Abstract: A rotary screw compressor (10) contains a slide valve system capable of tolerating greater misalignment between multiple bores (14, 16, 18). A control piston (28) is connected to a slide valve (26) by a flexible connecting member (30) capable of transmitting tensile axial force. Screw compressor discharge chamber pressure acts on the discharge end face of the slide valve (26) to maintain the flexible member (30) in perpetual tension, allowing the control piston head (28) to control the axial position of the slide valve (26) as if connected by a rigid member.
SLIDE VALVE SYSTEM FOR A SCREW COMPRESSOR

BACKGROUND

This invention relates generally to the field of screw compressors. Specifically, it relates to screw compressor slide valve systems.

Screw-type compressors are commonly used in refrigeration and air conditioning systems. Interlocking male and female rotors located in parallel intersecting bores define compression pockets between meshed rotor lobes. Compressors consisting of two rotors are most common, but other configurations having three or more rotors situated so as to act in pairs are known in the art. Fluid enters a suction port near one axial end of a rotor pair and exits near the opposite end through a discharge port." Initially, the compression pocket communicates with the suction port. As the rotors turn, the compression pocket becomes trapped between male and female rotor lobes and the rotor bore wall. The compression pocket becomes smaller as it is translated axially downstream, compressing the fluid within. Finally, the compression pocket rotates into communication with a discharge port and the compressed fluid exits.

Volume $V_i$ is defined as the compression pocket volume at the instant the pocket first becomes sealed from the suction port. Volume $V_z$ is defined as the pocket volume just before the compression pocket first communicates with the discharge port. Compressor volumetric flow rate (capacity) depends on the magnitude of $V_i$. The larger the value of $V_i$, the greater the compressor capacity, assuming the rotors maintain a constant angular velocity. Rotor, inlet port, and rotor housing geometry define the initial size of the sealed compression pocket. Capacity is therefore fixed for a particular screw compressor operating at a fixed angular speed.

Compressors limited to operating at fixed capacity sacrifice efficiency, particularly when operating under varying load conditions. Because compressor capacity is proportional to system cooling capacity, it is desirable to vary capacity to match dynamic cooling loads. To vary capacity while maintaining a constant rotor angular speed, screw compressors commonly incorporate a slide valve. In a conventional two-rotor screw compressor, the slide valve is located in the cusp of the
bores housing the interlocking rotors. The slide valve is movable linearly in this sleeve along an axis parallel to the axis of the rotors, forming a portion of the bore wall. As each set of rotor teeth contact the slide valve, a new compression pocket is sealed and compression begins. Altering the axial position of the slide valve effectively changes the axial point at which compression begins. Due to screw rotor geometry, the compression pocket formed by intermeshing screw rotor lobes is largest at the rotors' suction end and smallest at the discharge end. Changing the axial point where compression begins increases or decreases Vi, and thereby increases or decreases compressor capacity.

The axial position of the slide valve is commonly controlled by actuating a control piston. Conventionally, the control piston is attached to the slide valve by a rigid connecting rod. This allows the piston to transfer either compressive force to move the slide-valve towards the suction port or tensile force to pull the slide valve towards the discharge port. It is common for the piston and slide valve assembly to reciprocate in a bore formed by multiple adjoining housing cases. To minimize wear and prevent binding, however, each of these housing cases must be carefully machined and precisely positioned so as to align their bores along a single axis. Such precision in machining and assembly greatly increases compressor cost. One known system, shown in U.S. Patent Publication 2005/0123422 A1, transfers motion to a piston using a relatively flexible rod attached at each end by non-rigid means, such as a ball joint. Another system, shown in U.S. Patent 5,081,876, employs magnetic coupling to transfer control piston motion to an exterior sensor measuring slide valve position. Such systems, however, retain a rigid rod as the means for transferring control piston motion to the slide valve itself.

SUMMARY

In exemplary embodiments of the invention, a screw compressor includes a linearly reciprocating slide valve system. The slide valve system includes a control piston axially movable in a piston sleeve, a biasing spring, a slide valve, and a flexible member connecting the control piston to the slide valve and capable of transmitting axial tensile force. In operation, screw compressor discharge pressure moves the slide valve in a first axial direction, while the flexible member moves the slide valve in a second axial direction.
BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a rotary screw compressor, partially cut away to reveal interior components.

FIG. 2A is a schematic view of the interior of the screw compressor, showing a slide valve in a fully unloaded position.

FIG. 2B is partial schematic view of the screw compressor, showing the slide valve in a partially loaded position.

FIG. 2C is partial schematic view of the screw compressor, showing the slide valve in a fully loaded position.

DETAILED DESCRIPTION

FIG. 1 provides a partial cut away perspective view of screw compressor 10. Screw compressor 10 includes motor case 12, rotor case 14, outlet case 16, slide case 18, motor stator 20, motor rotor 22, male screw rotor 24a, female screw rotor 24b, slide valve 26, control piston 28, flexible connecting member 30, suction inlet 32, and discharge outlet 34. Motor case 12 is attached to rotor case 14, forming one end cap of screw compressor 10. Motor case 12 and rotor case 14 together house motor stator 20, motor rotor 22, and male and female screw rotor set 24. Motor rotor 22 drives male screw rotor 24a or female screw rotor 24b. Outlet case 16 is attached to the end of rotor case 14 opposite of motor case 12. Outlet case 16 contains slide valve 26. Slide case 18 is attached to the remaining end of outlet case 16, forming the other end cap of screw compressor 10. Control piston 28 reciprocates within slide case 18, varying compressor capacity by changing the axial position of slide valve 26. Flexible connecting member 30 connects control piston 28 to slide valve 26. Low pressure working fluid enters suction inlet 32, is compressed by male and female screw rotors 24a and 24b, and exits discharge outlet 34. In the embodiment shown, screw compressor 10 comprises a two-screw compressor. However, in other embodiments, the present invention is readily applicable to compressors having three, four or more screw rotors that employ a reciprocating slide valve system.

FIG. 2A shows a schematic cross-sectional view of rotary screw compressor 10. The end of rotor case 14 adjoining outlet case 16 includes suction chamber 40, male and female screw rotors 24, screw rotor lobes 42, and screw rotor bore 44. Working fluid enters through suction chamber 40 into a compression pocket formed between screw rotor lobes 42 and screw rotor bore 44. As motor
rotor 22 rotates male and female screw rotors 24, compression pocket volume is reduced as the pocket is translated towards outlet case 16.

Outlet case 16 contains discharge port 46, discharge chamber 48, and slide valve 26. Fluid exits the compression pocket formed between screw rotor lobes 42 through discharge port 46 and into discharge chamber 48. Discharge port 46 may be radial or axial, depending on the shape and position of slide valve 26.

Screw compressor 10 controls capacity by altering the axial position of slide valve 26. When slide valve 26 reaches the mechanical limit of its axial motion away from male and female screw rotors 24, compressor 10 capacity is at a minimum. The present invention provides an innovative slide valve system 50, where a means for connecting slide valve 26 to a control piston head is flexible rather than rigid. FIG. 2A shows slide valve system 50 in this fully unloaded configuration.

In FIG. 2A, slide valve system 50 includes control piston 28, control piston sleeve 54, biasing spring 56, o-ring seal 58, first piston chamber 60, second piston chamber 62, first sleeve lip 64, second sleeve lip 66, flexible connecting member 30, connectors 70a and 70b, slide valve 26, and means for controlling first piston chamber pressure 72. Slide valve system 50 is now in an intermediate stage of loading, operating at some percentage of full capacity. The axial position of control piston 28 controls the axial position of slide valve 26 and therefore compressor capacity. Control piston 28 fits inside control piston sleeve 54 and is capable of reciprocating linearly along the vertical axis of sleeve 54. Control piston 28 may be counter-bored from the underside to allow secure seating of biasing spring 56. Control piston 28 is also sufficiently elongated in the axial direction to minimize torsional binding when the periphery of the head experiences asymmetric frictional forces. O-ring seal 58 prevents fluid leakage across control piston 28, separating first piston chamber 60 from second piston chamber 62. First sleeve lip 64 defines the limit of control piston 28 motion. When control piston 28 is pressed against first sleeve lip 64, slide valve 26 is in the fully unloaded position. Second sleeve lip 66 is positioned at the base of control piston sleeve 54. Second sleeve lip 66 is of dimensions sufficient to provide adequate retention of biasing spring 56 when control piston 28 is fully depressed. Biasing spring 56 is secured such that the lower end is pressed against second sleeve lip 66 and the upper end is seated in the underside of control piston 28. Biasing spring 56 is designed to remain in
compression even when released to its maximum length. Biasing spring 56 is at its maximum length when control piston 28 is pressed against first sleeve lip 64, as shown in FIG. 2A.

Flexible connecting member 30 connects control piston 28 to slide valve 26. Flexible connecting member 30 may comprise any non-rigid component capable of reliably transferring tensile loads, such as a wire rope or cable. Flexible connecting member 30 may be formed of any material, metallic or non-metallic, which has sufficient axial tensile strength and is capable of enduring cyclical loading. Flexible connecting member 30 is connected to control piston 28 by connector 70a and to slide valve 26 by connector 70b. Connectors 70a and 70b may include threaded connectors or any other means for securely attaching flexible connecting member 30.

FIG. 2B shows slide valve system 50 in a partially loaded position. Slide valve system 50 is actuated by pressurizing first piston chamber 60 to overcome opposing force from biasing spring 56. Biasing spring 56 is designed such that it overpowers ambient first piston chamber 60 pressure, pressing control piston 28 against first sleeve lip 64. Means for controlling first piston chamber pressure 72 then increases pressure in first piston chamber 60. Such means generally include at least one solenoid valve controlling the flow of a working fluid, such as oil. Solenoid valves allow for continuous, rather than stepwise control of chamber pressure. When pressure in first piston chamber 60 overcomes the force of biasing spring 56, control piston 28 is driven axially towards male and female screw rotors 24. This motion compresses biasing spring 56 and releases the tension on flexible connecting member 30. Releasing tension on flexible connecting member 56 allows pressure in discharge chamber 48 to move slide valve 26 towards the partially loaded position shown in FIG. 2B and maintain flexible connecting member 30 in tension.

FIG. 2C shows slide valve system 50 in a fully loaded position. Flexible connecting member 30 remains in tension even with control piston 28 fully compressed. Slide valve 26 is located such that one axial end is always exposed to suction chamber 40 and the other end to discharge chamber 48, acting as an effective seal between the two chambers. Due to the nature of screw compressors, discharge chamber 48 pressure is always higher than suction chamber 40 pressure. Pressure in discharge chamber 40 therefore biases slide valve 26 towards suction chamber 40. maintaining tension in flexible connecting member 30 even when
control piston 28 is driven to the fully loaded position. Biasing spring 56 and flexible connecting member 30 are sized so that when control piston 28 is in the fully loaded position as shown in FIG. 2C, discharge pressure can drive slide valve 26 all the way to the position that allows rotary screw compressor 10 to operate at full design capacity.

To unload compressor 10, first piston chamber pressure control means 72 decreases first piston chamber 60 pressure until biasing spring 56 can force control piston 28 once again towards the unload position. Flexible connecting member 30 pulls slide valve 26 towards the unload position, and slide valve system 50 returns to the partially loaded state of FIG. 2B or the fully unloaded state of FIG. 2A.

A slide valve assembly often must reciprocate in multiple aligned bores. Slide valve assembly 50, as shown in FIGS. 2A, 2B, and 2C, actuates in three separate mated bores: rotor case 14, outlet case 16, and slide case 18. If control piston 28 and slide valve 26 were connected by a rigid rod as in prior art, the length of the assembly would require that the multiple bores be precisely aligned. Such precision requires expensive machining and manufacturing processes as well as costly alignment dowels. Flexible connecting member 30 allows system 50 to tolerate greater misalignment while retaining the ability to transfer control piston 28 motion in either direction to slide valve 26. By increasing system tolerance of misalignment, slide valve system 50 decreases system cost. Because connecting member 30 is flexible, it does not translate misalignment into torsional forces on the control piston head and the slide valve. Therefore, the bores of slide valve assembly 50 need not be as precisely machined. This design also has the potential to increase useful life of screw compressors by decreasing wear in the slide valve assembly. Because the flexible member transfers only axial tensile forces, misalignment creates less friction between slide valve system components and the walls of the bores they reciprocate in. Furthermore, bushings designed to accommodate wear due to misalignment could be eliminated. Flexible connecting member 30 allows slide valve assembly 50 to tolerate greater misalignments between any number of multiple bores. Its use is not limited to the three mated bores shown in FIGS. 2A, 2B and 2C.

Screw compressors commonly incorporate a slide valve system as a means to control compressor capacity. Such systems generally use rigid rods to
connect the control piston to the slide valve, requiring precise and therefore expensive alignment of internal components. The present invention uses flexible connecting member 30 in place of a rigid rod. Controlling pressure in first piston chamber 60 causes control piston 28 and slide valve 26 move in unison in either direction, as if connected by a rigid member. In this manner, flexible connecting member 30 retains the functionality of a rigid connecting rod while tolerating greater misalignment. When integrated into a screw compressor, slide valve system 50 decreases both manufacturing costs and system wear and increases system reliability and lifetime.

While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.
CLAIMS:

What is claimed is:
1. A linearly reciprocating slide valve system for a rotary screw compressor, comprising:
   a control piston, axially movable in a piston sleeve;
   a biasing spring for applying a bias force to the control piston;
   a slide valve; and
   a flexible member connecting the control piston to the slide valve, capable of transmitting axial tensile force.
2. The slide valve system of claim 1, further comprising means for controlling first piston chamber pressure so as to axially position the control piston.
3. The slide valve system of claim 2, wherein the means for controlling first piston chamber pressure is a solenoid valve.
4. The slide valve system of claim 1, wherein the control piston is biased towards an unloaded position by the biasing spring.
5. The slide valve system of claim 1, wherein a discharge side of the slide valve is always in communication with screw compressor discharge pressure.
6. The slide valve system of claim 1, wherein the flexible member connecting the control piston and the slide valve is a metallic cable.
7. The slide valve system of claim 1, wherein the flexible member is a rope formed of non-metallic fibers.
8. The slide valve system of claim 1, wherein the flexible member includes a combination of metallic and non-metallic fiber.
9. The slide valve system of claim 1, wherein the control piston is elongated in an axial direction.
10. The slide valve system of claim 1, wherein a counter bore is located on an interior face of the control piston head, dimensioned so as to securely seat one end of the biasing spring.
11. The slide valve system of claim 1, further comprising a first piston sleeve lip, located near a closed end of the piston sleeve and limiting permissible control piston motion towards a fully unloaded position.
12. The slide valve system of claim 11, further comprising a second piston sleeve lip, located where the piston sleeve intersects the compressor discharge cavity, opposite the closed end of the piston sleeve.

13. The slide valve system of claim 12, wherein the biasing spring is compressed between the interior face of the control piston and the second piston sleeve lip.

14. A variable capacity screw compressor, comprising:
   a motor rotor and motor stator;
   intermeshing male and female screw rotors, located within a screw rotor housing, each of the rotors having helical lobes having radially outward tip portions and intervening radially inward root portions, at least one of the male rotor and the female rotor driven by the motor rotor;
   a suction port connecting to a suction chamber;
   a discharge port connecting to a discharge chamber;
   a control piston, axially movable in a piston sleeve;
   a biasing spring, compressed between an interior face of the control piston and the second piston sleeve lip;
   a slide valve;
   a flexible member connecting the control piston to the slide valve and capable of transmitting axial tensile force; and
   means for controlling a piston chamber pressure so as to control axial position of the control piston in the piston sleeve.

15. The screw compressor of claim 14, wherein a discharge side of the slide valve is in communication with screw compressor discharge pressure.

16. The screw compressor of claim 14, further comprising a first piston sleeve lip, located near a closed end of the piston sleeve and limiting permissible control piston motion towards a fully unloaded position.

17. The screw compressor of claim 16, further comprising a second piston sleeve lip, located where the piston sleeve intersects the compressor discharge cavity, opposite the closed end of the piston sleeve.

18. The screw compressor of claim 17, wherein the biasing spring is compressed between the interior face of the control piston and the second piston sleeve lip.
19. A method for controlling position of a slide valve of a screw compressor, the method comprising:
   moving a control piston in a first axial direction to allow discharge pressure in a discharge chamber of the screw compressor to move the slide valve in the first axial direction to a position determined by a flexible connecting member connecting the control piston to the slide valve; and moving the control piston in a second axial direction so that tensile force transmitted by the flexible connector moves the slide valve the same distance in the second axial direction.

20. The method of claim 19, where moving a control piston in a first axial direction further comprises exposing an exterior face of a control piston to an independently controlled-pressure sufficient to overcome an opposing biasing spring force and relieve tension on the flexible connecting member.

21. The method of claim 20, wherein moving a control piston in a first axial direction further comprises exposing a discharge end face of the slide valve to system discharge pressure to bias the slide valve towards the fully loaded position and maintain the flexible connecting member in tension.

22. The method of claim 19, wherein moving the control piston in a second axial direction comprises relieving pressure on the exterior face of the control piston to allow the biasing spring force to return the control piston and the slide valve towards an unloaded position.
AMENDED CLAIMS
received by the International Bureau on
16 June 2008 (16.06.2008)

1. A linearly reciprocating slide valve system for a rotary screw compressor, comprising:
   a control piston, axially movable in a piston sleeve;
   a biasing spring for applying a bias force to the control piston;
   a slide valve axially movable in a rotor bore; and
   a flexible member linearly connecting the control piston to the slide valve, capable of transmitting axial tensile force.

2. The slide valve system of claim 1, wherein the control piston is biased towards an unloaded position by the biasing spring.

3. The slide valve system of claim 1, wherein a discharge side of the slide valve is always in communication with screw compressor discharge pressure.

4. The slide valve system of claim 1, wherein the flexible member connecting the control piston and the slide valve is a metallic cable.

5. The slide valve system of claim 1, wherein the flexible member is a rope formed of non-metallic fibers.

6. The slide valve system of claim 1, wherein the flexible member includes a combination of metallic and non-metallic fiber.

7. The slide valve system of claim 1, wherein a counter bore is located on an interior face of the control piston head, dimensioned so as to securely seat one end of the biasing spring.

8. The slide valve system of claim 7, further comprising a first piston sleeve lip, located near a closed end of the piston sleeve and limiting permissible control piston motion towards a fully unloaded position.

9. The slide valve system of claim 8, further comprising a second piston sleeve lip, located between the rotor bore and the piston sleeve, the second piston sleeve lip having an aperture for receiving the flexible member.

10. The slide valve system of claim 9, wherein the biasing spring is compressed between the interior face of the control piston and the second piston sleeve lip.

11. A variable capacity screw compressor, comprising:
   a motor rotor and motor stator;
   intermeshing male and female screw rotors, located within a screw rotor housing, each of the rotors having helical lobes having radially outward tip portions and intervening radially inward root portions.
portions, at least one of the male rotor and the female rotor
driven by the motor rotor;
a suction port connecting to a suction chamber;
a discharge port connecting to a discharge chamber;
a control piston, axially movable in a piston sleeve;
a first piston sleeve lip positioned between the discharge chamber and
the piston sleeve;
a biasing spring, compressed within the piston sleeve between the
control piston and the piston sleeve lip;
a slide valve disposed adjacent the intermeshing male and female
screw rotors within the screw rotor housing;
a flexible member extending through the piston sleeve lip and linearly
connecting the control piston to the slide valve and capable of
transmitting axial tensile force; and
means for controlling a piston chamber pressure so as to control axial
position of the control piston in the piston sleeve.

12. The screw compressor of claim 11, wherein a discharge side of the slide valve is
in communication with screw compressor discharge pressure.

13. The system of claim 12 wherein the rotor bore, the aperture and the piston
sleeve are approximately axially aligned.

14. The system of claim 13 wherein the flexible member accommodates
misalignment between the rotor bore, the aperture and the piston sleeve.

15. The system of claim 13 wherein the flexible member inhibits torsional force
transmission between the control piston and the slide valve.

16. The screw compressor of claim 11 wherein the flexible member accommodates
for axial misalignment between the piston sleeve, the first piston sleeve lip and the
screw rotor housing, and prevents torque transmission between the slide valve and
the control piston.

17. The screw compressor of claim 11, further comprising a second piston sleeve lip,
located near a closed end of the piston sleeve and limiting permissible control piston
motion towards a fully unloaded position.

18. The screw compressor of claim 13, wherein the biasing spring is compressed
between the interior face of the control piston and the first piston sleeve lip.
19. A method for controlling position of a slide valve of a screw compressor, the method comprising:

- moving a control piston in a first axial direction to allow discharge pressure in a discharge chamber of the screw compressor to move the slide valve in the first axial direction to a position determined by a flexible connecting member linearly connecting the control piston to the slide valve; and
- moving the control piston in a second axial direction so that tensile force transmitted by the flexible connector moves the slide valve the same distance in the second axial direction.

20. The method of claim 19, where moving a control piston in a first axial direction further comprises exposing an exterior face of a control piston to an independently controlled pressure sufficient to overcome an opposing biasing spring force and relieve tension on the flexible connecting member.

21. The method of claim 20, wherein moving a control piston in a first axial direction further comprises exposing a discharge end face of the slide valve to system discharge pressure to bias the slide valve towards the fully loaded position and maintain the flexible connecting member in tension.

22. The method of claim 20, wherein moving the control piston in a second axial direction comprises relieving pressure on the exterior face of the control piston to allow the biasing spring force to return the control piston and the slide valve towards an unloaded position.
STATEMENT UNDER ARTICLE 19 (1)

This is in response to the Written Opinion of the International Searching Authority dated 21 April 2008. Enclosed are replacement sheets 8 - 10. With this amendment, original claims 1, 11, 12, 14, 16, 18, 19 and 22 have been amended. Original claims 2, 3, 9 and 17 have been canceled. Original claims 4-8, 10, 13, 15, 20 and 21 are unchanged. Original claims 4 - 8 and 10 - 15 have been renumbered as claims 2 - 6 and 7 - 12. Four new claims have been added and have been numbered as claims 13 - 16. Original claim 16 has been renumbered as claim 17.

Specific claim amendments reflected in the replacement sheets are as follows:

Original claim 1 has been amended to further specify that the slide valve is axially movable in a rotor bore, and that the flexible member linearly connects the control piston to the slide valve.

Original claim 11 has been amended to depend from new claim 7.

Original claim 12 has been amended to specify the second piston sleeve lip is located between the rotor bore and the piston sleeve and that the second piston sleeve lip has an aperture for receiving the flexible member.

Original claim 14 has been amended to further include a first piston sleeve lip positioned between the discharge chamber and the piston sleeve. Original claim 14 has also been
amended to further specify that the biasing spring is compressed within the piston sleeve, that the slide valve is disposed adjacent the intermeshing screw rotors within the screw rotor housing, and that the flexible member extends through the piston sleeve lip to linearly connect to the control piston.

Original claim 16 has been amended to change a "first" piston sleeve lip to a "second" piston sleeve lip.

Original claim 18 has been amended to depend from new claim 17 and to change the "second" piston sleeve lip to the "first" piston sleeve lip.

Original claim 19 has been amended to specify that the flexible connecting member linearly connects the control piston with the slide valve.

Original claim 22 has been amended to depend from claim 20.

New claim 13 has been added to specify that the rotor bore, the aperture and the piston sleeve are approximately axially aligned.

New claim 14 has been added to specify that the flexible member accommodates misalignment between the rotor bore, the aperture and the piston sleeve.

New claim 15 has been added to specify that the flexible member inhibits torsional force transmission between the control piston and the slide valve.

New claim 16 has been added to specify that the flexible member accommodates misalignment between the rotor bore, the aperture and the piston sleeve, and inhibits torsional force transmission between the rotor bore, the aperture and the piston sleeve.

A copy of PCT POWER OF ATTORNEY appointing the undersigned as agent is also enclosed.
INTERNATIONAL SEARCH REPORT

PCT/US07/21634

A CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F01 C 1/16 (2008.01)
USPC - 418/9

According to International Patent Classification (IPC) or to both national classification and IPC

B FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - F01C 1/16 (2008.01)
USPC - 418/9

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Patbase

C DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1-18</td>
</tr>
</tbody>
</table>

Date of the actual completion of the international search
30 January 2008

Date of mailing of the international search report
21 APR 2008

Name and mailing address of the ISA/US
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450
Facsimile No 571-273-3201

Authorized officer
Blame R Copenheaver
PCT Helpdesk 571 272-4300
PCT OSP 571 272-7774

Form PCT/ISAy210 (second sheet) (April 2007)