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71 Applicant: **PNEUMO CORPORATION**
4800 Prudential Tower
Boston Massachusetts 02199(US)

72 Inventor: **McPherson, Robert R.**
16712 Saybrook Lane Apt. B209
Huntington Harbor California 92649(US)

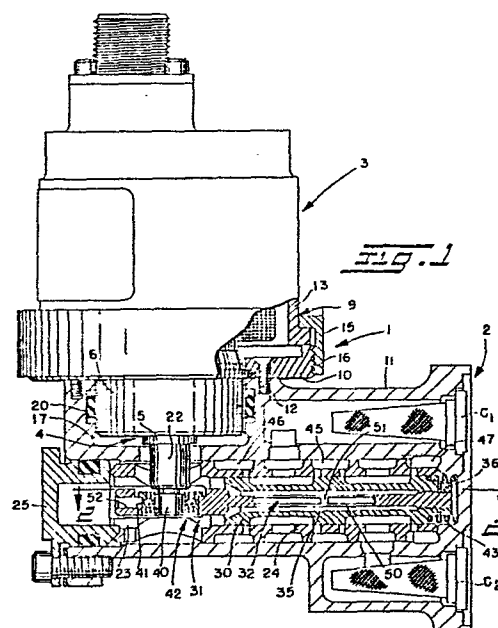
72 Inventor: **Vanderlaan, Robert D.**
724 Fineview
Kalamazoo Michigan 49007(US)

72 Inventor: **Meulendyk, John W.**
1120 Hol-hi Drive
Kalamazoo Michigan 49008(US)

74 Representative: **Topps, Ronald et al,**
D. YOUNG & CO 10 Staple Inn
London WC1V 7RD(GB)

54 **Direct drive valve and force motor assembly.**

57 Assembly includes a direct flexible quill drive (32) between the motor output shaft (22) and valve plunger (30). When the output of the motor (3) is rotary, the centerline of the motor output shaft is oriented 90° relative to the centerline of the valve (30) and has an eccentric offset that provides the gearing to transfer the angular rotation of the motor into linear motion of the valve. The motor may readily be connected and disconnected from the drive quill by a simple pushing or pulling motion without requiring a lock of any sort therebetween. The drive quill (32) desirably has a generally rectangular cross-section with the thinner dimension being in the operational bend plane of the quill to provide the desired flexibility in the operational bend plane and stiffness in the opposite plane. Intermediate the ends of the quill may be an enlarged center dam portion (51) to provide column stiffening of the quill when the quill is deflected under high load to contact a surrounding wall portion (35).



DIRECT DRIVE VALVE AND FORCE MOTOR ASSEMBLY

This invention relates generally as indicated to a direct drive valve and force motor assembly, and more particularly to a novel drive linkage mechanism for transferring the output of the motor to the valve to provide controlled selective movement of the valve plunger or other mechanism driven thereby.

In certain types of high pressure fluid proportional servo control systems such as a control actuation system for aircraft in which the fluid pressure may for example be on the order of 1000 psi or more, it has been found advantageous to use a direct drive valve of relatively short stroke. However, the manner in which the output of the force motor that is used to drive the valve is transferred to the valve can have a marked effect on the size and energy requirements of the motor as well as on the preciseness with which the valve movements are controlled by the motor.

According to the present invention, in one aspect thereof a direct flexible quill drive is provided between the motor output shaft and valve plunger. When the output of the motor is rotary, the motor output shaft rotates about a centerline which is 90° to the centerline of the valve and has an eccentric offset that provides the gearing to transfer a relatively large motor angular rotation into a relatively short valve motion. The flexible quill accommodates the rise and fall motion about the eccentric null without inducing unacceptable plunger side loads and associated friction. The 90° relationship between the motor centerline and valve centerline eliminates the adverse effects (i.e. null shifts) of motor shaft end play, shock, vibration and thermal dimensional changes within the motor, as well as fluid pressure variations.

In accordance with a further aspect of the invention, an anti-friction bearing connection may be provided between the eccentric offset and quill to provide a relatively low friction pivot point resulting in a highly efficient linkage under adverse chip shear loading requirements and the like.

In accordance with yet another aspect of the invention, the drive quill side loads acting on the motor shaft will apply a light load to the motor

shaft and bearings to remove any backlash or play in the bearings (including any redundant bearings) and reduce the hysteresis in the critical null region.

5 In accordance with still another aspect of the invention, the motor may readily be connected and/or disconnected from the drive quill by a simple pushing or pulling motion without requiring a lock of any sort therebetween.

In accordance with a further aspect of the invention, the linkage cosine geometry of the drive quill may be matched with the motor cosine torque output to provide maximum utilization of the output work potential.

10 In accordance with a still further aspect of the invention, the drive quill desirably has a generally rectangular cross-section with the thinner dimension being in the operational bend plane to provide the desired flexibility in such plane and a stiffness in the opposite plane to prevent the bearing from working off the motor shaft.

15 In accordance with yet another aspect of the invention, the drive quill may have an enlarged center dam portion intermediate the ends thereof to provide column stiffening when the drive quill is deflected under high load to cause the dam portion to contact a surrounding wall portion.

20 An embodiment of the invention will now be described, by way of an example, with reference to the accompanying drawings, in which:

Figure 1 is a fragmentary longitudinal section through a direct drive valve and force motor assembly including a preferred form of direct linkage drive mechanism according to the present invention between the motor output shaft and valve plunger;

25 Figure 2 is a fragmentary longitudinal section through the valve member of Figure 1, taken on the plane of the line 2-2 thereof, showing the linkage drive mechanism in elevation; and

Figure 3 is an enlarged transverse section through the drive linkage of Figure 2, taken on the plane of the line 3-3.

30 Referring now in detail to the drawings and initially to Figure 1, a preferred form of direct drive valve and force motor assembly in accordance with this invention is designated generally by reference numeral 1 and consists of a valve member 2 which may be directly driven by a force motor

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3. Preferably, such motor is a non-commutated two pole stationary coil rotary magnet motor. As shown, such motor includes a rotor assembly 4 having a rotor shaft 5 journal mounted within a rotor casing 6 adjacent opposite ends thereof by rotor shaft bearings suitably supported by common casing structure. A stator and housing assembly 9 surrounds the rotor casing.

A holddown member 10 may be used to clamp the rotor casing to the valve housing 11 as by means of mounting bolts 12, whereas the stator housing 13 may be removably attached to the rotor casing as by means of a threaded sleeve 15 having threaded engagement with an external threaded surface 16 on the holddown member. When thus installed, the rotor casing 6 extends into a cavity 17 in the valve housing thus exposing the interior of the rotor casing to the fluid pressure within the valve housing. This provides the advantages of a wet motor design, including eliminating the need for a dynamic shaft seal and providing a lubricating fluid for the rotor bearings. A static seal 20 surrounds the rotor casing to keep the stator and housing assembly 9 dry thus allowing replacement of the stator and housing assembly without disturbing the rotor casing 6 and rotor assembly 4.

When the motor 3 is a rotary force motor such as shown in Figure 1, the motor output shaft 22 extends perpendicularly into a longitudinal bore 23 in the valve housing 11. Contained within the bore 23 is a valve sleeve 24 which may be held against movement within the bore as by means of a closure member 25 suitably retained in the outer end of the bore. Within the valve sleeve is an axially movable valve plunger 30. The motor output shaft 22 is drivingly connected to the valve plunger 30 by a drive linkage mechanism 31 consisting of a flexible drive shaft or quill 32 connected at its opposite ends to the valve plunger and motor output shaft, respectively. The valve plunger 30 being tubular includes an axial bore 35 through which the drive quill extends for connection to the end of the valve plunger furthest from the motor output shaft as by means of a threaded connection 36. It will be appreciated that the effective length of the quill may be adjusted at its threaded end to permit adjustment of the neutral or null position of the valve plunger relative to a null position of the force motor.

At its other end, the drive quill extends outwardly beyond the valve plunger for connection to the motor output shaft. The outer end of the motor output shaft is provided with an eccentric 40 which extends through a transverse bore 41 in the other end of the drive quill. The eccentric rotates about a 90° centerline relationship between the motor and valve to convert rotary motion to linear motion. The flexible quill drive between the motor eccentric and valve plunger accommodates such eccentric drive movements without inducing unacceptable plunger side loads and associated friction.

An antifriction bearing connection 42 may be provided between the eccentric 40 and drive quill 32 to provide a low friction pivot point therebetween resulting in a highly efficient linkage under adverse chip shear loading requirements and the like.

The 90° centerline relationship between the motor and valve eliminates adverse effects (i.e., null shifts) of return pressure variations as well as motor shaft end play, shock, vibration and thermal dimensional changes within the motor. Moreover, as the quill is deflected, the quill side loads acting on the motor shaft apply a relatively light load to the motor shaft 22 and rotor shaft bearings as well as to the antifriction bearing connection 42 to remove any backlash or play in the bearings and reduce hysteresis in the critical null region. Such a 90° centerline relationship between the motor and valve also has the advantage that the motor may readily be connected and/or disconnected from the drive quill by a simple pushing or pulling motion without requiring a lock of any sort therebetween.

Another advantage in using such a drive linkage mechanism 31 is that the cosine geometry of the linkage can be matched with the motor cosine torque output to provide maximum utilization of the output work potential of the motor. The stator windings of a two-pole motor can be graded to optimize the torque versus rotation profile in order to achieve a substantially cosine relationship between the applied motor current and the rotational angle to complement the cosine function that such drive linkage mechanism tends to follow to produce a substantially constant force output over a relatively large excursion of the rotor shaft. Such optimization can

be used to obtain a maximum useful work angle of up to $\pm 60^\circ$ or more of motor output shaft rotation. The torsional spring load and chip shear energy optimization occurs when the peak electrical power equals the maximum spring load at the maximum rotational travel.

5 The offset of the motor eccentric 40 provides the necessary gearing to transfer a large motor angular rotation into a relatively short valve motion without the minimum practical offset limitations that exist in the straight rotary to rotary motion. Also, such linkage gearing greatly reduces the effect of any unbalanced plunger masses and/or flow forces
10 being reflected back to the motor and allows for easy mass balancing within the motor.

 With the valve plunger 30 in the valve null position shown in Figure 1, fluid flow to and from the cylinder ports C_1 and C_2 is blocked. A light load spring 43 may be interposed between the inner end of the bore 23
15 and the adjacent end of the valve plunger to bias the valve plunger in such valve null position.

 Controlled selective movement of the valve plunger by the force motor will cause the valve plunger to move out of the null position respectively to connect one of the cylinder ports C_1 , C_2 to a common center
20 system supply pressure groove 45 and the other cylinder port to one or the other of the system return pressure grooves 46, 47 on opposite sides of the system supply pressure groove 45.

 The force motor input may be controlled by command signals received from control augmentation system electronics and the like to serve
25 as a control input to the valve plunger. Also, system redundancy may be accomplished by providing multiple parallel coils within the motor, whereby if one coil or its associated electronics should fail, its counterpart channel will maintain control by equalizing the failed channel force effect. The ability to sense which channel has failed may be provided for in the failure
30 monitoring electronics such that when detected, the failed channel is decoupled and made passive.

 The drive quill 32 has a reduced diameter flexible link portion 50 extending between the end mounting portions. To provide the required

flexibility of the drive quill and reduce the loads on the drive quill in the operational bend plane while at the same time give it the desired stiffness in the opposite plane to prevent the bearing from working off the eccentric, the flexible link portion 50 desirably has a rectangular cross-sectional configuration with the narrower dimension X being in the operational bend plane parallel to the axis of the motor output shaft and the wider dimension Y being in the opposite plane perpendicular to such axis as shown in Figures 2 and 3.

The amount of clearance between the inner wall of the plunger bore 35 in which the drive quill 32 is slidably received and the drive quill in the operational bend plane must of course be sufficient to accommodate the eccentric drive movements of the quill during the full range of angular rotation of the motor output shaft. However, an enlarged center dam portion 51 is desirably provided intermediate the ends of the flexible link portion 50 to provide column stiffening of the drive quill when the drive quill is sufficiently deflected under high load to cause the dam to contact the inner wall of the valve plunger bore as shown in phantom lines in Figure 2.

The drive quill may be made from round bar stock from which material is removed from opposite sides to form the thinner section X except in the middle where the bar may be left intact to provide the enlarged center dam portion 51 as aforesaid.

Although the valve plunger is shown being driven by a rotary force motor, a linear force motor may also be used in place of the rotary force motor. For this, the drive quill may be provided at its force motor connection end with a threaded axial bore 52 for connection to the linear drive element of a linear force motor. With a linear force motor, the flexible quill will accommodate any misalignment between the drive member and valve plunger without applying significant side loads to the valve plunger.

Also, while a slide valve is shown, such valve could be a proportionally operated valve of the ball or poppet type. Also, the drive linkage mechanism 31 could be used to drive other mechanisms as well.

Although the invention has been shown and described with respect to a certain preferred embodiment, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of the specification. The present invention
5 includes all such equivalent alterations and modifications, and is limited only by the scope of the claims.

CLAIMS:

1. A direct drive valve and force motor assembly comprising a valve member containing a linearly movable tubular valve plunger, a force motor having a force motor drive adjacent one end of said valve plunger, and link means drivingly interconnecting said force motor drive and valve plunger, said link means being connected at one end to the other end of said valve plunger opposite said force motor drive and extending through and out of said tubular valve plunger for connection at its other end to said force motor drive, said link means having a flexible link portion spaced from the inside wall of said tubular valve plunger for accommodating any translinear movement between opposite ends of said link means during driving of said valve plunger by said force motor drive without applying significant side loads to said valve plunger.

2. The assembly of claim 1 wherein said force motor is a rotary force motor, and said force motor drive extends perpendicularly to the axial centerline of said valve plunger, said force motor drive having an eccentric on the outer end thereof which extends into a transverse bore in the other end of said link means, said flexible link portion of said link means accommodating the rise and fall of said eccentric during rotation by said force motor, the flexing of said flexible link portion of said link means during rotation of said eccentric applying a light load on said force motor drive which removes backlash and reduces hysteresis in the critical null region.

3. The assembly of claim 1 further comprising means for adjusting the effective length of said link means to permit adjustment of the neutral or null position of said valve plunger relative to a null position of said force motor.

4. The assembly of claim 1 wherein said force motor includes a rotor casing and rotor assembly journaled in said rotor casing and a stator and housing assembly surrounding said rotor casing, and said force motor drive extends axially outwardly from one end of said rotor casing, and said valve member includes a valve housing containing a cavity adjacent said one end of said valve plunger, the longitudinal axis of said cavity being

perpendicular to the longitudinal axis of said valve plunger, said rotor casing and said force motor drive extending into said cavity with the axis of said force motor drive being perpendicular to the axis of said valve plunger, said force motor drive having an eccentric on the outer end thereof to which said other end of said link means is connected, and means for clamping said rotor casing to said valve housing.

5. In combination, a valve member comprising a valve housing containing a longitudinal bore, and a valve plunger axially movable in said longitudinal bore between a valve null position and one or more operating positions, and a rotary force motor for driving said valve plunger between said positions, said force motor including a motor output shaft extending into a cavity in said valve housing adjacent one end of said valve plunger, the centerline of said motor output shaft being perpendicular to the centerline of said valve plunger, an eccentric on the outer end of said motor output shaft, and a flexible quill having opposite ends connected to said valve plunger and eccentric, respectively, said quill being generally rectangular in cross-section with the thinnest dimension being in the operational bend plane of said quill parallel to the longitudinal axis of said motor output shaft and the thicker dimension being in the opposite plane perpendicular to the axis of the motor output shaft to provide the required flexibility of said quill and reduced loads on said quill in the operational bend plane while at the same time giving said quill stiffness in the opposite plane to prevent said quill from working off said motor output shaft.

6. A direct drive and force motor assembly comprising a linearly movable tubular plunger, a force motor having a force motor drive adjacent one end of said plunger, and link means drivingly interconnecting said force motor drive and plunger, said link means being connected at one end to the other end of said plunger opposite said force motor drive and extending through and out of said plunger for connection at its other end to said force motor drive, said link means having a flexible link portion spaced from the inside wall of said plunger for accommodating any translinear movement between opposite ends of said link means during driving of said plunger by said force motor drive without applying significant side loads to said plunger.

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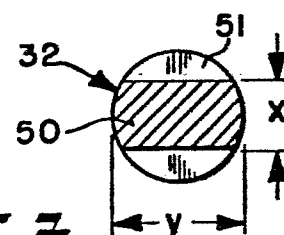
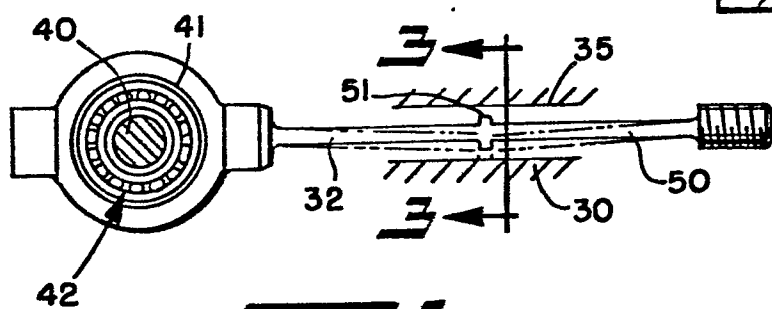
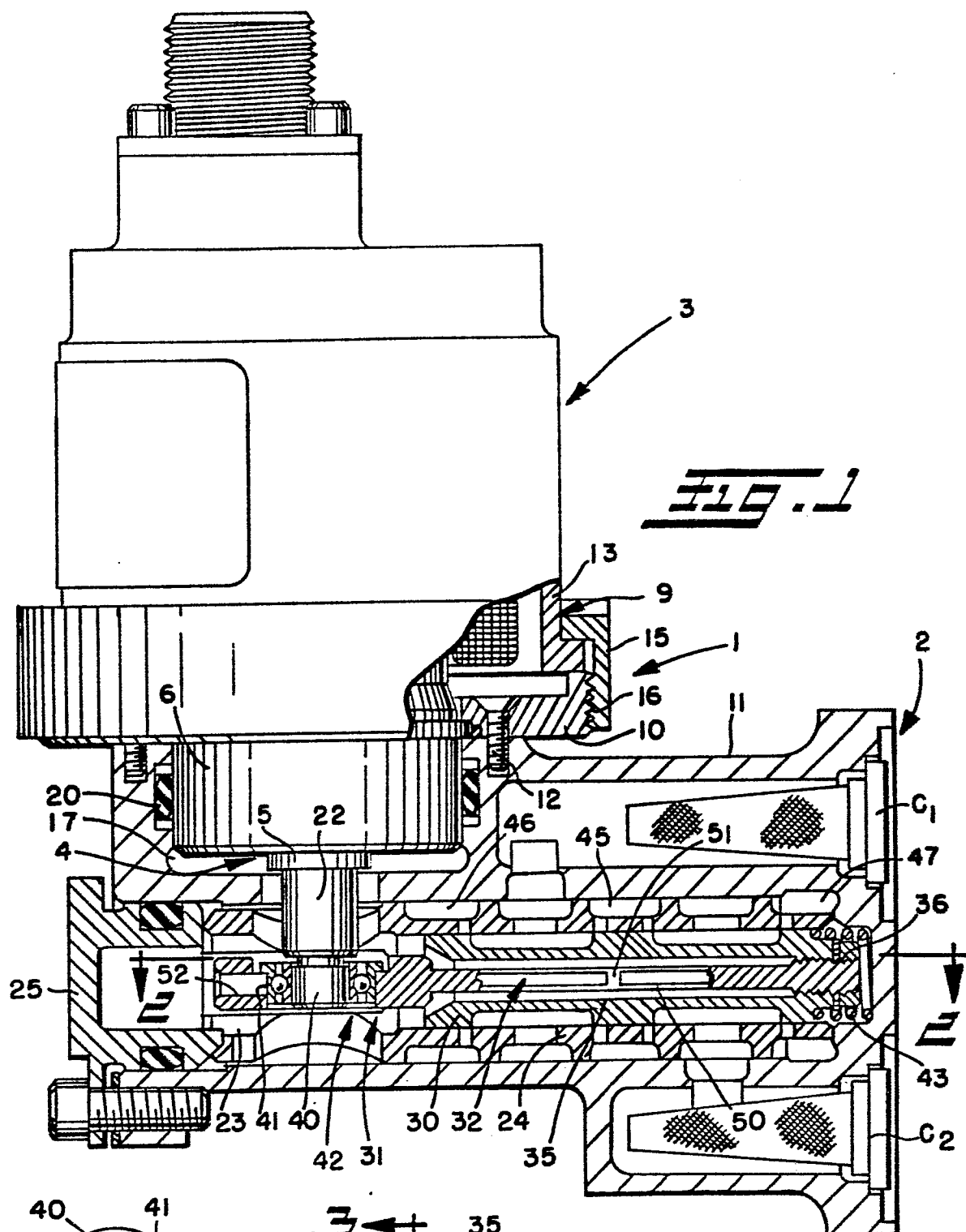
7. The assembly of claim 6 wherein said force motor is a rotary force motor, and said force motor drive extends perpendicularly to the axial centerline of said plunger, said force motor drive having an eccentric on the outer end thereof which extends into a transverse bore in the other end of said link means, said flexible link portion of said link means accommodating the rise and fall of said eccentric during rotation by said force motor.

8. The assembly of claim 7 further comprising bearing means mounting said other end of said link means on said eccentric to provide a relatively low friction point therebetween resulting in a highly efficient linkage under adverse loading requirements, said link means causing a side load to be applied to said bearing means which removes any backlash in said bearing means.

9. The assembly of claim 8 wherein the thickness of said flexible link portion of said link means is less in the operational bend plane parallel to the axis of the force motor drive than in the opposite plane perpendicular to such axis to provide flexibility and reduced loads in the operational bend plane and stiffness in the opposite plane to prevent said bearing means from working off said eccentric.

10. The assembly of claim 9 further comprising an enlarged center dam portion intermediate the ends of said flexible link portion to provide column stiffening of said flexible link portion when said dam portion is deflected into engagement with the inner wall of said bore in said tubular valve plunger.

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European Patent
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EUROPEAN SEARCH REPORT

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Application Number

EP 84 30 6028

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.4)
X	GB-A-2 085 129 (KONTAK MANUFACTURING CO. LTD.) * Whole document *	1,2,6-8	F 15 B 13/044
Y		3,4	
Y	FR-A-2 253 961 (ROBERT BOSCH GmbH) * Figures 1,2,4,5 *	3,4	
A	FR-A-2 116 921 (COMPAGNIE FRANCAISE DES PETROLES)		
A	US-A-2 938 503 (H.H. LAUCKS)		
A	FR-A-1 361 337 (R. LEDUC et al.)		TECHNICAL FIELDS SEARCHED (Int. Cl.4) F 15 B
A	EP-A-0 080 888 (PNEUMO CORP.)		
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 07-08-1985	Examiner FRANKS N.M.
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	