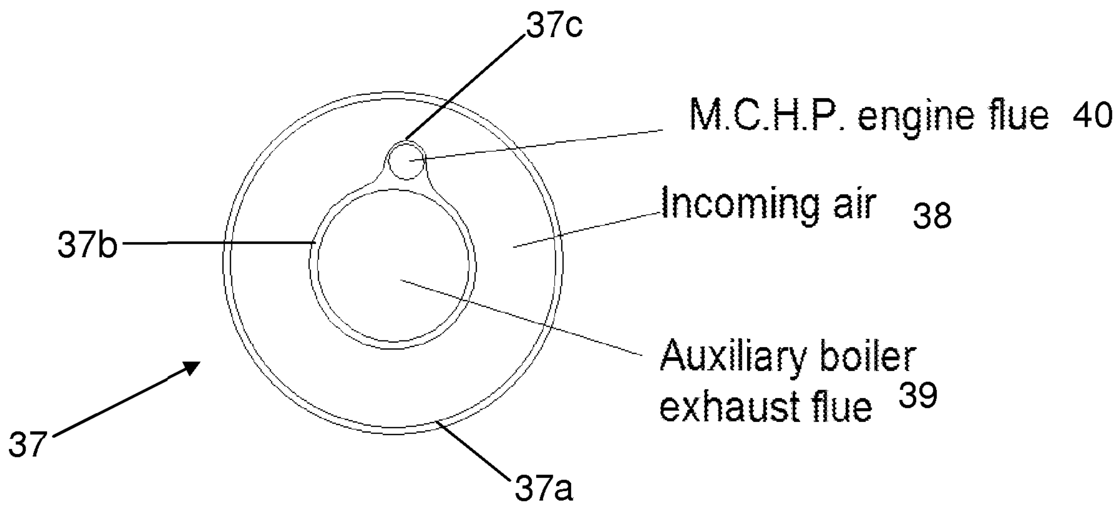


Figure 3a

Cross-section a-a

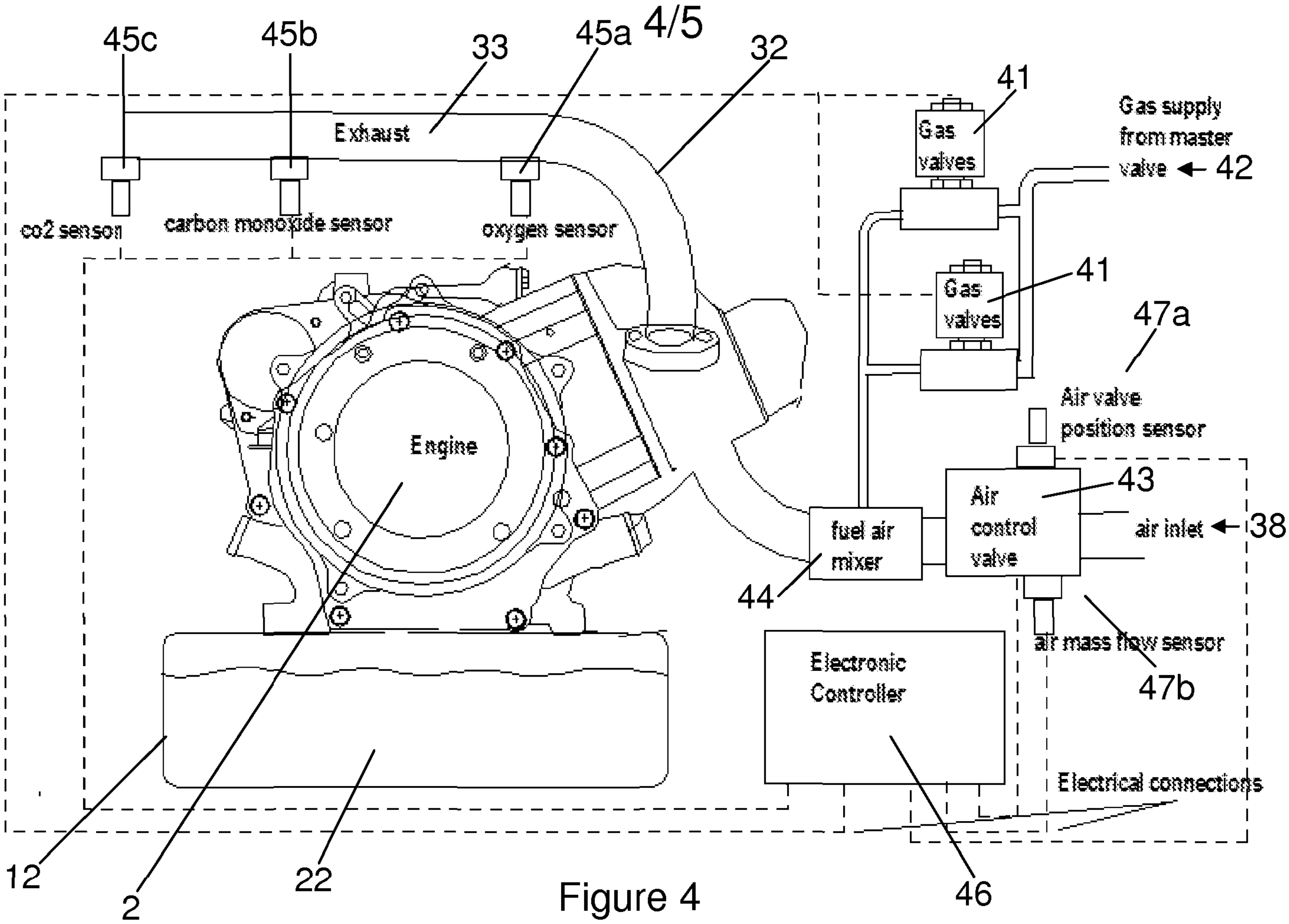


Figure 4

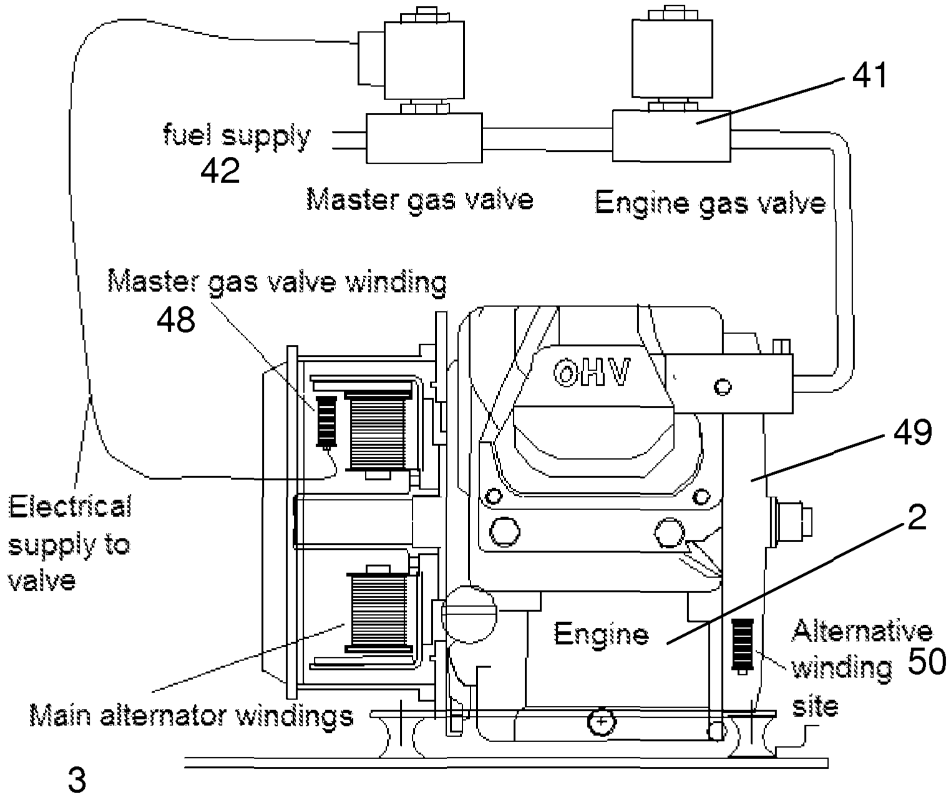


Figure 5

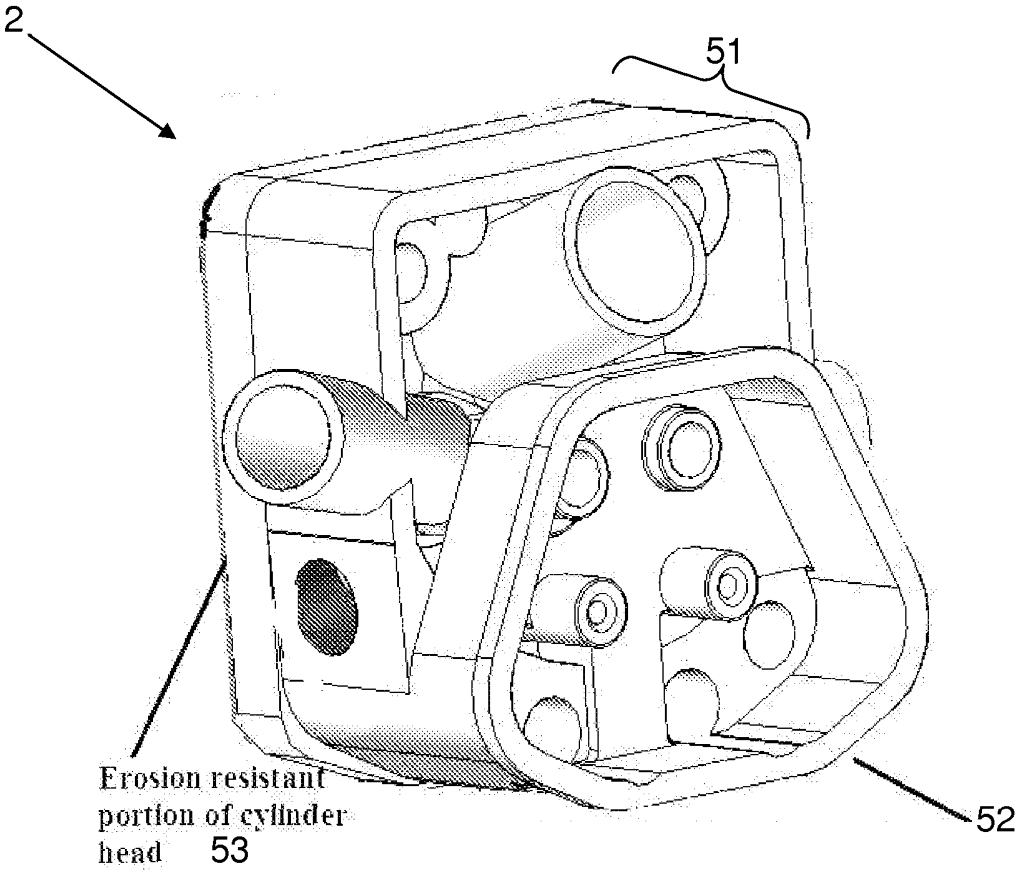


Figure 6

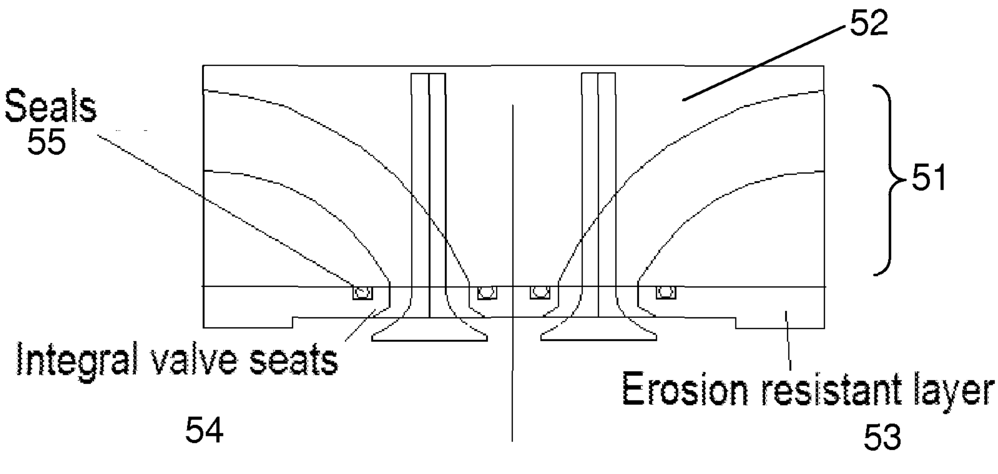


Figure 6a

# MICRO COMBINED HEAT AND POWER UNIT

## FIELD OF THE INVENTION

The present invention relates to a micro combined heat and power unit.

## BACKGROUND OF THE INVENTION

Micro combined heat and power (mCHP) units have recently been developed for domestic buildings or small/medium commercial business units. mCHP is an example of co-generation where energy is provided in several forms.

A mCHP unit uses a generator to convert fuel into electrical energy, which can be used in the building. A by-product of generating the electricity is the production of heat. In a normal generator set up, this heat would be wasted. However, in a mCHP unit, this heat is used to heat the occupied space in the building in which it is installed. In this way, the overall efficiency of the unit can be between 90 and 95 % (energy input/useful energy output).

mCHP units in domestic or small/medium commercial buildings typically generate more heat energy than electrical energy and are controlled primarily by heat demand. The useful heat energy is typically provided in the form of hot water, which is utilised by either a central heating system and/or hot water for cooking, cleaning, bathing, drinking etc.

The ratio of useful heat energy to electrical energy output by a typical mCHP unit is in the region of 3:1. That is, for every 3kW of useful heat energy produced, 1kW of electricity is produced. If the requirements of the building use the electricity and heat in this proportion then all is well. However, if the electrical demand fluctuates significantly as is often the case, then mCHP units can often provide more electrical energy than is currently demanded for a given heat demand.

One of the major benefits of mCHP units is that this excess electrical energy can be exported to the national electrical grid and sold to the relevant utility company.

mCHP units therefore typically comprise an engine-driven electrical generator and a heat exchanger for converting waste heat energy from the engine to useful heat energy in a working fluid (typically hot water).

A variety of internal and external combustion engines have been suggested or successfully developed for use in mCHP units. These include internal combustion piston engines (compression ignition or spark ignition) gas turbines, or external combustion engines, such as the Sterling engine for example.

These different engine types may run on a variety of fuels. Natural gas is particularly suitable since many homes and small/medium sized office buildings are already connected to a supply of natural gas. A variety of other gaseous fuels may similarly be used, such as propane, methane, hydrogen or LPG. Liquefied fuels are also suitable, particularly for internal combustion engines.

## SUMMARY OF THE INVENTION

A first aspect of the invention provides a micro combined heat and power (mCHP) unit comprising: an electric generator for generating electrical energy, an internal combustion (IC) engine for driving the generator, a first heat exchanger configured to transfer waste heat energy from the IC engine and/or the generator to useful heat energy in a working fluid, a fuel burner, and a second heat exchanger configured to transfer the heat of combustion from the burner exhaust to useful heat energy in the working fluid.

A second aspect of the invention provides a method of operating a micro combined heat and power (mCHP) unit comprising an electric generator for generating electrical energy, an internal combustion (IC) engine for driving the generator, a first heat exchanger configured to transfer waste heat energy from the IC engine and/or the generator to useful heat energy in a working fluid, a fuel burner, and a second heat exchanger configured to transfer the heat of combustion from the burner exhaust to useful heat energy in the working fluid; the method comprising selectively operating the fuel burner and/or the IC engine driven electric generator.

The invention according to the first and second aspects is advantageous in that it becomes possible to generate additional useful heat energy for times when the heat demand exceeds the heat available from the engine-driven generator alone. The boost heat facility provided by the burner widens the appeal of the unit and allows the unit to replace a standard boiler instead of being in addition to it, which saves space, cost and complexity.

The IC engine and/or the fuel burner may be operable using gaseous fuel, preferably natural gas, propane, methane or LPG.

The IC engine and the fuel burner may each be operable using the same fuel type.

The mCHP unit may further comprise a control valve for controlling a supply of fuel to the IC engine and/or the fuel burner.

The mCHP unit may further comprise a diverter valve for controlling the flow of the working fluid through the first and/or second heat exchangers.

The mCHP unit may further comprise a controller connected to the control valve and to the diverter valve.

The working fluid may be water, preferably for a central heating system.

The first heat exchanger may include a conduit for transporting the working fluid through and/or around the IC engine, such that during operation the working fluid is heated and the IC engine is cooled.

The first heat exchanger may include a conduit for transporting the working fluid through and/or around the generator, such that during operation the working fluid is heated and the generator is cooled.

The mCHP unit may further comprise a conduit for transporting the working fluid through an exhaust system of the IC engine, the exhaust system including a heat exchanger such that during operation the working fluid is heated and the exhaust system is cooled.

The mCHP unit may further comprise a pump for pumping the working fluid from an inlet to an outlet of the unit.

The generator is preferably an alternator.

The mCHP unit may further comprise a rectifier for converting AC output by the alternator to DC, and an inverter for converting DC output by the rectifier to AC at a predetermined frequency.

The fuel burner may be operable independently of the IC engine driven electric generator.

Preferably, operation of the fuel burner during operation of the IC engine driven electric generator increases the ratio of useful heat energy output to electrical energy output by the unit.

The mCHP unit may further comprise a mixing chamber for mixing air with fuel for supplying to the IC engine.

The mCHP unit according may further comprise a mixing chamber for mixing air with fuel for supplying to the fuel burner.

The mCHP unit may further comprise a cabinet, which houses the IC engine, generator, fuel burner and heat exchangers.

The mCHP unit may further comprise a wall mounting for mounting the unit to a wall.

The ratio of useful heat energy output to electrical energy output by the unit may be approximately 3:1 when the IC engine driven electric generator is operating and the gas burner is not operating.

The ratio of useful heat energy output to electrical energy output by the unit is increased when the IC engine driven electric generator is operating whilst the gas burner is operating.

A third aspect of the invention provides a micro combined heat and power (mCHP) unit comprising: an electric generator for generating electrical energy, an internal combustion (IC) engine for driving the generator, a first heat exchanger configured to transfer waste heat energy from the IC engine and/or the generator to useful heat energy in a working fluid, a fuel burner, a second heat exchanger configured to transfer the heat of combustion from the burner exhaust to useful heat energy in the working fluid, and a controller connected to the IC engine and to the fuel burner, wherein the controller is configured to determine a temperature of the IC engine and to operate the fuel burner prior to operation of the IC engine when the temperature of the engine is below a predetermined level.

A fourth aspect of the invention provides a method of operating a micro combined heat and power (mCHP) unit comprising an electric generator for generating electrical energy, an internal combustion (IC) engine for driving the generator, a first heat exchanger configured to transfer waste heat energy from the IC engine and/or the generator to useful heat energy in a working fluid, a fuel burner, a second heat exchanger configured to transfer the heat of combustion from the burner exhaust to useful heat energy in the working fluid, and a controller connected to the IC engine and to the fuel burner; the method comprising using the controller to determine a temperature of the IC engine, and to operate the fuel burner prior to operation of the IC engine when the temperature of the engine is below a predetermined level.

The invention according to the third and fourth aspects is advantageous in that the engine can be raised to around its operating temperature before it is started, leading to vastly reduced wear rates in the engine. In addition it becomes possible to pre-warm the lubricating oil so as to remove condensing water from an oil tank or sump associated with the engine, thus lengthening the life of the unit.

The first heat exchanger may be configured to transfer useful heat energy from the working fluid to raise the temperature of the IC engine prior to operation of the IC engine.

The mCHP unit may further comprise a pump for pumping the working fluid through the mCHP unit.

The controller may be configured to start the IC engine when the temperature of the engine is at or above the predetermined level.

The first heat exchanger may be configured to transfer heat between an oil sump of the IC engine and the working fluid.

The first heat exchanger may be configured to transfer heat between an engine block of the IC engine and the working fluid.

The first heat exchanger may be configured to transfer heat between an exhaust system of the IC engine and the working fluid.

The first heat exchanger may be configured to transfer heat between a conduit, which passes around the outside of the IC engine, and the working fluid.

The mCHP unit may further comprise a control valve for controlling a supply of fuel to the IC engine and/or the fuel burner.

The mCHP unit may further comprise a diverter valve for controlling the flow of the working fluid through the first and/or second heat exchangers.

The controller may be connected to the control valve and to the diverter valve.

The controller may be connected to one or more temperature sensors within or adjacent the engine.

The method may further comprise using the first heat exchanger to transfer useful heat energy from the working fluid to raise the temperature of the IC engine prior to operation of the IC engine.

The method may further comprise pumping the working fluid through the mCHP unit to transfer heat energy from the second heat exchanger to the first heat exchanger during operation of the fuel burner and prior to operation of the IC engine.

The method may further comprise using the controller to start the IC engine when the temperature of the engine is at or above the predetermined level.

The method may further comprise using the controller to operate a control valve for controlling a supply of fuel to the IC engine and/or the fuel burner.

The method may further comprise using the controller to operate a diverter valve for controlling the flow of the working fluid through the first and/or second heat exchangers.

A fifth aspect of the invention provides a micro combined heat and power (mCHP) unit comprising: an electric generator for generating electrical energy, an engine for driving the generator, a first heat exchanger configured to transfer waste heat energy from the engine and/or the generator to useful heat energy in a working fluid, and an electrical heating element for heating the working fluid.

A sixth aspect of the invention provides a method of operating a micro combined heat and power (mCHP) unit comprising an electric generator for generating electrical energy, an engine for driving the generator, a first heat exchanger configured to transfer waste heat energy from the engine and/or the generator to useful heat energy in a working fluid, and an electrical heating element; the method comprising energising the heating element to heat the working fluid.

The invention according to the fifth and sixth aspects is advantageous in that the heating element can be used to boost the heat energy output of the unit. In addition, the engine can be raised to around its operating temperature before it is started, leading to vastly reduced wear rates in the engine. In addition it becomes possible to pre-warm the lubricating oil so as to remove condensing water from an oil tank or sump associated with the engine, thus lengthening the life of the unit.

The mCHP unit may further comprise a fuel burner and a second heat exchanger configured to transfer the heat of combustion from the burner exhaust to useful heat energy in the working fluid.

The engine may be an internal combustion (IC) engine.

The working fluid may be water, preferably for a central heating system.

The electrical heating element may be powered by electrical energy generated by the generator.

The electrical heating element may be disposed within a circuit for conveying the working fluid through the mCHP unit.

The heating element may be an emersion heater.

The working fluid circuit may include a heat exchanger within an exhaust system of the engine, and the heating element may be disposed within the heat exchanger.

The working fluid circuit may include a conduit which passes around the engine, and the heating element may be disposed within the conduit.

The working fluid circuit may pass through an oil sump of the engine.

The working fluid circuit may pass though an engine block of the engine.

The mCHP unit may further comprise a pump for pumping the working fluid through the mCHP unit.

The mCHP unit may further comprise a controller connected to the electrical heating element for controlling operation of the heating element.

The working fluid may be passed around and/or through the engine, and the heating element may be energised to pre-heat the engine prior to operation.

The working fluid may be passed through an oil sump of the engine, and the heating element may be energised to heat oil in the sump.

The heating element may be energised whilst the engine is operating so as to increase the ratio of useful heat energy output to electrical energy output from the unit.

A seventh aspect of the invention provides a micro combined heat and power (mCHP) unit comprising: an electric generator for generating electrical energy, an engine for driving the generator, a heat exchanger configured to transfer waste heat energy from the engine exhaust to useful heat energy in a working fluid, the heat exchanger comprising a first section and a second section, the first section having a working fluid inlet and a working fluid outlet, and the second section having a working fluid inlet and a working fluid outlet, an exhaust conduit arranged to convey the engine exhaust from the engine through the first section and then through the second section of the heat exchanger, and a working fluid conduit arranged to convey the working fluid from the working fluid outlet of the second section of the heat exchanger towards the working fluid inlet of the first section of the heat exchanger.

An eighth aspect of the invention provides a method of efficiently transferring waste heat energy to useful heat energy in a micro combined heat and power (mCHP) unit, the mCHP unit comprising an electric generator for generating electrical energy, an engine for driving the generator, and a heat exchanger configured to transfer waste heat energy from the engine exhaust to useful heat energy in a working fluid, the heat exchanger comprising a first section and a second section, the first section having a working fluid inlet and a working fluid outlet, and the second section having a working fluid inlet and a working fluid outlet, the method comprising: conveying the engine exhaust from the engine through the first section and then through the second section of the heat exchanger, and conveying the working fluid from the working fluid outlet of the second section of the heat exchanger towards the working fluid inlet of the first section of the heat exchanger.

The invention according to the seventh and eighth aspects is advantageous in that the fluid path through the heat exchanger is adapted to increase the efficiency of heat transfer from the engine exhaust to the working fluid.

The first and second sections of the heat exchanger may be attached or integrally formed.

The first section of the heat exchanger preferably has a higher operating temperature than the second section of the heat exchanger.

The operating temperature of the second section of the heat exchanger may be sufficiently low to cause condensation of steam in the exhaust.

The first and second heat exchanger sections may have a plate-like, or tubular, construction to direct the working fluid therethrough.

The heat exchanger may further comprise thermal insulation between the first and second sections.

The mCHP unit may further comprise a pump for pumping the working fluid through the mCHP unit.

The working fluid may be water, preferably for a central heating system.

The working fluid conduit may be arranged to convey the working fluid through the engine between exiting the working fluid outlet of the second section of the heat exchanger and entering the working fluid inlet of the first section of the heat exchanger.

The mCHP unit may further comprise a second working fluid conduit arranged to convey the working fluid through the generator and towards the working fluid inlet of the second section of the heat exchanger.

The engine may be an internal combustion (IC) engine.

The IC engine may be operable using gaseous fuel, preferably natural gas, methane, propane or LPG.

The first section of the heat exchanger is preferably operated at a higher temperature than the second section of the heat exchanger.

A ninth aspect of the invention provides a flue system for a micro combined heat and power (mCHP) unit having an engine and a separate fuel burner, the flue system comprising: a first flue arranged to convey exhaust from the engine, a second flue arranged to convey exhaust from the burner, the first and second flues being arranged to prevent mixing of the exhaust from the engine with the exhaust from the burner within the flue system.

A tenth aspect of the invention provides a method of using a flue system for a micro combined heat and power (mCHP) unit having an engine and a separate fuel burner; the method comprising conveying exhaust from the engine using a first flue of the flue system, conveying exhaust from the burner using a second flue of the flue system, and preventing mixing of the exhaust from the engine with the exhaust from the burner within the flue system.

The invention according to the ninth and tenth aspects is advantageous in that the separate flues for the burner and the engine reduce pressure cross talk or interference which may otherwise cause fuelling and instability problems for the burner. It also removes the tendency to back feed gas into the burner flue from the IC engine flue and vice versa.

The second flue may have an internal diameter larger than that of the first flue.

The flue system may further comprise a conduit arranged to convey air to the engine and/or the burner, wherein the first and second flues are disposed inside the conduit.

The conduit may be arranged to convey air to only one of the engine and the burner, and a second conduit may be arranged to convey air to the other of the engine and the burner.

The flues may be substantially concentrically arranged with respect to the conduit.

The first and second flues may be substantially linear.

One of the first and second flues may be spirally arranged around the other of the first and second flues.

The first and second flues may be integrally formed.

The first flue may be fixed to the second flue.

A further aspect of the invention provides a micro combined heat and power (mCHP) unit comprising: an engine for driving an electric generator to generate electrical energy and useful heat energy, a fuel burner for combusting a fuel to generate useful heat energy, and a flue system in accordance with the ninth aspect of the invention.

The engine may be an internal combustion (IC) engine.

The mCHP unit may further comprise a first heat exchanger configured to transfer waste heat energy from the engine and/or the generator to useful heat energy in a working fluid.

The first flue may be arranged downstream of the first heat exchanger.

The mCHP unit may further comprise a second heat exchanger configured to transfer the heat of combustion from the burner exhaust to useful heat energy in a working fluid.

The second flue may be arranged downstream of the second heat exchanger.

The method may further comprise conveying air to the engine and/or the burner using the conduit such that there is a transfer of heat from the exhaust in the flues to the air within the conduit.

An eleventh aspect of the invention provides a micro combined heat and power (mCHP) unit comprising: an electric generator for generating electrical energy, an internal combustion (IC) engine for driving the generator, a heat exchanger configured to transfer waste heat energy from the engine and/or the generator to useful heat energy in a working fluid, a plurality of fixed flow gas valves for controlling supply of gaseous fuel to the IC engine, and a proportional air control valve for controlling supply of air to the IC engine.

A twelfth aspect of the invention provides a method of operating a micro combined heat and power (mCHP) unit comprising an electric generator for generating electrical energy, an internal combustion (IC) engine for driving the generator, and a heat exchanger configured to transfer waste heat energy from the engine and/or the generator to useful heat energy in a working fluid; the method comprising selectively supplying one of a plurality of predetermined fixed flow rates of gaseous fuel to the IC engine and proportionately controlling supply of air to the IC engine to optimise the fuel/air mixture.

The invention according to the eleventh and twelfth aspects is advantageous in that it becomes possible to use certified, relatively inexpensive standard gas valves with fixed metering and yet provide an optimal fuel/air mixture to the engine by use of the proportional air control valve.

Each gas valve is preferably a normally closed solenoid valve.

Each gas valve may be identical.

The gaseous fuel may be selected from the group including: natural gas, methane, propane or LPG.

One of the gas valves may be operable to supply a flow of gas corresponding to an idle power setting of the IC engine.

The plurality of gas valves may be operable mutually exclusively.

At least some of the plurality of gas valves may be operable simultaneously.

Instructions for controlling the gas valves may be provided manually or from a controller.

The mCHP unit may further comprise a controller connected to the gas valves and to the proportional air control valve for controlling the flow rate of air through the air control valve.

The controller preferably stores a set of instructions for controlling the air control valve in accordance with a setting of the gas valves.

The controller may additionally be configured to modify the flow rate of air through the air control valve based upon feedback from one or more sensors.

The sensor(s) may include one or more gas sensors in an exhaust system of the IC engine.

The gas sensor(s) may be selected from the group including: a carbon dioxide sensor, a carbon monoxide sensor, and a lambda sensor.

The sensor(s) may include one or more air mass flow sensors for sensing the flow of air through the air control valve.

The sensor(s) may include a valve position sensor in the air control valve.

The mCHP unit according may further comprise a mixing chamber for mixing the fuel and air before entering the IC engine.

Selection of the flow rate of gaseous fuel may be provided manually or from a controller.

The method may further comprise controlling the flow rate of air through the air control valve based upon the instant setting of the gas valves.

The method may further comprise modifying the flow rate of air through the air control valve based upon feedback from one or more sensors.

A thirteenth aspect of the invention provides a micro combined heat and power (mCHP) unit comprising: an electric generator for generating electrical energy, an engine for driving the generator, a solenoid valve for controlling the supply of fuel to the engine, and an electrical winding and magnet set operable to generate electrical energy when the engine is running, wherein the winding/magnet set is electrically connected to the solenoid valve for maintaining the valve in an open state when the engine is running.

A fourteenth aspect of the invention provides a method of operating a micro combined heat and power (mCHP) unit having an engine driven electric generator and a solenoid valve for controlling the supply of fuel to the engine, the method comprising generating electricity when the engine is running to power the solenoid so as to maintain the valve in an open state.

The invention according to the thirteenth and fourteenth aspects is advantageous in that should the engine stop, or a mechanical malfunction occur, the generator will stop and the voltage in the winding/magnet set will collapse, causing the solenoid valve to close, thus switching off the supply of fuel to the engine and making the unit safe.

The generator is preferably an alternator.

The engine may include a flywheel and the winding/magnet set may be disposed adjacent the flywheel.

Alternatively, the winding/magnet set may be disposed adjacent the generator.

The winding/magnet set may share a magnet and stator core with the generator.

The valve is preferably a normally closed valve.

The engine may be operable using gaseous fuel, preferably natural gas, methane, propane or LPG.

The valve may be a master valve.

The engine is preferably an internal combustion (IC) engine.

The method may further comprise opening the valve for a predetermined period of time during an engine start up routine.

The valve is preferably normally closed.

A fifteenth aspect of the invention provides a cylinder head for an internal combustion (IC) engine, the cylinder head comprising a main body portion and a second portion of material different than the main body portion, and wherein the second portion includes one or more valve seats.

A sixteenth aspect of the invention provides a method of forming a cylinder head for an internal combustion (IC) engine, the method comprising forming a main body portion of the cylinder head, forming a second portion of the cylinder head from material different than the main body portion, wherein the second portion includes one or more valve seats, and attaching the second portion to the main body portion.

The invention according to the fifteenth and sixteenth aspects is advantageous in that the dissimilar materials for the cylinder head may be selected according to function to enhance the life of the engine without significantly increasing cost, weight, etc.

The second portion may be a layer attached to the main body portion.

The second portion may comprise a material of greater resistance to distortion and/or corrosion and/or erosion than the material of the main body portion.

The second portion may include material selected from the group including: bronze and stainless steel.

The main body portion may include material selected from the group including: aluminium and iron.

The main body portion may be unitary.

The cylinder head may further comprise one or more seals between the main body portion and the second portion.

The seal(s) may be provided around one or more passages in the cylinder head.

The passages may include one or more of: an inlet, an exhaust air outlet, and a coolant passage.

A further aspect of the invention provides an IC engine comprising the cylinder head according to the fifteenth aspect.

The engine may be an overhead valve engine, side valve engine, or semi-overhead valve engine.

The engine may be a two stroke engine or a four stroke engine.

The IC engine may be suitable for use in a micro combined heat and power (mCHP) unit.

A further aspect of the invention provides a micro combined heat and power (mCHP) unit including the cylinder head or the IC engine according to the fifteenth aspect of the invention.

The main body portion may be formed by casting, machining or forging.

The or each valve seat may be formed by machining the second portion.

The method may further comprise providing one or more seal members between the main body portion and the second portion.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 illustrates an assembly view of an embodiment of the mCHP unit;

Figure 2 illustrates part of the mCHP unit of Figure 1 showing the engine exhaust gas heat exchanger in detail;

Figure 3 illustrates the mCHP unit of Figure 1 connected to a multiple flue passing through a wall of a building in which the mCHP unit is installed, and Figure 3a illustrates the cross section view through the multiple flue along line a-a;

Figure 4 illustrates the mCHP unit of Figure 1 and shows in detail the fuel control system for the internal combustion engine;

Figure 5 illustrates part of the mCHP unit of Figure 1 and shows in detail a safety device for the master gas valve; and

Figure 6 illustrates the cylinder head for the internal combustion engine of the mCHP unit of Figure 1, and Figure 6a illustrates a partial cross section view through the cylinder head.

DETAILED DESCRIPTION OF EMBODIMENT(S)

Figure 1 illustrates a schematic assembly view of key components of an mCHP unit 1. The unit 1 comprises an internal combustion engine 2, an alternator 3 (shown in Figure 5) driven by the engine 2 and a separate gas burner 4 which forms part of a gas booster boiler 5. The engine 2, alternator 3, and burner 4 are disposed within a single wall or floor mounted enclosure or cabinet/housing (not shown).

The alternator 3 produces electrical energy when the engine 2 is running. A water circuit 6 runs around the engine 2 to transfer waste heat energy from the engine to useful heat energy in the form of hot water. In the embodiment depicted in Figure 1, the water circuit 6 is coupled to a central heating system, not shown in Figure 1 but indicated generally by reference numeral 7. The water circuit 6 is additionally plumbed in parallel to the gas booster boiler 5 with a three way valve 8 to selectively control the flow of water through the exhaust/water heat exchanger 14 and/or the gas booster boiler 5.

The water circuit 6 includes a "cool" water inlet 9 for connection to the central heating system 7, a water pump 10, a water conduit 11 which passes through an oil sump 12 of the engine 2, a water conduit 13 connected between the water conduit 11 and an exhaust/water heat exchanger 14, and a water conduit 15 connected between the heat exchanger 14 and the valve 8.

In parallel, a water conduit 16 is branched from the water conduit 13 and connected to an inlet 17 of the gas booster boiler 5. A water conduit 18 is connected between an outlet 19 of the gas booster boiler 5 and the valve 8. Valve 8 is coupled by water conduit 19 to another three way valve 20 arranged to control the flow of water to either continue around the water circuit 6 or to exit the water circuit 6 via outlet 21 coupled to the central heating system 7.

Although not visible in Figure 1, the water circuit 6 additionally flows through the engine 2 as will be described in detail with reference to Figure 2.

It will be appreciated that whilst the mCHP unit 1 is shown connected to a central heating system 7, it could alternatively or additionally be connected to a hot water cylinder for supplying hot water for cooking, cleaning, bathing, drinking etc. in the building in which the unit 1 is installed.

The internal combustion engine 2 is operable using mains natural gas or LPG. However, the same, or a similar, internal combustion engine may be adapted to run on a wider variety of gaseous or liquid fuels, as will be appreciated by those skilled in the art.

The engine 2 is coupled to the alternator 3 such that when the engine 2 is running, the alternator 3 generates electrical energy. The engine 2 is a four stroke overhead valve internal combustion (IC) engine, which produces most of its output energy over about $45^{\circ}$ of crank shaft rotation, every 2 crank revolutions. This has the potential for quite large crank shaft speed cyclic variations. If the speed variations are transmitted to the alternator 3, then this would lead to distortion of the AC wave form of the electrical output, and also result in engine rocking and vibration.

To combat this, a smooth coupling is provided between the engine 2 and the alternator 3. Essentially, the smoothing coupling stores energy during the power stroke of the engine 2, and releases it in a controlled manner to the alternator 3 over the remaining time before the next power stroke. The smoothing coupling therefore enables the AC wave form of the alternator electrical output to be bought closer to sinusoidal form, and in turn reduces engine rocking, vibration, and cyclic speed variations.

The AC electrical output of the alternator 3 is rectified and inverted to provide a constant AC output of a predetermined frequency corresponding to mains electrical power. This may be, for example, 50 or 60 kHz depending on the country of use. The electrical output from the unit 1 may therefore be used to power electrical appliances within the building, or exported to the national electricity grid.

Most of the heat from the engine 2 is transferred to useful heat energy in the water circuit 6 when the engine 2 is running. As described previously, relatively cool water is fed from the central heating system 7 of the building in which the mCHP unit 1 is installed via inlet 9 to the water pump 10. This relatively cool water is passed through the water conduit 11 which is disposed in the oil sump 12 of the engine 2.

When the engine is running, oil 22 in the sump 12 is fed by oil pump 23 through oil filter 24 to the engine 2. Oil which drains back from the engine 2 into the sump 12 therefore heats up until the engine 2 reaches a steady operating temperature. The thermal energy of the oil 22 in the sump 12 is transferred through the walls of the water conduit 11 to heat the water in the water circuit 6.

Water in the water circuit 6 then proceeds via water conduit 13 where it enters the exhaust/water heat exchanger 14. The exhaust/water heat exchanger 14 will be described in detail below with respect to Figure 2 but essentially transfers waste heat energy from the engine exhaust to further raise the temperature of the water in water circuit 6.

The water which exits the exhaust/water heat exchanger 14 is transferred by water conduit 15 to valve 8. When the engine is running, valve 8 controls the flow of hot water from water conduit 15 to water conduit 19. During normal operation of the mCHP unit 1 valve 20 directs the hot water from water conduit 19 to the outlet 21 which is connected to the central heating system 7. The hot water flows through the central heating system 7 and this heat is used to heat the occupied space in the building such that relatively cool water returns from the central heating system at inlet 9.

As can be seen, the mCHP unit 1 uses fuel supplied to the engine 2 to provide both electrical energy and useful heat energy output. The IC engined mCHP unit 1 produces useful heat energy and electrical energy in the ratio of approximately 3:1. That is, for every 3kW of heat produced, 1kW of electricity is produced. If the requirements of the building using the heat and electricity are in this proportion then all is well. However, many buildings typically experience relatively large fluctuations in electrical energy usage.

A major benefit of mCHP units is that excess electrical energy can be exported to the national electricity grid and the mCHP unit operator is compensated by the utility company for a net export of electrical energy. However, some central governments are limiting the amount of electrical energy that can be exported to the national electricity grid by a domestic installation. If the mCHP unit produces heat and electricity in the ratio of 3:1 and the cap on the amount of electrical energy that can be exported is, for example, 2kW then the practical limit on the heat output of the unit would be around 6kW. However, this is unlikely to be sufficient for most domestic applications at certain times of the year.

Therefore, the mCHP unit 1 includes the additional gas booster boiler 5 with the gas burner 4 such that it becomes possible to operate the mCHP unit 1 to produce more heat when required, without increasing the electrical output. This boost heat facility widens the appeal of the mCHP unit 1 and allows the unit to replace a standard domestic boiler instead of being installed in addition to it, thus saving space, cost and complexity.

The gas booster boiler 5 is plumbed in parallel to the water circuit 6. Valve 8 is operable to control the flow of water in the water circuit 6 such that it flows through the exhaust/water heat exchanger 14 and/or through the gas booster boiler 5. When the boiler 5 is operating water flows via water conduit 16, which is connected to inlet 17 of the gas booster boiler 5, and heated water flows from outlet 19 via water conduit 18 through valve 8 to water conduit 19.

The gas booster boiler 5 is of known type and familiar to those skilled in the art. By firing the gas booster boiler 5, the heat output of the mCHP unit 1 can be boosted without increasing the electrical output. A mCHP unit having only an internal combustion engine with a heat output rating of, say, 6kW can be boosted with an additional 15 to 20kW of heat output by the addition of the gas booster boiler 5.

The exhaust/water heat exchanger 14 further comprises an electrical heater (immersion heater) 25. The electrical heater 25 can therefore be used to convert electrical energy into heat energy in the water flowing in the water circuit 6. The electrical heater 25 is, in the embodiment depicted in Figure 1, situated in a water jacket of the exhaust/water heat exchanger 14. However, it will be appreciated that the electrical heater 25 could be disposed at a variety of other positions around the water circuit 6 within the mCHP unit 1. The electrical immersion heater 25 is of known type and so will not be described in further detail here. The electrical heater is coupled to a controller for controlling the operation of the electrical heater 25.

The gas booster boiler 5 and the electrical heated 25 are adapted to perform a variety of functions. These functions are generally complimentary and so in some instances, it may not be necessary to provide both the gas booster boiler 5 and the electrical heater 25 within the same mCHP unit. However, in the preferred implementation shown in Figure 1, both boiler 5 and electrical heater 25 are provided in addition to the engine-driven alternator 2, 3.

When the engine 2 is running to drive the alternator 3 the ratio of the amount of heat energy to the amount of electrical energy produced is dependent upon the engine speed but is generally approximately 3:1. If the requirements for the building in which the unit 1 is installed and using the electricity and heat generated by the mCHP unit 1 are in this proportion then all is well. However, there are several benefits in being able to produce more heat than required by using some of the electrical output and converting it to heat in the system.

A further, and equally important use, for the electrical heater 25 or the boiler 5 is to preheat the engine 2 and engine oil 22 before start up of the engine 2 from a cold start, so as to minimise where on the engine moving parts. This is made possible, because the electrical heater 25 or boiler 5 is adapted to heat water in the water circuit 6, which passes through the oil sump 12 by means of water conduit 11. Although not shown in Figure 1, the water circuit 6 also passes through the engine block of engine 2, as mentioned previously.

When the engine 2 is running at normal operating temperature, flow of water around the water circuit 6 which passes through the engine block is arranged to cool the engine and heat the water. By a reverse process, when the engine 2 is not running, hot water flowing around the water circuit 6 can be used to heat the engine 2 before start up so as to minimise wear on the engine moving parts.

A yet further use for the electrical water heater 25, or boiler 5, is to heat the oil 22 in the oil tank 12 when the engine 2 is not running so as to induce any condensation in the oil 22 to evaporate. Condensation can form in the oil 22 since the engine 2 has a normal operating temperature of around 90-100 degrees Celsius, whilst the oil in the tank 22 will be around 60-70 degrees when the engine is operating. Therefore, the speed at which condensation evaporates from the oil is limited. The process for heating the oil 22 by exchange of heat energy from water flowing in the water circuit 6 through water conduit 11, which is in contact with oil 22 in the sump 12, is substantially the same process as that described above.

Prior to start up of the engine 2 from cold, valve 20 can be positioned so as to shut off flow of water from outlet 21 to the central heating system 7. In this way, water in the water circuit 6 pumped by water pump 10 can flow through the exhaust/water heat exchanger 14 where it is heated by the electrical heater 25 and/or through the booster boiler 5 (depending on the operating status of the boiler 5 and the position of valve 8) and returned via conduit 19 to the water pump 10. Water continues to flow around the water circuit 6 until the engine 2 and/or the oil 22 has reached a desired temperature.

When the engine 2 is running, valve 20 may be positioned so as to direct water in water conduit 19 from outlet 21 through the central heating system 7 and back through inlet 9. In this way, the electrical heater 25 and/or boiler 5 is operable to provide a boost heat function so as to provide additional heat energy to the building above that recovered from the waste heat from the engine 2.

The gas burner 4 of the gas booster boiler 5 is connected to a controller for controlling the supply of fuel to the gas burner 4 and this will be described in detail below with reference to Figure 4. The controller for the electrical heater 25 and the gas burner 4 may be a single controller, or may be separate controllers. Either or both of these controllers may receive feedback from one or more sensors within the mCHP unit 1. For example, the or each controller may be connected to one or more temperature sensors disposed in the oil sump 12 and/or the engine 2. Additionally, or alternatively, the or each controller may be connected to a sensor disposed within the oil sump 22 for sensing accumulation of condensation in the oil 22.

The gas booster boiler 5 is essentially a heat exchanger for transferring the heat of combustion from the burner exhaust generated by the gas burner 4 into useful heat energy in the water which flows through the gas booster boiler 5 as part of the water circuit 6.

The valve 8 is a diverter valve for controlling the flow of water through the exhaust/water heat exchanger 14 and/or the gas booster boiler 5. The valve 8 is operatively coupled to a controller for controlling the position of the valve 8.

In a preferred embodiment, the engine 2 is operable using the same fuel as the gas burner 4. This has significant advantages in reducing the number of separate fuel supplies necessary for operating the mCHP unit 1. However, it will be appreciated that the burner 4 for the booster boiler 5 may be adapted to run on a different gaseous fuel or indeed a liquid fuel as appropriate. The fuel for the burner 4 of the booster boiler 5 may be different from that used by the engine 2.

One or more control valves (not shown) may be provided for controlling the supply of fuel to the burner 4 and the engine 2. This may be a single control valve or may be a separate control valve for each of the burner 4 and the engine 2. The or each control valve is connected to a controller for controlling operation of the or each control valve. The or each controller for the diverter valve 8 and for the or each control valve for the burner 4 and engine 2 may be operatively coupled such that water flows in the relevant portion of the water circuit 6 according to whether the engine 2 and/or the burner 4 are in operation.

Figure 2 illustrates part of the mCHP unit 1 and shows the exhaust/water heat exchanger 14 in greater detail. The heat exchanger 14 includes a first “hot” section 26 and a second “cool” condensing section 27. The hot section 26 has a water inlet 28 and a water outlet 29. The condensing section 27 has a water inlet 30 and a water outlet 31. An exhaust conduit 32 is arranged to convey hot exhaust gas 33 from the engine 2 through the hot section 26 and then through the condensing section 27 of the heat exchanger 14. The exhaust/water heat exchanger 14 is connected to the water circuit 6 as follows.

Water is pumped by the water pump 10 via water conduit 13 to the inlet 30 of the condensing section 27. The water flows through the condensing section 27 and around the exhaust conduit 32 which passes therethrough and then exits via outlet 31. A water conduit 34 is connected to the outlet 31 of the condensing section 27 and is arranged to convey the water towards the inlet 28 of the hot section 26 of the exhaust/water heat exchanger 14.

In the embodiment shown in Figure 2, the water conduit 34 does not convey the water directly to the inlet 28 of the hot section 26 of the heat exchanger 14. Instead, the water conduit 34 is arranged to convey the water from the outlet 31 so as to pass through the engine 2 and then out via water conduit 35 to the inlet 28. However, it will be appreciated that water conduit 34 may be connected directly between outlet 31 and inlet 28. Water which enters the hot section 26 of the heat exchanger 14 via inlet 28 flows through the hot section 26 of the heat exchanger 14 and around the exhaust conduit 32 and then exits via outlet 29 which is connected to water conduit 15.

For the mCHP unit 1 to achieve good efficiency, it is important that the maximum amount of heat is extracted from the exhaust of the engine 2. To extract the heat from the exhaust gases they are passed through heat exchanger 14 in which the heat is transferred from the exhaust gas to cooling water in the water circuit 6. How well the heat is extracted from the exhaust gases is a function of the difference in the temperature of the exhaust gas and the cooling water.

The heat exchanger 14 is configured so as to maximise the difference in temperature of the exhaust gas and the cooling water by the arrangement of the heat exchanger 14 and the path of the cooling water through the heat exchanger 14. This design ensures that the steam content of the engine exhaust 33 condenses in the heat exchanger 14 over as wide a working range as possible, thus liberating the latent heat of vaporisation which exchanges more heat energy into the water circuit 6. The condensing of the steam in the exhaust gas 33 takes place in the condensing section 27.

The hot section 26 and the condensing section 27 of the heat exchanger 14 are shown in Figure 2 as a single unit with thermal insulation 36 between the hot section 26 and the condensing section 27 so as to improve the thermal performance of the heat exchanger 14. However, in an alternative embodiment, the hot section 26 and the condensing section 27 may be two discrete heat exchanger units which together form the heat exchanger 14. Each heat exchanger section 26, 27 may be of conventional type and may, for example, have a plate-like, or tubular construction to direct the water through the section.

In the embodiment shown in Figure 2, water from the central heating system 7 is directed through the oil sump 12 before being directed via water conduit 13 in to the condensing section 27 of the heat exchanger 14. In an alternative embodiment, the relatively cool water from the central heating 7 may be conveyed directly to the condensing section 27.

In a yet further alternative embodiment, the alternator 3 may be water cooled and the relatively cool water from the central heating system 7 may be directed first through the water cooled alternator before being directed in to the condensing section 27 of heat exchanger 14. Passing the water through the water cooled alternator first has benefits in that for maximum electrical efficiency, the alternator 3 should be operated at the lowest temperature possible. However, there may be a trade off between the electrical efficiency of the alternator 3 and the thermal efficiency of the heat exchanger 14.

Also, in the embodiment depicted in Figure 2, the water conduit 34 is arranged to convey cooling water through the engine 2 after exiting the condensing section 27 and before entering the hot section 26 of the heat exchanger 14. This cooling water may pass through other components in the mCHP unit 1. In particular, the water may pass through the engine 2 crank case, cylinder barrel and/or cylinder head after leaving the condensing section 27 but before entering the hot section 26 of heat exchanger 14.

In order to reduce NOx emissions from the IC engine exhaust so as to achieve levels similar to that for gas boiler emissions, an advanced exhaust system (not shown) may additionally be provided. If the combustion temperature in the IC engine 2 exceeds a certain value, NOx can be produced as a product of combustion. The advanced exhaust system is operable to control the maximum temperature of the combustion process by recycling some of the exhaust gas into the inlet charge of the IC engine 2, such that the harmful NOx emissions can be controlled.

Figure 3 illustrates the wall or floor mounted mCHP unit 1 connected to a multiple balanced flue 37, which passes through a wall 38 of the building in which the mCHP unit 1 is installed so as to connect the mCHP unit 1 with ambient air outside the building. A cross section through the flue 37 along line a-a is shown in Figure 3a.

As shown in Figure 3a, the multiple balanced flue 37 comprises an outer conduit 37a, a first inner conduit 37b generally concentrically arranged within the outer conduit 37a, and a second inner conduit 37c disposed within the outer conduit 37a and integrally formed with the outer wall of the first inner conduit 37b.

A space 38 between the outer conduit 37a and the first inner conduit 37b is arranged to convey the incoming ambient air from outside the building towards the mCHP unit 1 for use in the combustion process by the engine 2 and/or the burner 4.

A space 39 bounded by the first inner conduit 37b is arranged to convey exhaust from the burner 4 of the gas booster (auxiliary) boiler 5 to the ambient air outside the building in which the mCHP unit 1 is installed.

A space 40 bounded by the second inner conduit 37c is arranged to convey exhaust from the engine 2 to ambient air outside the building in which the mCHP unit 1 is installed.

The IC engine 2 exhaust will typically be at a higher pressure than the gas booster boiler exhaust, and will also have an inevitable tendency to pulse and carry slightly more contaminants. It is therefore preferable to keep the two exhaust streams separate so as to prevent mixing of the exhaust from the engine 2 with exhaust from the burner 4 within the flue 37.

Keeping the two exhaust streams separate eliminates, or at least reduces, pressure cross talk or interference which may cause fuelling and instability problems in control of the gas booster boiler 5. By keeping the two exhaust streams separate both within the mCHP unit 1 and within the flue 37 it also avoids any tendency to back-feed gas into the boiler heat exchanger 5 from the internal combustion engine 2 and vice versa.

For good thermal efficiency of the overall system, the conduit 37c which carries the engine flue 40 is in direct thermal contact with the incoming air supply 38 thus giving good heat exchange between outgoing flue gas and the incoming air supply. As can clearly be seen in Figure 3a, the conduit 37c is significantly smaller than the conduit 37b and so a large proportion of the outer surface of the conduit 37b is in direct contact with the incoming air supply 38 which again provides good thermal efficiency due to the heat exchange between the outgoing boiler exhaust flue 39 and the incoming air supply 38.

In the embodiment described above with reference to Figures 3 and 3a, the conduit 37c which carries the engine flue 40 is generally straight and runs parallel to the conduit 37b which carries the auxiliary boiler exhaust flue 39. However, several alternative arrangements are envisaged. For example, the conduit 37c need not be integrally formed with the conduit 37b. A plurality of the conduits 37c may be provided arranged spaced around the conduit 37b. The or each conduit 37c may be spirally, as opposed to linearly, arranged around the conduit 37b. One or more of these alternatives may provide improved heat transfer which may need to be offset against the increased cost of production more complex flue arrangement.

In a yet further alternative embodiment, the incoming air for the burner 4 and the engine 2 need not be conveyed along a common conduit. Instead, separate conduits may be provided for the incoming air for each of the burner 4 and the engine 2. In the case of separate air conduits, each air conduit may have one or other of the engine flue 40 and exhaust flue 39 conduits concentrically or otherwise disposed therein.

Figure 4 illustrates part of the mCHP unit 1 and in particular shows the engine 2 and a fuel control system for controlling the supply of fuel to the engine 2. Internal combustion engines for best efficiency and emission control must run in a tightly governed manner as far as fuel/air mixture is concerned. Many outside influences conspire to change the fuel/air mixture such as ambient air pressure, humidity, spark emission timing, and engine wear rates. In the case of an internal combustion engine for a vehicle, for example, the amount of fuel would be proportionally metered to obtain the ideal running mixture. However, this is quite difficult to achieve within the safety regulations governing gas supply and valve suppliers for domestic or small/medium business gas appliances.

The mCHP unit 1 includes a fuel control system comprising a plurality of fixed flow gas valves 41 coupled to the gas supply from a master valve 42, an air control valve 43 coupled to an air inlet at one end of the incoming air flue 38, a fuel air mixer 44 coupled to each of the plurality of gas valves 41 and to the air control valve 43. The engine exhaust conduit 32 includes a plurality of exhaust sensors including an oxygen (Lambda) sensor 45a, a carbon monoxide sensor 45b and a carbon dioxide sensor 45c.

The sensors 45a, b, c are coupled to an electronic controller unit (ECU) 46 for the engine 2. The ECU 46 is also coupled to each of the plurality of gas valves 41. The gas valves 41 are normally closed solenoid gas valves. The air control valve 43 also includes a plurality of sensors, including an air valve position sensor 47a and an air mass flow sensor 47b. The air control valve 43 and its sensors 47a, 47b are each electrically connected to the ECU 46.

The fuel control system illustrated schematically in Figure 4 is particularly advantageous in that off-the-shelf, certified, low cost, normally closed solenoid gas valves 41 can be used in the fuel control system operable to supply a constantly monitored optimum fuel/air mixture to the internal combustion engine 2, for optimum power, safety and emission control performance of the engine 2.

The supply of gas from master valve 42 is regulated by one or more of the plurality of gas valves 41. For example, one of the gas valves 41 may be used for a low power output such as idle speed, whilst another or other gas valves 41 may be used to supply varying levels of power up to full power.

The gas valves 41 may be selectively opened individually under instruction from the ECU 46. The plurality of gas valves 41 may be operable mutually exclusively. That is to say, when one of the valves 41 is open, the or each of the other gas valves 41 must be closed. In such a mutually exclusive scenario, the gas valves 41 are each of fixed (but different) flow rates. In a preferred embodiment, at least some of the plurality of gas valves 41 are operable simultaneously. Selectively opening additional gas valves 41 increases the level of power up to full power. In this case, at least some of the plurality of gas valves may be identical in terms of their fixed flow rate.

If the air supply is not modulated to each of these valve open configurations then poor combustion will take place. Accordingly, the air control valve 43 is a proportional air control valve. The air control valve 43 is controlled by ECU 46 depending upon the status of the plurality of gas valves 41 and depending upon information received from the variety of exhaust sensors 45a, b, c, air valve position sensor 47a, and air mass flow sensor 47b.

The ECU 46 includes a software algorithm configured for each operable combination of the plurality of gas valves 41 to select, within parameters, where to set the air mass flow and thus provide instructions to the air control valve 43. However, importantly, the ECU 46 is operable to modify the position of the air control valve 43 within those predetermined parameters (selected according to the condition of the plurality of gas valves 41) so as to optimise the engine burn by adjusting the proportional air control valve 43 thereby adjusting the air mass flow through the valve 43. Finally, the correct amount of air for the fuel selected is mixed in the fuel air mixing chamber 44 before entering the engine 2.

It will be appreciated by those skilled in the art that not all of the sensors described above with reference to Figure 4 need be included in the fuel control system for the engine 2 and yet further that additional or alternative sensors may be used. For example, the air valve position sensor 47a may be optionally provided. Furthermore, not all of the exhaust sensors identified above may be required.

Whilst in the preferred embodiment described above, one or more of the gas valves 41 are selectively opened under control of the ECU 46, it will be appreciated by those skilled in the art that opening of the gas valves 41 may be instead be performed manually. The ECU 46 may then instead be operable to determine the status of each of the plurality of gas valves 41 and control the proportional air control valve 43 accordingly to provide the optimum fuel/air mixture.

Figure 5 illustrates part of the mCHP unit 1 showing a safety system for shutting off the master gas valve 42 to stop the supply of gas to the engine 2 in the event of engine failure. For gas appliance certification, the mCHP unit 1 must have an infallible means of determining that the engine 2 (or the alternator 3 driven by the engine 2) is running in order to maintain the master gas valve 42 in an open position during operation of the mCHP unit 1.

In one embodiment, the mCHP unit 1 includes an electrical winding and magnet set 48 electrically connected to the normally closed solenoid master gas valve 42. The winding/magnet set is preferably disposed adjacent the main alternator windings 3 such that when the engine 2 is running and the alternator 3 is generating electrical energy, the electrical winding and magnet set 48 acts as an extra, small alternator to provide sufficient electrical power to maintain the solenoid master gas valve 42 open. The winding/magnet set may share a magnet and stator core with the main alternator 3.

Should the engine 2 stop, or a mechanical malfunction occur, the alternator 3 will stop and the voltage in the extra winding 48 will collapse, causing the normally closed solenoid master gas valve 42 to shut, shutting off the supply of gas to the engine 2 thus making the mCHP unit 1 safe.

During the start up of a gas appliance, gas regulations may provide that the master gas valve 42 can be opened for a predetermined period of time to allow the combustion process to be started. By the end of the predetermined period of time, a feedback mechanism has to be able to determine that a combustion has been established, and a signal sent to the master gas valve to keep it switched on, or, if combustion cannot be verified, the master gas valve 42 must shut to prevent any more gas being delivered. The feedback mechanism must continuously monitor the combustion, and if the combustion fails for any reason, must allow the master gas valve 42 to close.

Therefore, a separate electrical supply (not shown) is connected to the normally closed solenoid master gas valve 42 so as to open the master gas valve 42 for the predetermined period of time during start up of the unit 1. After this predetermined period of time has elapsed, the master gas valve 42 will only remain open so long as the winding/magnet set 48 continues to provide sufficient electrical supply to the solenoid gas valve 42. The predetermined period of time may be, for example, 10 seconds.

Naturally, an internal combustion engine such as the engine 2 operates with non-continuous combustion and so existing techniques (such as thermocouples, or exhaust gas ionisation detection) commonly used for determining continuous combustion of a gas burner cannot be used for the engine 2.

In an alternative embodiment, the electrical winding/magnet set 48 could instead be situated in a flywheel 49 of the engine 2, as shown by the alternative winding site 50 indicated in Figure 5.

Figure 6 illustrates part of the IC engine 2 used in the mCHP unit 1. In particular, Figure 6 illustrates the cylinder head 51 of the engine 2. Usually, the main body of the cylinder head of an IC engine is cast, machined, or forged in one piece. The operation of an IC engine for long periods using gaseous fuel (propane, LPG, methane etc) can be problematical as the fuel does not provide lubrication to the valve guides or valve seats of the engine. This is a particular problem with mCHP units as they are required to run for long periods without maintenance, and the required total life is comparatively long, for example 10,000 hours.

During the combustion process, corrosive, erosive or other damaging effects may be experienced by the cylinder head, particularly around the valve seats. The cylinder head of an IC engine is typically made of aluminium or iron. However, these materials are not sufficiently damage resistant to satisfy the long total life required of a gas fuelled IC engine for an mCHP unit.

More highly damage resistant materials, such as bronze and stainless steel for example, are well known but use of such materials for the whole cylinder head would lead to a sharp increase in cost of the engine and would also increase the weight of the mCHP unit overall.

In accordance with one embodiment, the cylinder head 51 of the IC engine 2 of the mCHP unit 1 comprises a main body portion 52 and a second portion 53 of material different than the main body portion 52. The second portion 53 is a layer of erosion resistant material, which is attached to the main body portion 52. The erosion resistant material 53 includes integral valve seats 54, as shown in the cross section view through the cylinder head 51 of Figure 6a.

The main body portion 52 is made of more traditional cylinder head materials, such as aluminium or iron for example. However, the erosion resistant layer may be made from bronze or stainless steel. The erosion resistant layer 53 is better able to resist distortion, corrosion and sinkage which would otherwise likely occur, particularly around the valve seats. This allows for a small amount of the more expensive damage resistant materials to be used than if the entire cylinder head 51 was composed of the more resistant material. This also helps keep the weight of the cylinder head 51 down as compared to if the entire cylinder head 51 was composed of the resistant material. The valve seats 54 may be machined directly into the erosion resistant layer 53 thus negating sinkage.

As best shown in Figure 6a, various seals 55 are provided to seal around inlet, exhaust air outlet, and coolant passages.

Whilst in the embodiment described above, the engine 2 is an overhead valve engine, it will be appreciated by those skilled in the art that the use of a different material around the valve seats as compared with that of the main body portion of the cylinder head is equally applicable to a side valve engine or a semi overhead valve engine or a two stroke engine.

Although the invention has been described above with reference to one or more preferred embodiments, it will be appreciated that various changes or modifications may be made without departing from the scope of the invention as defined in the appended claims.

## Claims

1. A micro combined heat and power (mCHP) unit comprising: an electric generator for generating electrical energy, an internal combustion (IC) engine for driving the generator, a first heat exchanger configured to transfer waste heat energy from the IC engine and/or the generator to useful heat energy in a working fluid, a fuel burner, and a second heat exchanger configured to transfer the heat of combustion from the burner exhaust to useful heat energy in the working fluid, and further comprising a conduit for transporting the working fluid through an exhaust system of the IC engine, the exhaust system including a heat exchanger such that during operation the working fluid is heated and the exhaust system is cooled.

2. A mCHP unit according to claim 1, wherein the IC engine and/or the fuel burner are operable using gaseous fuel, preferably natural gas, propane, methane or LPG.

3. A mCHP unit according to claim 1 or 2, wherein the IC engine and the fuel burner are each operable using the same fuel type.

4. A mCHP unit according to any preceding claim, further comprising a control valve for controlling a supply of fuel to the IC engine and/or the fuel burner.

5. A mCHP unit according to any preceding claim, further comprising a diverter valve for controlling the flow of the working fluid through the first and/or second heat exchangers.

6. A mCHP unit according to claims 4 and 5, further comprising a controller connected to the control valve and to the diverter valve.

7. A mCHP unit according to any preceding claim, wherein the working fluid is water, preferably for a central heating system.

8. A mCHP unit according to any preceding claim, wherein the first heat exchanger includes a conduit for transporting the working fluid through and/or

around the IC engine, such that during operation the working fluid is heated and the IC engine is cooled.

9. A mCHP unit according to any preceding claim, wherein the first heat exchanger includes a conduit for transporting the working fluid through and/or around the generator, such that during operation the working fluid is heated and the generator is cooled.

10. A mCHP unit according to any preceding claim, further comprising a pump for pumping the working fluid from an inlet to an outlet of the unit.

11. A mCHP unit according to any preceding claim, wherein the generator is an alternator.

12. A mCHP unit according to claim 11, further comprising a rectifier for converting AC output by the alternator to DC, and an inverter for converting DC output by the rectifier to AC at a predetermined frequency.

13. A mCHP unit according to any preceding claim, wherein the fuel burner is operable independently of the IC engine driven electric generator.

14. A mCHP unit according to claim 13, wherein operation of the fuel burner during operation of the IC engine driven electric generator increases the ratio of useful heat energy output to electrical energy output by the unit.

15. A mCHP unit according to any preceding claim, further comprising a mixing chamber for mixing air with fuel for supplying to the IC engine.

16. A mCHP unit according to any preceding claim, further comprising a mixing chamber for mixing air with fuel for supplying to the fuel burner.

17. A mCHP unit according to any preceding claim, further comprising a cabinet, which houses the IC engine, generator, fuel burner and heat exchangers.

18. A mCHP unit according to any preceding claim, further comprising a wall mounting for mounting the unit to a wall.

19. A method of operating a micro combined heat and power (mCHP) unit comprising an electric generator for generating electrical energy, an internal combustion (IC) engine for driving the generator, a first heat exchanger configured to transfer waste heat energy from the IC engine and/or the generator to useful heat energy in a working fluid, a fuel burner, and a second heat exchanger configured to transfer the heat of combustion from the burner exhaust to useful heat energy in the working fluid; and a conduit for transporting the working fluid through an exhaust system of the IC engine, the exhaust system including a heat exchanger such that during operation the working fluid is heated and the exhaust system is cooled; the method comprising selectively operating the fuel burner and/or the IC engine driven electric generator.

**Application No:** GB1203034.2 **Examiner:** Mr Alastair Kelly
**Claims searched:** 1-19 **Date of search:** 4 April 2012

## Patents Act 1977: Search Report under Section 17

**Documents considered to be relevant:**

| Category | Relevant to claims | Identity of document and passage or figure of particular relevance |
|---|---|---|
| Y | 1-19 | WO2008/001107 A1 [MICROGEN ENERGY LTD] See abstract and figures |
| Y | 1-19 | US2006/213196 A1 [SUKIOKA] See abstract and figures and note paragraph [0106] |
| Y | 1-19 | EP0952406 A2 [MANDEL] See abstract and figures |
| Y | 1-19 | GB2387641 A [GASFORCE] See abstract and figures |
| Y | 5, 6 | JP2000297963 A [HONDA] See figures and note abstract attached |
| Y | 5, 6 | JP02301651 A [MITSUBISHI] See figures and note abstract attached |
| Y | 5, 6 | DE29605834 U [WIDMANN] See figures and note abstract attached |
| Y | 12 | JP2007002688 A [EBARA] See figures and abstract attached |
| Y | 12 | EP1191659 A2 [HONDA] See abstract and figures |
| Y | 17, 18 | WO2004/101982 A1 [MICROGEN ENERGY LTD] See abstract and figures |
| Y | 17, 18 | WO2004/015261 A1 [MICROGEN ENERGY LTD] See abstract and figures |

Categories:

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|---|---|---|---|
| X | Document indicating lack of novelty or inventive step | A | Document indicating technological background and/or state of the art. |
| Y | Document indicating lack of inventive step if combined with one or more other documents of same category. | P | Document published on or after the declared priority date but before the filing date of this invention. |
| & | Member of the same patent family | E | Patent document published on or after, but with priority date earlier than, the filing date of this application. |

## Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC$^{X}$ :

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Worldwide search of patent documents classified in the following areas of the IPC

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| F01B; F01K; F02C; F02G; F24D |

The following online and other databases have been used in the preparation of this search report

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| EPODOC, WPI |

## International Classification:

| Subclass | Subgroup | Valid From |
|---|---|---|
| F24D | 0003/08 | 01/01/2006 |
| F23J | 0011/00 | 01/01/2006 |
| F24D | 0017/00 | 01/01/2006 |