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

(11) EP 3 370 017 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
05.09.2018 Bulletin 2018/36

(51) Int Cl.:
F25B 7/00 (2006.01) *F25B 49/02* (2006.01)
F25B 9/00 (2006.01)

(21) Application number: **17159173.8**

(22) Date of filing: **03.03.2017**

(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: **Huurre Group Oy**
01610 Vantaa (FI)

(72) Inventor: **Lindroos, Kåre**
01610 Vantaa (FI)

(74) Representative: **Kolster Oy Ab**
(Salmisaarenaukio 1)
P.O. Box 204
00181 Helsinki (FI)

(54) MULTI-MODE REFRIGERATION SYSTEM

(57) A multi-mode refrigeration system (100). A control unit (102) selects (110) an operation mode: activate (112) a first interface (150) and set (C) a first evaporation temperature to a refrigeration unit (140) to optimize operation with a first external refrigeration system (170) to maintain a first temperature requirement; or activate (114) a second interface (152) and set (C) a second evaporation temperature to the refrigeration unit (140) to optimize operation with a second external refrigeration system (180) to maintain a second temperature requirement, set a target for heat (+) produced with the a heat recovery unit (130), control (C) the heat recovery unit (130) to produce an amount of heat (+) meeting the target, and transmit (C) a control signal through a control interface (154) to a third external refrigeration system (182) to regulate its operation so that the second external refrigeration system (180) is capable of producing enough heat (+) reclaimed with the heat recovery unit (130) to meet the target.

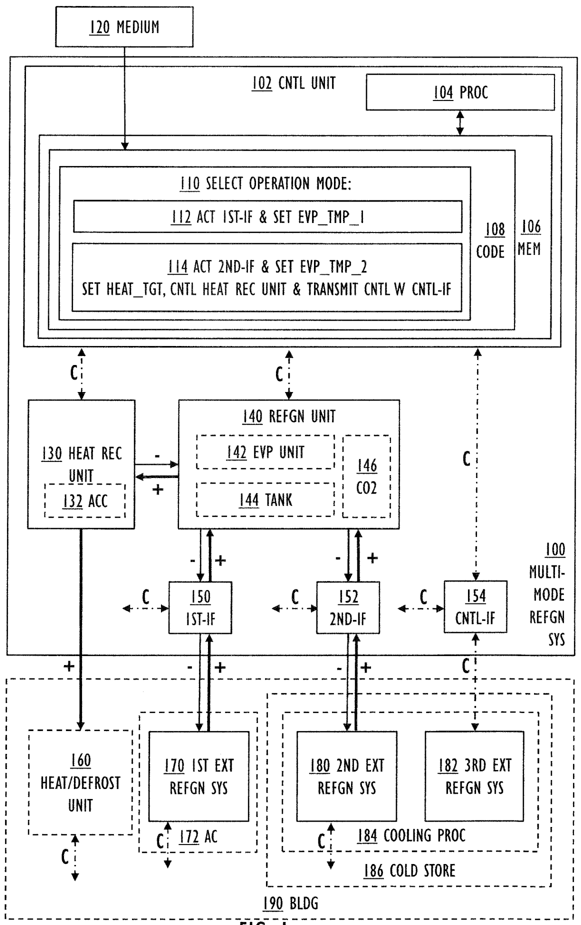

FIG. 1

EP 3 370 017 A1

Description

Field

[0001] The invention relates to a multi-mode refrigeration system.

Background

[0002] IPC class F25 discloses combined heating and refrigeration systems. As sustainable development becomes more important, further sophistication in development and operation of such systems is desirable.

Brief description

[0003] The present invention seeks to provide an improved multi-mode refrigeration system.

[0004] According to an aspect of the present invention, there is provided a multi-mode refrigeration system as specified in claim 1.

[0005] According to another aspect of the present invention, there is provided a control unit for the multi-mode refrigeration system as specified in claim 9.

[0006] According to another aspect of the present invention, there is provided a computer-readable medium comprising computer program code for the control unit as specified in claim 10.

[0007] The invention may provide the advantage that the same multi-mode refrigeration unit may be used flexibly and optimized for different cooling functions. An optimized efficiency may be obtained as the system operates in two different operation modes taking into account cooling and heating needs.

List of drawings

[0008] Example embodiments of the present invention are described below, by way of example only, with reference to the accompanying drawing, in which Figure 1 illustrates example embodiments of the multi-mode refrigeration system.

Description of embodiments

[0009] The following embodiments are only examples. Although the specification may refer to "an" embodiment in several locations, this does not necessarily mean that each such reference is to the same embodiment(s), or that the feature only applies to a single embodiment. Single features of different embodiments may also be combined to provide other embodiments. Furthermore, words "comprising" and "including" should be understood as not limiting the described embodiments to consist of only those features that have been mentioned and such embodiments may contain also features/structures that have not been specifically mentioned.

[0010] As illustrated in Figure 1, a multi-mode refrigeration system 100 comprises a refrigeration unit 140 to produce cold, referenced with '-', and a heat recovery unit 130 coupled with the refrigeration unit 140 to produce heat, referenced with '+'.

[0011] In an example embodiment, the refrigeration unit 140 operates according to the well-known vapour-compression cycle.

[0012] In an example embodiment, the heat recovery unit 130 operates according to the well-known heat pump principle. Note that the heat recovery unit 130 may comprise one or more heat reclaim accumulators 132. In such a system, the refrigeration unit 140 acts as a heat source, and the heat reclaim accumulators 132 as the heat sink.

[0013] Furthermore, the multi-mode refrigeration system 100 comprises three interfaces: a first interface 150 to exchange heat energy +- with a first external refrigeration system 170 with a first temperature requirement, a second interface 152 to exchange heat energy +- with a second external refrigeration system 180 with a second temperature requirement, and a control interface 154 to control, referenced with 'C', a third external refrigeration system 182.

[0014] The first interface 150 and the second interface 152 may be implemented with appropriate tubes and valves controllable by the control unit 102.

[0015] The control interface 154 as well as the other control interfaces C controlled by the control unit 102 may be implemented with appropriate wired/wireless communication technologies and standard/proprietary protocols such as an industrial control bus. In an example embodiment, the wireless communication is implemented with a suitable cellular communication technology such as GSM, GPRS, EGPRS, WCDMA, UMTS, 3GPP, IMT, LTE, LTE-A, etc. and/or with a suitable non-cellular communication technology such as Bluetooth, Bluetooth Low Energy, Wi-Fi, WLAN, Zigbee, etc.

[0016] In an example embodiment, the wired communication is implemented with a suitable communication technology utilizing coaxial cable, twisted pair or fibre optic such as LAN or the Ethernet. In an example embodiment, a fieldbus (such as PROFIBUS, DANBUSS, or Modbus) may be utilized for the communication. The communication traffic may also be transported (in an encrypted form, for example) in the Internet.

[0017] The multi-mode refrigeration system 100 also comprises a control unit 102 to select 110 an operation mode (for the multi-mode refrigeration system 100).

[0018] The multi-mode refrigeration system 100 operates in two different modes.

[0019] In the first mode, the control unit 102 activates 112 the first interface 150 and sets C a first evaporation temperature to the refrigeration unit 140 to optimize operation with the first external refrigeration system 170 to maintain the first temperature requirement.

[0020] In the second mode, the control unit 102 activates 114 the second interface 152 and sets C a second evaporation temperature to the refrigeration unit 140 to optimize operation with the second external refrigeration system 180 to maintain the second temperature requirement, sets a target for heat + produced with the heat recovery unit 130, controls C the heat recovery unit 130 to produce an amount of heat + meeting the target, and transmits C a control signal through the control interface 154 to the third external refrigeration system 182 to regulate its operation so that the second external refrigeration system 180 is capable of producing enough heat + reclaimed with the heat recovery unit 130 to meet the target.

[0021] With these two modes 112, 114, the multi-mode refrigeration system 100 is capable of operating with two different entities: in the first mode 112 with the first external refrigeration system 170, and in the second mode 114 in concert with the second external refrigeration system 180 and the third external refrigeration system 182 and the heat recovery unit 130. An advantage may be that an utilization rate of the multi-mode refrigeration system 100 may be increased. This may be especially beneficial if the multi-mode refrigeration system 100 operates in a more efficient manner with the second external refrigeration system 180 than the third external refrigeration system 182.

[0022] Note that the first evaporation temperature and the second evaporation temperature are selected such that each of them optimizes the operation in their mode with the refrigeration unit 140. As the first evaporation temperature and the second evaporation temperature are different, an energy-optimized solution in each operation mode 112, 114 is obtained.

[0023] In an example embodiment, the operation of the first external refrigeration system 170 is periodical, and operation of the second external refrigeration system 180 is auxiliary to a third external refrigeration system 182.

[0024] The periodical nature may refer to seasons: in colder climates, the first external refrigeration system 170 may need to be used only during the summer months, for example. The periodical nature may also refer to time of day: the first external refrigeration system 170 may need to be used only during daytime. The periodical nature may also refer to some other periodicity: the first external refrigeration system 170 needs to be used during previously determined periods or during "on-the-fly" determined periods.

[0025] In an example embodiment, the control unit 102 maintains a clock and receives an outdoor temperature, and time (and date or day of week) and outdoor temperature are used as parameters in determining a beginning and an end for the operation period of the first mode.

[0026] The operation of the second external refrigeration system 180 may then occur between these periods, according to a predetermined plan or on a "as needed" basis.

[0027] The second external refrigeration system 180 may be 'auxiliary' to the third external refrigeration system 182 in the sense that the third external refrigeration system 182 is the main system, and its operation may be adjusted so that the second external refrigeration system 180 gets enough use (regarding time and required cooling power) so that the heat recovery unit 130 is able to match its required heat output.

[0028] In an example embodiment, the control unit 102 may obtain temperatures from temperature sensors placed in various places, by a tank 144, between an evaporation unit 142 and the tank 144 etc. in order to optimize the operation. The control unit 102 performs the control by adjusting a pump of the evaporation unit 142, the refrigeration unit 140 and its suction pressure, pumps interacting with the interfaces 150, 152, a pump of the heat recovery unit 130, various valves, and temperature settings.

[0029] In an example embodiment, the first external refrigeration system 170 belongs to an air conditioning system 172 of a building 190, and the second external refrigeration system 180 augments another cooling process 184 in a building 190. The air conditioning system 172 of the building 190 may be a part of HVAC (heating, ventilation and air conditioning) of the building 190.

[0030] As was explained earlier, in certain climates, the first external refrigeration system 170 needs to be operated as a part of the air conditioning system 172 only during summer months.

[0031] In an example embodiment, the other cooling process 184 implements a cold store 186 in a confined space in the building 190. The cold store 186 may be a warehouse for refrigerated or frozen goods, for example. The cold store 186 may be a part of HVAC&R (heating, ventilation, air conditioning and refrigeration) of the building 190.

[0032] Even though Figure 1 only illustrates one building, 190, the operation of the multi-mode refrigeration system 100 may be coupled with one or more buildings 190. Accordingly, in an example embodiment, the first external refrigeration system 170, the second external refrigeration system 180, the third external refrigeration system 182 and the heat recovery unit 130 direct their effect to one or more buildings 190.

[0033] In an example embodiment, the heat recovery unit 130 is configured to output + the produced heat to at least one of a heating unit 160 of a building 190, a heating unit 160 of a water supply, a defrosting unit 160 of the first external refrigeration system 170, a defrosting unit 160 of the second external refrigeration system 180, a defrosting unit 160 of the third external refrigeration system 182.

[0034] In an example embodiment, the refrigeration unit 140 comprises one or more evaporation units 142 and one or more refrigeration system tanks 144, and the first evaporation temperature or the second evaporation temperature optimizes the operation by optimizing operation of the one or more evaporation units 142 and the one or more refrigeration system tanks 144. Note that this may provide an advantage that the components, the evaporation unit 142, the tank 144 and the required liquid circuit, need not be duplicated, but the same components operate, alternatively, with the first external refrigeration system 170 or the second external refrigeration system 180.

[0035] In an example embodiment, the refrigeration unit 140 operates with liquid carbon dioxide 146 as a refrigerant.

[0036] In an example embodiment, the refrigeration unit 140 operates with supercritical carbon dioxide as the refrigerant, wherein the carbon dioxide is in a fluid state where it is held at or above its critical temperature and critical pressure.

[0037] However, the example embodiments are not restricted to these refrigerants, but other refrigerants known in the art may be applied as well.

[0038] In an example embodiment, the control unit 102 may be implemented as an industrial controller. The control unit 102 may operate in a centralized fashion, even as a single control apparatus, or, in a distributed fashion, comprising more than one interacting and communicating control apparatuses.

[0039] In an example embodiment, the control unit 102 may be implemented as a stand-alone computing apparatus, such as a computer or a server.

[0040] Depending on the required processing power, the control unit 102 may be implemented with computer technology, such as a laptop, an industrial computer, or an unit with one or more microprocessors.

[0041] In an example embodiment, the control unit 102 is a general-purpose off-the-shelf computing device, as opposed to a purpose-build proprietary equipment, whereby research & development costs will be lower as only the special-purpose software (and not the hardware) needs to be designed, implemented and tested. Also, the server may be implemented as a general-purpose off-the-shelf computing device with an appropriate software.

[0042] Alternatively, or additionally, at least a part of the required processing may be performed according to a client-server architecture, a cloud computing architecture, a peer-to-peer system, or another applicable computing architecture.

[0043] In an example embodiment, the control unit 102 for the multi-mode refrigeration system 100 comprises one or more processors 104, and one or more memories 106 including computer program code 108.

[0044] The one or more memories 106 and the computer program code 108 are configured to, with the one or more processors 104, cause the control unit 102 to select 110 the operation mode and perform the above-described operations.

[0045] An example embodiment provides also a computer-readable medium 120 comprising the computer program code 108 for the control unit 102, which, when loaded into the control unit 102 and executed by the control unit 102, causes the control unit 102 to select 110 the operation mode and perform the described operations.

[0046] The term 'processor' 104 refers to a device that is capable of processing data. Depending on the processing power needed, the control unit 102 may comprise several processors 104 such as parallel processors or a multicore processor.

[0047] The term 'memory' 108 refers to a device that is capable of storing data run-time (= working memory) or permanently (= non-volatile memory). The working memory and the non-volatile memory may be implemented by a random-access memory (RAM), dynamic RAM (DRAM), static RAM (SRAM), a flash memory, a solid state disk (SSD), PROM (programmable read-only memory), a suitable semiconductor, or any other means of implementing an electrical computer memory.

[0048] The processor 104 and the memory 106 may be implemented by an electronic circuitry. A non-exhaustive list of implementation techniques for the processor 104 and the memory 106 includes, but is not limited to: logic components, standard integrated circuits, application-specific integrated circuits (ASIC), system-on-a-chip (SoC), application-specific standard products (ASSP), microprocessors, microcontrollers, digital signal processors, special-purpose computer chips, field-programmable gate arrays (FPGA), and other suitable electronics structures.

[0049] The computer program code 108 may be implemented by software and/or hardware. In an example embodiment, the software may be written by a suitable programming language (a high-level programming language, such as C, C++, or Java, or a low-level programming language, such as a machine language, or an assembler, for example), and the resulting executable code 108 may be stored on the memory 106 and run by the processor 104. In an alternative example embodiment, the functionality of the hardware may be designed by a suitable hardware description language (such as Verilog or VHDL), and transformed into a gate-level netlist (describing standard cells and the electrical connections between them), and after further phases the chip implementing the processor 104 memory 106 and the code 108 may be fabricated with photo masks describing the circuitry.

[0050] In an example embodiment, the operations of the computer program code 108 may be divided into functional modules, sub-routines, methods, classes, objects, applets, macros, etc., depending on the software design methodology and the programming language used. In modern programming environments, there are software libraries, i.e. compilations of ready-made functions, which may be utilized by the computer program code 108 for performing a wide variety of standard operations. In an example embodiment, the computer program code 108 may be in source code form, object code form, executable file, or in some intermediate form.

[0051] The computer-readable medium 120 may comprise at least the following: any entity or device capable of carrying the computer program code 108 to the control unit 102, a record medium, a computer memory, a read-only memory, an electrical carrier signal, a telecommunications signal, and a software distribution medium. In some jurisdictions, depending on the legislation and the patent practice, the computer-readable medium 120 may not be the telecommunications signal. In an example embodiment, the computer-readable medium 120 may be a computer-readable storage medium. In an example embodiment, the computer-readable medium 120 may be a non-transitory computer-readable storage medium.

[0052] It will be obvious to a person skilled in the art that, as technology advances, the inventive concept can be implemented in various ways. The invention and its embodiments are not limited to the example embodiments described above but may vary within the scope of the claims.

Claims

1. A multi-mode refrigeration system (100) comprising:

a refrigeration unit (140) to produce cold (-);
a heat recovery unit (130) coupled with the refrigeration unit (140) to produce heat (+);
a first interface (150) to exchange heat energy (+-) with a first external refrigeration system (170) with a first temperature requirement;
a second interface (152) to exchange heat energy (+-) with a second external refrigeration system (180) with a second temperature requirement;
a control interface (154) to control (C) a third external refrigeration system (182); and
a control unit (102) to select (110) an operation mode:

activate (112) the first interface (150) and set (C) a first evaporation temperature to the refrigeration unit (140) to optimize operation with the first external refrigeration system (170) to maintain the first temperature requirement; or
activate (114) the second interface (152) and set (C) a second evaporation temperature to the refrigeration unit (140) to optimize operation with the second external refrigeration system (180) to maintain the second temperature requirement, set a target for heat (+) produced with the heat recovery unit (130), control (C) the heat recovery unit (130) to produce an amount of heat (+) meeting the target, and transmit (C) a control signal through the control interface (154) to the third external refrigeration system (182) to regulate its operation so that the second external refrigeration system (180) is capable of producing enough heat (+) reclaimed with the heat recovery unit (130) to meet the target.

2. The system of claim 1, wherein operation of the first external refrigeration system (170) is periodical, and operation of the second external refrigeration system (180) is auxiliary to a third external refrigeration system (182).

3. The system of any preceding claim, wherein the first external refrigeration system (170) belongs to an air conditioning system (172) of a building (190), and the second external refrigeration system (180) augments another cooling process (184) in a building (190).

4. The system of claim 3, wherein the other cooling process (184) implements a cold store (186) in a confined space in the building (190).

5. The system of any preceding claim, wherein the first external refrigeration system (170), the second external refrigeration system (180), the third external refrigeration system (182) and the heat recovery unit (130) direct their effect to one or more buildings (190).

6. The system of any preceding claim, wherein the heat recovery unit (130) is configured to output (+) the produced heat to at least one of a heating unit (160) of a building (190), a heating unit (160) of a water supply, a defrosting unit (160) of the first external refrigeration system (170), a defrosting unit (160) of the second external refrigeration system (180), a defrosting unit (160) of the third external refrigeration system (182).

7. The system of any preceding claim, wherein the refrigeration unit (140) comprises one or more evaporation units (142) and one or more refrigeration system tanks (144), and the first evaporation temperature or the second evaporation temperature optimizes the operation by optimizing operation of the one or more evaporation units (142) and the one or more refrigeration system tanks (144).

8. The system of any preceding claim, wherein the refrigeration unit (140) operates with liquid carbon dioxide (146) as a refrigerant.

9. The control unit (102) for the multi-mode refrigeration system (100) of any preceding claim 1 to 8 comprising:

one or more processors (104); and
one or more memories (106) including computer program code (108),
and the one or more memories (106) and the computer program code (108) are configured to, with the one or more processors (104), cause the control unit (102) to select (110) the operation mode and perform the described opera-

tions.

10. A computer-readable medium (120) comprising the computer program code (108) for the control unit (102) of claim 9, which, when loaded into the control unit (102) and executed by the control unit (102), causes the control unit (102) to select (110) the operation mode and perform the described operations.

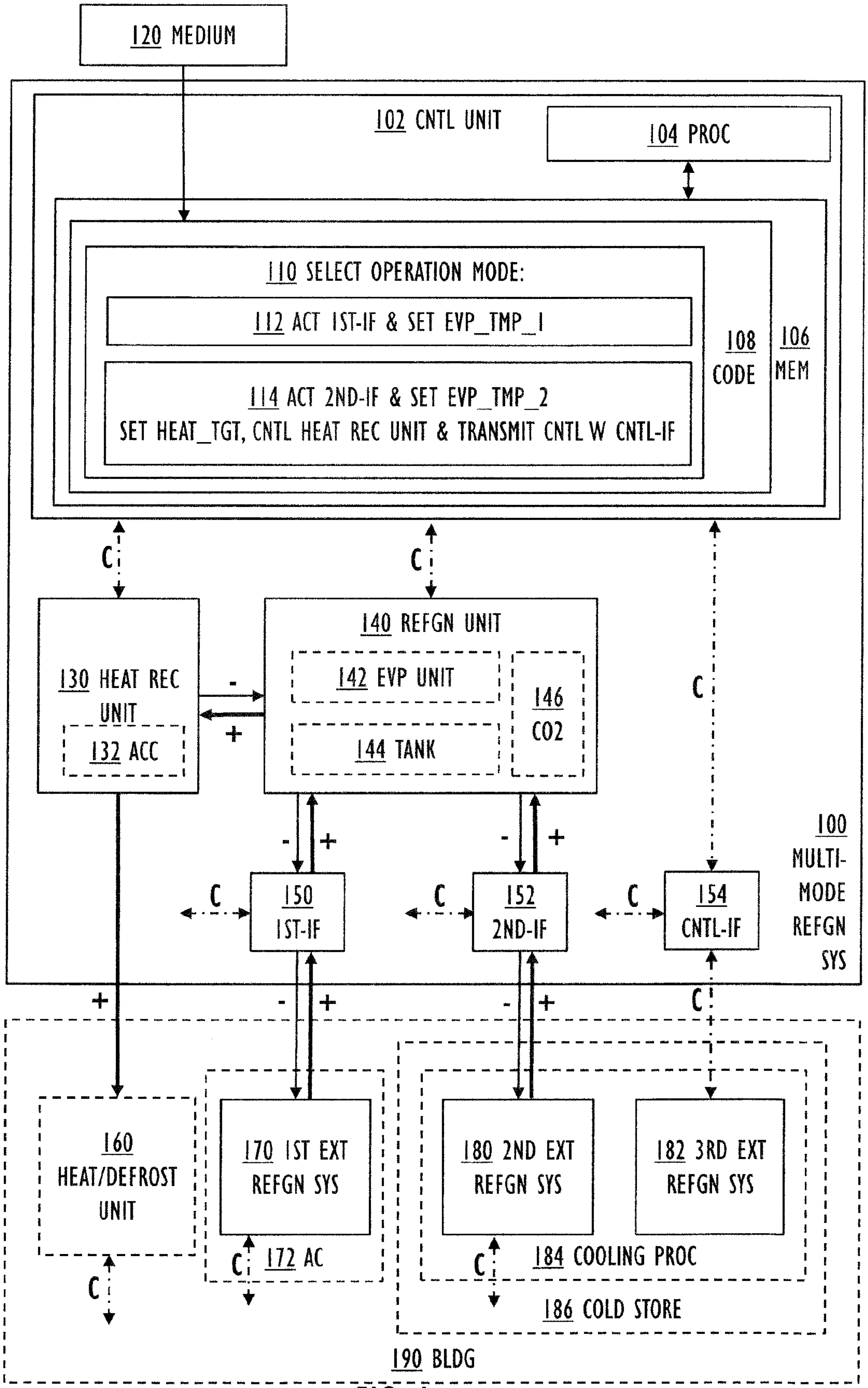
120 MEDIUM
102 CNTL UNIT
104 PROC
110 SELECT OPERATION MODE:
112 ACT 1ST-IF & SET EVP_TMP_1
114 ACT 2ND-IF & SET EVP_TMP_2
SET HEAT_TGT, CNTL HEAT REC UNIT & TRANSMIT CNTL W CNTL-IF
108 CODE
106 MEM
C
130 HEAT REC UNIT
132 ACC
140 REFGN UNIT
142 EVP UNIT
144 TANK
146 CO2
150 1ST-IF
152 2ND-IF
154 CNTL-IF
100 MULTI-MODE REFGN SYS
160 HEAT/DEFROST UNIT
170 1ST EXT REFGN SYS
172 AC
180 2ND EXT REFGN SYS
182 3RD EXT REFGN SYS
184 COOLING PROC
186 COLD STORE
190 BLDG

FIG. 1

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 17 15 9173

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	EP 2 937 649 A1 (MITSUBISHI ELECTRIC CORP [JP]) 28 October 2015 (2015-10-28) * paragraph [0018] - paragraph [0293]; figures 1-15 *	1-10	INV. F25B7/00 F25B49/02 F25B9/00
X	EP 2 363 663 A1 (DAIKIN IND LTD [JP]; DAIKIN EUROPE NV [BE]) 7 September 2011 (2011-09-07) * paragraph [0048] - paragraph [0218]; figures 1-4 *	1-10	
X	EP 2 416 092 A1 (DAIKIN IND LTD [JP]; DAIKIN EUROPE NV [BE]) 8 February 2012 (2012-02-08) * paragraph [0041] - paragraph [0207]; figures 1-5 *	1-10	
X	EP 2 479 519 A2 (LG ELECTRONICS INC [KR]) 25 July 2012 (2012-07-25) * paragraph [0029] - paragraph [0110]; figures 1-9 *	1-10	
			TECHNICAL FIELDS SEARCHED (IPC)
			F25B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	4 September 2017	Szilagyi, Barnabas

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 15 9173

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.

04-09-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2937649 A1	28-10-2015	EP 2937649 A1	28-10-2015
		JP 5921719 B2	24-05-2016
		JP WO2014097870 A1	12-01-2017
		US 2015285545 A1	08-10-2015
		WO 2014097439 A1	26-06-2014
		WO 2014097870 A1	26-06-2014
EP 2363663 A1	07-09-2011	CN 102713460 A	03-10-2012
		EP 2363663 A1	07-09-2011
		JP 5806940 B2	10-11-2015
		JP WO2011080805 A1	09-05-2013
		US 2012285188 A1	15-11-2012
		WO 2011080805 A1	07-07-2011
EP 2416092 A1	08-02-2012	CN 102725599 A	10-10-2012
		EP 2416092 A1	08-02-2012
		JP 5312613 B2	09-10-2013
		JP WO2011092742 A1	23-05-2013
		US 2012297806 A1	29-11-2012
		WO 2011092742 A1	04-08-2011
EP 2479519 A2	25-07-2012	EP 2479519 A2	25-07-2012
		JP 5563609 B2	30-07-2014
		JP 2012154619 A	16-08-2012
		KR 20120085396 A	01-08-2012
		US 2012186284 A1	26-07-2012

EPO FORM P0459

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