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

(11) EP 2 161 519 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
10.03.2010 Bulletin 2010/10

(51) Int Cl.:
F25B 31/00 *(2006.01)*

(21) Application number: **09251462.9**

(22) Date of filing: **01.06.2009**

(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 MK MT NL NO PL PT RO SE SI SK TR
Designated Extension States:
AL BA RS

(30) Priority: **03.09.2008 US 203164**

(71) Applicant: **Scroll Technologies**
Arkadelphia, AR 71923 (US)

(72) Inventor: **Hahn, Gregory W.**
Arkadelphia, AR 71923 (US)

(74) Representative: **Shanks, Andrew et al**
Marks & Clerk LLP
Aurora
120 Bothwell Street
Glasgow
G2 7JS (GB)

(54) Oil return algorithm for capacity modulated compressor

(57) A control for a compressor motor is programmed to operate the motor at at least one low capacity and at least one higher capacity. The control is operable to estimate an amount of oil which will have migrated from said compressor shell, at least when the compressor is operating at the lower capacity rate. The motor control moves the compressor motor from the lower capacity to at least one higher capacity once the estimated quantity of oil exceeds a predetermined limit. The capacity may be related to space.

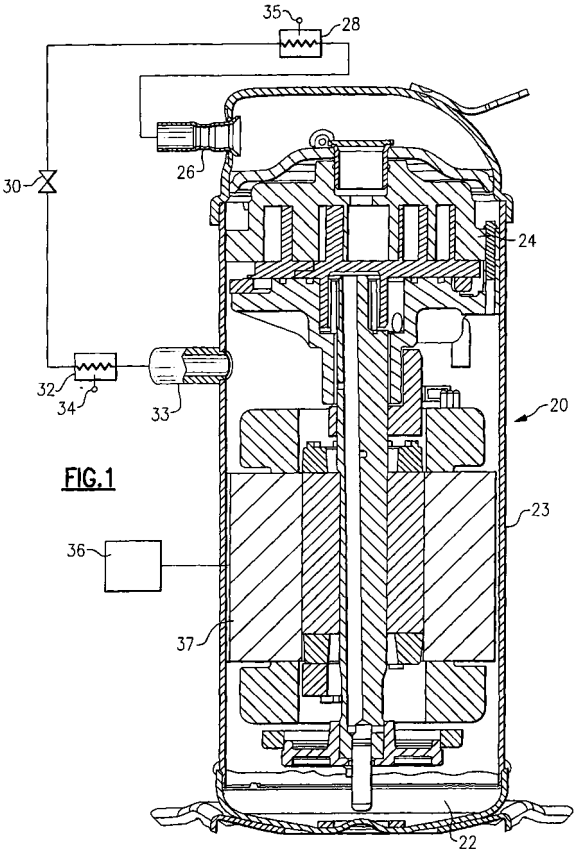


FIG.1

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Description

BACKGROUND OF THE INVENTION

[0001] This application relates to an algorithm for ensuring adequate oil return in a refrigerant system including a capacity modulated compressor.

[0002] Compressors are utilized as an integral part of a refrigerant system. In general, a compressor compresses a refrigerant and passes it downstream to a condenser. Refrigerant from the condenser passes through an expansion device, and then through an evaporator. From the evaporator, the refrigerant returns to the compressor.

[0003] Lubricant is included in the refrigerant system, typically an Air Conditioner, Heat Pump or refrigeration application, and is particularly important to lubricate moving parts in the compressor. However, the lubricant becomes entrained in the refrigerant, and can flow with the refrigerant throughout the refrigerant system. As such, there may sometimes be an inadequate supply of lubricant returned to the compressor. Lubricant can sit in other areas of the refrigerant system, and in particular in the condenser and evaporator.

[0004] Recently, system energy efficiency improvements have resulted in the compressor and refrigerant systems being of a variable capacity. Typical applications of the compressor's ability to vary capacity include variable speed, multi-stepped modulation, PWM of compression element engagement, or other means of affecting capacity and the mass flow rates of the compressor. Thus, should the cooling demand on the refrigerant system be low, the compressor may be operated at a lower capacity to improve energy efficiency. While operating at a higher capacity, the refrigerant may well drive sufficient lubricant back from the condenser and evaporator to the compressor such that there is an adequate lubricant supply. However, at lower capacities, it may sometimes be difficult to adequately drive the lubricant back.

[0005] One known system periodically provides an increase in speed when the compressor is operating at the lower speed. The increased speed is maintained for a short period of time to drive lubricant back to the compressor. However, the increase in speed is not tied to any existing conditions in the refrigerant system, and thus may be operated too frequently, or not frequently enough. Of course, operating at the increased speed too frequency somewhat defeats the purpose of operating the compressor at the lower speed. On the other hand, running at the higher speed to return lubricant too infrequently would be even more undesirable.

SUMMARY OF THE INVENTION

[0006] In a disclosed embodiment of this invention, system conditions are monitored to predict an amount of oil migration from the compressor during low capacity operation. When a particular amount of lubricant is deemed to have migrated from the compressor, an increased compressor capacity is run for a period of time. As an example of a particular application of the invention, a variable speed compressor is used.

[0007] These and other features of the present invention can be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

Figure 1 schematically shows a refrigerant system.
Figure 2 is a chart showing oil loss per hour at various compressor speeds.
Figure 3 is a flowchart.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0009] A refrigerant system 20 is illustrated in Figure 1. A compressor shell 23 includes a lubricant sump 22, which maintains a quantity of lubricant. A compressor pump unit 24 compresses refrigerant and delivers the refrigerant to a discharge tube 26. From the discharge tube 26, the lubricant passes through a condenser 28, an expansion device 30, an evaporator 32, and back through a suction tube 33 into the compressor shell 23.

[0010] A control 36 for a compressor motor 37 may operate the compressor motor 37 at various speeds. Thus, the compressor may be operating at a relatively low speed to increase energy efficiency when a cooling demand is also low.

[0011] Sensors 34 and 35 monitor a condition, such as pressure, at the evaporator 32 and condenser 28, respectively. Alternatively, sensors that monitor temperature or an estimated saturated refrigerant temperature can be used to detect the conditions the compressor is operating at, These conditions may be sent to the control 36 to assist in quantifying the amount of oil which has likely migrated outwardly of the compressor shell 23 into other system components at low

speed operation.

[0012] As shown in Figure 2, a curve may be developed which equates oil loss for a period of time for various low compressor speeds. Thus, as shown, at some point, here 2400 rpm, the oil loss no longer occurs. However, at other speeds, there is pronounced oil loss.

[0013] The present invention integrates the amount of oil loss over time based upon a relationship such as shown in Figure 2, and actuates the motor control 36 to increase the speed of the motor for a short period of oil return time when that integrated amount passes a particular limit.

[0014] Thus, as shown in the flowchart of Figure 3, the amount of oil loss is calculated and the speed is increased when the amount passes a limit.

[0015] In one embodiment, the compressor speed may be ramped up from the low energy efficiency speed to a predetermined amount, e.g., 2400 rpm in a compressor having the characteristics as shown below, for a short period of time (e.g. 3 seconds).

[0016] The point at which the oil return speed-up will occur can be defined as a function of the pressure at the suction and discharge of the compressor, as a function of compressor capacity or based upon other variables. A ten coefficient map can be utilized to set a curve similar to that shown in Figure 2.

[0017] Thus, the oil loss rate may be calculated as:

$$\text{oil loss rate (oz/hr)} = a1 + a2(PE) + a3(PC) + a4(PE)^2 + a5(PE)(PC) + a6(PC)^2 + a7(PE)^3 + a8(PE)^2(PC) + a9(PE)(PC)^2 + a10(PC)^3.$$

[0018] The oil loss rate shown above is based upon the pressure at the evaporator and the pressure at the condenser. The same form of equation could be applied to evap and condensing temperatures. It could also be multiplied by a multiplier which brings in a capacity level factor. One such multiplier factor may be determined by the following equation:
Multiplier factor = b1 (Rc) ^3 + b2 (Rc) ^2 + b3 (Rc) + b4.
Where

$$Rc = \text{Current capacity level/Max capacity level}$$

[0019] As an example of this, for variable speed compressors this would be the current rpm/max RPM.

[0020] With the present invention, and once an adequate curve is developed, the quantity of oil which is "lost" or which has migrated from the compressor is calculated, or integrated, over time while the compressor is operating at a low capacity. Once that quantity exceeds a predetermined limit, then the compressor capacity is ramped up to the oil return speed for a short period of time.

[0021] In one application, the amount of oil lost is calculated in a plurality of discrete time units when the compressor is operating at a lower speed. As an example, this can occur every five seconds.

[0022] Although an embodiment of this invention has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.

Claims

1. A compressor comprising:

a compressor pump unit, and said compressor pump unit and said motor being housed within a shell, said shell having a sump for maintaining a quantity of lubricant;
a control for said compressor, said control being programmed to operate at at least one low capacity and at least one higher capacity, and said control also being operable to estimate an amount of oil which will have migrated from said compressor shell at least when said compressor is operating at said at least one lower capacity, and said motor control being operable to move said compressor motor from the at least one lower capacity to the at least one higher capacity once the estimated quantity of oil exceeds a predetermined limit.

2. The compressor as set forth in claim 1, wherein said at least one lower capacity and said at least one higher capacity

are achieved by varying the speed of the motor.

3. The compressor as set forth in claim 1 or 2, wherein said estimate of the amount of oil is based upon pressures in the system, or
is based upon the pressures at both a condenser and an evaporator that are connected to said compressor.

4. The compressor as set forth in claim 3, wherein the amount of oil estimate is based upon the estimated saturated temperature at both a condenser and an evaporator that are connected to said compressor

5. The compressor as set forth in any preceding claim, wherein said estimate of the amount of oil is based upon temperature measurements.

6. The compressor as set forth in any preceding claim, wherein a multiplier factor which includes a Capacity ratio quantity multiplied by an oil loss rate calculated from the pressures or estimate of saturated temperatures at said condenser and said evaporator.

7. A refrigerant system comprising:

a condenser, an evaporator, an expansion device and a compressor;
the compressor having a motor for driving a compressor pump unit, and said compressor pump unit and motor being housed within a shell, said shell having a sump for maintaining a quantity of lubricant, a control for said motor, said control being programmed to operate at at least one low capacity and at least one higher capacity, and said control also being operable to estimate an amount of oil which will have migrated from said compressor shell at least when said compressor is operating at said at least one lower capacity, and said motor control being operable to move said compressor motor from the at least one lower capacity to the at least one higher capacity once the estimated quantity of oil exceeds a predetermined limit.

8. The refrigerant system as set forth in claim 7, wherein said estimate of the amount of oil lost is based upon pressures in the system, or
is based upon the pressures at both the condenser and the evaporator.

9. The refrigerant system as set forth in claim 7 or 8, wherein a multiplier factor which includes an RPM quantity is multiplied by an oil loss rate calculated from the pressures at said condenser and said evaporator.

10. The refrigerant system as set forth in claim 7, 8, or 9, wherein said at least one lower capacity and said at least one higher capacity are achieved by varying the speed of the motor.

11. A method of operating a compressor comprising the steps of:

(a) operating a motor for a compressor at at least one low capacity and at least one higher capacity;
(b) estimating an amount of oil which will have migrated from a compressor shell at least when said compressor is operating at said at least one lower capacity rate; and
(c) moving said motor from the at least one lower capacity to the at least one higher capacity once the estimated quantity of oil exceeds a predetermined limit.

12. The method as set forth in claim 11, wherein said estimate of the amount of oil lost is based upon pressures in the system, or
is based upon the pressures at both a condenser and an evaporator that are connected to said compressor.

13. The method as set forth in claim 11 or 12, wherein a multiplier factor which includes an RPM quantity is multiplied by an oil loss rate calculated from the pressures at said condenser and said evaporator.

14. The method as set forth in claim 11, 12 or 13, wherein said at least one lower capacity and said at least one higher capacity are achieved by varying the speed of the motor

15. The method as set forth in claim 11, 12, 13 or 14, wherein said estimate of the amount of oil is based upon temperature measurements.

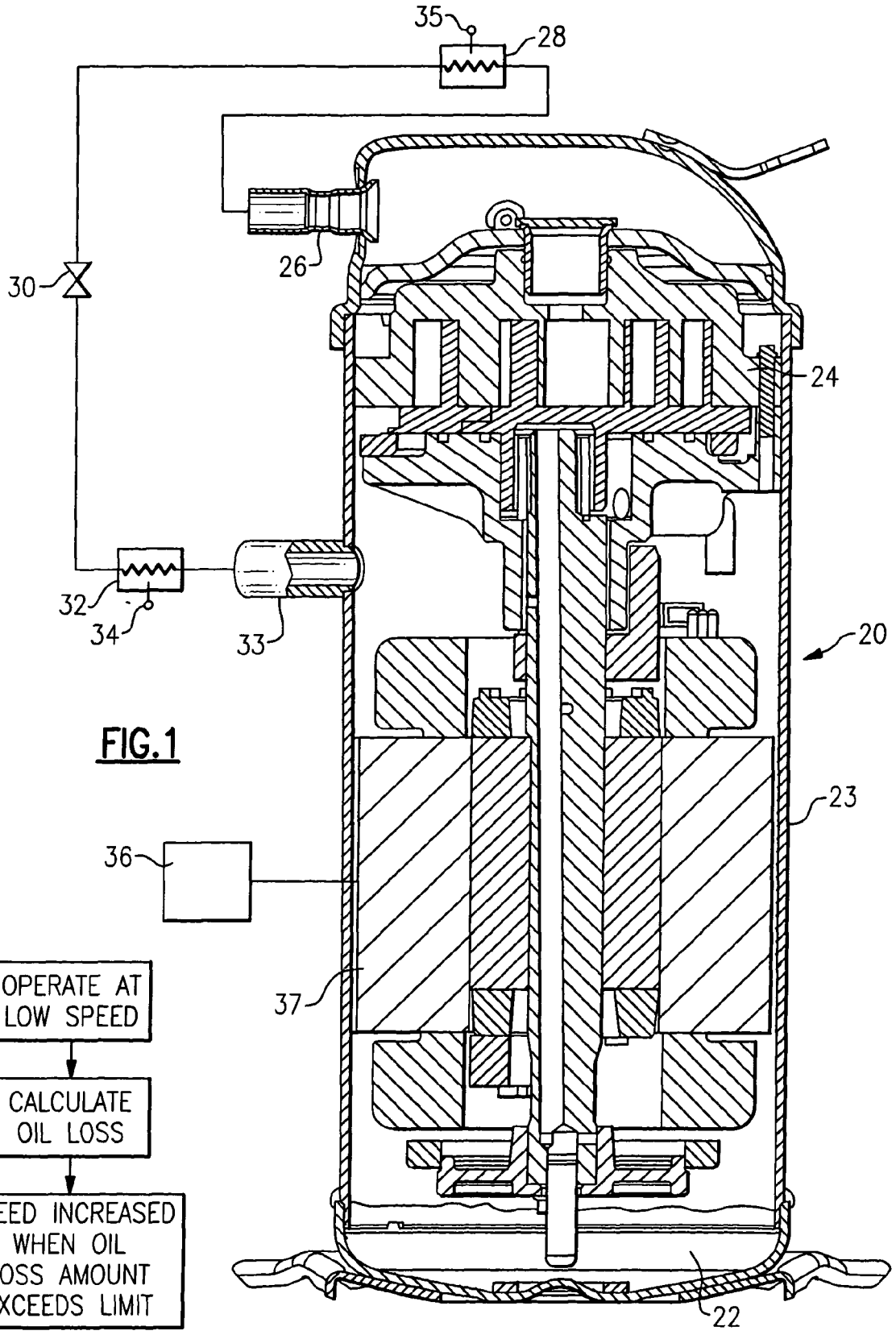

35
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FIG.1

OPERATE AT LOW SPEED
CALCULATE OIL LOSS
SPEED INCREASED WHEN OIL LOSS AMOUNT EXCEEDS LIMIT

FIG.3

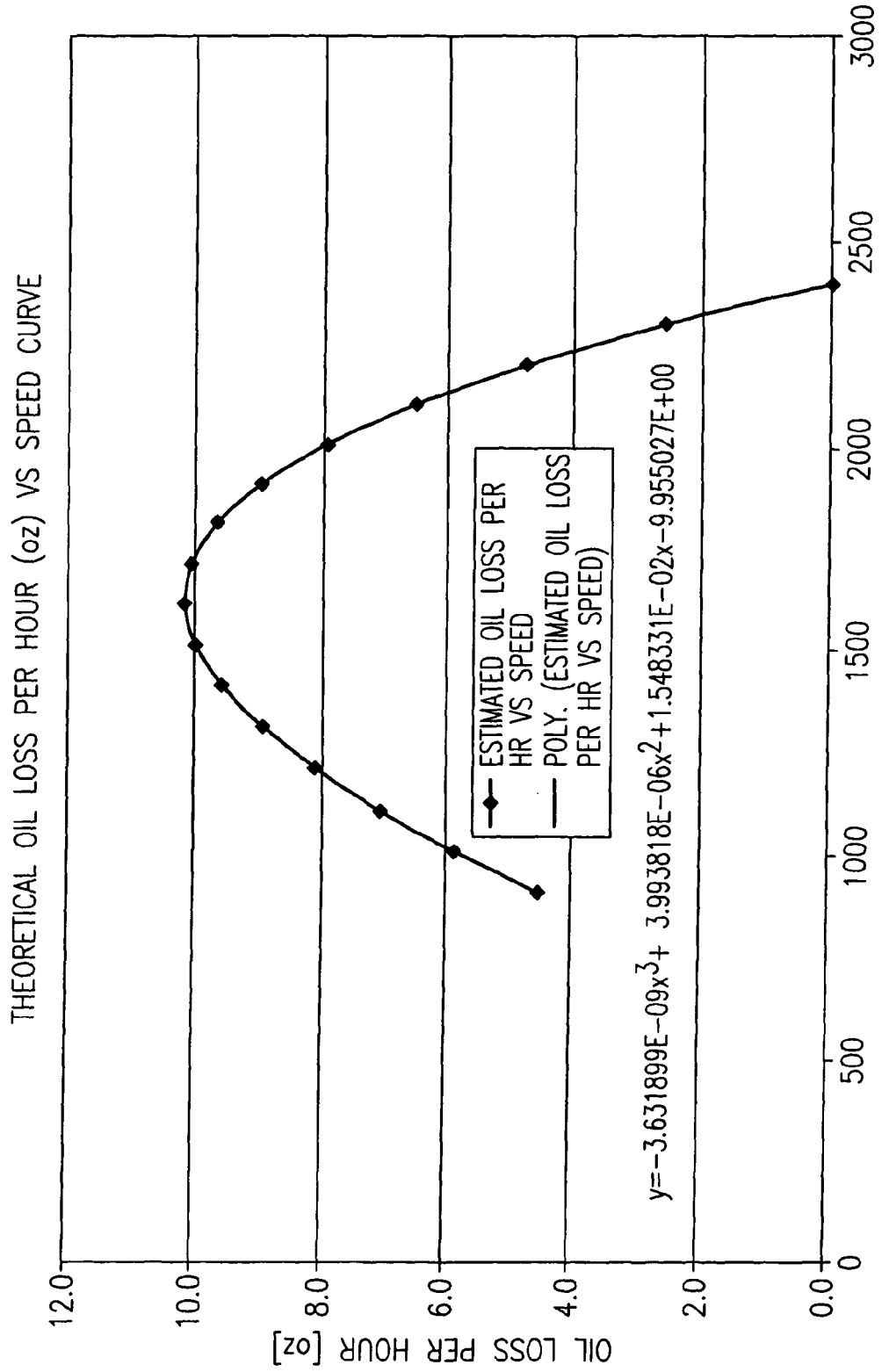

THEORETICAL OIL LOSS PER HOUR (oz) VS SPEED CURVE
OIL LOSS PER HOUR [oz]
12.0
10.0
8.0
6.0
4.0
2.0
0.0
0
500
1000
1500
2000
2500
3000
SPEED RPM
ESTIMATED OIL LOSS PER HR VS SPEED
POLY. (ESTIMATED OIL LOSS PER HR VS SPEED)
y=-3.631899E-09x3+ 3.993818E-06x2+1.548331E-02x-9.955027E+00

FIG.2

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EUROPEAN SEARCH REPORT

Application Number
EP 09 25 1462

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 2008/134701 A1 (CHRISTENSEN OLE MOELGAARD [DK] ET AL) 12 June 2008 (2008-06-12) * paragraphs [0015], [0017], [0018], [0034]; figures *	1-15	INV. F25B31/00
X	US 5 067 326 A (ALSENZ RICHARD H [US]) 26 November 1991 (1991-11-26) * column 4, line 67 - column 5, line 7; figures *	1-15	
A	US 2003/051494 A1 (OHYA SHIGEKI [JP]) 20 March 2003 (2003-03-20) * paragraph [0010] *	1-15	
			TECHNICAL FIELDS SEARCHED (IPC) F25B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	26 October 2009	Ritter, Christoph

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
O : non-written disclosure
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E : earlier patent document, but published on, or after the filing date
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 09 25 1462

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
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26-10-2009

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