

HYDRAULIC ENGINE

[0001] The present application claims the filing date of Chinese Utility Model application Nr. 201821362545.7 as its priority date, which was filed with CNIPA (China National Intellectual Property Administration) on 23 August 2018, and has the title of Cold Engine. All relevant content and/or subject matter of the earlier priority application is hereby incorporated by reference wherever appropriate.

[0002] The present application relates to a hydraulic engine and methods of making and using the hydraulic engine. The hydraulic engine is alternatively known as a Cold Engine. The present application also relates to a hydraulic engine which provides a new and improved way to drive certain components of a machine. The machine can be an engine or motor for converting one form of energy into mechanical energy, or vice versa.

[0003] An Internal Combustion Engine (ICE) is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine, the expansion of the high-temperature and high-pressure gases produced by combustion applies direct force to some component of the engine. The force is applied typically to pistons, turbine blades, rotor or a nozzle. This force moves the component over a distance, transforming chemical energy into useful mechanical energy.

[0004] In contrast, in external combustion engines, such as steam or Stirling engines, energy is delivered to a working fluid not consisting of, mixed with, or contaminated by combustion products. Working fluids can be air, hot water, pressurized water or even liquid sodium, heated in a boiler. An example is a railway locomotive driven by steam where the steam is generated by burning coal heating a water in the boiler. The water evaporates, condenses and is reused.

[0005] ICEs are usually powered by energy-dense fuels such as gasoline or diesel, liquids derived from fossil fuels. While there are many stationary applications, most ICEs are used in mobile applications and are the dominant power supply for vehicles such as cars, aircraft, and boats.

[0006] Typically, an ICE is fed with fossil fuels like natural gas or petroleum products such as gasoline, diesel fuel or fuel oil. There is a growing usage of renewable fuels like biodiesel for compression ignition engines and bioethanol or methanol for spark ignition engines. Hydrogen is sometimes used, and can be obtained from either fossil fuels or renewable energy.

[0007] Heat is transformed to mechanical energy by change of volume with increasing pressure acting on it. The change of volume can be caused by change of temperature. In Internal Combustion Engine, the volume of gas in an enclosure is heated rapidly usually by fuels derived from fossil fuels. Heat can also be transformed to mechanical energy by flow of working fluid like in a Rankine cycle system where steam is formed by heating water to achieve a high pressure and allow to discharge and expand to lower pressure causing vanes or impeller to rotate.

[0008] As long as there is pressure difference with change in volume caused by heat, mechanical energy can be produced. A common method, is using a high temperature heat which is fuelled by materials that have hydrogen and carbon elements content. Free energy from the sun will need bulky infrastructure, thus costly and not flexible to implement. The ambient environment (air) become heat sink for these engines to work properly without melting down.

[0009] Internal Combustion Engine requires high temperature to operate making it inefficient. Fossil fuels are depleting faster than they are replaced. Fossil fuels pollute the environment we live in affecting our health and is a contributing factor to global warming which is a result of the combustion of the fossil fuels. Therefore, the present application provides a solution to address the mentioned problems.

[0010] The present application aims to provide one or more new and useful hydraulic engine for driving some components in the engine. The present application further aims to provide one or more new and useful methods for making, assembling, disassembling, installing, configuring, maintaining, repairing and using the one or more devices for hydraulic engine. Essential features of the application are provided by one or more independent claims, whilst advantageous features are presented by their dependent claims respectively.

[0011] According to a first aspect, the present application provides a hydraulic engine. The hydraulic engine comprises a source for supplying a working fluid; a heat transfer system for supplying heat to the working fluid; and one or more hydraulic motors for converting a hydraulic flow of the working fluid into a mechanical motion of the one or more hydraulic motors. In the hydraulic engine, the working fluid flows out of the source, then absorb heat from the heat transfer system and finally drives the hydraulic motor.

[0012] The hydraulic motor comprises a mechanical actuator that converts a hydraulic pressure of the flowing working fluid into a torque and angular rotation or a displacement of the hydraulic motor. The hydraulic motor may comprise vane motor, gear motors, generator motor, axial plunger motor or a combination of the foregoing objects. In this way, a hydraulic energy of the flowing working fluid is converted into a mechanical energy of the hydraulic motor. The mechanical energy may be further converted to other energies such as an electrical energy if the hydraulic motor is connected to an electrical generator. Therefore, the hydraulic engine may have many applications in a variety of industries if a working load such as a pump or a powertrain is connected to the hydraulic motor.

[0013] The working fluid is a pressurized gas or liquid that actuates a machine. Examples include steam in a steam engine, air in a hot air engine and hydraulic fluid in a hydraulic motor or hydraulic cylinder. In a thermodynamic system, the working fluid is a liquid or gas that absorbs or transmits energy. The working fluid may have several characteristics such as desired thermodynamic properties, being non-corrosive to mechanical components (such as the hydraulic motor), and being safe to use (such as non-toxicity, inflammability and not causing to ozone depletion or climate change). In particular, the desired thermodynamic properties optionally comprise a boiling point below an operation temperature, a high heat of vaporization, a moderate density in liquid form, a relatively high density in gaseous form, and a high critical temperature. The boiling point and the gas density are further influenced by an operating pressure.

[0014] In some implementations, the working fluid comprises one or more liquefied gases (also called liquid gases). The liquefied gas may be used either as the fresh working fluid in the open source or the cycling working fluid in the closed-loop source or the semi closed-loop source. The liquefied gas may comprise ammonia, sulfur dioxide, inert gases and nitrogen in a liquid state or a coexistence of the liquid state and a gas state. The

liquefied gas optionally comprises liquefied carbon dioxide (also called liquid carbon dioxide). Carbon dioxide (CO₂ (R-744)) is non-flammable, non-ozone depleting, and has a global warming potential (GWP) of 1. Carbon dioxide can thus be used as the refrigerant (liquid or/and gas) in climate control systems for cars, residential air conditioning, hot water pumps, commercial refrigeration, and vending machines. In particular, carbon dioxide has a major advantage of working at very low temperature in the hydraulic engine. In other words, the liquefied carbon dioxide can raise a pressure significantly (such as many times) even if a temperature rises by a few degrees Celsius when the temperature is low (such as around minus 55 degrees Celsius). In addition, the liquefied carbon dioxide is stored in the high pressure vessel in a liquid state or in a gas state. Alternatively, the liquefied carbon dioxide stored in the high pressure vessel is optionally in an equilibrium of a liquid state and a gas state.

[0015] In addition to the liquefied gas, the working fluid optionally comprises air, (CH₄) methane, fluorocarbons (such as chlorofluorocarbons, hydrofluorocarbons (HFC), perfluorocarbons (FC), chlorofluorocarbons (CFC), and hydrochlorofluorocarbons (HCFC)), or non-halogenated hydrocarbons (such as propane). In an extreme case that the hydraulic engine operates at a temperature higher than the ambient temperature, the working fluid may comprise water, pressurized water or even liquid sodium that needs a very high temperature heat to be an effective working fluid.

[0016] The source of the hydraulic engine may comprise an open source, a closed-loop source, a semi closed-loop source according to a specific design of the hydraulic engine. In some implementations, the source optionally comprises an open source for providing a fresh working fluid as the working fluid flowing through the hydraulic engine. In particular, the fresh working liquid has a low temperature and a high pressure. The fresh working fluid absorbs thermal energy or heat while flowing by the heat transfer system and thus becomes a heated working fluid with a much higher pressure. The heated working fluid then flows through and drives the hydraulic motor; and finally flows out of the hydraulic engine and does not return to the open source.

[0017] When the liquefied carbon dioxide is adopted as the fresh working fluid, the open source optionally comprises a supply of dry ice for providing the liquefied carbon dioxide to the hydraulic engine. The dry ice is turned into the liquefied carbon dioxide at a temperature below a sublimation temperature of the dry ice.

[0018] In some implementations, the source optionally comprises a closed-loop source for circulating a cycling working fluid as the working fluid in the hydraulic engine. Similar to the fresh working fluid from the open source, the cycling working fluid also has a low temperature and a high pressure before flowing by the heat transfer system. However, the cycling working fluid returns to the closed-loop source after flowing through the hydraulic motor. Therefore, the hydraulic engine comprising the closed-loop source is considered as a closed system in thermodynamics. In other words, the hydraulic engine may exchange energy with a surrounding environment and does not have any substance exchange. In addition to the closed-loop source, the source may also comprise the open source as a backup for the closed-loop source. When the closed-loop source fails, the hydraulic engine can still work normally by using the open source.

[0019] The closed-loop source may comprise a high pressure vessel (such as a reservoir cylinder) for storing the cycling working fluid at an ambient temperature, a low pressure vessel (such as an expansion cylinder) for receiving the cycling working fluid at a low temperature, and a circulating system for driving the cycling working fluid to circulate in the hydraulic engine. The high pressure vessel has a first inlet and a first outlet; while the low pressure vessel has a second inlet and a second outlet. The second inlet of the low pressure vessel is configured to be connected to the first outlet of the high pressure vessel. The circulating system is configured to connect to the second outlet of the low pressure vessel and the first inlet of the high pressure vessel.

[0020] The high pressure vessel may be a hollow container, a hollow cylinder, a hollow tank, a hollow receptacle, a silo or a hollow chamber. The high pressure vessel is also known as a reservoir cylinder may have a thick wall or a wall constructed of a dense material to withstand an internal pressure exerted from a vessel interior. The internal pressure is higher than the atmospheric pressure (101,325 Pascal or 1.01325 bar or 14.6969 pounds per square inch). The internal pressure of exerted from the high pressure vessel interior can be seventy bars (70 bar) or more. The high pressure vessel can be made of brass, aluminum, hardened steel or stainless steel with a substantial wall thickness of ten millimeters (10 mm) and more.

[0021] The inlet and the outlet specifically a high pressure inlet portion and a high pressure outlet portion each comprises at least one valve. The high pressure inlet portion

comprises a high pressure inlet valve which may use a ball valve, a return inlet and a pressure relief valve. The ball valve which is used for filling or releasing the working fluid in the high pressure cylinder uses a hollow, perforated and pivoting ball to control flow through it. It is open when the ball's hole is in line with the flow and closed when it is

5 pivoted 90-degrees by the valve handle. The handle lies flat in alignment with the flow when open, and is perpendicular to it when closed, making for easy visual confirmation of the valve's status (open or close). It can be auto driven. The return inlet for receiving back the working fluid to the high pressure cylinder. A check valve is connected in series to the return inlet to prevent the working fluid from flowing out of the high pressure cylinder.

10 The pressure relief valve is a type of safety valve used to limit the pressure in a system; pressure might otherwise build up and create a process upset, instrument or equipment failure, or cause the cylinder to rupture. The pressure is relieved by allowing a pressurised fluid to flow from an auxiliary passage out of the high pressure vessel. The relief valve is designed or set to open at a predetermined set pressure to protect the high

15 pressure vessel and other equipment from being subjected to pressures that exceed their design limits. When the set pressure is exceeded, the relief valve becomes the "path of least resistance" as the valve is forced open and the fluid (liquid or/and gas) is diverted through the auxiliary route.

20 [0022] The high pressure outlet portion comprises a high pressure outlet valve. The high pressure inlet valve is disposed before the high pressure vessel in which the working fluid enters. The high pressure outlet valve is disposed at the outlet portion in which the working fluid discharges from the high pressure vessel to a low pressure vessel. The high pressure outlet valve is known as a start/stop valve is connected at the bottom of the high

25 pressure cylinder either directly or via a pipe so that the working fluid flow out is always in liquid state first. The start/stop (on/off) valve is used for systems that do not need the flow throttled or controlled. The valve opens to allow flow and closes to stop flow. They are also known as on/off service or block valves. It is often used with a manual hand wheel, but can be automated with an actuator. The start/stop valve is used when the fluid

30 (liquid or/and gas) flow needs to be diverted or for mixing applications when exact measurements are not required. Automated start/stop valve may be used in safety management systems to immediately shut off the system in an emergency situation. For the present application which works with air or gas, the start/stop (on/off) valve is used to regulate the flow through a piping (conduit)

[0023] The two valves can be independently operable to control the flow of fluid either going in or going out of the high pressure vessel. The high pressure inlet valve and the high pressure outlet valve can also be operable in unison. The control of the two valves can be performed using mechanical means (gears, shafts, relay) which is further controlled by electronic means (computer) either locally or remotely.

[0024] Alternatively, the high pressure vessel may be a conduit, a pipe, a duct, a channel that can have a cylindrical or other polygon cross-sectional area. In other words, the high pressure vessel is an enclosed body with at least two extremities unenclosed. The two extremities may have a screw cap on each extremity for fastening to each separate heat exchanger. The screw cap has an aperture disposed in the center in which the screw cap is slidably communicating with the high pressure vessel.

[0025] The inlet of the low pressure vessel specifically a low pressure inlet portion comprises a low pressure inlet valve. The low pressure inlet valve is disposed before the fluid enters the low pressure vessel in which the working fluid enters. The low pressure inlet valve regulates the flow of the working fluid into the low pressure vessel. The low pressure inlet valve is also known as a pressure reducing valve. The pressure reducing valve maintains a constant outlet pressure at the low pressure vessel despite a higher inlet pressure from the high pressure vessel.

[0026] The low pressure vessel comprises a wall that can withstand an interior pressure of at least seventy bar (70 bar) which is seventy times higher than the atmospheric pressure of one bar. The low pressure vessel can be made of brass, hardened steel, aluminum or stainless steel with a substantial wall thickness of ten millimeters (10 mm) or more.

[0027] In particular, the circulating system optionally further comprises a circulating pump for pushing the cycling working fluid to flow back to the high pressure vessel. Since the cycling working fluid may lose too much hydraulic pressure in the hydraulic motor, the circulating pump supplements an additional energy to the cycling working fluid for flowing from the hydraulic motor to the first inlet of the high pressure vessel.

[0028] In some implementations, the closed-loop source optionally further comprises a pressure reducing valve that connects the high pressure vessel to the low pressure

vessel. The hydraulic engine may further comprise an alternative connector (e.g. tube, pipe, duct, path) that connects the high pressure vessel to the low pressure vessel.

[0029] The closed-loop source optionally further comprises one or more high-pressure pumps (also known as high-head pumps) or compressors for enhancing a pressure of the working fluid for matching with an operation pressure of the hydraulic motor. The high-pressure pump may comprise a positive displacement pump, an impulse pump, a velocity pump, a gravity pump, a steam pump and a valveless pump (e.g. impedance pump, valveless rope pump). The positive displacement pump may further comprise a rotary lobe pump, a progressive cavity pump, a rotary gear pump, a piston pump, a diaphragm pump, a screw pump, a gear pump, a hydraulic pump, a rotary vane pump, a peristaltic pump, a rope pump, a flexible impeller pump. In particular, the progressing cavity can develop a very high pressure at a low volume. For example, when the liquefied carbon dioxide is adopted as the cycling working liquid, the high-pressure pump should enhance the pressure to at least seventy (70) bars.

[0030] The closed-loop source optionally further comprises one or more Joule-Thomson devices (such as narrow orifices) for cooling the working fluid from the high pressure vessel in a throttling process (also known as an adiabatic process). The Joule-Thomson device has one or more throttles. The Joule-Thomson device is alternatively known as Joule-Kelvin device, Kelvin-Joule device, or Joule-Thomson expansion device because the device causes temperature to change of a gas or liquid when the liquid or gas is forced through a valve or porous plug while kept insulated so that no heat is exchanged with the environment. The expansion of gas to liquid undergoes an adiabatic expansion process such that the gas or liquid has no heat exchange with the ambient environment of the low pressure vessel. Alternatively, the heat exchange between the low pressure vessel and the ambient environment is not sufficient (e.g. negligible) to maintain temperature of the gas or liquid during the expansion. In practice, one or more of the Joule-Thomson devices of different sizes can be connected in serial or parallel such that the one or more Joule-Thomson devices have multiple valves or porous plugs for expansion under force or pressure.

[0031] The closed-loop source optionally further comprises a warming device attached to the Joule-Thomson device. The throttling process cannot be over performed for preventing the cycling working fluid from being turned into a solid state if the temperature

drops below a solidification temperature of the cycling working fluid. For example, the liquefied carbon dioxide would have a temperature of minus 78 degrees Celsius after the pressure drops to 1 bar. In this case, the warming device turns the cycling working fluid from a solid state to a liquid state.

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[0032] The closed-loop source optionally comprises a bypass conduit for connecting the high pressure vessel with the low pressure vessel for equalizing a pressure of the high pressure vessel. In other words, a portion of the cycling working fluid flows from the high pressure vessel to the low pressure vessel via the bypass conduit when a pressure in the high pressure vessel rises beyond an upper limit. As a result, the hydraulic engine forms a closed system in thermodynamics with the bypass conduit.

[0033] Alternatively, the high pressure vessel may comprise a pressure releasing valve for releasing a portion of the working fluid outside the hydraulic engine when the pressure in the high pressure vessel is higher than the upper limit. In contrast to the closed-loop source with the bypass conduit, the specific source with the pressure releasing valve is called a semi closed-loop source. In addition, the semi closed-loop source may further comprise a supplementing source for automatically filling the high pressure vessel with the working fluid when the pressure of the high pressure vessel drops below a lower limit.

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[0034] The closed-loop source optionally comprises a warning device for sending a warning message when the cycling working fluid has a low flow rate. The warning device may comprise a light indicator, a sound indicator or a combination thereof that would be activated when the flow rate is lower than a pre-determined value. The hydraulic engine would be suspended or stopped until additional working fluid is filled into the high pressure vessel as the cycling working fluid.

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[0035] The heat transfer system comprises a rotary device for transferring the cycling working fluid from the low pressure to the high pressure vessel. For example, the rotary device is serially connected to the circulating pump for transferring the cycling working fluid from the outlet of the low pressure vessel to the inlet of the high pressure vessel. The rotary device may comprise a main chamber for receiving the cycling working fluid, and a heating chamber (also called an auxiliary chamber) for receiving a refrigerant, the first chamber and second chamber being separated from and contiguous with each other.

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[0036] The rotary device may comprise one or more movable vanes that are configured to extend from a rotor to a cylindrical wall of the rotary device. The rotary device may comprise an inner wall for providing the main chamber and the outer wall (e.g. chassis) for providing the auxiliary chamber. The inner wall comprises a portion that is thermally
5 conductive along the auxiliary chamber while the outer wall is thermally conductive.

[0037] The heat exchanger can comprise an auxiliary heat exchanger for keeping the refrigerant inside, whilst the auxiliary heat exchanger is connected to the auxiliary chamber of the rotary device. The auxiliary heat exchanger is optionally configured to
10 collect or gather heat from the surrounding environment or waste heat, or transfer heat from the refrigerant to a cooling application.

[0038] The heat transfer system optionally comprises a main heat exchanger that joins the rotary device to the second outlet of the low pressure vessel, and the main heat
15 exchanger is optionally connected to the working chamber of the rotary device. The main heat exchanger further comprises an independent heat exchanger configured to be located before the at least one hydraulic motor, wherein the working fluid flows from the at least one independent heat exchanger to the at least one hydraulic motor. Alternatively,
the main heat exchanger further comprises at least one integrated heat exchanger
20 configured to be installed to the at least one hydraulic motor, wherein the working fluid passing by the at least one integrated heat exchanger while flowing through the at least one hydraulic motor.

[0039] The independent heat exchanger optionally has a higher efficiency of heat
25 exchange with the working fluid, but is often bulky in size. In contrast, the integrated heat exchange may have a limited capacity of heat exchange, but save space. The heat transfer system is optionally selected according to the working fluid. For example, the integrated heat exchange is efficient enough for liquefied carbon dioxide which can raise the pressure significantly even if the temperature increases by a few degree Celsius.

[0040] The auxiliary heat exchanger optionally further comprises a first auxiliary heat exchanger (such as a first heat gathering sub-system for collecting or gathering heat from the surrounding environment or waste heat, or transfer heat from the refrigerant to a
cooling application.

[0041] The auxiliary heat exchanger further comprises a second auxiliary heat exchanger (such as a second heat gathering subsystem) for transferring heat from the refrigerant to a cooling application.

5 [0042] The heat transfer system optionally comprises a return heat exchanger for further raising the temperature of the cycling working fluid in order to match a temperature of the high pressure vessel before the cycling working fluid flows back to the high pressure vessel. In the closed-loop source, the temperature of the cycling working fluid after the return heat exchange should be raised around the temperature of the high pressure
10 vessel.

[0043] In particular, the return heat exchange collects (or absorbs) heat from an external medium. For example, if the temperature of the high pressure vessel is around an ambient temperature such as 30 degrees Celsius, the return exchange collects heat from
15 a surrounding environment at an ambient temperature or waste heat (low-grade heat); and then transfers the collected heat to the working fluid for raising the temperature of the working fluid also close to the ambient temperature.

[0044] The main heat exchange, the auxiliary exchanger or the return heat exchanger
20 may comprise a passive heat exchanger such as a heat sink, an active heat exchanger or a combination of the passive heat exchanger and the active heat exchanger. The active heat exchanger optionally comprises a double pipe heat exchanger, a shell and tube heat exchanger, a plate heat exchanger, a plate and shell heat exchanger, an adiabatic wheel heat exchanger, a plate fin heat exchanger, a pillow plate heat exchanger,
25 a fluid heat exchanger, a waste heat recovery unit, a dynamic scraped surface heat exchanger, a phase-change heat exchanger, a direct contact heat exchanger, a microchannel heat exchanger or a combination of the foregoing objects.

[0045] The heat transfer system may get in contact with the working fluid directly or
30 indirectly, according to the specific heat exchanger. For example, a simple heat exchanger (such as the passive heat exchanger or the double pipe heat exchanger) is efficient enough if the liquefied gas is adopted as the working fluid.

[0046] The heat transfer system or heat exchanger is a device used to transfer heat
35 between a solid object and a fluid (liquid or/and gas), or between two or more fluids. Heat

exchanger may include one or more of the following types; a shell and tube heat exchanger, a plate heat exchanger, a plate and shell heat exchanger, an adiabatic wheel heat exchanger, a plate fin heat exchanger, a pillow plate heat exchanger, a fluid heat exchanger, a waste heat recovery unit, a dynamic scraped surface heat exchanger, a phase-change heat exchanger, a direct contact heat exchanger, and a microchannel heat exchanger.

[0047] The heat exchanger may comprise a pump for driving the working fluid from the outlet of the low pressure vessel to the inlet of the high pressure vessel. The heat exchanger is configured to absorb heat from an external medium (of the heat exchanger) for raising the pressure of the working fluid at the heat exchanger. The pump moves fluids (liquid or/and gas) by mechanical action. The pump between the low pressure vessel and the heat exchanger uses a high pressure pump. The high pressure pump raises the pressure from around 15 atmospheric bar at the low pressure vessel to 70 atmospheric bar and above at the heat exchanger.

[0048] The high pressure vessel is connected to the low pressure vessel and connected to the at least one heat exchanger by an alternative connector, for example a tube, a pipe, a duct, a path or a conduit. The tube is made from stainless steel or flexible hose with an outside diameter (OD) about 6 millimeters or more. The tube wall thickness about 2 millimeters or more.

[0049] The heat exchanger further comprises a rotary device connected to the high pressure pump for transferring the working fluid from the outlet of the low pressure vessel to the high pressure inlet of the high pressure vessel. The rotary device comprises at least one movable vane that is configured to extend from a rotor to a (cylindrical) wall of the rotary device. The rotary device can further be a turbine with fan blades attached to a rotating shaft. The fluid is injected into the rotary device which propels the fan blades.

[0050] In the hydraulic engine, the operating temperature is shifted lower to about minus 55 degrees Celsius and any rise in temperature even by a few degrees can raise the pressure many times. Such increase in pressure when discharges to lower pressure will generate a flow of the working fluid likes a hydro power generator.

[0051] A very cold liquid carbon dioxide is an ideal working fluid for the hydraulic engine. It is easily produced on site next to the application and remains in liquid state in a closed loop cycle. The very cold liquid carbon dioxide easily heats up in a short time with a few degree rise, raising the pressure to at least a hundred bars. The discharged cold liquid carbon dioxide warms up a little and remains way below zero degree Celsius, allowing further use in freeze desalination for getting fresh water out from seawater or waste water and thereafter as chilled water for cooling application. It may be discharged at around ambient temperature if it is subjected to very high temperature refrigerant or external heat source.

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[0052] The heat exchangers can be powered by a single-phase, a two-phase or a three-phased power from an electrical grid. Each valve can be controlled by an actuator which is connected to a computer providing a remote control of each valve independently or in unison.

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[0053] A filtering means may optionally be added providing filtration of the liquid carbon dioxide. There may be cases where impurities are mixed in the fluid and formed solid carbon dioxide which may damage the internal components of the heat exchanger, the rotary device and the valves.

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[0054] The fresh working fluid from the open source or the cycling working fluid from the closed-loop source are turned into the hot working fluid that would rapidly undergoes a significant change in volume in the hydraulic motor. The hot working fluid may partially evaporative in the process and produce the higher pressure in the hydraulic motor.

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[0055] The hydraulic motor may also comprise one or more non-return valves for preventing backflow of the cycling working fluid. The non-return valve is also known as a check valve, clack valve, or one-way valve that normally allows fluid (liquid or gas) to flow through it in only one direction. Hence, the one or more non-return valves prevent the hydraulic motor from reversing as the backward is a lower pressure zone. The fluid in hydraulic motor must absorbs enough heat to overcome the forward pressure and creates the forward flow. Since the ambient heat engine operates at pressure values substantially higher than its ambient environment, the one or more non-return valves can insulate or separate parts of the ambient heat engine for fault isolation or maintenance.

35 The non-return valves may be connected in parallel to allow higher flowrate. Such many

non-return valves in parallel can be housed in one compact block thus reducing the physical size. The one or more non-return valves can also be connected to the low pressure heat exchanger, the high pressure heat exchanger, the Joule-Thomson device or a combination of any of these for directing flow of the fluid.

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[0056] The hydraulic engine may comprise a plurality of hydraulic motors connected in series, no matter the source is either the open source or the closed-loop source. The working fluid flows through the plurality of hydraulic motors in sequence, if the pressure is still high enough to drive the plurality of hydraulic motors. In contrast, the hydraulic engine may further comprise one or more additional heating devices for further heating the working fluid when the temperature of the working fluid is still low. Therefore, the pressure of the working fluid is continuously raised by being heated by the additional heating devices.

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[0057] Alternatively, the working fluid may flow through an external heat exchanger such that the working fluid is optionally applicable to a cooling application, such as desalination of seawater or waste water. Since the temperature of the working fluid is still well below the water freezing point of zero degree Celsius, the working fluid can freeze fresh water from the seawater or the waste water.

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[0058] The connection between each component is easily disassembled for maintenance. Maintenance can comprise cleaning by using acid cleaning, sandblasting, high pressure water jet, bullet cleaning, drill rods or using ultrasound (micro vibration); and replacing defective components.

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[0059] The hydraulic engine of the present application may be compact and thus suitable with scalability to drive loads like electric generators, or pumps as well as powertrains of movable vehicles or directly drive the wheel or propeller, performing like the current Internal Combustion Engine. In addition, the discharged very cold liquid carbon dioxide needs to get back to ambient temperature and hence the thermal energy required can be obtained by cooling applications like lowering the temperature in a closed or opened area. If the discharged very cold liquid carbon dioxide is below water freezing point, it can use further like freeze desalination of getting fresh water from seawater or waste water and thereafter for cooling applications. The hydraulic engine is more useful than Internal Combustion Engine (ICE) as it can take the low grade thermal energy of waste heat or

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ambient heat from surroundings as energy source for generating power as well as fresh water and cooling. If heating source is added to provide more energy source, it is best to add in a very high temperature reactor for decomposition of wet organic waste as after the process, the waste heat can be recovered by the hydraulic engine for more energy source. With this reactor, the hydraulic engine can function to provide power, freshwater and wet organic wastes disposal in an area especially a remote place self-sustainable in basic utilities. It can deliver these utilities at site making power transmission line, water and sewage piping network redundant.

10 [0060] According to a second aspect, the present application provides a method of making the hydraulic engine. The method of making the hydraulic engine comprises a first step of providing a source for supplying a working fluid; a second step of providing a heat transfer system for supplying heat to the working fluid; a third step of providing one or more hydraulic motors; and a fourth step of assembling the source, the heat transfer system and the hydraulic motor.

[0061] The method of making may further comprise a step of installing a main heat exchanger to the heat transfer system for heating the working fluid. The method of making may further comprise a step of installing an auxiliary heat exchanger to the heat transfer system for heating a refrigerant. The method of making may further comprise a step of installing at least one non-return valve for preventing the working fluid from back flowing.

[0062] The first step of providing a source optionally further comprises a step of providing a resource of the working fluid; a step of providing a converter for converting the resource of the working fluid into a fresh working fluid at an open source as the source; and a step of connecting the open source to the heat transfer system and the at least one hydraulic motor. The fresh working fluid does not flow back to the open source. In addition, if the liquefied carbon dioxide is adopted as the fresh working fluid, the resource comprises a supply of dry ice such as a dry ice tank or reservoir.

[0063] Alternatively, the first step of providing a source optionally further comprises a step of providing a high pressure vessel for storing a cycling working fluid; a step of providing a low pressure vessel for receiving the cycling working fluid; a step of providing a circulating system for driving the cycling working fluid; and a step of assembling the

high pressure vessel, the low pressure vessel and the circulating system for forming a closed-loop source as the source. The cycling working fluid flows back to the high pressure vessel.

5 [0064] The method of making may also comprise a step of installing a circulating pump to the circulating system for pushing the cycling working fluid to flow in the hydraulic engine, from the hydraulic motor to the high pressure vessel. The method of making may also comprise a step of installing a return heat exchanger to the heat transfer system for further raising a temperature of the cycling working fluid after flowing out of the hydraulic
10 motor. The method of making may also comprise a step of installing a bypass conduit to the high pressure vessel for equalizing a pressure of the high pressure vessel. The method of making may also comprise a step of installing a pressure reducing valve connecting the high pressure vessel to the low pressure vessel for maintaining a constant pressure at the second outlet of the low pressure vessel.

15 [0065] According to a third aspect, the present application provides a method of using the hydraulic engine. The method of using the hydraulic engine comprises a first step of supplying a working fluid from a source; a second step of operating a heat transfer system for supplying heat to the working fluid; and a third step of operating at least one hydraulic
20 motor. The working fluid flows through and drives the at least one hydraulic motor.

[0066] The method of using the hydraulic engine may further comprise a step of operating a main heat exchanger of the heat transfer system for heating the working fluid. The method of using the hydraulic engine may further comprise a step of operating an
25 auxiliary heat exchanger of the heat transfer system for heating a refrigerant. The method of using the hydraulic engine may further comprise a step of unlocking at least one non-return valve for preventing the working fluid from back flowing. The first step of supplying a working fluid from a source further comprise a step of supplying a resource of the working fluid; and converting the resource of the working fluid into a fresh working fluid
30 at an open source as the source. The fresh working fluid does not flow back to the open source.

[0067] Alternatively, the first step of supplying a working fluid from a source further comprise a step of releasing a cycling working fluid from a high pressure vessel; a step
35 of receiving the cycling working fluid into a low pressure vessel; and a step of driving the

cycling working fluid by a circulating system. The cycling working fluid flows back to the high pressure vessel.

[0068] The method of using the hydraulic engine may further comprise a step of operating a circulating pump to the circulating system for pushing the cycling working fluid to flow in the hydraulic engine, from the hydraulic motor to the high pressure vessel. The method of using the hydraulic engine may further comprise a step of operating a return heat exchanger to the heat transfer system for further raising a temperature of the cycling working fluid after flowing out of the hydraulic motor. The method of using the hydraulic engine may further comprise a step of opening a bypass conduit to the high pressure vessel for equalizing a pressure of the high pressure vessel. The method of using the hydraulic engine may further comprise a step of unlocking a pressure reducing valve connecting the high pressure vessel to the low pressure vessel for maintaining a constant pressure at the second outlet of the low pressure vessel.

[0069] The accompanying figures (Figs.) illustrate embodiments and serve to explain principles of the disclosed embodiments. It is to be understood, however, that these figures are presented for purposes of illustration only, and not for defining limits of relevant inventions.

Fig. 1 illustrates a schematic of a first hydraulic engine;
Fig. 2 illustrates a process flow of the first hydraulic engine;
Fig. 3 illustrates a schematic of a second hydraulic engine;
Fig. 4 illustrates a schematic of a third hydraulic engine; and
Fig. 5 illustrates a schematic of a rotary device in the first, the second or the third hydraulic engine.

[0070] Exemplary, non-limiting embodiments of the present application will now be described with references to the above-mentioned figures.

[0071] Fig. 1 illustrates a schematic of a first hydraulic engine assembly 100. The hydraulic engine assembly 100 comprising a reservoir cylinder 102, an expansion cylinder 104, a high pressure pump 106, a rotary device 108, a plurality of heat exchanger, a heat transfer pump 110, a plurality of valve, and a plurality of conduit. The plurality of heat exchanger comprises a first heat gathering sub-system 112 (heat exchanger 1) 112 a second heat gathering -subsystem (heat exchanger 2) 114, and a return heat

exchanger (heat exchanger 3) 116. The plurality of valve and conduit will be described in detail in the following paragraphs.

[0072] An internal combustion engine (ICE) uses fossil fuel which can be petrol and couple with an intake of air and an ignition at a correct timing, an explosion is created producing expanding air as the propellant to drive a piston. In contrast, the hydraulic engine uses a heated up cold fluid as the propellant to drive some components which may include the piston, a fan blade, a turbine, or any device that can harvest a kinetic energy.

[0073] In the hydraulic engine assembly 100, the reservoir cylinder 102 is connected to the expansion cylinder 104. The reservoir cylinder 102 has an opened brim 138 at a top portion and a reservoir cylinder outlet 136 at a bottom portion. A three-port adaptor 118 comprises a pressure release valve 120 is screwingly (e.g. connecting by screw-like device) attached to the opened brim. The opened brim has a corresponding screw thread along an inner periphery thereof. The three-port adaptor 118 comprises a first port 122 for a return inlet with a check valve "D" 124, a second port 126 with a ball valve 128 for filling up of liquid carbon dioxide from external source or emptying the carbon dioxide from the hydraulic engine assembly 100 and a third port 130 comprises a bypass inlet 132. The reservoir cylinder 102 contains a liquid carbon dioxide 134 which seats at the bottom portion. The liquid carbon dioxide 134 flows regulated into a reservoir-expansion conduit 140 and into the expansion cylinder 104. The reservoir cylinder 102 is made of aluminum which has a height of about four hundred millimeters (400 mm), an outer diameter of about a hundred and twenty millimeters (120 mm) with a wall thickness of about ten millimeters (10.0 mm). The actual size and shape of the reservoir cylinder 102 depends on the desired amount of liquid carbon dioxide 134 intended to hold to meet the operation requirement and fit into the assembly 100. The reservoir cylinder outlet 136 has an inner diameter of about fifteen millimeters (15 mm). The opened brim 138 has an outer diameter of about twenty-five millimeters (25 mm). The word "diameter" implicitly relates to the part as being circular in shape.

[0074] The reservoir-expansion conduit 140 is screwingly attached (e.g. via Archimedes' screw) to the reservoir cylinder outlet 136 of the bottom portion. The reservoir-expansion conduit 140 has a first end communicatively connected to the bottom portion of the reservoir cylinder 102 and a second end sealingly communicating into the expansion

cylinder 104. The reservoir-expansion conduit 140 is made of stainless steel tube with an outer diameter (OD) of about twenty millimeters (20 mm). The expansion cylinder 104 has a top section and a bottom section. The bottom section has an exposed circular section. A cold liquid carbon dioxide 144 is seated at the bottom section. The cold liquid carbon dioxide 144 herein is colder than the liquid carbon dioxide 134 at the reservoir cylinder 102 and is at a lower pressure. The dimension of the expansion cylinder 104 is based on the desired volume of the cold liquid carbon dioxide and in this example, it is six times smaller in volume than the reservoir cylinder 102.

[0075] Immediately after the expansion, the carbon dioxide gets extremely cold and condense back in higher density, higher than the liquid carbon dioxide 134 in the reservoir cylinder 102. The cold liquid carbon dioxide 144 formed just the right amount needed for feeding the high pressure pump 106 at every instance. The expansion cylinder 104 gets very cold and needs to warm up to prevent the carbon dioxide from solidifying. This is a source of very cold energy for other application like freezing desalination of fresh water from sea or waste water or simply having a fan blowing to get the coolness and water from condensation.

[0076] Interposed between the first end and the second end of the reservoir-expansion conduit 140 is a start/stop valve 142. The second end is extended into a top section of the expansion cylinder 104 which has a pressure reducing valve 146 terminating thereof and a check valve "F" 148 is attached in case a sudden increase in pressure in the expansion cylinder 104 which is higher than the pressure in the reservoir cylinder 102, the check valve "F" releases the liquid carbon dioxide back 134 to the reservoir cylinder 102. The check valve "F" 148 is connected to a bypass conduit 150. The bypass conduit 150 is connected to the bypass inlet 132 which is attached to the reservoir cylinder 102 so that any increase in pressure in the expansion cylinder 104 over the pressure in the reservoir cylinder 102 can be equalized.

[0077] The bottom section of the expansion cylinder 104 has a funnel tapering end. The funnel tapering end has an outer peripheral screw thread. A check valve "A" is coupled to the funnel tapering end by a corresponding screw thread. The check valve "A" is connected to a pump inlet of the high pressure pump 106. The high pressure pump 106 has the pump inlet and a pump outlet.

[0078] The liquid carbon dioxide 134 flows regulated out of the expansion cylinder 104 normally to the check valve "A". The check valve "F" provides a channel for the carbon dioxide to flow back to the reservoir cylinder 102. The carbon dioxide accesses check valve "F" only when there is an exceptional high pressure compare to the reservoir cylinder 102 forcing the carbon dioxide to take the bypass conduit 150 back into the reservoir cylinder 102. Therefore, the first hydraulic engine assembly 100 comprises a closed-loop source 101 for providing the liquefied carbon dioxide as a cycling working fluid. The first hydraulic engine assembly 100 is considered as a closed system in thermodynamics.

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[0079] The pump outlet of the high pressure pump 106 is connected to the rotary device 108 via a pump-rotary conduit 154. The rotary device 108 has two chambers; a working chamber and a heat chamber. Each chamber has one input port and one output port.

15 [0080] The working chamber's input port has a check valve "B" 156 attached thereto and an output port has a check valve "C" 158. The heat chamber's input port has a check valve "E" 160 attached thereto and an output port with no valve. Check valve "B" 156 receives the high pressured cold liquid carbon dioxide 144 from the pump outlet of the high pressure pump 106 to the working chamber of the rotary device 108. Check valve
20 "E" 160 receives the refrigerant from the heat transfer pump 110 to the heat chamber of the rotary device 108. The refrigerant brings in the heat for the cold liquid carbon dioxide, in one direction, either clockwise or anti clockwise.

[0081] The rotary device 108 has a plurality of vane in the working chamber that is
25 centrally attached to a rotating shaft also known as a rotor. Each vane is positioned equidistant from adjacent vane as determined by the angle. The rotary device 108 in Fig. 1 shows eight vanes which means the angle to position the one vane will be forty-five degrees (45°) from the second vane. Each vane is constructed to have close contact with an interior peripheral wall with the end of the vane attached with a pliable membrane, for
30 example a rubber piece. Each vane is specially formed to catch the pressured, fast flowing liquid carbon dioxide 134 maximally. The liquid carbon dioxide 134 is ejected into the rotary device 108 from the check valve "B" 156. The rotating vanes will in turn rotate another device which is not shown here.

[0082] The very cold liquid carbon dioxide first enters the rotary device 108 at the working chamber's input port, check valve "B" 156. The cold liquid carbon dioxide 144 picks up heat from the rotary device 108 inner wall. The heat is mostly transferred from the heat chamber brought in by the refrigerant. The temperature of the cold liquid carbon dioxide 144 rises and the pressure increases. The pressure at the input port specifically check valve "B" 156 is high as a result of the high pressure pump 106. The pressure at check valve "B" 156 is always higher than the first output port, check valve "B". The pressure flow from a high pressure plenum to a lower pressure plenum which drives the vanes and hence driving the rotor on the shaft to perform work.

[0083] The liquid carbon dioxide 134 exits through the check valve "C" and enters the return heat exchanger (heat exchanger 3) 116 where the liquid carbon dioxide 134 pick up more heat to raise its temperature to at least close to an ambient temperature. The carbon dioxide discharges from the return heat exchanger flows through a return-reservoir conduit 162 back to the reservoir cylinder 102 via the check valve "D" 124. A discharge ball valve 164 is attached to the return-reservoir conduit 162 close to the check valve "D" 124 for releasing the fluid inside the hydraulic engine assembly 100. The discharge ball valve 164 is initially opened in an initial setup to allow any residual carbon dioxide to be discharged. The discharging provides a flushing out of the initial fluid before filling the hydraulic engine assembly 100 with only carbon dioxide. The discharge ball valve 164 will remain close after the initial setup.

[0084] The refrigerant is pumped through the first heat gathering sub-system (heat exchanger 1) 112 gathering heat from its path. In other words, harnessing heat from any sources that can raise the temperature of the refrigerant. Such heat source can be wasted heat from other processes and or ambient heat where the processes can be work performed by the other parts inside the hydraulic engine assembly 100. The refrigerant (e.g. water) then flows out from the first heat gathering sub-system (heat exchanger 1) 112 to the heat chamber input port, check valve "E" 160.

[0085] Functionally, the reservoir cylinder 102 is to hold and contain a fluid specifically the liquid carbon dioxide 134 in a pressurized environment. An internal pressure inside the reservoir cylinder 102 is set at 70 to 80 atmospheric bar.

[0086] The pressure release valve 120 located at the top portion of the reservoir cylinder 102 provides a release of the pressure if it is over 150 bar in the reservoir cylinder 102.

[0087] The discharge ball valve 164 that is along the return-reservoir conduit 162, the start/stop valve 142 and the pressure reducing valve 146 along the reservoir-expansion conduit 140 provide another release channel during the infilling of the liquid carbon dioxide 134 into the reservoir cylinder 102.

[0088] The check valve "B" 156 prevents the cold liquid carbon dioxide 144 from back flowing. The cold liquid carbon dioxide 144 exits the outlet of the rotary device 108 with a higher temperature, to return to the reservoir cylinder 102 through the return heat exchanger (heat exchanger 3) 116 which can gather more heat to raise the return liquid carbon dioxide 134 temperature to around 20 degrees Celsius for a new cycle in a closed loop operation.

[0089] The check valve "C" 158 prevents the cold liquid carbon dioxide 144 from flowing back to the working chamber of the rotary device 108 after discharging therefrom. The check valve "D" 124 prevents the liquid carbon dioxide 134 from flowing back to the return heat exchanger (heat exchanger 3) 116. The check valve "F" 148 provides a control of the flow of the cold liquid carbon dioxide 144 when it gets warmer with the pressure higher than the liquid carbon dioxide 134 in the reservoir cylinder 102 to return back to the reservoir cylinder 102 through the bypass conduit 150.

[0090] In use, the reservoir cylinder 102 is filled to 70 bar or higher, the start/stop valve 142 is opened allowing the liquid carbon dioxide 134 to discharge through the pressure reducing valve into 146 the expansion cylinder 104. The temperature in the reservoir cylinder 102 is at 30°C with a reservoir cylinder 102 pressure of 70 bar just to maintain the carbon dioxide in its liquid and gaseous phase. Proportionally, if the temperature in the reservoir cylinder 102 is lowered, the reservoir cylinder 102 pressure will also be lowered which will be elaborated in an example detailed in the next paragraph.

[0091] The liquid carbon dioxide 134 in the reservoir cylinder 102 is discharged to the expansion cylinder 104 to a pressure of 20 bar (from 70 bar to 20 bar) forming a cold liquid carbon dioxide 144 at minus 20 degrees Celsius (from 30 °C to -20°C) or lower. In order to obtain the cold liquid carbon dioxide 144, the liquid carbon dioxide 134 from the

reservoir cylinder 102 is discharged to a pressure of about 5.18 bar at a temperature of minus 56.5 degrees Celsius. (-56.5°C). A magnitude below the mentioned two parameters, for example, a lower pressure and a lower temperature will result in a solid carbon dioxide. The cold liquid carbon dioxide 144 at minus 20 degrees Celsius, 20 bars
5 has a density of about 1040 kg per cubic metre

[0092] The pressure of the cold liquid carbon dioxide 144 is then increased to match the pressure at the reservoir cylinder 102 (70 bar) by using a high pressure pump 106 before feeding into the input port (check valve "B" 156) of the rotary device 108. Notably, the
10 load resistance created by the vanes on the rotor of the rotary device 108 causes the high pressure pump 106 to increase the pressure of the cold liquid carbon dioxide 144 at the input port (check valve "B" 156).

[0093] Just for illustrative purpose, a kilogram of solid carbon dioxide in an isochoric
15 process absorbs 10 Kilo-Joules of heat, the temperature of the cold liquid carbon dioxide 144 in the first chamber of the rotary device 108 rises to about minus 15 degrees Celsius (-15 °C) from -20 °C and the pressure can increase from 70 bar to about 100 bar.

[0094] Work is performed when a unit force is used to displaced an object according to
20 the definition of work done in physics. The final temperature of the cold liquid carbon dioxide 144 may be at below 30 degrees Celsius depending of the heat transfer rate. It is important the discharged carbon dioxide temperature be around 15 degrees Celsius and above with the pressure at 70 bars, it can then be recycled to form the cold liquid carbon dioxide 144 at minus 20 degrees Celsius or lower, 20 bars or lower but above 5.2
25 bars to complete the closed loop cycle without further supplying fresh external supply of liquid carbon dioxide 134.

[0095] Returning to the discussion on the high pressure pump 106, the cold liquid carbon dioxide 144 is drawn in by the high pressure pump 106. The check valve "A" 152 is
30 inserted to prevent back flow to the expansion cylinder 104 when the hydraulic engine stops operating. The high pressure pump 106 increases the pressure of the cold liquid carbon dioxide 144 to at least the same pressure in the reservoir cylinder 102.

[0096] The cold liquid carbon dioxide 144 enters the input port (check valve "B" 156) of
35 the working chamber 168 of the rotary device 108 absorbing the heat from the periphery

wall of the rotary device 108 causing its temperature to rise and hence an increase in pressure and expansion to push the movable vanes in the working chamber 168 of the rotary device 108 turning its rotor and shaft thus transforming the heat energy to mechanical energy.

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[0097] The heat is introduced into the housing of the rotary device 108 by the heat transfer pump 110 with the first heat gathering subsystem (heat exchanger 1) 112 where the heat of at least over 15 degrees Celsius can be harvested. The higher the temperature, more heat energy can be transferred for the hydraulic engine to deliver more power. The refrigerant or hot heat transfer fluid 166 is delivered close to the input port (check valve “E” 160) of the working chamber of the rotary device 108 and flow into the heat chamber where the cold liquid carbon dioxide 144 flow close and where the chambers inner wall of the rotary device 108 is not thermally insulated. The heat transfer fluid 166 exits the rotary device 108 colder and flow through a second heat gathering subsystem 114 where the coldness can be transferred out for cooling application and eventually warming up the heat transfer fluid 166. The check valve “E” 160 is inserted to prevent the heat transfer fluid 166 back flowing.

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[0098] Fig. 2 illustrates a process flow of the hydraulic engine detailing the flow of the liquid carbon dioxide 134 as described in Fig. 1. The reservoir cylinder 102 provides a reservoir 103 for the storage of the liquid carbon dioxide 134. The expansion cylinder 104 provides an expansion chamber 105 for the expansion of the liquid carbon dioxide 134 within. In an unlikely event that the liquid carbon dioxide 134 expands in volume and increase in pressure, the carbon dioxide will be directed back to the reservoir cylinder 102 via the check valve “F” 148 and the bypass inlet 132.

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[0099] The pressurized cold liquid carbon dioxide 144 then driven by the high pressure pump 106 is forced into the rotary device 108 via the check valve “B” 156. The rotary device 108 comprises the working chamber 168, the heat chamber 170, a plurality of vane 172, a rotor 174, a shaft 175, the two input ports 176,178 and the two output ports 180,182. The first input port 176 is attached with the check valve “B” 156. The corresponding output port known as a first output port 180 is attached with the check valve “C” 158. The second input port 178 is attached with the check valve “E” 160 with the corresponding output port known as a second output port 182 without any valve. The vanes 172 having two ends. A first end is attached to the centre shaft 175 and a second

end to a wall of the rotor 174. The rotor 174 is circumferentially engaged with an inner periphery wall of a hollow cylinder 184 which will be described in Fig. 3.

[0100] Fig. 3 illustrates a schematic of a second hydraulic engine assembly 200. The second hydraulic engine assembly 200 has a similar structure with the first hydraulic engine assembly 100. However, the hydraulic engine assembly 200 does not have the bypass conduit 150. Instead, second hydraulic engine assembly 200 comprise a pressure releasing valve 204 installed on the reservoir cylinder 102. When the pressure of the reservoir cylinder 102 rises beyond an upper limit, a portion of the carbon dioxide is released from the reservoir cylinder 102 via the pressure releasing valve 204. Therefore, the second hydraulic engine assembly 200 comprises a semi closed-loop source 201 for providing the liquefied carbon dioxide as the working fluid.

[0101] Fig. 4 illustrates a schematic of a third hydraulic engine assembly 300. In contrast to the closed-loop source 101 of the first hydraulic engine assembly 100 and the semi closed-loop source 201 of the second hydraulic engine assembly 200, the third hydraulic engine assembly 300 comprises an open source 301. Since the open source 301 is more compact, the third hydraulic engine assembly 300 is more suitable for portable usage.

[0102] Fig. 5 illustrates a schematic of a cross-sectional view of the rotary device 108 for the first hydraulic engine assembly 100, the second hydraulic engine assembly 200 or the third hydraulic engine assembly 300. A chassis 186 comprises a hollow cylinder providing a protective housing for the components therein. Within the hollow cylinder is a working chamber 168. The working chamber 168 has the shaft 175 located in the centre of the rotor 174. The shaft 175 is supported by the rotor 174. There are eight vanes located 45° between each vane 172 extending and spreading from the centre of the shaft 175. Each opposite end of the eight vanes 172 touching an inner wall thermal insulation 188 along an inner periphery wall of the hollow cylinder 184. The eight vanes 172 are supported by the shaft 175 and the rotor 174. In other words, the rotor 174 rotates with the shaft 175 and the vanes 172 within the chamber 168,170 in one direction (either clockwise or anti-clockwise) as shown by a directional arrow 190. The rotor 174 forms a communicative seal with the hollow cylinder preventing any fluid (carbon dioxide) from seeping through a seam between the hollow cylinder and the rotor 174.

[0103] Along an outer periphery wall of the chassis is the first input port 176 to the working chamber 168, the second input port 178 to the heat chamber 168, the first output port 180 of the working chamber 168 and the second output port 182 of the heat chamber 168. Basically there are two input ports 176,178 and two output ports 180,182.

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[0104] The chassis 186 has an outer diameter of about two hundred and fifty millimetres (250 mm) with a chassis wall thickness of about twenty millimetres (20 mm) and a chassis length of about two hundred millimetres (200 mm). Observing the cross-sectional rotary device 108 as a clock. The first input port 176 of the working chamber 168 is located between a two o'clock and a three o'clock position. The second input port 178 of the heat chamber 168 is located between the three o'clock and a four o'clock position. The second output port 182 of the heat chamber 168 is located between a five o'clock and a six o'clock position. The first output port 180 of working chamber 168 is located between a eight o'clock and a nine o'clock position. The two input ports 176,178 and the two output ports 180,182 have an inner diameter of about fifteen millimetres (15 mm) extend through the chassis wall from the outer periphery wall to an inner peripheral wall for the working chamber 168 ports while both ports of the heat chamber 168 stop at the heat chamber 168. Along the inner periphery wall is a lining that overlays the inner periphery wall. The lining is known as the inner wall thermal insulation which is shown in Fig. 3 indicated with small black circles/balls which maintain the cold temperature within. The insulation is made of Teflon. The Teflon coating ensures that the vanes can rotate smoothly. The inner wall thermal insulation also protects the integrity of the chassis wall from the extreme temperature fluctuation.

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[0105] The 20 mm chassis wall specifically in between the outer periphery wall and the inner periphery wall is a hollow cavity as shown in Fig. 3 with the mini rectangles that lined the chassis wall. The chassis wall is the heat chamber 170 providing a channel for the hot refrigerant to flow. The second input port 178 and the second output port 182 of the heat chamber 168 communicate with the heat chamber 168 in supplying and discharging the refrigerant respectively.

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[0106] The input port 176 of the working chamber 168 and the first output port 180 of the working chamber 168 communicate with the working chamber 168 within. The second input port 178 of the heat chamber 168 and the second output port 182 of the heat chamber 168 also communicate with the heat chamber 168 within.

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[0107] The liquid carbon dioxide 134 fills the working chamber 168 in the hollow cylinder in contact with the vanes and the rotor in the rotary device 108. A volume of the liquid carbon dioxide 134 in the working chamber 168 remains the same while the liquid carbon dioxide 134 moves from the first input port 176 to the first output port 180 of the working chamber 168 of the rotary device 108. A heat source is applied to the section of the rotary device 108 specifically at the check valve "E" 160 where the refrigerant is pumped into heat chamber 168 of the rotary device 108. The refrigerant heat up the rotary device 108 inner periphery wall. The cold liquid carbon dioxide 144 get heated up when flowing by the not thermal insulated section, raising its temperature and pressure. The increase in carbon dioxide pressure generates a high shaft torque in the rotary device 108 creating kinetic energy to drive a mechanical load like a generator or a turbine.

[0108] The heat source is in fact the heat gathering subsystem (heat exchanger 3) 116 which is connected to the check valve "E" 160. The heat source is applied to drive the mechanical load and enable the liquid carbon dioxide to circulate in the hydraulic engine.

[0109] The shaft of rotary device 108 incorporates a ratchet and pawl gear system (not shown in the diagram) or similar device to ensure only one direction rotation in accordance to the flow of the liquid carbon dioxide 134. As the carbon dioxide exists the rotary device 108 can be still very cold, it can be passed to another rotary device 108 or a few more in sequence until the carbon dioxide temperature is warm enough to discharge to form the cold liquid carbon dioxide 144 without solidifying.

[0110] In use, the very cold liquid carbon dioxide is initially injected into the working chamber 168 via the first input port 176 driven by the high pressure pump 106. The pressurised cold liquid carbon dioxide 144 expands significantly in the working chamber 168 due to a higher temperature therein. The sudden change in pressure drives the vane 172 in a clockwise direction from a shaft view. The cold liquid carbon dioxide 144 increases its basal temperature to become the cold liquid carbon dioxide 144. The cold liquid carbon dioxide 144 is discharged via the first output port 180 at the opposite side of the first input port 176.

[0111] In the application, unless specified otherwise, the terms "comprising", "comprise", and grammatical variants thereof, intended to represent "open" or "inclusive" language

such that they include recited elements but also permit inclusion of additional, non-explicitly recited elements.

[0112] As used herein, the term "about", in the context of concentrations of components of the formulations, typically means +/- 5% of the stated value, more typically +/- 4% of the stated value, more typically +/- 3% of the stated value, more typically, +/- 2% of the stated value, even more typically +/- 1% of the stated value, and even more typically +/- 0.5% of the stated value.

[0113] Throughout this disclosure, certain embodiments may be disclosed in a range format. The description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

[0114] It will be apparent that various other modifications and adaptations of the application will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the application and it is intended that all such modifications and adaptations come within the scope of the appended claims.

Reference Numerals

	100	first hydraulic engine;
	101	closed-loop source;
5	102	reservoir cylinder
	103	reservoir
	104	expansion cylinder
	105	expansion chamber
	106	high pressure pump
10	108	rotary device
	110	heat transfer pump
	112	first heat gathering sub-system (heat exchanger 1)
	114	second heat gathering sub-system (heat exchanger 2)
	116	return heat exchanger (heat exchanger 3)
15	118	three-port adaptor
	120	pressure release valve
	122	first port
	124	check valve "D"
	126	second port
20	128	ball valve
	130	third port
	132	bypass inlet
	134	liquid carbon dioxide
	136	reservoir cylinder outlet
25	138	opened brim
	140	reservoir-expansion conduit
	142	start/stop valve
	144	cold liquid carbon dioxide
	146	pressure reducing valve
30	148	check valve "F"
	150	bypass conduit
	152	check valve "A"

	154	pump-rotary conduit
	156	check valve "B"
	158	check valve "C"
	160	check valve "E"
5	162	return-reservoir conduit
	164	discharge ball valve
	166	refrigerant or hot heat transfer fluid
	168	working chamber
	170	heat chamber
10	172	vane
	174	rotor
	175	shaft
	176	first input port
	178	second input port
15	180	first output port
	182	second output port
	184	inner periphery wall of the hollow cylinder
	186	chassis
	188	inner wall thermal insulation
20	190	directional arrow;
	200	second hydraulic engine;
	201	semi closed-loop source;
	204	pressure releasing valve;
	300	third hydraulic engine;
25	301	open source;

Claims

1. A hydraulic engine, comprising
 - a source for supplying a working fluid;
 - 5 ➤ a heat transfer system for supplying heat to the working fluid; and
 - at least one hydraulic motor for converting a hydraulic flow of the working fluid into a mechanical motion of the at least one hydraulic motor.
2. The hydraulic engine of claim 1, wherein
 - 10 the source comprises a closed-loop source for circulating a cycling working fluid as the working fluid in the hydraulic engine.
3. The hydraulic engine of claim 2, wherein the closed-loop source further comprises
 - 15 ➤ a high pressure vessel for storing the cycling working fluid, the high pressure vessel having a first inlet and a first outlet;
 - a low pressure vessel for receiving the cycling working fluid, the low pressure vessel having a second inlet and a second outlet wherein the second inlet is configured to be connected to the first outlet of the high pressure vessel; and
 - 20 ➤ a circulating system for driving the cycling working fluid to circulate in the hydraulic engine, the circulating system being configured to connect the second outlet of the low pressure vessel with the first inlet of the high pressure vessel.
4. The hydraulic engine of claim 3, wherein the circulating system further comprises a circulating pump for pushing the cycling working fluid to flow back to the high pressure vessel.
5. The hydraulic engine of claim 1, wherein the heat transfer system comprises a return heat exchanger for further raising the temperature of the cycling working fluid.

6. The hydraulic engine of claim 1, wherein the heat transfer system comprises a rotary device for transferring the cycling working fluid from the low pressure to the high pressure vessel.

5 7. The hydraulic engine of claim 6, wherein the rotary device comprises a working chamber for receiving the working fluid, and a heating chamber for receiving a refrigerant, wherein the working chamber and the heating chamber are separated from and contiguous with each other.

10 8. The hydraulic engine of claim 1, wherein the heat transfer system further comprises an auxiliary heat exchanger for keeping the refrigerant, the auxiliary heat exchanger being connected to the heating chamber.

15 9. The hydraulic engine of claim 1, wherein the heat transfer system further comprises a main heat exchanger that joins the rotary device to the second outlet of the low pressure vessel, the main heat exchanger being connected to the working chamber of the rotary device.

20 10. The hydraulic engine of any of the preceding claims, wherein the working fluid comprises at least one liquefied gas.

25 11. The hydraulic engine of claim 2, wherein the closed-loop source further comprises at least one high-pressure pump or compressor for enhancing a pressure of the working fluid for matching with an operation pressure of the hydraulic motor.

30 12. The hydraulic engine of claim 3, wherein the circulating system comprises at least one non-return valve for preventing backflow of the cycling working fluid.

35 13. The hydraulic engine of claim 2, wherein the closed-loop source comprises a warning device for sending a warning message when the cycling working fluid has a low flow rate.

14. The hydraulic engine of claim 2, wherein
the closed-loop source further comprises a bypass conduit for connecting the high
pressure vessel with the low pressure vessel for equalizing a pressure of the high
5 pressure vessel.
15. The hydraulic engine of claim 8, wherein
the auxiliary heat exchanger further comprises a first auxiliary heat exchanger for
collecting heat from the surrounding environment or waste heat, or transfer heat
10 from the refrigerant to a cooling application.
16. A method of making a hydraulic engine, comprising:
- providing a source for supplying a working fluid;
 - providing a heat transfer system for supplying heat to the working fluid;
 - 15 ➤ providing at least one hydraulic motor; and
 - assembling the source, the heat transfer system and the at least one
hydraulic motor.
17. The method of making the hydraulic engine of claim 16, further comprising:
20 installing a main heat exchanger to the heat transfer system for heating the
working fluid.
18. The method of making the hydraulic engine of claim 16 or 17, further comprising:
installing an auxiliary heat exchanger to the heat transfer system for heating a
25 refrigerant.
19. The method of making the hydraulic engine of any of the preceding claims 16 to
18, wherein
the providing a source further comprises:
- 30 ➤ providing a resource of the working fluid;
 - providing a converter for converting the resource of the working fluid into a
fresh working fluid at an open source as the source; and
 - connecting the open source to the heat transfer system and the at least one
hydraulic motor;
 - 35 wherein the fresh working fluid does not flow back to the open source.

20. The method of making the hydraulic engine of any of the preceding claims 16 to 19, wherein

the providing a source further comprises:

- providing a high pressure vessel for storing a cycling working fluid;
- providing a low pressure vessel for receiving the cycling working fluid;
- providing a circulating system for driving the cycling working fluid; and
- assembling the high pressure vessel, the low pressure vessel and the circulating system for forming a closed-loop source as the source;

wherein the cycling working fluid flows back to the high pressure vessel.

21. The method of making the hydraulic engine of claim 20, further comprising: installing a return heat exchanger to the heat transfer system for further raising a temperature of the cycling working fluid after flowing out of the hydraulic motor.

22. The method of making the hydraulic engine of claim 20 or 21, further comprising: installing a bypass conduit to the high pressure vessel for equalizing a pressure of the high pressure vessel.

23. A method of using a hydraulic engine, comprising:

- supplying a working fluid from a source;
- operating a heat transfer system for supplying heat to the working fluid; and
- operating at least one hydraulic motor;

wherein the working fluid flows through and drives the at least one hydraulic motor.

24. The method of using the hydraulic engine of claim 23, wherein the supplying a working fluid from a source further comprises:

- supplying a resource of the working fluid; and
- converting the resource of the working fluid into a fresh working fluid at an open source as the source;

wherein the fresh working fluid does not flow back to the open source.

25. The method of making the hydraulic engine of claim 23 or 24, wherein the supplying a working fluid from a source further comprises:

- releasing a cycling working fluid from a high pressure vessel;
 - receiving the cycling working fluid into a low pressure vessel; and
 - driving the cycling working fluid by a circulating system;
- wherein the cycling working fluid flows back to the high pressure vessel.

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