(12) UK Patent Application (19) GB (11) 2 267 947 (13) A

(43) Date of A publication 22.12.1993

(21) Application No 9212821.4

(22) Date of filing 17.06.1992

(71) Applicant
GEC Alsthom Limited

(Incorporated in the United Kingdom)

Mill Road, Rugby, Warwickshire, CV21 1BD, United Kingdom

(72) Inventor
Michael Peter Reece

(74) Agent and/or Address for Service
The General Electric Company plc
GEC Patent Department, Waterhouse Lane, Chelmsford, Essex, CM1 2QX, United Kingdom

(51) INT CL[5]
F16F 9/53

(52) UK CL (Edition L)
F2S SBG S204
U1S S1831

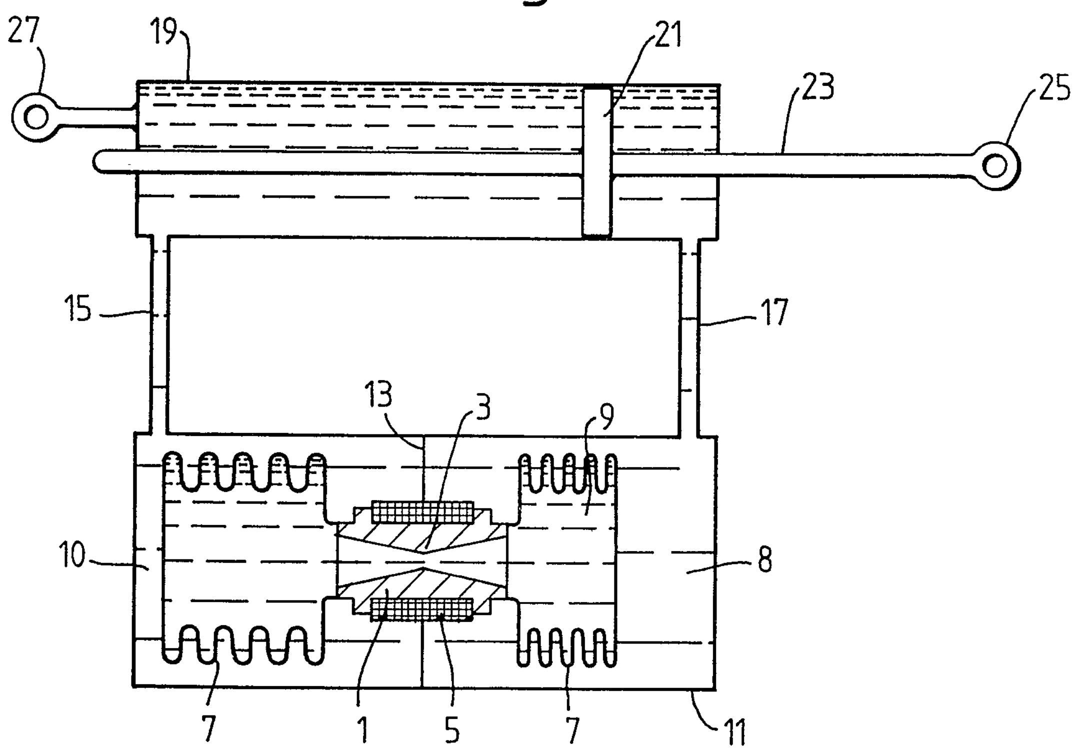
(56) Documents cited
EP 0257932 A2

(58) Field of search
UK CL (Edition K) F2S SBG SXB
INT CL[5] F16F
Online databases: WPI

(54) **Controllable motion-damper**

(57) A damper for railway vehicles, comprises two 'rubber' bellows (7) connected by a nozzle (1). The nozzle consists of a tapered orifice in the form of two conical bores, apex to apex, diverging from a common cross-section (3), this unit being completely full of a damping fluid (9) which consists of soft-iron particles suspended in oil or hydraulic fluid. This whole unit extends between two fluid containers (8, 10) which are compressed differentially from a double acting master cylinder (19). Such differential pressure causes one bellows (7) to be compressed and the other to expand so pumping the damping fluid through the nozzle (1) and exerting a damping force, which is controlled by the current supplied to a coil (5). In an alternative device, the damper is mounted in a piston (Fig. 3).

Fig. 2.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig. 1.

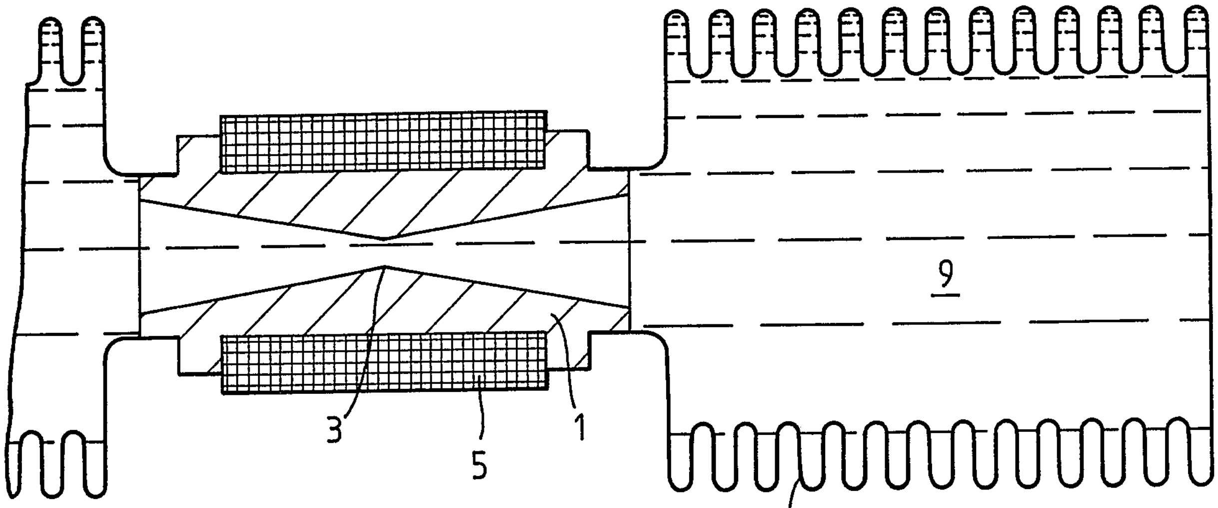


Fig. 2.

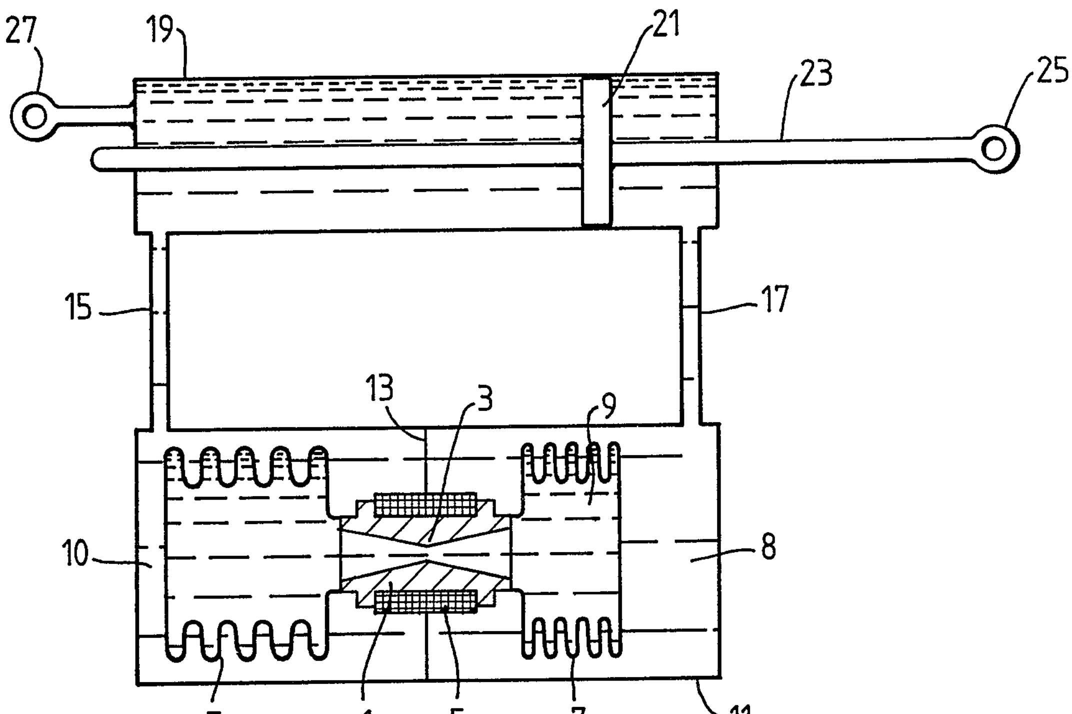


Fig. 3.

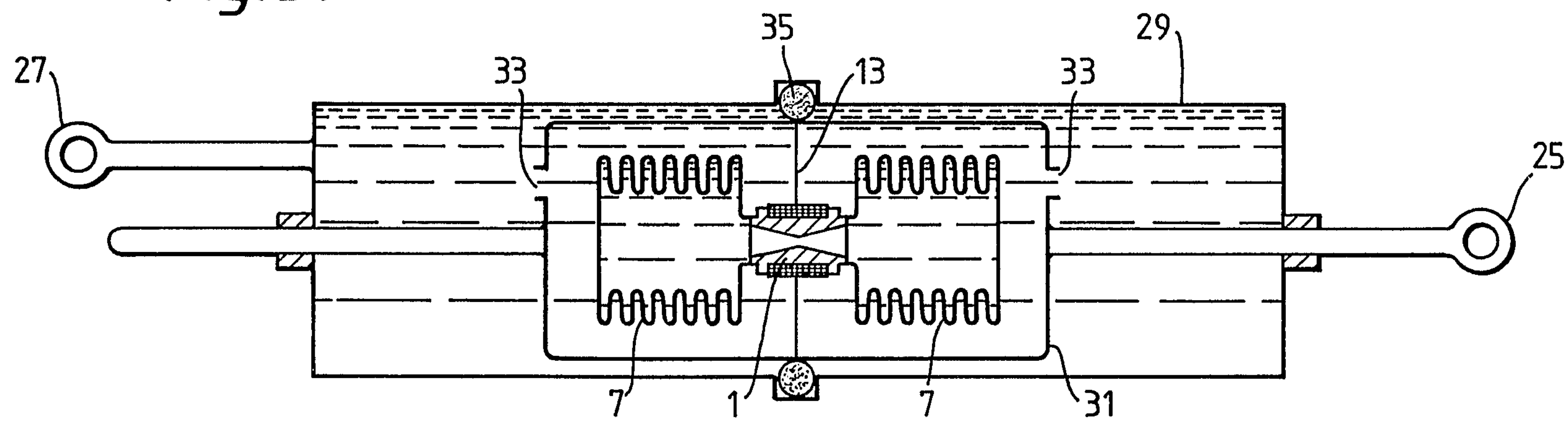
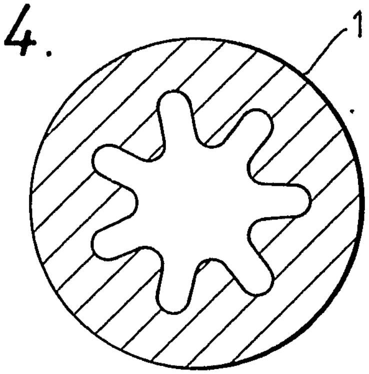


Fig. 4.



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Controllable Motion-Damper

This invention relates to controllable motion-dampers particularly but not exclusively for damping vehicle body motion. Controllable dampers for vehicles are known in which, for example, two or more hydraulic cylinder dampers are 'switched' in parallel to control the stiffness according to detected vibration frequency. A convenient method of doing this is to use a single cylinder with two or more orifices which are opened and closed as the conditions require.

In railway vehicles particularly, there is a demand for dampers with a very high operating speed and it is found that known controllable dampers are not satisfatory in this respect. Additionally, dampers such as described above have a step change control and in many application continuous control is highly desirable.

One object of the present invention therefore is to provide a continuously controllable motion damper with a very high operating speed.

According to the present invention, a controllable motion damper comprises a volume of damping fluid contained within two flexible envelopes connected by a nozzle, the two envelopes being externally subject to differential pressure resulting in operation from differential movement between members linked by the damper, the differential pressure causing the damping fluid to be forced through the nozzle from one envelope to the other, and the nozzle comprising two sections diverging gradually from a minimum common cross-section, the damping fluid being a suspension of low coercivity magnetic particles, and electromagnetic means being provided for producing a controllable magnetic field within the nozzle to control the viscosity of the damping fluid.

It will be appreciated that the reference to the "viscosity" of the magnetic suspension is not to the classical viscosity of the fluid; it is rather to the 'stiffness' or 'strength' resulting from the inclination of the magnetic particles to conform to the field pattern. It should be understood that in this specification it is this 'non-Newtonian viscosity' that is referred to.

Preferably, each section of the nozzle diverges continuously with a taper angle between 5° and 20° and preferably in the region of 10°. The envelopes may be of compressible bellows form.

Each of the envelopes may be enclosed in a respective inexpansible enclosure containing hydraulic fluid between the envelope and the enclosure wall, the two enclosures being connected to a source of differential pressure so that as hydraulic fluid is pumped into one enclosure in operation the enclosed envelope is compressed to cause the damping fluid to pass through the nozzle. The two enclosures may be provided by a single cylinder having a partition through which the nozzle extends. The source of differential pressure may comprise a master cylinder having a double action piston, connections to the enclosures being taken from the master cylinder on each side of the piston, the piston being adapted for connection as a link between the damped members.

Alternatively, the envelopes may be mounted in respective inexpansible enclosures having a common wall through which the nozzle extends, the enclosures together forming a common piston in a cylindrical housing, each enclosure being open to a respective end of the cylindrical housing, the enclosures and housing being full of hydraulic fluid, and the piston being adapted for connection as a link between the members, the arrangement being such that movement of the piston causes compression of the hydraulic fluid in one end of the housing and in the associated enclosure, compression of the associated envelope, and pumping of the damping fluid through the nozzle.

The bore of the nozzle may be grooved axially so that a cross section of the bore exhibits a corrugated wall.

A damper according to any preceding claim, wherein the bore of the nozzle has at least a lining of mechanically refractory material for resisting erosion by passage of the damping fluid.

The electromagnetic means may comprise a coil wound around the nozzle at least in the region of the minimum common cross-section.

Preferably the coil extends along the nozzle between positions within the length of the nozzle.

Two embodiments of controllable motion-dampler in accordance with the invention will now be described, by way of example, with reference to the accompanying drawings, of which:

Figure 1 is a diagram of a central feature of the damper, ie a nozzle limiting the flow of damping flud;

Figure 2 is a diagram of the main features of one embodiment of damper;

Figure 2 is a diagram of an alternative embodiment;

and Figure 3 is a diagram of a cross section of a modified version of the nozzle of Figure 1.

Referring now to Figure 1 of the drawings, this shows, very diagrammatically, a damping nozzle 1 and part of the associated apparatus. The nozzle 1 consists of a ceramic cylinder having a double conical bore which diverges in both directions from the central minimum common cross-section 3 with a total taper angle of approximately 10°. The central part of the nozzle is wrapped with a coil 5 such as, when energised, to produce an axial magnetic field in the nozzle bore.

Since a rapid response is required, the field must follow a current change very quickly. Consequently the nozzle 1 must not be conductive (which would result in inductive inertia). It must also not be magnetic in order that the flux passes at least equally through the bore as the nozzle.

At each end of the nozzle a flexible envelope 7 is connected, this being formed from a durable rubber-type material. The envelope 7 has a wall of bellows form to permit a change in volume of the envelope. The space contained by the two bellows and the nozzle is filled completely with a damping fluid 9 which consists of a suspension of soft-iron particles in oil or hydraulic brake fluid. The particles need to be sufficiently small and spherical that they do not pack hard when left standing for long periods. While soft-iron is a common and cheap material, other magnetic materials will be suitable if they are of sufficiently low coercivity. When the current is removed from the coil 5 it is required that the particles become substantially de-magnetised.

Referring now to Figure 2, this shows one convenient arrangement for operating the damper of Figure 1. The two envelopes 7 are mounted in a cylinder 11 which has a central partition 13 sealed to and supporting the central nozzle assembly of nozzle 1 and coil 5. Two enclosures 8 and 10 are thus formed, each of which encloses one of the envelopes 7.

The cylinder 11 is closed but for two pipe connections 15,17 to a piston cylinder 19. This contains a double acting piston 21, the pipe connections being to opposite sides of the piston. The two cylinders 11 and 19 are completely full of hydraulic fluid as used for example, in fluid drive systems. There may in practice be a reservoir and a non-return valve, not shown. The piston 21 is mounted on a piston rod 23 which extends through sliding seals in the cylinder 19 in both directions. The total volume of fluid contained in the cylinder 19 is therefore unchanged as the piston moves since there is always the same volume of rod 23 within the cylinder 19. The piston rod 23 has one end coupling 25 adapted for coupling to one of two parts of a vehicle which in operation move relatively to each other with varying degrees of shock. The cylinder 19 has a fixed coupling 27 (shown very diagrammatically), which couples to the other of these two relatively movable parts. On a train carriage the piston rod coupling 25 would couple to the bogie, say, and the cylinder coupling 27 to the carriage body.

In operation, relative movement of the body and bogie causes the piston 21 to move in the cylinder 19. As illustrated, the piston has moved to the right. This causes the hydraulic fluid to be driven down the pipe 17 into the right-hand enclosure 8 of the cylinder 11. This cylinder is conveniently of metal and inexpansible and consequently a positive pressure is exerted on the right-hand envelope 7. At the same time, movement of piston 21 to the right causes fluid to be sucked up the pipe 15 so producing a negative pressure on the left-hand envelope 7. The cylinder 19 thus acts as a source of pressure differential which compresses the right-hand envelope 7 and expands the left-hand envelope. The damping fluid 9 contained within the envelopes 7 is thus driven through the nozzle 1. In doing so a restraining force is exerted on the relative movement of piston rod 23 and cylinder 19 and thus on relative movement of the parts to which they are coupled.

In the nozzle 1 there is an inherent resistance to flow due to the restricted orifice, having a minimum cross-section 3. This resistance can, however, be increased very considerably by creation of the magnetic field previously referred to. The coil current is increased at a rate, and to a value, determined in a feedback loop. As the field arises the magnetic particles in the damper fluid 9 tend to cling together so that what was previously a fairly free flowing fluid becomes a viscous semi-liquid.

The force resisting the shock movement increases with the velocity of the movement but also increases fairly linearly with the magnetising current. With minimal inductance the current and therefore the magnetic field and the damping force can be increased very rapidly.

In the design of the nozzle 1 it is important that there is no great step change as the damping fluid 9 emerges from the nozzle into the envelope 7. It is essential therefore that the bore of the nozzle is tapered at not too shallow an angle. 30° (total) taper angle is a reasonable minimum although the disadvantageous effect now to be described will occur to a greater and lesser extent as this angle is decreased and increased respectively.

If the bore of the nozzle were cylindrical, application of the magnetic field would tend to produce a cylindrical plug of semi-solid damping 'fluid'. This plug would be driven through the fluid in the envelope like a bolt and the resistance and damping force would be reduced. To make the 'plug' drag on the main body of fluid, the area of contact between the two is increased, by widening the nozzle exit.

A further improvement is made by restricting the coil length to less than that of the nozzle so that there is a portion of damping fluid at the ends of the nozzle not enclosed by the coil and which is therefore subjected to magnetic field of smaller intensity. The effect of these two modifications is to grade the transition between the more nearly solid damping 'fluid' in the nozzle and the more liquid fluid in the envelope 7.

A highly efficient smoothly controllable damper is thus provided having a very rapid response to shock movements and to the application of control current.

While in the above described embodiment the nozzle is totally of ceramic to provide an erosion resistant bore to the nozzle, other refractory materials may be used, even non magnetic low conductivity metal alloys. A further modification is to use a nozzle having suitable magnetic and conductive characteristics but merely coated with refractory material. It will be clear of course that a damping fluid carrying iron particles in suspension will be very erosive. It is for this reason that the damping fluid is isolated from any sliding surface in the described embodiments.

It will be apparent from the described arrangement of Figure 2 that the 'master' cylinder 19 can be positioned suitably for the members to be damped, while the damping cylinder 11 can be positioned remotely. The pipes 15 and 17 may be rigid or flexible.

In an alternative embodiment, shown in Figure 3 the whole arrangement is incorporated in a single cylinder 29. This acts in the same manner as the master cylinder of Figure 2, the cylinder itself being coupled (27) to one of the damped members and the piston rod 23 being coupled (25) to the other. In this case however, the piston 31 is closely similar to the 'slave' unit 11 of Figure 2. Thus the cylinder 31 carries the damping unit 1, 7 and 7 mounted on a partition 13 which divides the cylinder 31 into two enclosures. In this case however, the two enclosures are open at vents 33 into the master cylinder 29. The cylinder 31 is slidable within cylinder 29, being sealed by O-ring 35 to separate the hydraulic fluid in the two ends of the master cylinder.

In operation, as the couplings 25 and 27 are thrust together, fluid in the left-hand end of cylinder 29 is forced into the left-hand end of 'piston' 31 so comprising the left-hand envelope 7. At the same time, hydraulic fluid in the right-hand end of cylinder 31 is sucked out, so expanding the right-hand envelope 7. Damping fluid is therefore forced from the left-hand envelope 7 to the right-hand envelope 7 through the nozzle 1. A magnetic field is created as before and a damping force restricting the flow of damping 'fluid' is created, depending on the velocity of approach of the couplings 25 and 27 and the magnetising current value.

In a modification of the nozzle of Figure 1 the tapered bore is corrugated, as shown in Figure 4. Again this tends to inhibit the formation of a magnetic plug of damping fluid when the semi-solidified fluid is forced out of the nozzle.

CLAIMS

1. A controllable motion damper comprising a volume of damping fluid contained within two flexible envelopes connected by a nozzle, the two envelopes being externally subject to differential pressure resulting in operation from differential movement between members linked by the damper, said differential pressure causing the damping fluid to be forced through the nozzle from one envelope to the other, and wherein said nozzle comprises two sections diverging gradually from a minimum common cross-section, the damping fluid is a suspension of low coercivity magnetic particles, and electromagnetic means are provided for producing a controllable magnetic field within the nozzle to control the viscosity of the damping fluid.

2. A damper according to Claim 1, wherein each section of said nozzle diverges continuously with a taper angle between 5° and 20°.

3. A damper according to Claim 1 or Claim 2, wherein each section of said nozzle diverges continuously with a taper angle of approximately 10°.

4. A damper according to any preceding claim, wherein said envelopes are of compressible bellows form.

5. A damper according to any preceding claim wherein each of the envelopes is enclosed in a respective inexpansible enclosure containing hydraulic fluid between the envelope and the enclosure wall, the two enclosures being connected to a source of said differential pressure so that as hydraulic fluid is pumped into one said enclosure in operation the enclosed envelope is compressed to cause the damping fluid to pass through the nozzle.

6. A damper according to Claim 5, wherein said two enclosures are provided by a single cylinder having a partition through which the nozzle extends.

7. A damper according to Claim 5 or Claim 6, wherein said source of differential pressure comprises a master cylinder having a double action piston, connections to said enclosures being taken from said master cylinder on each side of said piston, the piston being adapted for connection as a link between said members.

8. A damper according to any of Claims 1, 2, 3 and 4, wherein said envelopes are mounted in respective inexpansible enclosures having a common wall through which said nozzle extends, said enclosures together forming a common piston in a cylindrical housing, each enclosure being open to a respective end of the cylindrical housing, the enclosures and housing being full of hydraulic fluid, and the piston being adapted for connection as a link between said members, the arrangement being such that movement of the piston causes compression of the hydraulic fluid in one end of the housing and in the associated enclosure, compression of the associated envelope, and pumping of the damping fluid through the nozzle.

9. A damper according to any preceding claim wherein the bore of said nozzle is grooved axially so that a cross section of the bore exhibits a corrugated wall.

10. A damper according to any preceding claim, wherein the bore of said nozzle has at least a lining of refractory material for resisting erosion by passage of said damping fluid.

11. A damper according to Claim 10, wherein said nozzle consists of ceramic material.

12. A damper according to any preceding claim, wherein said electromagnetic means comprises a coil wound around said nozzle at least in the region of said minimum common cross-section.

13. A damper according to Claim 12, wherein said coil extends along said nozzle between positions within the length of the nozzle.

14. A controllable motion damper substantially as hereinbefore described with reference to Figure 1 and Figure 2, or to Figure 1 and Figure 3, or as modified in accordance with Figure 4.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number
9212821.4

Relevant Technical fields

(i) UK Cl (Edition K) F2S (SBG,SXB)

(ii) Int Cl (Edition 5) F16F

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASES: WPI

Search Examiner

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Date of Search

23 JULY 1992

Documents considered relevant following a search in respect of claims 1-14

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	EP 0257932 A2 (LORD) note Figure 4 when including elements 44	

SF2(p)

GEM - doc99\fil000062

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

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