(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 486 588 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
22.05.2019 Bulletin 2019/21

(21) Application number: **17020538.9**

(22) Date of filing: **20.11.2017**

(51) Int Cl.:
F25J 1/00 *(2006.01)* ***F25J 1/02*** *(2006.01)*
F25B 9/00 *(2006.01)* ***F25B 40/00*** *(2006.01)*

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(71) Applicant: **Linde Aktiengesellschaft**
80331 München (DE)

(72) Inventors:
- **Hibbitt, Ian**
  Hognaston, Ashbourne
  Derbyshire DE16 1PR (GB)
- **Mills, Simon**
  Sheffield, S6 1WG (GB)

(54) METHOD AND APPARATUS FOR COOLING A SYSTEM

(57) The invention relates to a method for cooling a system (150) that is intended for use with a first medium (a) in liquid form, the first medium (a) being supplied to the system (150) in gaseous form, wherein the first medium (a) is cooled by means of a first heat exchanger (130) using a second medium (b) prior to being supplied to the system (150), and an apparatus (100) for cooling a system (150).

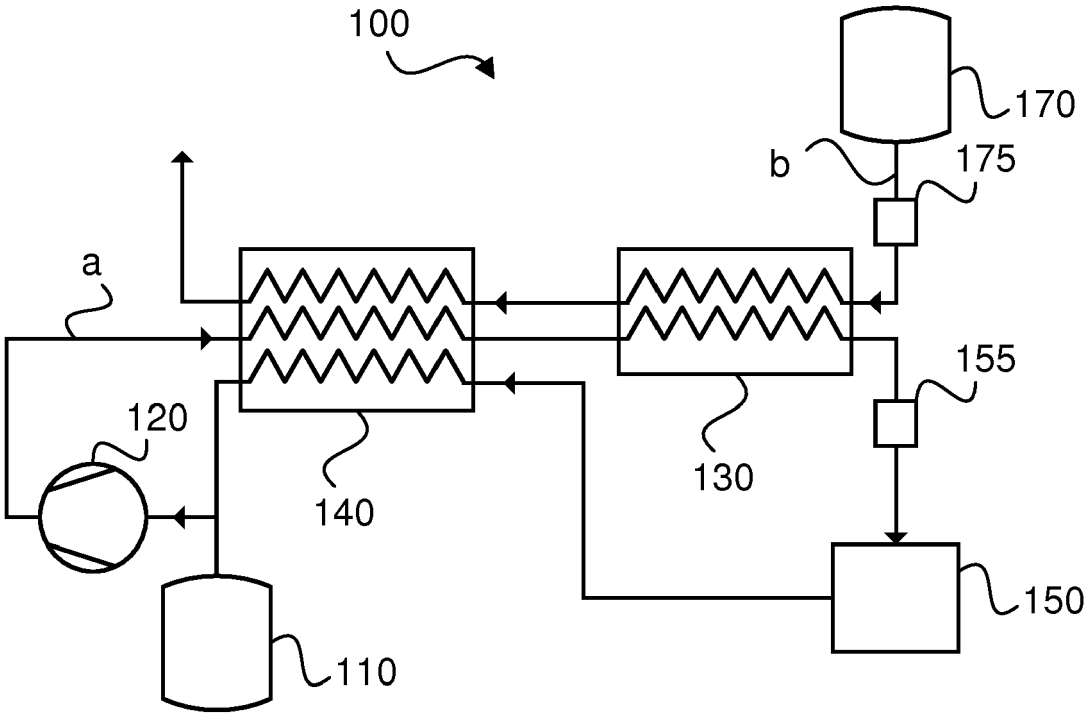

Fig. 1

EP 3 486 588 A1

Description

Technical Field

[0001] The invention relates to a method and an apparatus for cooling a system that is intended for use with a medium like hydrogen in liquid form.

Prior Art

[0002] Different systems like engines that are intended to be used with and are used with medium in liquid form like liquid hydrogen exist. Typically, such systems have to be pre-cooled, i.e. they have to be cooled prior to using them with the medium in liquid form.

[0003] Since cooling with the medium the system is intended to be used with in liquid form is inefficient in most cases due to high thermal masses of the system, other media, typically with higher liquefaction temperature, are used. Such a medium typically is supplied to the system in liquid form. For example, a system intended to be used with liquid hydrogen can be pre-cooled by supplying liquid nitrogen to the system.

[0004] However, using such other media typically causes impurities remaining in the system that, in most cases, freeze out when the medium the system is intended to be used with is supplied. For example, nitrogen is frozen out when exposed to liquid hydrogen. This can cause failures in the system.

[0005] The present invention aims at improving the cooling or pre-cooling of such systems intended for use with a medium in liquid form.

Disclosure of the Invention

[0006] This object is achieved by providing a method and an apparatus according to the independent claims.

[0007] A method according to the invention serves for cooling a system that is intended for use with a first medium in liquid form. For cooling this system, the first medium is supplied to the system in gaseous form, wherein the first medium is cooled by means of a first heat exchanger using a second medium prior to being supplied to the system. That is, neither the first medium is supplied to the system in liquid form nor another medium is supplied to the system in order to cool the system.

[0008] This, on the one hand, overcomes the problem that any medium other than the medium the system is intended to be used with will cause impurities, and, on the other hand, does not require a high amount of the first medium in liquid form. The latter, typically requires on-site liquefaction and causes high costs.

[0009] Advantageously, the second medium has a higher liquefaction temperature than the first medium has. This improves energy efficiency since only a small amount of energy is necessary to cool the second medium, which, in particular, can be provided in liquid form prior to being supplied to the first heat exchanger. A preferred second medium is nitrogen and a preferred first medium is hydrogen, since several systems exist using hydrogen in liquid form. However, also other media like helium or neon can be used as first medium.

[0010] It is of advantage if the first medium is further cooled by means of a second heat exchanger using the first medium flowing back from the system prior to being cooled by means of the first heat exchanger. That is, the first medium is cooled in a first stage by means of the second heat exchanger and it is further cooled in a second stage by means of the first heat exchanger. Also, several of such second heat exchangers can be used, in particular depending on the cooling power of the heat exchangers and the cooling power needed to cool the system with a desired cooling rate. This further improves energy efficiency since the first medium flowing back from the system can be used for cooling first medium still to be supplied to the system. This can be further improved in that the first medium is further cooled by means of the second heat exchanger using the second medium.

[0011] Preferably, such flow of medium is established in that the first medium is supplied to the system within a circular flow including a compressor and/or a blower. The second medium can be provided by an appropriate source and after it has passed the heat exchangers it can be vented to atmosphere. Of course, re-use of the second medium is also possible.

[0012] Advantageously, a flowrate of the first medium and/or a flowrate of the second medium are controlled depending on a desired cooling rate of the system. For this purpose, appropriate controlling units can be used. In this way shock-cooling of the system can be prevented.

[0013] Preferably, an engine is used as the system to be cooled. For engines that are used with medium like hydrogen in liquid form, it is very important to prevent any impurities in the engine. Such engines can be used, for example, within the aerospace and space industries, potentially within an aircraft, a flying machine or an aerospace vehicle, though not limited to such industries.

[0014] A further object of the invention is an apparatus for cooling a system that is intended for use with a first medium in liquid form, the apparatus being arranged to supply the first medium to the system in gaseous form. The apparatus comprises at least one heat exchanger being arranged to cool the first medium using a second medium prior to being supplied to the system. Preferably, the apparatus is adapted to perform a method according to the invention.

[0015] In respect of further embodiments and advantages of the apparatus it is referred to the statements above in order to avoid repetition.

[0016] The invention will now be further described with reference to the accompanying drawings, which show a preferred embodiment.

Brief description of the drawings

[0017]

Fig. 1 schematically shows an apparatus, with which the method of the present invention can advantageously be implemented.

Detailed description of the drawings

[0018] In Fig. 1, an apparatus or system 100 according to the invention in a preferred embodiment is shown, with which the method of the present invention can advantageously be implemented.

[0019] Gaseous hydrogen as a first medium, provided by a hydrogen source 110 is supplied to a hydrogen circuit in the form of a closed loop, the hydrogen being denoted by steam a. The hydrogen a is driven in the circuit by means of a blower or compressor 120. In the circuit the hydrogen passes two heat exchangers, in particular a second heat exchanger 140 and then a first heat exchanger 130 (terms used in the sense of the present invention).

[0020] After the hydrogen a has passed the first heat exchanger 130 it is supplied to the system 150, which, for example, can be an engine. After the hydrogen a has passed the system 150 it is fed back to the blower or compressor 120 via the second heat exchanger 130.

[0021] Further, nitrogen as a second medium, denoted by stream b, is provided by means of a liquid nitrogen source 170 and supplied to the first heat exchanger 130 and further to the second heat exchanger 140. After the nitrogen b has passed the second heat exchanger 140 it is vented to atmosphere. However, it is also possible that the nitrogen is collected for re-use or it is used in another application.

[0022] Also, a control unit 175 is provided which is adapted to control a flowrate of the nitrogen b through the heat exchangers 130 and 140. It is, for example, also possible to control a temperature. By means of that control unit 175 the cooling rate of the hydrogen to be cooled can be adjusted. It is to be noted that such a control unit (including, for example, an adjustable valve) can be provided in the stream of nitrogen before or after each of the heat exchangers 130 and 140.

[0023] Further, a control unit 155 is provided to control the flow of the hydrogen a in order to adjust a desired cooling rate of the system 150 in order to, for example, prevent a shock cooling of the system 150.

[0024] In this way the system 150 can be cooled down to, for example, -192°C without contamination of the system with impurities.

Claims

1. Method for cooling a system (150) that is intended for use with a first medium (a) in liquid form, the first medium (a) being supplied to the system (150) in gaseous form,

   wherein the first medium (a) is cooled by means of a first heat exchanger (130) using a second medium (b) prior to being supplied to the system (150).

2. Method according to claim 1, wherein the first medium (a) is further cooled by means of a second heat exchanger (140) using the first medium (a) flowing back from the system (150) prior to being cooled by means of the first heat exchanger (130).

3. Method according to claim 2, wherein the first medium (a) is further cooled by means of the second heat exchanger (140) using the second medium (b).

4. Method according to anyone of the preceding claims, wherein a flowrate of the first medium (a) and/or a flowrate of the second medium (b) are controlled depending on a desired cooling rate of the system (150).

5. Method according to any one of the preceding claims, wherein the second medium (b) is provided in liquid form prior to being supplied to the first heat exchanger (130).

6. Method according to any one of the preceding claims, wherein the first medium (a) is supplied to the system within a circular flow including a compressor (120) and/or a blower.

7. Method according to any one of the preceding claims, wherein the second medium (b) has a higher liquefaction temperature than the first medium (a) has.

8. Method according to any one of the preceding claims, wherein hydrogen, helium or neon is used as the first medium (a), and/or wherein nitrogen is used as the second medium (b).

9. Method according to any one of the preceding claims, wherein an engine is used as the system (150) to be cooled.

10. Apparatus (100) for cooling a system (150) that is intended for use with a first medium (a) in liquid form, the apparatus (100) being arranged to supplying the first medium (a) to the system (150) in gaseous form,

    comprising at least one heat exchanger (130, 140) being arranged to cooling the first medium (a) using a second medium (b) prior to being supplied to the system (150).

11. Apparatus (100) according to claim 10, being adapted to perform a method according to any one of claims 1 to 9.

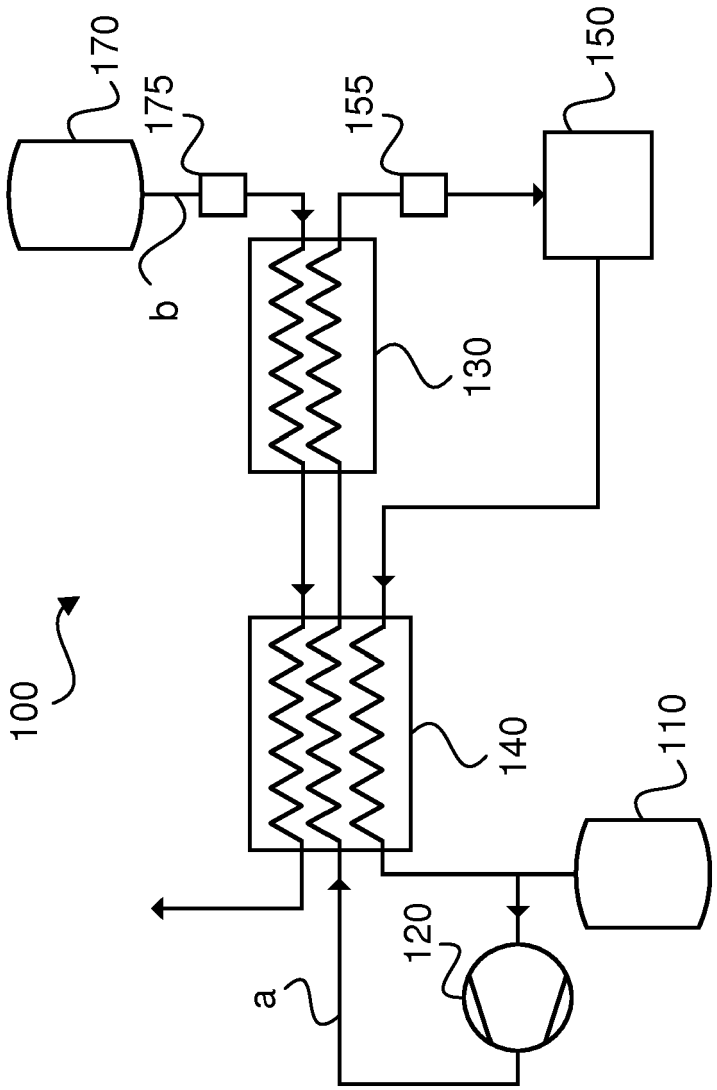

Fig. 1

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 17 02 0538

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2005/016187 A1 (KUDARAVALLI RAVIKUMAR [US]) 27 January 2005 (2005-01-27) * figure 1 * * paragraph [0001] * * paragraph [0006] * * paragraph [0012] - paragraph [0017] * * paragraph [0020] * -----	1-11	INV. F25J1/00 F25J1/02 F25B9/00 F25B40/00
X Y	EP 0 916 890 A2 (AIR PROD & CHEM [US]) 19 May 1999 (1999-05-19) * figure 1 * * paragraph [0003] * * paragraph [0021] - paragraph [0024] * * paragraph [0031] - paragraph [0032] * * paragraph [0034] * -----	1,4-11 2,3	
Y A	US 2016/341452 A1 (BONNE FREDERIC [FR] ET AL) 24 November 2016 (2016-11-24) * figure 1 * * paragraph [0009] - paragraph [0011] * * paragraph [0015] - paragraph [0018] * * paragraph [0087] * -----	2,3 1,4-11	TECHNICAL FIELDS SEARCHED (IPC) F25J F25B
Y A	DE 10 2008 007923 A1 (LINDE AG [DE]) 13 August 2009 (2009-08-13) * figure 1 * * paragraph [0001] * * paragraph [0014] * -----	2,3 1,4-11	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	26 April 2018	Karspeck, Sabine

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 02 0538

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

26-04-2018

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2005016187 A1	27-01-2005	AU 2004202906 A1	20-01-2005
		CN 1575746 A	09-02-2005
		JP 4572404 B2	04-11-2010
		JP 2005028132 A	03-02-2005
		US 2005016187 A1	27-01-2005
EP 0916890 A2	19-05-1999	CA 2253107 C	26-12-2000
		CN 1232953 A	27-10-1999
		EP 0916890 A2	19-05-1999
		JP 2982148 B2	22-11-1999
		JP H11224813 A	17-08-1999
		US 5960636 A	05-10-1999
US 2016341452 A1	24-11-2016	CN 105934641 A	07-09-2016
		EP 3077736 A1	12-10-2016
		FR 3014544 A1	12-06-2015
		JP 2016539307 A	15-12-2016
		US 2016341452 A1	24-11-2016
		WO 2015082788 A1	11-06-2015
DE 102008007923 A1	13-08-2009	DE 102008007923 A1	13-08-2009
		FR 2927403 A1	14-08-2009
		JP 2009186175 A	20-08-2009
		US 2009199579 A1	13-08-2009

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82