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(54) **Title**: CONTROL OF SYSTEM WITH GAS BASED CYCLE

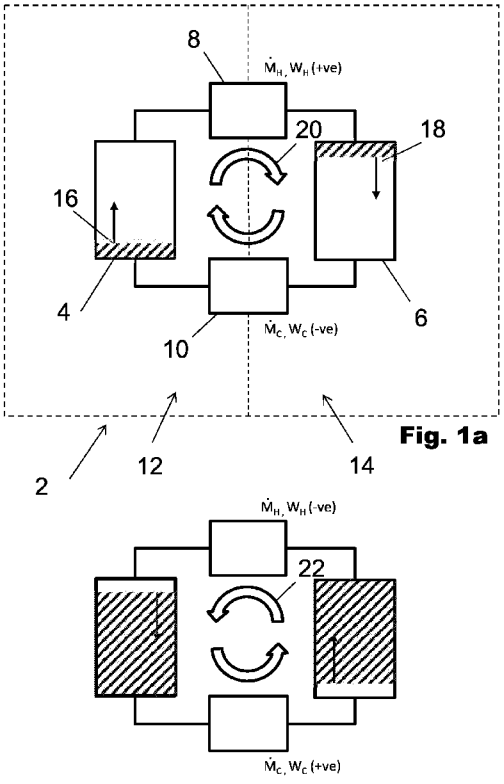

Fig. 1a

Fig. 1b

(57) **Abstract**: System (2) for carrying out a gas based thermodynamic cycle in which a gas is compressed in at least one compressor (8) in one part of the cycle and is expanded in at least one expander (10) operating simultaneously in an upstream or downstream part of the cycle, wherein the change in absolute internal power with gas mass flow rate differs as between the compressor and the expander and wherein the system comprises a control system configured to make selective adjustments so as individually to control, either directly or indirectly, the respective gas mass flow rates through each of the compressor and expander. The system may be an energy storage system including a pumped heat energy storage system configured to provide independent graduated control of system pressure and output power by selective adjustment of the respective gas mass flow rates through each half-engine.

WO 2013/164564 A3

UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
INV. F01K3/02 F01K3/12 F01K7/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/251711 A1 (HOWES JONATHAN SEBASTIAN [GB] ET AL) 7 October 2010 (2010-10-07)	1-4,6,7, 10-12, 17-20, 30,65
A	paragraphs [0102] - [0117]; figures 1-3	8,9, 13-16, 21-29,31

X	US 2012/060501 A1 (HEMRLE JAROSLAV [CH] ET AL) 15 March 2012 (2012-03-15) paragraphs [0038] - [0062]; figures 1-3	1-7,30

X	WO 2012/013978 A2 (ISENTROPIC LTD [GB]; HOWES JONATHAN SEBASTIAN [GB]; MACNAGHTEN JAMES [] 2 February 2012 (2012-02-02)	1,30,32, 42,43, 45-51, 61-65
	page 15, line 6 - line 21; figures 1-5	

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 November 2013	17/12/2013

Name and mailing address of the ISA/	Authorized officer
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 400 120 A1 (ABB RESEARCH LTD [CH]) 28 December 2011 (2011-12-28) paragraphs [0046] - [0052]; figures 1a,1b	1,30
X	US 2012/080168 A1 (HEMRLE JAROSLAV [CH] ET AL) 5 April 2012 (2012-04-05) paragraphs [0034] - [0040]; figures 2,3	1
A	US 2011/061379 A1 (MISSELHORN JUERGEN [DE]) 17 March 2011 (2011-03-17) paragraphs [0052] - [0130]; figures 1-5	32,42-65

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB2013/050593

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

1-32(completely); 42-65(partially)

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-31(completely); 65(partially)

   System and method for carrying out a gas based thermodynamic cycle in which a gas is compressed in at least one compressor in one part of the cycle and is expanded in at least one expander operating simultaneously in an upstream or downstream part of the cycle, wherein the change in absolute internal power with gas mass flow rate differs as between the compressor and the expander and wherein the system comprises a control system configured to make selective adjustments so as individually to control, either directly or indirectly, the respective gas mass flow rates through each of the compressor and expander.

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2. claims: 32(completely); 42-65(partially)

   Apparatus and method for compressing and expanding a gas comprising a positive displacement device, wherein a control system is configured to run an operating mode of the apparatus in which flow rate gradually changes such that the function of the working volume changes from compression to expansion, or vice versa, over a series of cycles by changing the timing of the respective HP and LP valve closure events.

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3. claims: 33-36(completely); 42-65(partially)

   Apparatus and method for compressing and/or expanding a gas comprising a positive displacement device, wherein a control system is configured to run an operating mode of the apparatus in which, during at least one cycle, there is either a net gas flow from the LP to HP region, or, a net gas flow from the HP to LP region, as well as bidirectional flow of gas through both the at least one HP valve and at least one LP valve in that mode of operation.

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4. claims: 37-39(completely); 42-65(partially)

   Apparatus and method for compressing and/or expanding a gas comprising a positive displacement device, wherein a control system is configured to run an operating mode of the apparatus that implements an algorithm using the relationship $b=Ka(Z/Y)+C$ that links the timing of every HP closure event to a LP valve closure event, whereby a, b, Y and Z are as identified according to Fig. 12 and K and C are constants of proportionality, in order to determine the LP and/or HP valve closure events for that operating mode.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

5. claims: 40(completely); 42-65(partially)

Apparatus and method for compressing and/or expanding a gas comprising a positive displacement device, wherein the control system is configured to run an operating mode of the apparatus in which, the timing of the respective HP and LP valve closure events changes from one matched pair to a different match pair of valve events over a series of cycles while the flow rate remains constant.

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6. claims: 41(completely); 42-65(partially)

Apparatus and method for compressing and/or expanding a gas comprising a positive displacement device, wherein a control system is configured to run an operating mode of the apparatus in which there is variation of the flow rate from one value to another value both lying between 100% compression flow rate and 100% expansion flow rate per cycle and both LP and HP valve timings are changing between at least some adjacent cycles.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2013/050593

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