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

(11) EP 2 172 725 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
07.04.2010 Bulletin 2010/14

(51) Int Cl.:
F25D 29/00 (2006.01)

(21) Application number: 08165845.2

(22) Date of filing: 03.10.2008

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

(71) Applicant: Whirlpool Corporation
Benton Harbor, MI 49022 (US)

(72) Inventors:
- Bianchi, Lorenzo
21025, Comerio (IT)
- Biotti, Carolina
21025, Comerio (IT)
- Monticelli, Enrica
21025, Comerio (IT)

(74) Representative: Guerci, Alessandro
Whirlpool Europe S.r.l.
Patent Department
Viale G. Borghi 27
21025 Comerio (VA) (IT)

(54) Refrigerator with optimized food preservation control

(57) A refrigerator regulates temperature and humidity and further controls the air inlet temperature and the speed of the same air to achieve improved food preservation results.

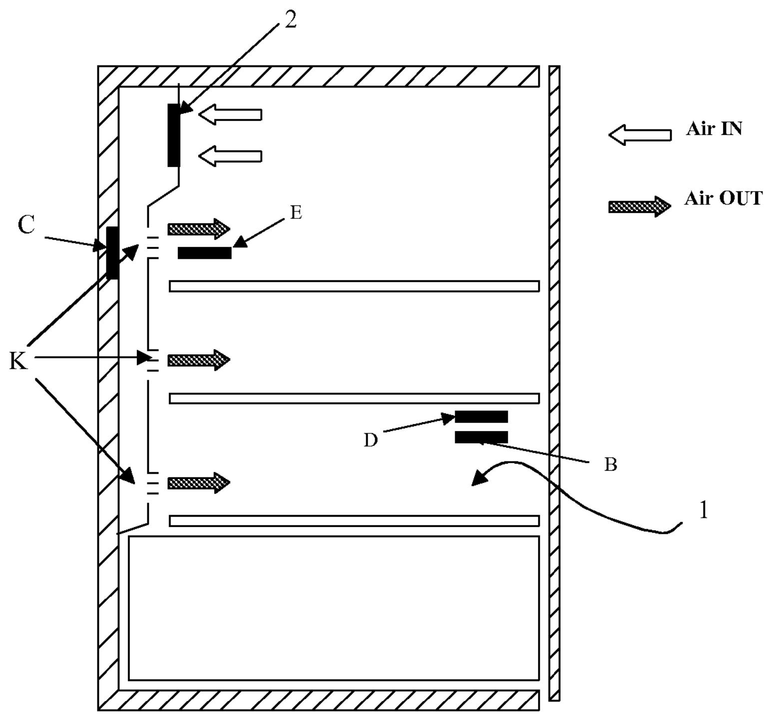

Fig. 1

Printed by Jouve, 75001 PARIS (FR)

Description

[0001] Object of the present invention is a refrigerator provided with improved food preservation capabilities and an improved food preservation method thereof.

[0002] It is known in the art how to control the temperature of a refrigerator cell, whenever the refrigerator is provided with a variable speed compressor. Methods using relative humidity sensors to control relative humidity (RH) of a refrigerator compartment are known as well.

[0003] Known are also food science theories describing processes of moisture migration from food to the ambient wherein food is placed, causing weight loss of the same food. As consequence of this phenomenon, food deteriorates its quality during the preservation time, especially when it is stored into a refrigerator compartment cooled with air streams forced trough a motorized fan (e.g. "No frost" refrigerators). The following simplified mathematical model can be used to explain the phenomenon of moisture migration from food to ambient:

$$M= m*A*(Ps*Aw - Pm),$$

wherein:

- M is the mass transfer from food to ambient (weight loss);
- m is the mass transfer coefficient;
- A is the food surface area;
- Ps is the saturated vapor pressure at the surface;
- Aw is the water activity;
- Pm is the vapor pressure above food surface (environmental parameter).

[0004] Parameters on the right side of the equation have direct impact in reducing the weigh of the food, and therefore prejudicing the food quality during preservation process. Known refrigerators do not preserve the food with preservation capabilities such as preventing an excessive weight loss, being not capable to control and regulate the parameters affecting the weight loss phenomena described in the equation. Moreover it is not disclosed in the art a method thereof for preventing an excessive weight loss of the food stored into a cavity cooled with cold air forced by means of a motorized fan.

[0005] Finally, none of the known refrigerators performs a control of the air temperature used for cooling the food, in order to prevent from the same food freezing bum damages.

[0006] The present invention is related to a fridge or similar that regulates temperature and humidity and that further controls the air inlet temperature and the speed of the same air to achieve improved food preservation results compared with existing refrigerators.

[0007] Other features and advantages of the present invention will become readily apparent to the skilled artisan from the following detailed description when read in light of the accompanying drawings, in which:

Fig. 1 shows a schematic architecture of a fridge according to the present invention.

Fig. 2 shows the logic architecture of a fridge according to the present invention

Fig. 3 shows a plot describing how the compressor speed control according to the present invention is performed.

Fig, 4 shows a plot describing how the fan speed control according to the present invention is performed

[0008] According to the above mentioned food theories, parameters affecting the loss of weigh of the food are strictly related to the food (i.e. Aw = food water activity, A = food surface area) and can't be modified. Other equation parameters depend on the environmental characteristics can be modified and controlled by a refrigerator and a method according to the present invention.

[0009] More specifically, m, that is the mass transfer coefficient, is directly related to air speed, and Ps and Pm, respectively the vapor pressure on and above the food surface, depends on air temperature and relative humidity. Therefore a refrigerator also provided with means for controlling such parameters during the food refrigeration process allows the execution of a method that improves the food preservation performances.

[0010] With reference to Fig 1 and 2 it is described the architecture of a refrigerator according to the present invention which includes a first temperature sensor B placed into a fridge cell or compartment 1, a second temperature sensor C measuring, in direct contact or not, the temperature of the evaporator (not shown) connected, in a refrigerant circuit, to a variable speed compressor (not shown). A relative humidity sensor D is also placed into the fridge cell or compartment together with a third temperature sensor E measuring the temperature at the air inlet Kin the fridge cell, said air forced into the cell with a motorized fan (not shown) rotating at a controlled speed.

[0011] According to the present invention, the control method applicable to regulate the refrigerator is a main control algorithm that accomplishes four tasks, following described and associated with an execution priority, that are executable according to any possible sequence or repetition of the same tasks, or executed in a more sophisticated combining algorithm such as a PID (Proportional, Integral, Derivative) algorithm, a multi loop predictive algorithm, a neural network or a fuzzy algorithm. The main control algorithm can also include a portion algorithm comprising a sequential execution of the task/s and another portion comprising a more sophisticated algorithm which executes more tasks at the same time.

[0012] Hereafter the task accomplished by the method of the present invention sorted by their decreasing execution priorities.

[0013] Temperature Control of the refrigerator.

[0014] This first task of the control algorithm concerns the fridge temperature control, which is the main aim that a control for refrigerators has to satisfy. It has the highest priority in the general routines execution.

[0015] This control is performed in a known way, provided that a variable speed compressor is used to regulate the temperature of the fridge cell or compartment FRIDGE TEMP to a preset value SET TEMP. For instance, a PID control is used to regulate the compressor in a closed loop with the fridge temperature sensor B, so that the speed of the compressor is adjusted in order to reach the required fridge temperature. Another example is depicted in Fig. 3 wherein the compressor can be driven at two different speeds levels, respectively COMP SPEED = HIGH SPEED and COMP SPEED = LOW SPEED. Whenever the difference between the temperature set for the cell SET TEMP and the temperature measured with the first temperature sensor B FRIDGE TEMP is greater than a second pre-defined value DELTA MAX1, the control runs the compressor at COMP SPEED = HI SPEED, for a fast temperature recovery.

[0016] In the other cases the control runs the compressor at minimum speed COMP SPEED = LOW SPEED. Other more sophisticated algorithms can be applied to define the optimal speed at which the compressor motor has to be driven. A time defrost operation is performed as well.

Relative Humidity regulation

[0017] A second task of the control algorithm concerns the control of the relative humidity R.H. allowing a better food preservation of the food articles in dependence on the food category (e.g. vegetables, meat and so on). This control feature is performed, for instance, by including a relative humidity sensor D into a closed loop control with the compressor, in which the operational parameters of the compressor such as the speed, the"on working time, and the"off"pausing time are regulated.

[0018] When this control task is performed, the relative humidity R.H. level is monitored through the R.H. sensor D so that it doesn't fall outside the optimal set R.H. range, which depends on the food contained into the compartment to which the control is applied. For instance, the optimal R.H. range could be set at between 90% and 95% for the compartment in which vegetables are stored, while a range between 70% - 80% can be set for compartments wherein meat is stored. When the R.H level is measured by R.H. sensor D outside of these optimal ranges, this humidity control is activated.

[0019] Humidity level can be adjusted by activating the compressor in on/off working mode. No humidity control is possible as long as the compressor runs continuously at the same speed.

[0020] Specifically, when the compressor is running, R.H level decreases. When the compressor is off, R.H. level increases, and it increases even more if the fridge fan motor is running.

[0021] Depending on the compressor speed used, on and off times are adjusted, to regulate the R.H. level. For instance, whenever a de-humidifying operation is needed, the compressor is driven at low speed and consequently "on" time becomes longer and air is dried out. Differently, if a higher humidity level is needed, compressor runs at higher speed and "on" time becomes shorter and fridge fan motor is kept running during the "off"-times.

Air inlet temperature control

[0022] With this third task the control algorithm optimizes the temperature measured by a third temperature sensor E of the air at the inlet K of the compartment by setting the proper compressor speed in relationship with the compartment conditions, for instance the temperature measured by the first temperature sensor B, and therefore controlling the temperature of the evaporator, which is measured with the second temperature sensor C, that cools the air entering at the inlet of the compartment.

[0023] In fact, according to known food preservation theories, the temperature of the air entering the compartment must be optimized in dependence of the temperature of the same compartment, which is linked with the temperature of the food stored into the same compartment, in order to prevent freezing bums, especially on vegetables and fruits. In particular, the gap between the two temperatures must be lower than a predetermined amount DELTA MAX2, which is a really critical parameter for food preservation because freezing bums can otherwise occur, especially when air inlet temperature is much colder more than the cell temperature. This predetermined temperature difference DELTA MAX2 is an acceptable value that avoids freezing damages which depend on the type of food stored, and which can be varied according to the type of food contained in the cell.

[0024] By regulating the compressor speed it is possible to regulate and keep under control this critical parameter.

[0025] With reference to Fig. 4 in performing this task control operates for instance in closed loop with the third temperature sensor E, keeping the difference between temperature read by first temperature sensor B and the third temperature sensor E below the maximum difference DELTA MAX2 allowable. Whenever the difference exceeds the maximum difference DELTA MAX2 value, the control reduces the compressor speed until temperature difference is again within the allowed range.

[0026] More sophisticated controls are applicable also to perform this task.

Air speed control

[0027] According to this fourth task the control algorithm continuously establishes and sets the optimal speed for the motorized fan on the basis of the actual operating conditions.

[0028] Specifically, the optimal speed is the best compromise between two opposite needs: from one side the need to keep the air speed as slow as possible to minimize food weight losses, and from the other side the need of increasing the air speed to cool down the fridge cell in a shorter time, especially when food at ambient temperature is introduced.

[0029] It follows that the motorized fan can be run at least at two fan speeds: the maximum speed MAX SPEED which depends on the fan motor requirements, and the minimum optimized speed MIN SPEED that reduces the food weight losses keeping the cell refrigerated. On the other side minimum settable speed obtainable from the motorized fan depends on the motor construction and on the driver method or controller. Therefore the minimum optimized speed MIN SPEED could correspond to the minimum settable speed, or to the speed calculated on the basis of measured parameters, such as the cell temperature, read by the first temperature sensor B, or by the third temperature sensor E, or by a combination the two signals read.

[0030] The air speed control decides whenever the motorized fan is active, and at which speed it has to be run.

[0031] For instance, the speed can be selected according to the following algorithm: whenever the difference between the temperature set for the cell SET TEMP and the temperature measured with the first temperature sensor B FRIDGE TEMP is greater than a second pre-defined value DELTA MAX3 the control runs the motor fan at maximum speed SPEED = MAX SPEED, for a fast temperature recovery.

[0032] In all the other cases the control runs the motor fan at minimum speed SPEED = MIN SPEED. The defined speed value is used for driving the motor fan at the requested speed. Other more sophisticated algorithms can be applied to define the optimal speed at which the motorized fan has to be run.

[0033] It is finally pointed out that not necessarily DELTA MAX1 = DELTA MAX2 = DELTA MAX3 and that, when accomplishing each of the described tasks, if the temperature set by the user SET TEMP is significantly colder that the cavity temperature FRIDGE TEMP, the controller will run the compressor at max speed to use all the available cooling capacity for a fast temperature pull-down.

[0034] In view of the above, a fridge and a method capable to adjust temperature and humidity in addition to the air inlet temperature and the speed of the same air have been disclosed, to achieve improved food preservation results compared with existing refrigerators.

Claims

1. Refrigerator comprising a cell (1) cooled at a predetermined temperature value measurable with a cell temperature sensor (B) located into the cell (1), the cell being cooled by means of cold airstreams generated by a fan which cooperates with an evaporator, the airstreams entering into said cell (1) through at least one cell air inlet (K),
characterized in that the refrigerator further comprises an air temperature sensor (E) for measuring the temperature of the airstreams at the cell inlet (K) and means for regulating the temperature at the cell inlet (K) at a value which is lower than a predetermined difference (DELTA) from said predetermined temperature value.

2. Refrigerator according to according to claim 1 wherein the temperature of said evaporator being adjustable to a second predetermined temperature value and measurable with an evaporator temperature sensor (C).

3. Refrigerator according to claims lor 2, wherein the fan is drivable at variable speed and the fan can be driven at least at a maximum speed and minimum speed.

4. Refrigerator according to any of the preceding claims, wherein the compressor is a variable speed compressor.

5. Refrigerator according to any of the preceding claims further comprising a relative humidity sensor (D) located into the cell (1) and means for actuating a humidity control.

6. Refrigerator according to any of the preceding claims further comprising means for a fast pull-down of the cavity temperature.

7. Method for controlling a refrigerator cavity comprising the task of:

    - regulating the cell temperature to a predetermined value,
    - regulating the cell humidity to a predetermined value, and
    - regulating the temperature of the air at the inlet of the cell lower that a predetermined amount from the cell predetermined temperature.

8. Method according to claim 7 **characterized in that** it further comprises regulating the air speed at the inlet of the cell.

9. Method according to claim 7 and/or 8 wherein the task of regulating the cell temperature has higher priority than the other tasks.

10. Method according to any of the claims from 7 to 9 wherein the task are executed sequentially or in par-

allel.

11. Method according to any of the claims from 7 to 10 wherein the execution of the method is a combination of the task

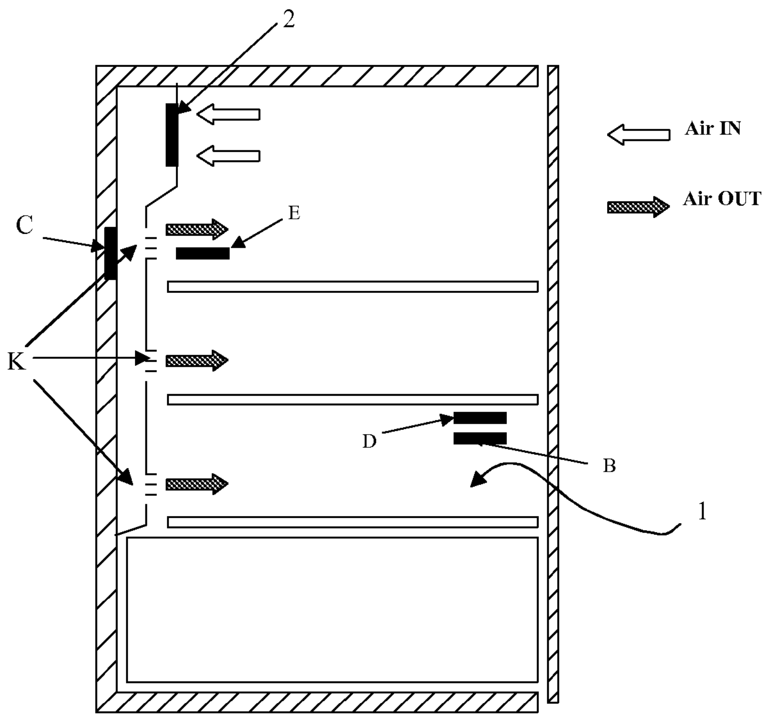
2
Air IN
Air OUT
C
E
K
D
B
1

Fig. 1

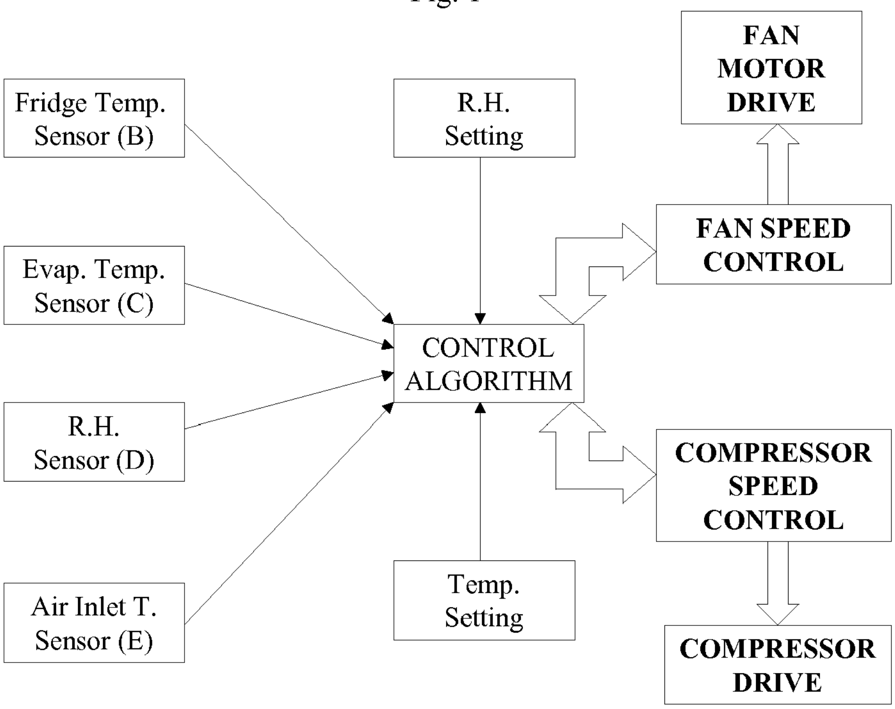
FAN MOTOR DRIVE
Fridge Temp. Sensor (B)
R.H. Setting
FAN SPEED CONTROL
Evap. Temp. Sensor (C)
CONTROL ALGORITHM
R.H. Sensor (D)
COMPRESSOR SPEED CONTROL
Air Inlet T. Sensor (E)
Temp. Setting
COMPRESSOR DRIVE

Fig. 2

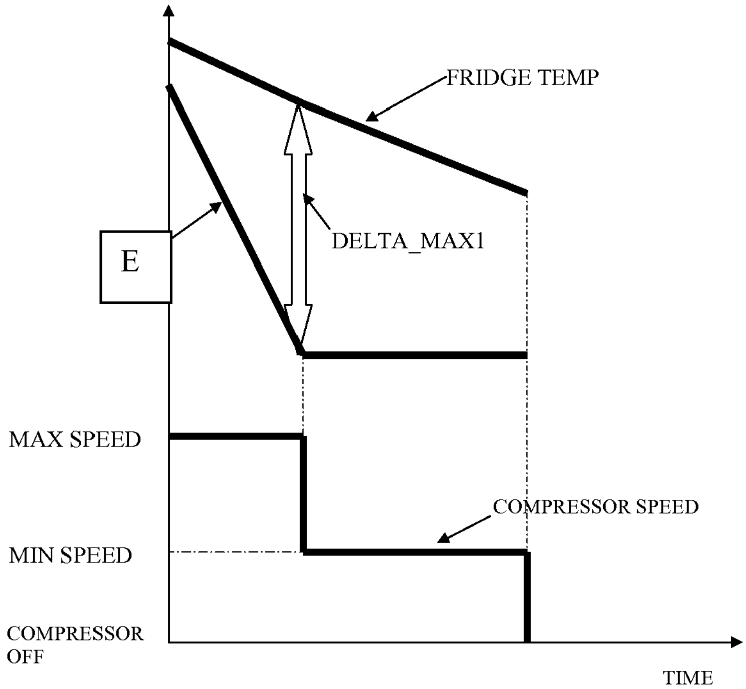
FRIDGE TEMP
DELTA_MAX1
E
MAX SPEED
COMPRESSOR SPEED
MIN SPEED
COMPRESSOR
OFF
TIME

Fig. 3

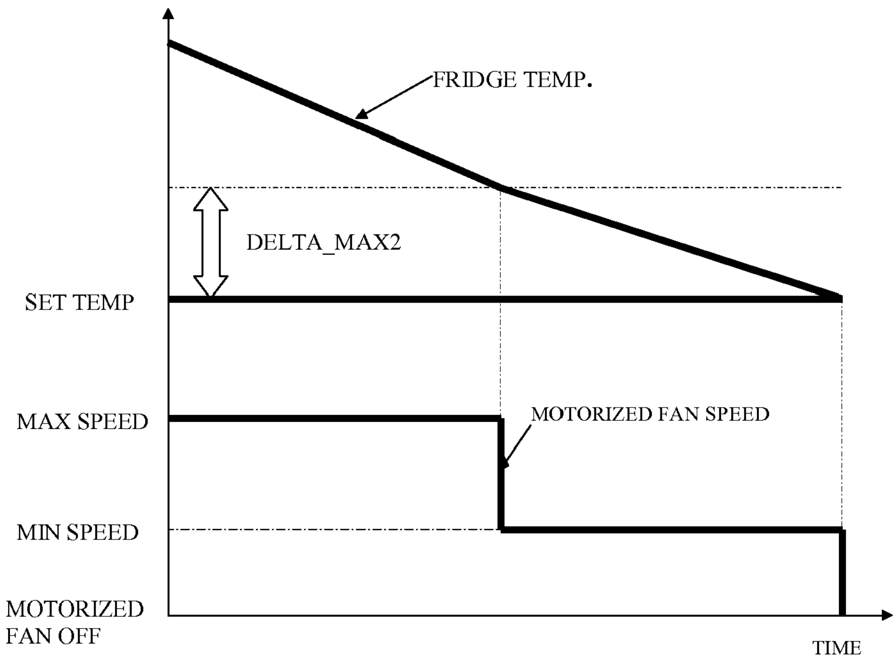
FRIDGE TEMP.
DELTA_MAX2
SET TEMP
MAX SPEED
MOTORIZED FAN SPEED
MIN SPEED
MOTORIZED
FAN OFF
TIME

Fig. 4

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 08 16 5845

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 3 609 988 A (BRIGHT JAMES A) 5 October 1971 (1971-10-05) * figures 1,6-8 * * column 5, line 53 - line 58 * * column 6, line 42 - line 48 * * column 7, line 30 - line 36 * -----	7,10,11	INV. F25D29/00
X	EP 0 592 004 A (DAEWOO ELECTRONICS CO LTD [KR]) 13 April 1994 (1994-04-13) * figure 2 * * page 4, line 31 - line 33 * -----	1,6	
A	US 6 694 754 B1 (SCHENK DENNIS G [US] ET AL) 24 February 2004 (2004-02-24) * figure 2 * -----	3,4	
A	EP 1 959 215 A (WHIRLPOOL CO [US]) 20 August 2008 (2008-08-20) * figures 1,3 * -----	2,3,5	
A	EP 1 935 293 A (HUSSMANN CORP [US]) 25 June 2008 (2008-06-25) * figure 2 * -----	1,2,6	TECHNICAL FIELDS SEARCHED (IPC) F25D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	31 March 2009	Dezso, Gabor

1

EPO FORM 1503 03.82 (P04C01)

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

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 08 16 5845

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.

31-03-2009

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3609988 A	05-10-1971	NONE	
EP 0592004 A	13-04-1994	AU 663006 B2	21-09-1995
		AU 4894893 A	28-04-1994
		CN 1085650 A	20-04-1994
		DE 69307078 D1	13-02-1997
		DE 69307078 T2	17-04-1997
		JP 3073636 B2	07-08-2000
		JP 6194022 A	15-07-1994
		US 5433086 A	18-07-1995
US 6694754 B1	24-02-2004	NONE	
EP 1959215 A	20-08-2008	US 2008196427 A1	21-08-2008
EP 1935293 A	25-06-2008	NONE	

EPO FORM P0459

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