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(12) # EUROPEAN PATENT APPLICATION

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(54) **Refrigeration system.**

(57) The interlobe discharge pressure (Pd) buildup is limited to controlling capacity in combination with economizer control. Economizer control can be in the form of refrigerant injection into the trapped volume or bypassing refrigerant from this trapped volume back to suction.

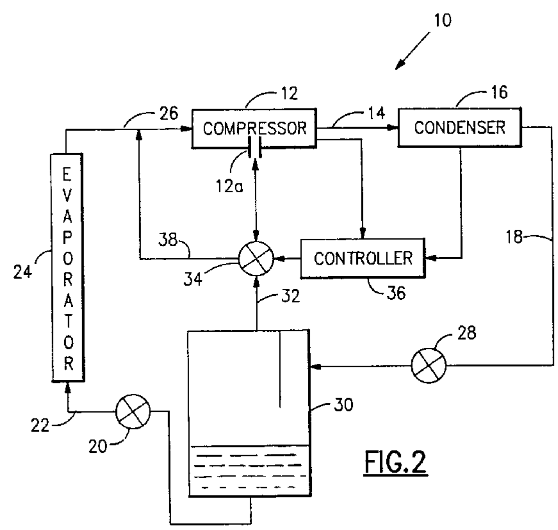

FIG.2

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This invention relates to refrigeration systems.

Positive displacement compressors are designed for a particular capacity but are normally operated over a range of capacities, usually less than the designed capacity, and thus require some means for modifying their operation if efficient operation is to be maintained. Often, the operation of a compressor at other than design conditions is inefficient due to overcompression or the like. It is also desirable to be able to unload a compressor to various percentages of capacity in fixed increments or over an entire range. Simultaneously, it is desirable to efficiently maintain the desired discharge pressure to suction pressure ratio, or V_i, for meeting system requirements. To meet these various requirements, a number of individual controls are used. In screw compressors, for example, capacity control is conventionally achieved by the use of a slide valve as well as by individual bypass valves. When a slide valve is used, it is located in and reciprocates in the cusp of the housing formed between the intersecting bores for the two rotors. The slide valve thus defines a portion of each bore and thereby compromises the integrity of the housing as well as making for a complicated device. The slide valve is reciprocatably positionable with respect to the axes of the rotors and can thus effectively change the start of compression by changing the closing point of the suction stroke and thereby controlling the amount of gas trapped and compressed.

The present invention is directed to V_i and capacity variation. Where, for example, V_i must be 3 to 1 under full load highest head conditions, the challenge is to avoid overcompression losses when the head pressure falls significantly.

Viewed from one aspect the present invention provides a refrigeration system as described in claim 1 of the accompanying claims.

Viewed from another aspect the present invention provides a method for operating a refrigeration system as described in claim 4 of the accompanying claims.

The present invention is directed to compensating for falling head pressure when full load V_i is 3 or some other number dependent upon the application. This may be initially achieved by bypassing economizer flow to suction thus reducing the maximum volume/mass flow induced pressure buildup in the machine. The next step is to unload the compressor in order to further reduce the effective V_i. Assuming only a fixed discharge port and full load V_i of 3, V_i will be 2.25 at 75% load and 1.5 at 50% load. What this means is that the compressor should be unloaded as the head pressure falls but that it should be done by limiting the maximum load as a function of the condensing pressure. For a slide valve without position indication, this can be done by determining the amperage draw (power consumption) versus % capacity for various condensing pressures. Then, as the head pressure falls, the compressor is only allowed to load up to a lesser amperage value which is readily sensed by a current transformer. A fundamental consideration of this approach is that when it gets colder outside, the head or condensing pressure will fall and normally less capacity is needed as well. With step type capacity control or position indication with a slide valve, fixed amperage measurement would not be necessary as capacity level would be known by the control logic.

Considering only discharge porting and capacity controlled by valves, V_i is always directly proportional to capacity so that as capacity drops, V_i drops. As an economizer is bypassed, V_i drops. Thus, V_i can be changed in two ways.

Further, it will be noted that the highest V_i is needed in hot weather which is also when the highest capacity is needed.

Thus, V_i may be controlled by controlling capacity in combination with an economizer control which can be used to inject refrigerant at some stage of the compression process, bypass to suction or be disabled.

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a graph of discharge pressure vs. loading (or capacity) for various operating conditions;

Figure 2 is a schematic representation of a refrigeration system;

Figure 3 is a schematic showing of the unwrapped rotors of a screw compressor; and

Figure 4 is a partially cutaway partial section view of a scroll compressor.

In Figure 1, the sequential points A-B-C-D-A represent a complete compressor cycle at full capacity. Specifically A-B represents the suction stroke when gas at suction pressure (P_s) is drawn into the compressor. At point B the suction stroke ceases and the compression stroke is initiated. From B to C the gas taken in on the suction stroke is compressed and the pressure of the gas is increased from P_s to Pd_1, the discharge pressure. At point C the trapped, compressed gas becomes exposed to the fixed discharge port and the discharge stroke begins. The actual discharge pressure will be a function of factors such as the head against which discharge takes place, but, ideally, the discharge stroke takes place at a constant pressure. From C to D discharge takes place until, nominally, all of the compressed trapped fluid is delivered. At D, the discharge path is shut off and the trapped volume becomes exposed to suction causing the cycle to return to point A and be completed.

To increase the capacity of the cycle represented by A-B-C-D-A, economizer injection is employed. Specifically, as described above, compression starts at point B but, when the cycle reaches point E, economizer injection takes place. Economizer injection is the adding of additional mass to the trapped volume and takes place during compression over the portion of the cycle represented by E-F. The economizer injection ceases at point F and compression continues until point G where the trapped, compressed gas becomes exposed to the fixed discharge port and the discharge stroke begins. Because more mass is within the trapped volume due to the economizer injection, the compression process from F to G results in a higher discharge pressure, Pd_2, at the time that the trapped volume is exposed to the fixed discharge port. Discharge takes place from G to H. Because there is more mass compressed to a higher pressure at point G than at point C, the cycle capacity is increased beyond the nominal design reference designated by cycle A-B-C-D-A.

To decrease the capacity of the cycle represented by A-B-C-D-A, two things can be done individually or in combination. First, the capacity or loading can be reduced, and, second, an economizer bypass can be used. The cycle A-I-J-K-A represents a reduced capacity or loading cycle and is similar to A-B-C-D-A except that it has a shorter suction cycle and reduced discharge pressure. Specifically, the suction stroke takes place from A to I with I, as illustrated, representing a trapped volume which is 50% of that represented by point B. Compression takes place from I to J where the trapped volume becomes exposed to the fixed discharge port. Because less mass is compressed, point J represents a lower discharge pressure, Pd_3, than that at point C.

The capacity of the cycle represented by A-B-C-D-A can be reduced by economizer bypass in the cycle represented by A-B-E-L-M-N-A. Starting at point E, gas is removed from the trapped volume until point L is reached. Thus, E-L is the reverse of E-F. From point L to point M, the remaining trapped volume is compressed until the trapped volume is exposed to the discharge port at point M. The discharge pressure at point M is Pd_4 and discharge takes place from M to N. Similarly, economizer bypass can be used to further reduce the capacity of the cycle represented by A-I-J-K-A.

Referring now to Figure 2, the numeral 10 generally designates a refrigeration circuit. Refrigerant circuit 10 includes a compressor 12 which compresses suction gas to a higher temperature and pressure and delivers it via discharge line 14 to condenser 16. In the condenser 16, the hot refrigerant gas gives up heat to the condenser air thereby cooling the compressed gas and changing the state of the refrigerant from a gas to a liquid. Liquid refrigerant flows from condenser 16 via liquid line 18 to thermostatic expansion valve, TXV, 20. As the liquid refrigerant passes through the orifice of TXV 20, some of the liquid refrigerant vaporizes into a gas (flash gas). The mixture of liquid and gaseous refrigerant then passes via distributor tubes 22 to the evaporator 24. Heat is absorbed by the refrigerant from the evaporator air by the balance of the liquid refrigerant causing it to vaporize in the coil of the evaporator 24. The vaporized refrigerant then flows via suction line 26 to compressor 12 to complete the fluid circuit.

The refrigeration system just described is conventional. The present invention places an expansion device 28 and an economizer 30 in line 18 between condenser 16 and TXV 20. Expansion device 28 may be an orifice, a valve responsive to the liquid level in condenser 16 or any other suitable device. Economizer 30 is connected to port 12a of compressor 12 via line 32 which contains valve 34 which is under the control of microprocessor controller 36. Valve 34 can be closed, provide fluid communication from economizer 30 to port 12a in compressor 12 which is in fluid communication with trapped volumes within compressor 12, or provide bypass from the trapped volumes via port 12a and bypass line 38 to suction line 26. Responsive to the sensed amperage draw by the compressor 12, or control logic, and responsive to sensed condenser pressure, controller 36 controls valve 34. If valve 34 is closed then cycles exemplified by A-B-C-D-A and by A-I-J-K-A would occur based upon the position of the capacity valves if compressor 12 is a screw compressor or other positive displacement compressor. If valve 34 is opened to permit flow from economizer 30 to trapped volumes in the compressor 12 then a cycle exemplified by A-B-E-F-G-H-A would occur. However, if valve 34 is opened to permit flow from trapped volumes in compressor 12 to suction line 26 via bypass line 38, then a cycle exemplified by A-B-E-L-M-N-A would occur.

Referring to Figure 3 where compressor 12 is a screw compressor and the numeral 41 represents the unwrapped male rotor while numeral 42 represents the unwrapped female rotor. Axial suction port 44 is located in end wall 45 and is in fluid communication with suction line 26. Axial discharge port 46 is located in end wall 47 and is in fluid communication with discharge line 14. The chevron shaped areas represent trapped volumes at various stages in the compression process starting with the cutoff of suction port 44 and progressing to a point just prior to communication with axial discharge port 46. Generally radial port 12a is in communication with essentially one trapped volume at a point in the compression process corresponding to point E and economizer injection or economizer bypass can take place under the control of valve 34 as described above. To permit a greater flow, a second radial port 12b may provide fluid communication with the same trapped volume as port 12a.

Referring now to Figure 4, the numeral 112 generally designates a scroll compressor having a first wrap 141, which is a fixed wrap, and a second wrap 142. As is conventional wraps 141 and 142 coact to define a plurality of pairs of trapped volumes. As illustrated, trapped volumes 101 and 102 form one pair as do trapped volumes 103 and 104. In the compression process, the trapped volumes move towards the center of the scroll wraps 141 and 142 until they become exposed to outlet 146 which is connected to discharge line 14. While screw compressors have trapped volumes on each rotor in communication with each other such that a single port 12a can communicate with trapped volumes on both rotors, this is not true for scroll compressors. As illustrated, port 112a is in fluid communication with trapped volume 101 whereas port 112b is in fluid communication with trapped volume. Ports 112a and 112b are formed along the fixed wrap 141 and are of a width which is preferably somewhat less than the thickness of wrap 142. In the illustrated position, ports 112a and 112b are partially covered by wrap 142 but cannot communicate with trapped volumes 103 and 104 for any position of wrap 142. For symmetry of loading it is preferred that the trapped volumes in communication with ports 112a and 112b are subject to the same conditions. Thus both port 112a and 112b would be preferably commonly manifolded to valve 34, but, if necessary or desired, they can be separately controlled for more steps in capacity control.

In at least preferred embodiments the invention serves to:

prevent severe overcompression in screw compression systems;

ensure that screw compressors always operate at near optimum performance; and

ensure that positive displacement compressors with V_i tied into capacity level are capable of always operating at near optimum performance.

Claims

1. A refrigeration system having compression ratio and capacity control comprising:

   a refrigeration circuit means serially including a compressor (12), a discharge line (14), a condenser (16), an economizer (30), an expansion device (20), an evaporator (24) and a suction line (26) leading back to said compressor;

   said compressor having port means (12a, 12b; 112a, 112b) in fluid communication with trapped volumes (101, 102) formed in said compressor when said compressor is operating;

   fluid passage means connecting said port means to said economizer and said suction line;

   valve means (34) in said fluid passage means for selectively communicating said trapped volumes with said economizer, or communicating said trapped volumes with said suction line whereby said refrigeration system can be selectively operated to have economizer injection or economizer bypass.

2. The refrigeration system of claim 1 further including means (36) for limiting loading of said compressor as a function of condensing pressure.

3. The refrigeration system of claims 1 or 2 wherein said valve means can selectively block fluid communication with said trapped volumes via said port means.

4. A method for operating a refrigeration system having pressure ratio and capacity control and a closed refrigeration circuit serially including compressor means (12), condenser means (16), economizer means (30), expansion means (20) and evaporator means (24) comprising the steps of:

   sensing condenser pressure;

   controlling loading of said compressor means as a function of condenser pressure;

   selectively connecting trapped volumes of gas in said compressor means to said economizer means for economizer injection or to the suction of said compressor means to control capacity.

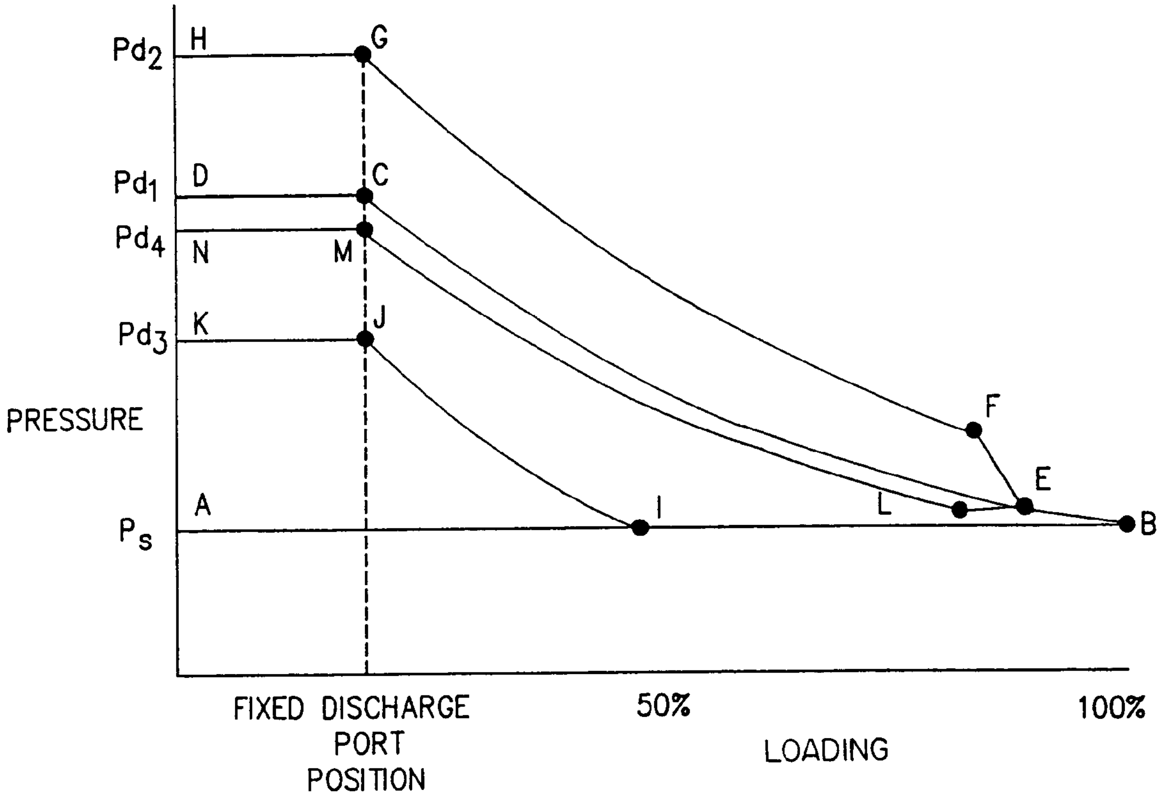
Pd2
H
G
Pd1
D
C
Pd4
N
M
Pd3
K
J
PRESSURE
F
E
A
I
L
B
Ps
FIXED DISCHARGE
PORT
POSITION
50%
100%
LOADING

FIG.1

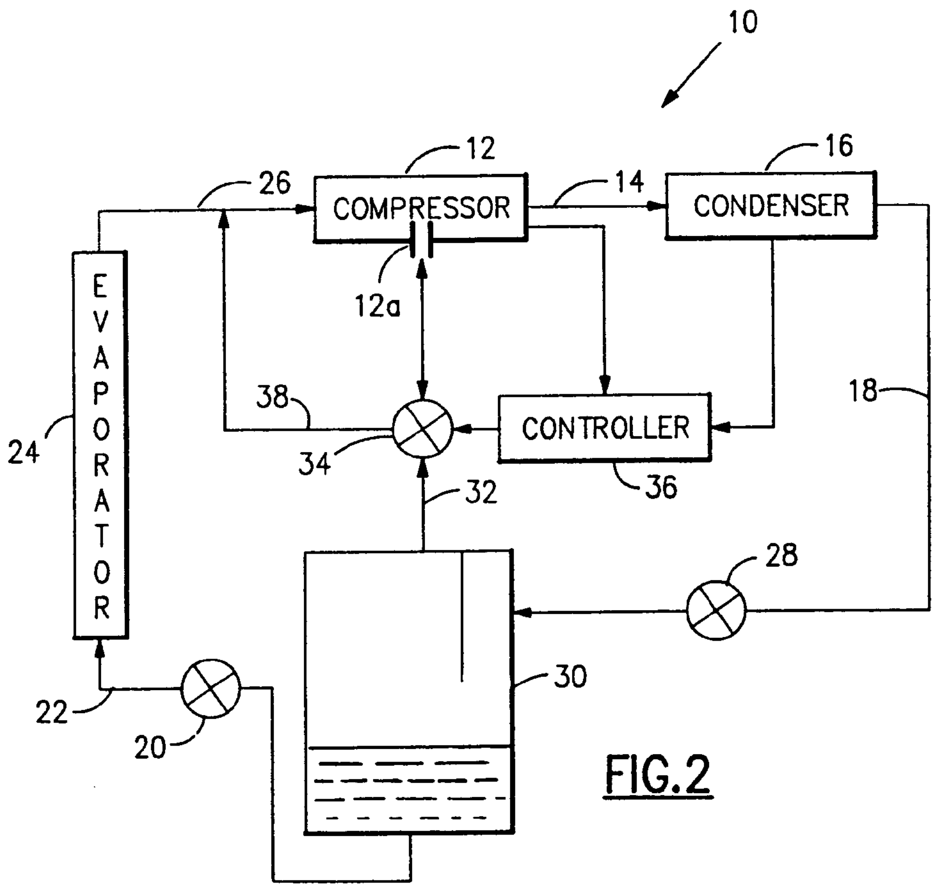
10
12
26
COMPRESSOR
14
16
CONDENSER
12a
E
V
A
P
O
R
A
T
O
R
38
18
CONTROLLER
24
34
36
32
28
30
22
20

FIG.2

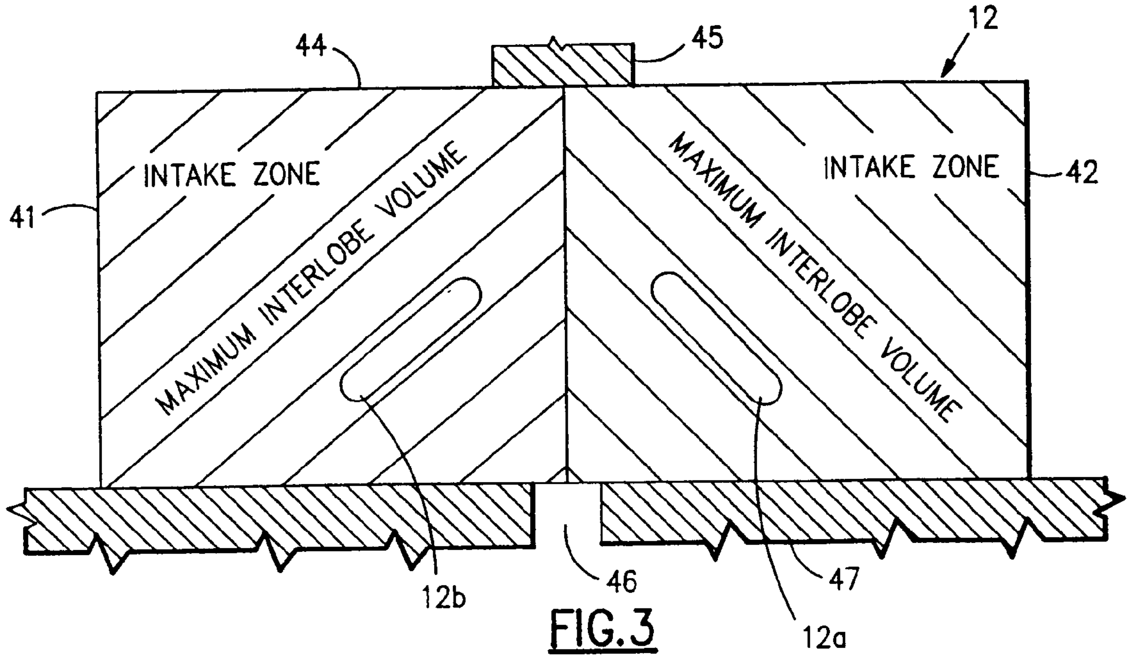
12
44
45
41
INTAKE ZONE
MAXIMUM INTERLOBE VOLUME
MAXIMUM INTERLOBE VOLUME
INTAKE ZONE
42
12b
46
47
12a

FIG.3

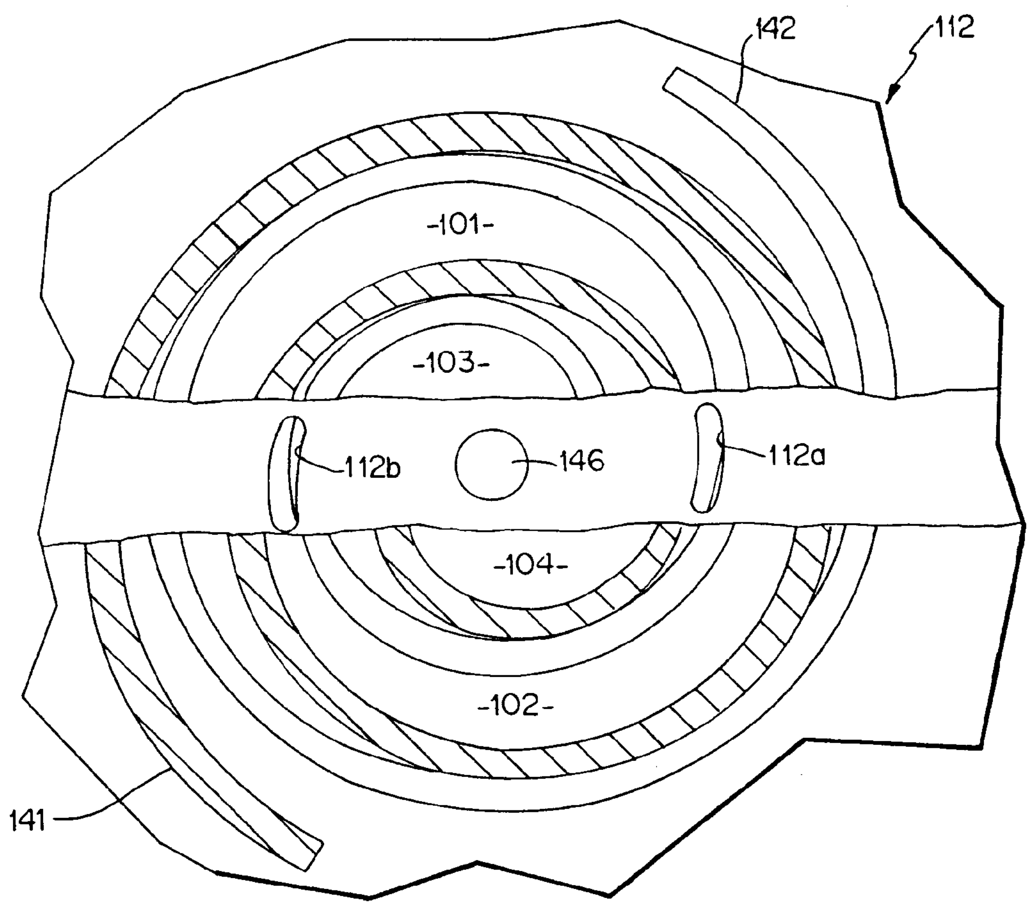
142
112
-101-
-103-
112b
146
112a
-104-
-102-
141

FIG.4

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EUROPEAN SEARCH REPORT

Application Number
EP 93302023.2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	US - A - 4 989 414 (MURAYAMA) * Fig. 8 *	1-4	F 25 B 31/00 F 25 B 49/02 F 25 B 41/04
A	US - A - 4 947 655 (SHAW) * Totality *	1-4	
A	US - A - 4 727 725 (NAGATA) * Totality *	1,4	
A	DE - A - 3 705 849 (SÜDDEUTSCHE KÜLLERFABRIK) * Totality *	1,4	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

F 25 B
F 04 C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	24-06-1993	WITTMANN

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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D : document cited in the application
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