CLAIMS

1 A roticulating thermodynamic apparatus having a **first fluid flow section** comprising :

a first shaft portion which defines, and is rotatable about, a first rotational axis;

a first axle defining a second rotational axis, the first shaft portion extending through the first axle;

a first piston member provided on the first shaft portion, the first piston member extending from the first axle towards a distal end of the first shaft portion;

a first rotor carried on the first axle;

the first rotor comprising :

a first chamber,

the first piston member extending across the first chamber;

a first casing wall adjacent the first chamber,

a first port and second port provided in the housing wall and each in flow communication with the first chamber;

whereby :

the first rotor and first axle are rotatable with the first shaft portion around the first rotational axis; and

the first rotor is pivotable about the axle about the second rotational axis to permit the first rotor to pivot relative to the first piston member as the first rotor rotates about the first rotational axis;

such that the **first fluid flow section** is configured for the passage of fluid between the first port and second port via the first chamber;

the apparatus further comprising a **second fluid flow section**, which comprises :

a second chamber,

a second housing wall adjacent the second chamber,

a third port and a fourth port provided in the second housing wall and each in flow communication with the second chamber,

such that the **second fluid flow section** is configured for the passage of fluid between the third port and fourth port via the second chamber;

the second port being in fluid communication with the third port via a first heat exchanger.

2 An apparatus as claimed in claim 1 wherein :

the second rotational axis is substantially perpendicular to the first rotational axis.

3 An apparatus as claimed in claim 1 or claim 2 wherein

the first rotor comprises the second chamber;

the first piston member extends from one side of the first axle along the first shaft portion; and

a second piston member extends from the other side of the first axle along the first shaft portion,

across the second chamber

to permit the first rotor to pivot relative to the second piston member as the first rotor rotates about the first rotational axis.

4 An apparatus as claimed in claim 3 wherein

the fourth port is in fluid communication with the first port via

a second heat exchanger.

5 An apparatus as claimed in any one of claims 2 to 4 wherein

the volumetric capacity of the first rotor first chamber is substantially the **same, less, or greater than** the volumetric capacity of first rotor second chamber.

6 An apparatus as claimed in any one of the preceding claims wherein

the first shaft portion, first axle and first piston member(s) are fixed relative to one another.

7 An apparatus as claimed in claim 1 or claim 2 which further comprises :

a second rotor comprising the second chamber,

a second shaft portion rotatable about the first rotational axis; and

the second shaft portion is coupled to the first shaft portion such that the first shaft portion and second shaft portion are rotatable together around the first rotational axis;

a second axle defining a third rotational axis, the second shaft portion extending through the second axle;

a second piston member provided on the second shaft portion, the second piston member extending from the second axle towards a distal end of the second shaft portion;

the second rotor carried on the second axle;

the second piston member extending across the second chamber;

whereby :

the second rotor and second axle are rotatable with the second shaft portion around the first rotational axis; and

the second rotor is pivotable about the second axle about the third rotational axis

to permit the second rotor to pivot relative to the second piston member as the second rotor rotates about the second rotational axis.

8 An apparatus as claimed in claim 7 wherein

the third rotational axis is substantially perpendicular to the first rotational axis.

9 An apparatus as claimed in claim 7 or claim 8 wherein

the first rotor comprises :

a first rotor second chamber,

the first piston member extending from one side of the first axle along the first shaft portion; and

a second piston member extends from the other side of the first axle along the first shaft portion,

across the first rotor second chamber

to permit the first rotor to pivot relative to the second piston member as the first rotor rotates about the first rotational axis; and

the second rotor comprises :

a second rotor first chamber

the second piston member extends from one side of the second axle along the second shaft portion; and

a second rotor first piston member extends from the other side of the second axle along the second shaft portion,

across the second rotor first chamber

to permit the second rotor to pivot relative to the second rotor first piston member as the second rotor rotates about the first rotational axis;

wherein :

the first rotor second chamber is in flow communication with :

a fifth port and
a sixth port;

to thereby form part of the **first fluid flow section,** and configured for the passage of fluid between the fifth port and sixth port via the first rotor second chamber;

the second rotor first chamber is in flow communication with

a seventh port and

an eighth port;

to thereby form part of the **second fluid flow section,** and configured for the passage of fluid between the seventh port and eighth port via the second rotor second chamber;

wherein the sixth port is in fluid communication with the seventh port via

the first heat exchanger.

10 An apparatus as claimed in any one of claims 7 to 9 wherein

the eight port is in fluid communication with the fifth port
via

a second heat exchanger.

11 An apparatus as claimed in claim 10 wherein

the fourth port is in fluid communication with the first port via the second heat exchanger.

12 An apparatus as claimed in any one of claims 9 to 11 wherein

the first chamber and second chamber of the first rotor have substantially the same volumetric capacity;

the first chamber and second chamber of the second rotor have substantially the same volumetric capacity;

the volumetric capacity of the first rotor chambers are substantially the **same, less, or greater than** the volumetric capacity of the second rotor chambers.

13 An apparatus as claimed in any one of claims 7 to 12 wherein

the first shaft portion is directly coupled to the second shaft portion such that

the first rotor and second rotor are operable to only rotate at the same speed as each other.

14 An apparatus as claimed in any one of claim 7 to 13 wherein

the second shaft portion, second axle and second piston member(s) are fixed relative to one another.

15 An apparatus as claimed in any one of claims 1 to 14 wherein

the first heat exchanger is operable as a **heat sink** to remove heat energy from fluid passing through it.

16 An apparatus as claimed claim 15 when dependent on claim 4 or claim 10 wherein

the second heat exchanger is operable as a **heat source** to add heat energy to fluid passing through it.

17 An apparatus as claimed in claim 15 wherein

the first heat exchanger comprises :

a chamber operable to permit fluid flow between the **first fluid flow section** and the **second fluid flow section**; and

an injector configured to inject a cryogenic medium into the chamber such that heat energy is transferred from the fluid to the cryogenic media.

18 An apparatus as claimed in any one of claims 1 to 14 wherein

the first heat exchanger is operable as a **heat source** to add heat energy to fluid passing through it.

19 An apparatus as claimed claim 15 when dependent on claim 4 or claim 10 wherein

the second heat exchanger is operable as a **heat sink** to remove heat energy from fluid passing through it.

20 An apparatus as claimed in claim 18 wherein

the first heat exchanger comprises :

a combustion chamber operable for continuous combustion.

21 An apparatus as claimed in any one of the preceding claims wherein

the or each chamber has an opening; and

the or each respective piston member extends from its respective axle across its corresponding chamber towards the corresponding opening.

22 An apparatus as claimed in any one of claims 1 to 21 wherein the apparatus further comprises :

a pivot actuator operable to pivot the rotor about the axle;

wherein the pivot actuator comprises :

a first guide feature provided on the rotor; and

a second guide feature provided on the housing;

the first guide feature operable to co-operate with the second guide feature to pivot the rotor about the axle.

23 An apparatus as claimed in any one of claims 1 to 21 wherein the apparatus further comprises :

a pivot actuator operable to pivot the rotor about the axle;

wherein the pivot actuator comprises :

a first guide feature on the rotor; and

a second guide feature on the housing;

the first guide feature being complementary in shape to the second guide feature; and

one of the first or second guide features defining a path which the other of the first or second guide feature, is constrained to follow;

the other of the first or second guide feature comprising a rotatable member which is operable to engage the path and rotate as it moves along the path.

24 An apparatus according to any of claims 22 or 23, wherein the second guide feature comprises a slewing ring configured to hold at least part of a bearing that is coupled with the housing.

25 An apparatus according to claim 24, wherein the first guide feature comprises a stylus configured to be coupled with the slewing ring.

26 An apparatus as claimed in claim 18, wherein the heat source comprises a substance passing through a duct in the first heat exchanger, wherein the apparatus provides cooling to the substance.

27 An apparatus as claimed in claim 26, wherein the fluid comprises air.

28 An apparatus as claimed in claims 26 or 27, wherein the apparatus comprises a motor coupled to the first shaft portion configured to drive the rotor around the first rotational axis.

29 An apparatus as claimed in claim 28, wherein the motor is reversible, such that when the motor is configured to drive the rotor around the first rotational axis in

a first direction, the first heat exchanger is operable to act as a heat source to transfer heat from the substance to the fluid, and wherein when the motor is configured to drive the rotor around the first rotational axis in a second direction, opposite to the first direction, the first heat exchanger is operable to act as a heat sink to transfer heat from the fluid to the substance.

30 An apparatus as claimed in any preceding claim, wherein the first fluid flow section and the second fluid flow section are two sides of the first rotor and wherein one of the first fluid flow section and the second fluid flow section is operable as a compressor and the other one of the first fluid flow section and the second fluid flow section is operable as an expander.