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(54) **INTERNAL COMBUSTION ENGINE WITH INTEGRATED WASTE HEAT RECOVERY SYSTEM**

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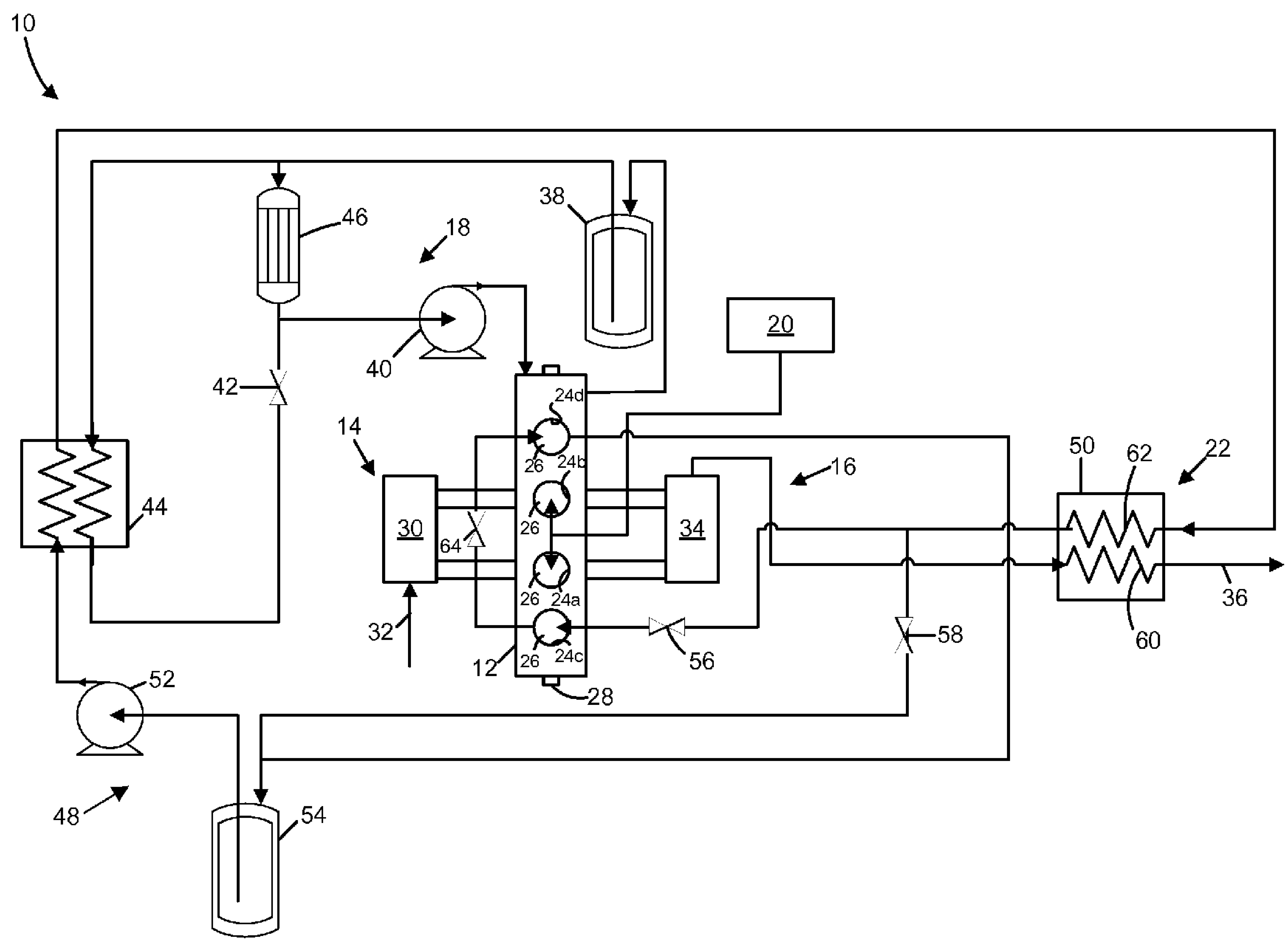
(57) **ABSTRACT**

An engine assembly may include a first heat exchanger, a fluid supply system providing a fluid flow to the first heat exchanger, a fuel system, an engine block defining first and second cylinder bores, a first piston disposed within the first cylinder bore, and a second piston disposed within the second cylinder bore. The first cylinder bore may receive fuel from the fuel system for combustion therein to drive the first piston. The fluid flow may be pressurized within the first heat exchanger and the pressurized fluid may be provided to the second cylinder bore to drive the second piston.



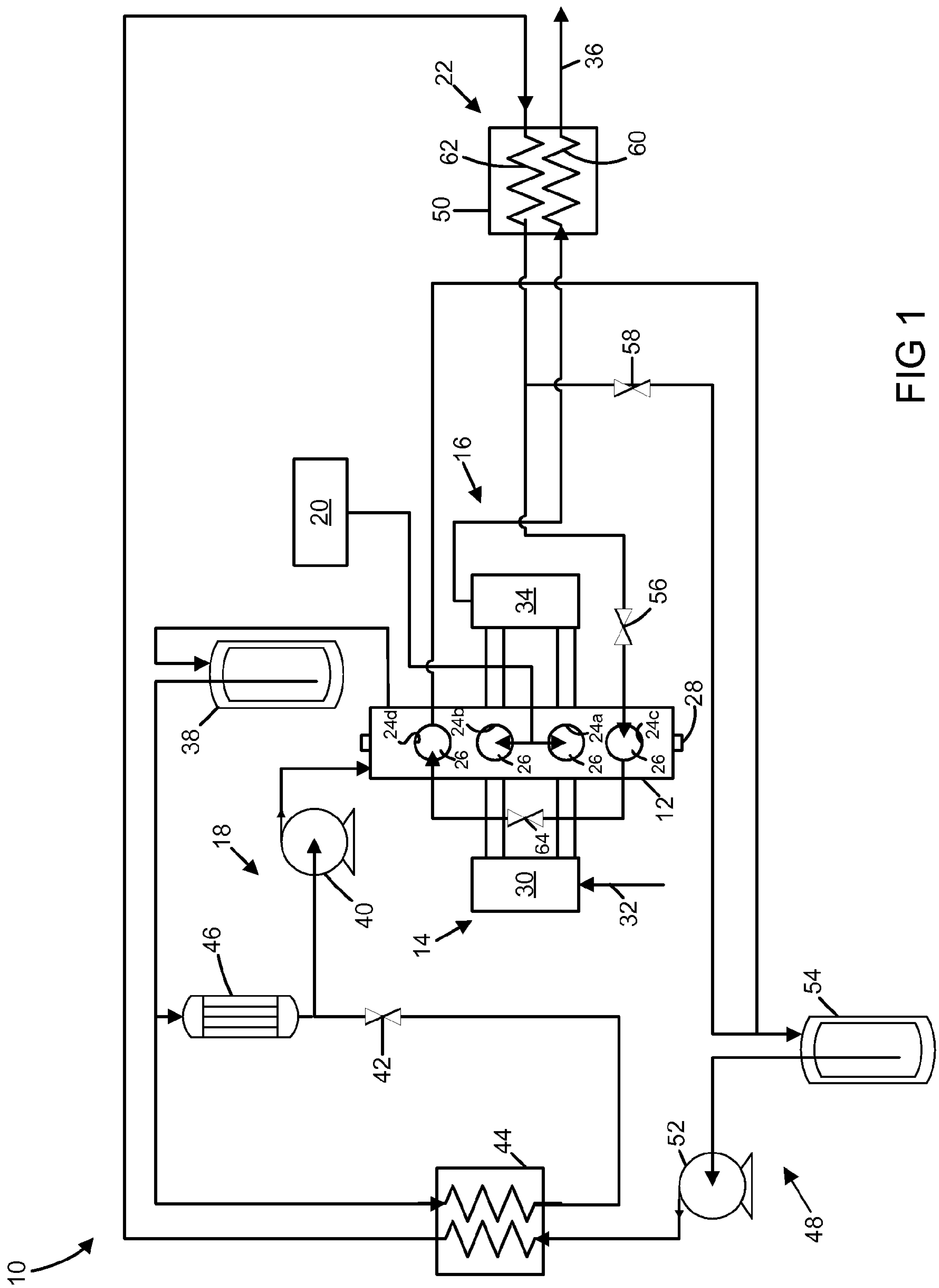

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FIG 1

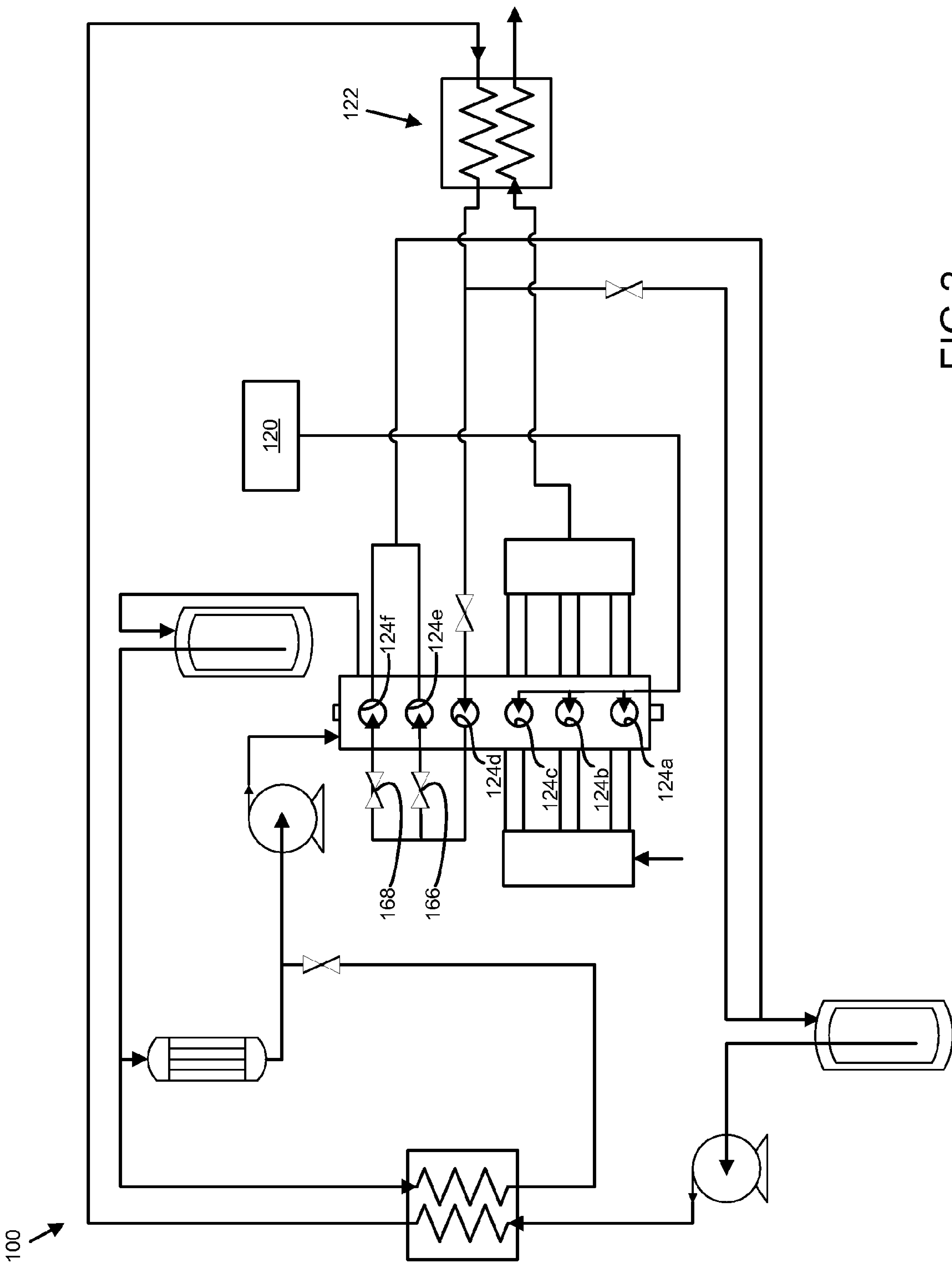

FIG 2

INTERNAL COMBUSTION ENGINE WITH INTEGRATED WASTE HEAT RECOVERY SYSTEM

FIELD

[0001] The present disclosure relates to engine assemblies including waste heat recovery systems.

BACKGROUND

[0002] This section provides background information related to the present disclosure which is not necessarily prior art.

[0003] Engine assemblies may include waste heat recovery systems to utilize heat produced by an engine. These systems may typically include an auxiliary expander device in fluid communication with a fluid heated by the engine. In order to couple the power generated by the expander to the engine, complicated coupling devices may be required. Additionally, the use of an auxiliary expander may generate excessive cost and packaging demands, as well as additional complexity for assembly.

SUMMARY

[0004] This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0005] An engine assembly may include a first heat exchanger, a fluid supply system providing a fluid flow to the first heat exchanger, a fuel system, an engine block defining first and second cylinder bores, a first piston disposed within the first cylinder bore, and a second piston disposed within the second cylinder bore. The first cylinder bore may receive fuel from the fuel system for combustion therein to drive the first piston. The fluid flow may be pressurized within the first heat exchanger and the pressurized fluid may be provided to the second cylinder bore to drive the second piston.

[0006] A method may include providing a fuel supply to a first cylinder bore of an engine block and igniting the fuel supply to power displacement of a first piston located in the first cylinder bore. The method may further include providing a fluid flow to a first heat exchanger to pressurize the fluid flow therein and providing the pressurized fluid flow to a second cylinder bore of the engine block to power displacement of a second piston locating in the second cylinder bore.

[0007] Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

DRAWINGS

[0008] The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

[0009] FIG. **1** is a schematic illustration of an engine assembly according to the present disclosure; and

[0010] FIG. **2** is a schematic illustration of an alternate engine assembly according to the present disclosure.

[0011] Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

DETAILED DESCRIPTION

[0012] Example embodiments will now be described more fully with reference to the accompanying drawings.

[0013] With reference to FIG. **1**, an engine assembly **10** may include an engine block **12**, an air intake system **14**, an exhaust system **16**, an engine cooling system **18**, a fuel system **20** and a waste heat recovery system **22**. The engine block **12** may define cylinder bores **24** having pistons **26** disposed therein and coupled to a crankshaft **28**. The engine block **12** may be formed as a unitary casting. The present non-limiting example illustrates an inline four cylinder engine configuration where first and second cylinder bores **24***a*, **24***b* are combustion cylinders and third and fourth cylinder bores **24***c*, **24***d* are pressure operated cylinders.

[0014] The air intake system **14** may include an intake manifold **30** in fluid communication with an air source **32** and the first and second cylinder bores **24***a*, **24***b*. The air intake system **14** may be isolated from the third and fourth cylinder bores **24***c*, **24***d*. The fuel system **20** may provide a fuel flow to the first and second cylinder bores **24***a*, **24***b*. The exhaust system **16** may include an exhaust manifold **34** in fluid communication with the first and second cylinder bores **24***a*, **24***b* and may be isolated from the third and fourth cylinder bores **24***c*, **24***d*. The exhaust manifold **34** may be in fluid communication with and provide an exhaust gas flow **36** from the first and second cylinders **24***a*, **24***b* to the waste heat recovery system **22**, as discussed below.

[0015] The engine cooling system **18** may include a coolant reservoir **38**, a coolant pump **40**, a thermostat valve **42**, a heat exchanger **44** and a cabin heater **46**. The coolant pump **40** may pump engine coolant from the coolant reservoir **38** through coolant passages (not shown) in the engine block **12** and then back to the coolant reservoir **38**. As the engine coolant passes through the engine block **12**, the coolant absorbs heat. The heated engine coolant is returned to the coolant reservoir **38**, as discussed above.

[0016] Before being returned to the engine block **12**, the engine coolant flows through the cabin heater **46** and/or the heat exchanger **44**. The cabin heater **46** and heat exchanger **44** may reduce a temperature of the coolant. More specifically, the cabin heater **46** may transfer the heat from the coolant to a vehicle interior. The heat exchanger **44** may additionally form part of the waste heat recovery system **22**, as discussed below. The amount of coolant flow passing through the heat exchanger **44** may be controlled by the thermostat valve **42**.

[0017] The waste heat recovery system **22** may include a fluid supply system **48** in fluid communication with a heat exchanger **50**. The fluid supply system **48** may include a pump **52**, a reservoir **54**, and first and second control valves **56**, **58**. The reservoir **54** may contain a fluid used the waste heat recovery system **22**. By way of non-limiting example, the fluid may include water. The reservoir **54** may additionally include a condenser to convert the fluid from a vapor form to a liquid. The heat exchanger **50** may include a first flow path **60** in fluid communication with the exhaust gas flow **36** exiting the first and second cylinders **24***a*, **24***b* and a second flow path **62** in fluid communication with the fluid from the fluid supply system **48**. The second flow path **62** may additionally be in fluid communication with the third cylinder **24***c*.

[0018] During operation, the fluid supply system **48** may force the fluid through the second flow path **62** in the heat exchanger **50**, where the exhaust gas **36** heats the fluid. The fluid may change from a liquid to a vapor based on the heating in the heat exchanger **50**. When the fluid transitions from liquid to the vapor, it may expand, increasing in pressure. The vapor is supplied to the third cylinder **24***c* where the increased pressure is applied to the piston **26** to assist in driving rotation of the crankshaft **28**. The amount of vapor supplied to the third cylinder **24***c* may be controlled by the first control valve **56**. Excess vapor may return to the reservoir **54** through the second control valve **58**.

[0019] After the power stroke of the third cylinder **24***c* is completed, the fluid may remain in the vapor state, and may therefore be used to power displacement of another piston **26**. More specifically, the third and fourth cylinders **24***c*, **24***d* may be in fluid communication with one another. Flow from the third cylinder **24***c* to the fourth cylinder **24***d* may be controlled by a third control valve **64**. The exhaust stroke of the piston **26** within the third cylinder **24***c* may provide the exhaust flow from the third cylinder **24***c* to the fourth cylinder **24***d*, where the piston **26** in the fourth cylinder **24***d* is displaced based on a pressure provided by the exhaust vapor from the third cylinder **24***c*. During the exhaust stroke of the piston **26** within the fourth cylinder **24***d*, the remaining vapor and/or liquid may be returned to the reservoir **54**.

[0020] In the present non-limiting example, the fluid flow may be provided to the heat exchanger **50** by the pump **52**. The fluid may first pass through the heat exchanger **44** of the cooling system **18** to provide an additional heat source for the fluid before passing through the heat exchanger **50**. Additionally, in the present non-limiting example, the first and second cylinders **24***a*, **24***b* (combustion cylinders) may be directly adjacent one another. The first and second cylinders **24***a*, **24***b* are generally located between the third and fourth cylinders **24***c*, **24***d*.

[0021] It is understood that while the first and third control valves **56**, **64** are schematically illustrated, each may be similar to an intake valve of an engine. Specifically, each of the first and third control valves **56**, **64** may be engaged with an engine camshaft (not shown) and may therefore be mechanically controlled. Further, while the engine assembly **10** is illustrated as an inline four-cylinder configuration, it is understood that the present teachings apply to a variety of other engine configurations including V-engines and horizontally opposed engines, as well as engines having more or less cylinders. For example, FIG. **2** illustrates the present teachings employed in an inline six cylinder arrangement.

[0022] Referring now to FIG. **2**, an alternate engine assembly **100** is schematically illustrated. As indicated above, the engine assembly **100** generally depicts an inline six cylinder engine employing a waste heat recovery system **122** generally similar to the waste heat recover system **22** of FIG. **1**. The engine assembly **100** may be generally similar to the engine assembly **10** shown in FIG. **1**. Therefore, it is understood that the description above generally applies with the exceptions noted below.

[0023] The engine assembly **100** may include an engine block defining first, second, and third cylinders **124***a*, **124***b*, **124***c* (combustion cylinders) in fluid communication with the fuel system **120** and fourth, fifth, and sixth cylinders **124***d*, **124***e*, **124***f* in fluid communication with the waste heat recovery system **122**. The fourth cylinder **124***d* may first receive the vapor from the waste heat recovery system **122** and the fifth and sixth cylinders **124***e*, **124***f* may receive exhaust vapor from the fourth cylinder **124***d*. Control valves **166**, **168** may control fluid communication between the fourth cylinder **124***d* and the fifth and sixth cylinders **124***e*, **124***f*.

[0024] In the inline six cylinder example shown in FIG. **2**, the first, second, and third cylinders **124***a*, **124***b*, **124***c* (combustion cylinders) may be directly adjacent one another. The fourth, fifth, and sixth cylinders **124***d*, **124***e*, **124***f* may each be directly adjacent to one another as well.

What is claimed is:

1. An engine assembly comprising:

a first heat exchanger;

a fluid supply system providing a fluid flow to the first heat exchanger, the fluid flow being pressurized within the first heat exchanger;

a fuel system;

an engine block defining first and second cylinder bores, the first cylinder bore receiving fuel from the fuel system for combustion therein and the second cylinder bore receiving pressurized fluid exiting the first heat exchanger;

a first piston disposed within the first cylinder bore and being reciprocally displaced by combustion within the first cylinder bore; and

a second piston disposed within the second cylinder bore and being reciprocally displaced by the pressurized fluid.

2. The engine assembly of claim **1**, wherein an exhaust gas produced by the combustion within the first cylinder bore is in fluid communication with the first heat exchanger, the exhaust gas providing a heat source to the first heat exchanger to raise the pressure of the fluid flow passing through the first heat exchanger.

3. The engine assembly of claim **1**, wherein the fluid flow enters the first heat exchanger as a liquid and exits the first heat exchanger as a vapor.

4. The engine assembly of claim **3**, wherein the fluid flow entering the first heat exchanger includes liquid water and the fluid flow exiting the first heat exchanger includes steam.

5. The engine assembly of claim **1**, further comprising an engine cooling system including a second heat exchanger having a engine coolant passing therethrough, the fluid supply system being in fluid communication with the second heat exchanger, the fluid flow being heated by the engine coolant passing through the second heat exchanger.

6. The engine assembly of claim **1**, wherein the engine block includes a third cylinder bore having a third piston disposed therein, the third cylinder bore receiving exhaust from the second cylinder bore to reciprocally drive the third piston.

7. The engine assembly of claim **6**, wherein the engine block includes a fourth cylinder bore having a fourth piston disposed therein, the fourth cylinder bore receiving fuel from the fuel system for combustion therein to reciprocally drive the fourth piston, the first and fourth cylinder bores being directly adjacent one another.

8. The engine assembly of claim **7**, wherein the second cylinder bore is adjacent to the first cylinder bore and the third cylinder bore is adjacent to the fourth cylinder bore.

9. The engine assembly of claim **7**, wherein the second and third cylinder bores are directly adjacent to one another.

10. The engine assembly of claim **1**, further comprising a crankshaft, the crankshaft engaged with and rotationally driven by the first and second pistons.

11. An engine waste heat recovery system comprising:
a first heat exchanger; and
a fluid supply system providing a fluid flow to the first heat exchanger, the fluid flow being pressurized within the first heat exchanger and provided to a first cylinder bore of an engine block to drive a first piston disposed therein, the engine block defining a second cylinder bore having a second piston disposed therein driven by combustion of fuel therein.

12. The engine waste heat recovery system of claim **11**, wherein the first heat exchanger is in fluid communication with an exhaust gas from the second cylinder bore, the exhaust gas providing a heat source to the first heat exchanger to raise the pressure of the fluid flow passing through the first heat exchanger.

13. The engine waste heat recovery system of claim **11**, wherein the fluid flow enters the first heat exchanger as a liquid and exits the first heat exchanger as a vapor.

14. The engine waste heat recovery system of claim **13**, wherein the fluid flow entering the first heat exchanger includes liquid water and the fluid flow exiting the first heat exchanger includes steam.

15. The engine waste heat recovery system of claim **11**, further comprising a second heat exchanger, the second heat exchanger being in fluid communication with an engine coolant and the fluid supply system, the fluid flow being heated by the engine coolant passing through the second heat exchanger.

16. A method comprising:
providing a fuel supply to a first cylinder bore of an engine block;
igniting the fuel supply to power displacement of a first piston located in the first cylinder bore;
providing a fluid flow to a first heat exchanger to pressurize the fluid flow therein; and
providing the pressurized fluid flow to a second cylinder bore of the engine block to power displacement of a second piston locating in the second cylinder bore.

17. The method of claim **16**, further comprising providing an exhaust gas from the first cylinder bore to the first heat exchanger to pressurize the fluid flow within the first heat exchanger.

18. The method of claim **16**, wherein the pressurization of the fluid flow includes heating the fluid flow to transform the fluid flow from a liquid to a vapor.

19. The method of claim **16**, wherein the providing a fluid flow includes providing water to the first heat exchanger and the pressurized fluid flow provided to the second cylinder bore includes steam.

20. The method of claim **16**, further comprising providing the pressurized fluid flow exiting the second cylinder bore to a third cylinder bore of the engine block during an exhaust stroke of the second piston.

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