

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 304613-RY	FOR FURTHER ACTION		See Form PCT/IPEA/416
International application No. PCT/IL2023/051160	International filing date (day/month/year) 09.11.2023	Priority date (day/month/year) 10.11.2022	
International Patent Classification (IPC) or national classification and IPC INV. F01K21/02			
Applicant TECHNION RESEARCH & DEVELOPMENT FOUNDATION LIMITED			
1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36. 2. This REPORT consists of a total of <u>9</u> sheets, including this cover sheet. 3. This report is also accompanied by ANNEXES, comprising: a. ☒ a total of <u>16</u> sheets, as follows: ☒ sheets of the description, claims and/or drawings which have been amended and/or sheets containing rectifications authorized by this Authority, unless those sheets were superseded or cancelled, and any accompanying letters (see Rules 46.5, 66.8, 70.16, 91.2, and Section 607 of the Administrative Instructions). ☐ sheets containing rectifications, where the decision was made by this Authority not to take them into account because they were not authorized by or notified to this Authority at the time when this Authority began to draw up this report, and any accompanying letters (Rules 66.4bis, 70.2(e), 70.16 and 91.2). ☐ superseded sheets and any accompanying letters, where this Authority either considers that the superseding sheets contain an amendment that goes beyond the disclosure in the international application as filed, or the superseding sheets were not accompanied by a letter indicating the basis for the amendments in the application as filed, as indicated in item 4 of Box No. I and the Supplemental Box (see Rule 70.16(b)). b. ☐ a separate electronic file containing a sequence listing (<i>sent to the International Bureau only</i>)			
4. This report contains indications relating to the following items: ☒ Box No. I Basis of the report ☐ Box No. II Priority ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability ☐ Box No. IV Lack of unity of invention ☒ Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement ☐ Box No. VI Certain documents cited ☐ Box No. VII Certain defects in the international application ☐ Box No. VIII Certain observations on the international application			
Date of submission of the demand 19.08.2024		Date of completion of this report 06.02.2025	
Name and mailing address of the international preliminary examining authority:  European Patent Office D-80298 Munich Tel. +49 89 2399 - 0		Authorized officer Röberg, Andreas Telephone No. +49 89 2399-4779 	

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/IL2023/051160

Box No. I Basis of the report

1. With regard to the **language**, this report is based on
- ☒ the international application in the language in which it was filed
 - ☐ a translation of the international application into , which is the language of a translation furnished for the purposes of:
 - ☐ international search (under Rules 12.3(a) and 23.1(b))
 - ☐ publication of the international application (under Rule 12.4(a))
 - ☐ international preliminary examination (under Rules 55.2(a) and/or 55.3(a) and (b))
2. With regard to the **elements*** of the international application, this report is based on (*replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report*):

Description, Pages

1-60 as originally filed

Claims, Numbers

1-52 filed in electronic form on 11-11-2024

Drawings, Sheets

1/13-13/13 as originally filed

- ☐ a sequence listing - see Supplemental Box Relating to Sequence Listing.
3. ☐ The amendments have resulted in the cancellation of:
- ☐ the description, pages
 - ☐ the claims, Nos.
 - ☐ the drawings, sheets/figs
 - ☐ the sequence listing (*specify*):
4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since either they are considered to go beyond the disclosure as filed, or they were not accompanied by a letter indicating the basis for the amendments in the application as filed, as indicated in the Supplemental Box (Rules 70.2(c) and (c-bis)):
- ☐ the description, pages
 - ☐ the claims, Nos.
 - ☐ the drawings, sheets/figs
 - ☐ the sequence listing (*specify*):
5. ☐ This report has been established:
- ☐ taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rules 66.1(d-bis) and 70.2(e)).
 - ☐ without taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91(Rules 66.4bis and 70.2(e)).

**INTERNATIONAL PRELIMINARY REPORT
ON PATENTABILITY**

International application No.
PCT/IL2023/051160

6. ☒ With regard to top-up searches (Rules 66.1 *ter* and 70.2(f)):
- ☒ A top-up search was carried out by this Authority on 20.01.2025 (all discovered documents are listed in the Supplemental Box Relating to Top-up Search).
 - ☐ Additional relevant documents have been discovered during the top-up search.
 - ☐ No top-up search was carried out by this Authority because it would serve no useful purpose.
7. ☐ Supplementary international search report(s) from Authority(ies) has/have been received and taken into account in establishing this report (Rule 45bis.8(b) and (c)).

* If item 4 applies, some or all of those sheets may be marked "superseded".

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes: Claims	<u>1-52</u>
	No: Claims	
Inventive step (IS)	Yes: Claims	<u>1-52</u>
	No: Claims	
Industrial applicability (IA)	Yes: Claims	<u>1-52</u>
	No: Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Amendments (A.34 PCT)

Claim 1 = original claim 1 + "wherein, in the discharging operational mode, the at least one hot HTL reservoir is selectively (i)-fluidically connectable-connected to the at least one two-phase turbine;
wherein, in ~~discharging~~ the charging operational mode or (ii)-mode, the at least one hot HTL reservoir is fluidically connectable-connected or thermally coupleable-coupled to the at least one two phase compressor
in-wherein the system is switchable between the discharging operational mode and the charging operational mode
wherein said at least one hot HTL reservoir is fluidically connected to the at least one two-phase turbine or fluidically connected or thermally coupled to the at least one two phase compressor" (reformulation of the switchable feature) + "or a compressor HTL reservoir" (introduced to overcome clarity, the feature present in original claim 1) + "the compressor HTL reservoir" (obvious correction) + "thereby, switching between the discharging operational mode and the charging operational mode switches the flow of the WF between the first flow path and the second flow path, respectively;" (reformulation of the switchable feature).

Claim 7 = original claim 7 + "the system is switchable between the discharging operational mode and the charging operational mode such that switching between the discharging operational mode and the charging operational mode switches the flow of the WF between the first flow path and the second flow path, respectively; and wherein in the charging mode, the at least one hot HTL reservoir is fluidically connected or thermally coupled to the at least one two phase compressor" (adaptation to the amendment of claim 1).

Claim 11 = original claim 11 + "second counterflow heat exchanger" (correction, see claim 8).

Claim 13 = original claim 13 + "the system is switchable between the discharging operational mode and the charging operational mode such that switching between the discharging operational mode and the charging operational mode switches the flow of the WF between the first flow path and the second flow path, respectively; and wherein in a discharging mode-mode, the at least one hot HTL reservoir is fluidically connected

to the at least one two-phase turbine" + "the at least one hot HTL reservoir is fluidically connected or thermally coupled to the at least one two phase compressor" (adaptation to the amendment of claim 1).

Claim 16 = original claim 16 + "the at least one first counterflow " (correction)

Claim 19 = original claim 19 + "comprising ~~both said~~ at least one first-second counterflow heat exchanger, disposed in the second flow path between the at least one compressor and said the at least one second evaporator and configured for heat exchanger, exchange between WF exiting from the at least one compressor and WF exiting from the at least one evaporator" (correction in line with claim 16, brought in line with claim 17, see arrangement of second counterflow heat exchanger).

Claims 36, 38 = original claims 36, 38 + clarification of the pendulum feature (page 54, lines 16 - 30).

Claim 49 = original claim 49 + "the at least one hot HTL reservoir is fluidically connected to the at least one two-phase turbine," (clarification in line with claim 1).

Claim 50 = original claim 50 + clarification of the feature "the at least one compressor/condenser" (original claim 50).

Claim 52 = newly introduced method claim which corresponds to the apparatus of claim 1.

Novelty and inventive step

Reference is made to the following document:

D1 US 2013/276447 A1 (CHAIX JEAN-EDMOND [FR]) 24 October 2013
(2013-10-24)

D1 is regarded as being the prior art closest to the subject-matter of claim 1, and discloses (paragraph [0080] - paragraph [0106]; figure 1):

A system (figure 1) for storing and retrieving energy in respective charging and discharging operational modes, comprising:
at least one hot heat transfer liquid "HTL" reservoir (82) containing hot HTL;
at least one two-phase turbine (impulse wheel 42) and at least one two-phase compressor (pump 72, 108) configured for compressing compressor HTL, being the same or different than the hot HTL of the hot reservoir (same);
wherein, in the discharging operational mode, the at least one hot HTL reservoir is fluidically connected to the at least one two-phase turbine (see direct

connecting line 88);

wherein, in the charging operational mode, the at least one hot HTL reservoir is fluidically connected or thermally coupled to the at least one two phase compressor (see connecting line 80);

~~wherein the system is switchable between the discharging operational mode and the charging operational mode;~~

~~wherein said at least one hot HTL reservoir is fluidically connected to the at least one two-phase turbine or fluidically connected or thermally coupled to the at least one two phase compressor for feeding hot HTL to the respective turbine in the discharging mode or for either heat exchanging between the compressor HTL or a compressor HTL reservoir and the HTL of the hot reservoir, when the compressor HTL and the hot HTL are different and when the compressor HTL reservoir and the hot HTL reservoir are different, or feeding hot HTL to the at least one compressor, when the compressor HTL and the hot HTL are the same and the compressor HTL reservoir and the hot HTL reservoir are the same, in the charging mode;~~

at least one condenser (see condenser 112) in fluid communication with the turbine for receiving and condensing a working fluid "WF" coming from the turbine;

at least one evaporator (the evaporation occurs in the injector 20, paragraphs [0084], [0085]) in fluid communication with the at least one compressor for receiving and evaporating WF (both WF and HTL) coming from the at least one compressor (72, 108), the at least one evaporator, being same or different element than the at least one condenser (here different because the condensation occurs in the turbine 42);

~~the discharging mode defines a first flow path of the WF and the charging mode defines a second flow path of the WF, thereby, switching between the discharging operational mode and the charging operational mode switches the flow of the WF between the first flow path and the second flow path, respectively; and~~

~~wherein in a discharging mode the WF flows in the first flow path from the at least one condenser to one or more nozzles within the at least one turbine, the nozzles (20) being configured to induce rotation of the turbine upon discharge of fluid therefrom, to thereby mix the WF with the HTL to form a HTL/WF mixture in said one or more nozzles (paragraph [0085]), in which the WF undergoes a quasi-isothermal expansion, causing acceleration of the HTL/WF mixture and discharge of the mixture through the one or more nozzles while reducing temperature of the HTL, the HTL/WF mixture discharged out of the one or more nozzles being received in at least one first separation zone configured to~~

~~separate the WF from the HTL, the HTL being recycled back to said at least one hot reservoir or to said one or more nozzles and the separated WF flowing into and received in the condenser to undergo condensation therein, the condensed WF discharged from the at least one condenser flows back to the turbine.~~

The subject-matter of claim 1 therefore differs from this known the system in that it is configured for operating in a charging and discharging mode

wherein the system is switchable between the discharging operational mode and the charging operational mode;

wherein said at least one hot HTL reservoir is (i) fluidically connected to the at least one two-phase turbine or (ii) fluidically connected or thermally coupled to the at least one two phase compressor for feeding hot HTL to the respective turbine in the discharging mode or for either heat exchanging between the compressor HTL or a compressor HTL reservoir and the HTL of the hot reservoir, when the compressor HTL and the hot HTL are different and when the compressor HTL reservoir and the hot HTL reservoir are different, or feeding hot HTL to the at least one compressor, when the compressor HTL and the hot HTL are the same and the compressor HTL reservoir and the hot HTL reservoir are the same, in the charging mode;

the discharging mode defines a first flow path of the WF and the charging mode defines a second flow path of the WF, thereby, switching between the discharging operational mode and the charging operational mode switches the flow of the WF between the first flow path and the second flow path, respectively; and

wherein in a discharging mode the WF flows in the first flow path from the at least one condenser to one or more nozzles within the at least one turbine,

in which [discharging mode] the WF undergoes a quasi-isothermal expansion, causing acceleration of the HTL/WF mixture and discharge of the mixture through the one or more nozzles while reducing temperature of the HTL, the HTL/WF mixture discharged out of the one or more nozzles being received in at least one first separation zone configured to separate the WF from the HTL, the HTL being recycled back to said at least one hot reservoir or to said one or more nozzles and the separated WF flowing into and received in the condenser to undergo condensation therein, the condensed WF discharged from the at least one condenser flows back to the turbine,

and is therefore new (Article 33(2) PCT).

The technical effect of this difference is that by using a heat transfer liquid the system is configured for a isothermal or quasi-isothermal process in a charging and discharging mode which increase the round-trip efficiency of the system.

The problem to be solved by the present invention may be regarded as increasing the thermal efficiency of the known system.

The solution to this problem proposed in claim 1 of the present application is considered as involving an inventive step (Article 33(3) PCT) for the following reasons: D1 shows a system wherein water is preheated and injected together with glycerol such that the water evaporates with heat from the glycerol and is isothermally or near isothermally evaporated and drives the impulse wheel 42 inside the enclosure 30. The enclosure 30 also operates as a gas-liquid separator by collecting the glycerol at the bottom of the enclosure and letting out residual steam through the recovery means 66 (paragraph [0095]). The recovered steam is de-superheated in heat exchanger 28 and condensed in condenser 112. Meanwhile the residual glycerol is returned to either the storage tank 82 or directly to the solar heated heating means 6. This system does not present any technical features for being operated in a charging mode nor a discharging mode. There are no thermal accumulators which could serve the purpose of a system which can be thermally charged or discharged. Furthermore there is only an isothermal expansion but no indication of isothermal (or quasi-isothermal) compression. D1 thus falls far from both alternatives of claim 1 according to which the HTL reservoir is either fluidically or thermally connected to the compressor such that also the compression can be done isothermally in the charging mode. The system of D1 can therefore not be used to thermally charge the HTL in a charging mode. This feature would also not be easily derived from a combination of the system of D1 with any system comprising a hot HTL reservoir. The subject-matter of claim 1 is therefore inventive.

Independent apparatus claims 7, 13 relate to the same system but various different modes of operation (claim 7: charging mode, claim 13: discharging and charging).

Independent apparatus claim 49 relates to a similar system with also a cold HTL reservoir in a discharging mode.

Independent apparatus claim 50 relates to a similar system with a heat exchanger between turbine and compressor and a charging and a discharging mode.

Independent method claim 52 corresponds to the system of claim 1.

Since all theses independent claims also comprise the arrangement for charging and discharging as well as the isothermal expansion and compression wherein D1 is the closest prior art their subject-matter is novel and inventive for the reasons given above.

Claims 2 - 6, 8 - 12, 14 - 48 and 51 are dependent on claims 1, 7, 13, 49 and 50 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

Industrial Applicability

The industrial applicability of the present application seems to be self-evident (Article 33(4) PCT).