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(54) **Damping arrangements.**

(57) A damping arrangement for use on a train of railway vehicles (1, 2, 3) for damping unwanted motion of a vehicle body (8) transmitted by a supporting bogie (5), the bogie being subject to shock movement resulting from track irregularity. Hydraulic dampers (7) fitted between the bogie (5) and body (8) are adapted (12, 14, 15, 16, 17 - Figure 2 ; 12, 18, 19, 20, 21 - Figure 3) to provide a number of discrete values of damping resistance. Shock movement is detected by accelerometers (23) fitted on one or more bogies ahead in the train. With a knowledge of the train speed (22) and the bogie spacing, the occurrence of jerks, etc. is 'predicted' for the following bogies and their dampers (7) controlled (12, 24) to provide the optimum resistance value for a smooth ride. No stored record of the track profile is required.

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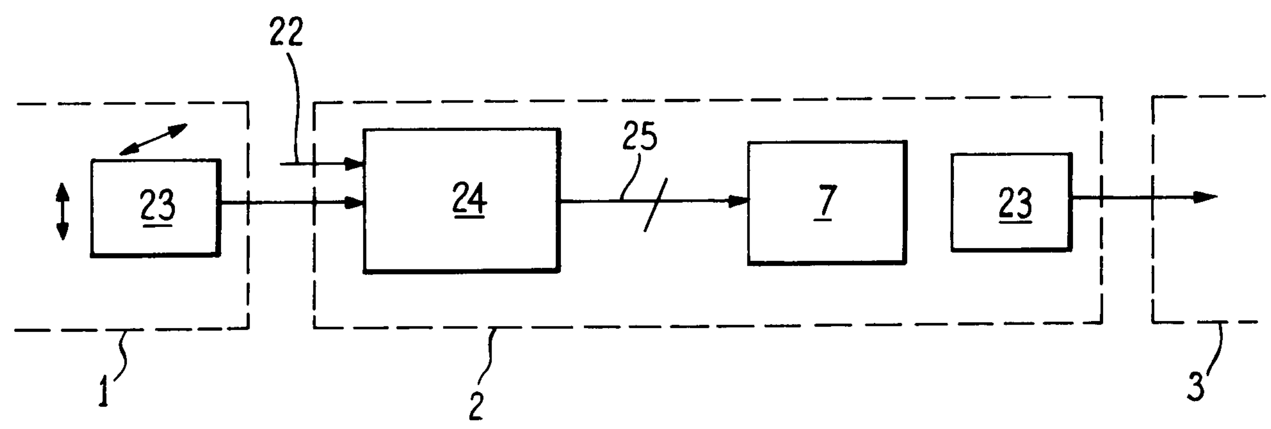

FIG. 4

This invention relates to damping arrangements for use on trains.

In limiting the parasitic accelerations applied to railway vehicles by unwanted movement of the bogies, the vehicle body is commonly supported from the bogie by springs which lower the natural frequency of oscillation of the body with respect to the bogie. Hydraulic dampers are fitted between vehicle body and bogies to damp oscillations which occur. It should be noted that the way in which hydraulic damping is conventionally applied tends to reduce the amplitude of low frequency oscillation but tends to increase high frequency forces transmitted to the vehicle. To reduce the magnitude of these high frequency forces, the hydraulic dampers can be fitted with "safety valves" to limit the maximum pressure in the damper and, therefore, the maximum forces applied to the vehicle body by the damper.

It is an object of the present invention to provide an improvement over the aforementioned damping arrangements.

According to one aspect of the invention there is provided a damping arrangement for use on a train of railway vehicles for damping unwanted motion of a vehicle body transmitted by a supporting bogie, the bogie being subject to shock movement resulting from track irregularity, the arrangement comprising damping means for coupling the vehicle body to the bogie, the damping means being controllable in dependence upon an indication of shock movement detected at one or more points in the train forward of said bogie to provide a changed damping resistance temporarily. No stored record of the track profile is needed.

In a preferred embodiment of the invention, said one or more points comprise one or more bogies in the train forward of said bogie. Said one or more bogies may comprise or include another bogie supporting said vehicle body.

According to another aspect of the invention, a damping arrangement as aforesaid further comprises means for detecting said shock movement and control means for controlling the damping means in response to the detected shock movement and to train speed. The control means may be adapted to determine the average shock movement experienced by a number of forward bogies in the train .

The damping means may be controllable to provide two or more predetermined values of damping resistance. Alternatively, the damping means may be controllable to provide a continuously variable value of damping resistance. The damping means may comprise a hydraulic damper, in which case such continuous control may be achieved by the use of a fluid of controllable viscosity.

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

Figure 1 shows a train of vehicles;

Figure 2 is a schematic illustration of a controllable hydraulic damper suitable for use in implementing the invention;

Figure 3 is a schematic illustration of another controllable hydraulic dampler; and

Figure 4 is a block diagram which illustrates the control of the dampers fitted on a vehicle in the train of Figure 1.

Referring to the drawings, in Figure 1 a train of railway vehicles, of which the first three only (1, 2, 3) are shown, is moving forward in a direction indicated by arrow 4. The leading vehicle may be a locomotive pulling the train. Each vehicle body 8 is supported at either end by a bogie 5, the bogies being coupled to the body 8 by stiff springs 6 in conventional manner. Hydraulic dampers 7 are fitted to each bogie 5 to damp forces transmitted to the vehicle body 8 as a result of shock movement resulting from, for example, track irregularity. As described so far, Figure 1 represents a conventional damping arrangement for use on a train.

In accordance with the invention, the damping performance is improved by controlling the resistance of the dampers 7. Such control takes account of the motion of the bogie and/or the body and adjusts the resistance of the damper as a function of time so that the resistance is low at instants when the bogie would be transmitting large forces to the body via a conventional damper, but is high when the bogie is quiescent and the body needs a high resistance damper to reduce the low frequency oscillation.

One way of achieving a controllable damping resistance in an hydraulic damper is shown schematically in Figure 2. Here, the damper 7 comprises a piston 9 movable within a cylinder 10 through a viscous fluid which provides the 'resistance'. A number of orifices 13, 14, 15 are provided in the piston head 11 to permit the piston 9 to move through the fluid against varying degrees of resistance. The orifices 13 are permanently open. Two orifices 13 are shown in Figure 2 but there may be any number, their size and number determining the maximum value of damping resistance that can be obtained. The other two orifices 14, 15 may be selectively either open or closed, being controlled by electro-hydraulic, for example solenoid-operated, valves 16, 17 respectively. The state of each valve 16, 17 is determined by control circuit 12. If the orifices 14, 15 are of different size, it will be apparent that four different values of resistance may be selected. If just one valve-controlled orifice is provided, only two values of resistance will be available. Using three or more controllable orifices, on the other hand, provides a greater number of resistance values but at the expense of increased complexity.

As shown in Figure 3, instead of using valve-controlled orifices in the piston head 11, the damping resistance of this type of hydraulic damper may be made adjustable by the provision of one or more "by-pass" paths (19, 20) for fluid connecting the fluid portions in the cylinder 10 which are separated by the piston head 11, there being a control valve (18, 21) in the or each such path.

The accelerations of the bogie in the lateral and vertical directions can be measured by accelerometers attached to the bogie, and these accelerations can be integrated to give velocity and again to give displacement.

For the control system to set the instantaneous value of the resistance of the damper optimally there is clearly a need for the control algorithms to be able to operate in 'negative time'. This can be achieved by taking a control signal from the next bogie in front, so that, in conjunction with the measured train speed, the likely future behaviour of the bogie under consideration can be predicted. Such an arrangement is illustrated in a block diagram in Figure 4. Two inputs are required to determine what value of damping resistance should be provided. One is the train speed 22, which may be provided as a common, centrally measured input for all vehicles. The second input comprises the output(s) of one or more accelerometers mounted on the next bogie ahead. These two inputs 22, 23 are supplied to a control processor 24, which is adapted to predict from the detected shock movement and the train speed what the 'optimum' damping should be at the vehicle in question. Control outputs 25 for controlling the dampers 7 on that vehicle's bogies are derived accordingly. Since there will be two or more bogies 5 supporting each vehicle, different control outputs may be generated for the dampers 7 on these bogies, which take account of the delay between different bogies of the same vehicle being subject to any detected shock movement. Cross-referring to Figure 1, it will be seen in Figure 4 that, by way of example, shock movement detected by accelerometers 23 on the leading vehicle 1 is used to control the damping provided on the following vehicle 2. The outputs of accelerometers 23 on vehicle 2 are similarly used to control the damping applied to vehicle 3, and so on along the complete train.

One consequence of the above arrangement is that no prediction can be made as to the shock movement that will be experienced by the forward vehicle 1. Conventional damping may, of course, be used. However, since this vehicle will usually be either a locomotive or a driving trailer this will not be a problem in practice. In a variation of the arrangement just described, shock movement detected at the forward bogie of one vehicle may be used to control the damping applied to one or more rearward bogies of the same vehicle, in addition to the forward bogie of the following vehicle. In this way only the improvement to ride at the forward end of the first vehicle will be less good than for the rest of the train.

It is of course not possible to predict the small amplitude sinusoidal movements of the bogie due to the inherent behaviour of perfectly coned wheels on perfect track. However, these movements are small and do not present a vehicle ride problem. The large amplitude "lurches" due to track irregularities, which are the shock movements which do cause ride problems, do however affect bogie after bogie in sequence as the train passes over the track irregularity. The occurrence of these "lurches" can therefore be predicted and used to "preset" the following dampers.

In an alternative strategy, the first, i.e. forward most, bogie of the train can be used to control all the following bogies, by obtaining a whole series of increasing time lags from train speed and bogie spacing.

A third strategy is to average the suitably delayed signals from a number of forward bogies and thus reduce the effect of variations in the response of different bogies, which will obviously not all respond identically to the track imperfection when they reach it.

Instead of stepwise modulation of the damper resistance, continuously variable modulation may be obtained by using, for example, a proportioning valve or a fluid whose viscosity can be controlled by, for example, the application of an electric field (an electrorheological fluid) or a magnetic field. In this way a very rapid response can be achieved leading to very good ride performance. In most cases, however, two-valve arrangements shown in Figures 2 and 3, giving four values of damping resistance, will be more than adequate to yield great improvements in vehicle ride quality.

Other types of damper whose resistance is variable and can be controlled may be used, for example, pneumatic, electromagnetic, mechanical, but in many cases the hydraulic damper will be preferred because it will usually be possible to fit it in place of an existing hydraulic damper, thus making the system suitable for retro-fitting as well as for use on new stock.

Damping arrangements in accordance with the invention will normally be used for controlling both lateral dampers and vertical dampers. Controlled lateral dampers will often be hydraulic, whilst controlled vertical dampers will be hydraulic or pneumatic or both.

It will usually be arranged that in the absence of electric power for the control system, the damper control valves will take up such conditions by means of springs that the damping provided by the damper has a magnitude which will give the best ride with constant damping.

The controllable dampers can also be fitted with pressure relief valves like standard dampers to limit maximum damping forces automatically.

The basic strategy for control of the controllable dampers may be based on the following general principles:

(1) When a bogie is not moving (laterally or vertically whichever is under consideration), then the value of damping resistance is controlled to allow the body of the vehicle to move towards equilibrium in any acceptable manner. It is likely that a value of resistance for critical or slight over damping might be chosen. However, in cases where the dampers are continuously variable, or where there are several values available, the resistance may be changed with time to achieve any other desired approach to equilibrium. In particular, a changing value of resistance can bring the body more rapidly, but smoothly to equilibrium without overshoot than does a constant resistance of value for critical damping.

(2) The value of damping resistance should be increased to relatively higher values at any time when the body and the bogie are moving in opposite absolute directions. The actual value of resistance selected should be chosen to give the maximum desired deceleration when the direction of motion of the body is away from the equilibrium position. When the direction of motion of the body is towards the equilibrium position, and the bogie is moving in the opposite direction, then similar general principles to those in paragraph (1) above can be applied.

(3) The value of damping resistance should be increased to relatively higher values when the bogie and body are moving in the same absolute direction and the absolute velocity of the body is greater than that of the bogie and the body is moving away from the equilibrium position. If the direction of motion of the body is towards the equilibrium position, then similar general principles to those in paragraph (1) above can be applied.

(4) On those occasions when the motion of the bogie would tend to accelerate the body away from the equilibrium position, either directly away or so vigorously towards the equilibrium position that it would go through the equilibrium position, then relatively low values of damping resistance should be selected.

(5) In all cases, instantaneous values of damping resistance will be chosen by the control processor so that the dampers do not impose excessive values of acceleration on the vehicle body.

One way of designing the system is to arrange the vehicle body natural frequency to be below those frequency components of track disturbances (the forcing function) which significantly affect ride, and then to use the active dampers to prevent, what with no damping would be a very soft rolling ride. If this ride were corrected with conventional dampers, the soft rolling ride would be removed, but jerks and shocks from track irregularities would be transferred to the vehicle body via the dampers. However, when the active dampers are used, shocks are not transmitted to the vehicle body, because the output of the relevant accelerometer on at least one forward bogie forewarns the damper control system that a shock will be appearing at a known time in the future, and the damper will be set to a low value of damping by the time the bogie movement occurs. Thus the bogie will jerk, the body will not. When smoother running is re-established (and predicted for some length of time by the forward bogie) then a higher damping resistance will be restored.

As well as measuring acceleration, velocity and displacement can be measured. The distance between bogie and body can either be measured directly or inferred from the difference of the integrals of acceleration for the bogie and the body. Direct measurement will usually be more satisfactory. The distance measurement can be used to ensure that a succession of repeated track irregularities does not push the body over to the bump stops. This will generally be done by ensuring that the 'high' damping chosen by the control equipment during quiescent periods is lowered as the body approaches the bump stops more closely. Then, in a given quiescent period, the damping resistance can be increased as the body approaches its steady state position (i.e. zero deflection) to bring it gently to rest. As soon as the body is at the zero deflection position, the control system will set the damping to a low value to minimise the effect of small amplitude high frequency bogie "noise" deflections.

In another control strategy, the "means" damping resistance value selected by the control system can be determined by the vigour of body movement, but modulated by prior detection of bogie jerks. Thus, if the body is moving laterally or rolling in space too vigorously, a high value of damping resistance will be selected, but only for times when the bogie will be quiescent.

The latter system would not normally include any damper for which controllable damping is not required, for example, yaw dampers. However, if adjustment of yaw damping were required to take account of changes of wheel conicity with wear, then this could obviously be done.

The improvement of ride which can be obtained using damping arrangements in accordance with the invention will depend on the frequency response of the system. However, even with comparatively low frequency responses great improvements can be made. For example, if the bogies of a vehicle are 10 metres apart, and the vehicle has a speed of 300 km/h (80 m/s) then the bogie-to-bogie transit time will be 125ms. Thus, there is no need for an electromagnetic valve to open in less than say 60ms, which is achievable without difficulty.

If the lateral natural frequency of the vehicle body is, say, 1Hz, then valves need to be able to open and close in a small fraction of one quarter cycle i.e. 250ms. An opening time of 60ms is clearly sufficient, therefore, to allow the controlled damper to work in a calculable manner on a 1Hz waveform.

Since even when a bogie is nominally quiescent, and the controlled damper has been set by the control system to a high value to allow the body to approach equilibrium slowly, there will always be unpredictable high frequency low amplitude "noise" emanating from the bogies, the dampers may be anchored, in the same manner as conventional dampers, with rubber bushed ends to give a low resistance for small movements. This form of active damper will allow maximum damping above critical damping to be used - not possible with the known "passive" dampers.

In a further embodiment of the invention, the electro-hydraulic valves may be used not only to select varying values of damping resistance, but also to select non-symmetrical damping resistances, i.e. to apply different damping resistances via dampers on either side of a bogie wheel pair. In this way resistance to motion in one direction is different from that in the other. This can be used, if applied to the vertical dampers, to apply tilt to a vehicle. The energy to apply the tilt can be derived from partial rectification of bogie noise.

In a similar manner, partial rectification of bogie noise can be used to provide lateral movements to the vehicle body, at frequencies below the resonant frequency, to correct for very long wavelength perturbations of railway track. Typically these long wavelength perturbations would be detected by accelerometers on the locomotive or driving trailer, and filtered to remove all except the relevant frequencies.

In a further embodiment of the invention, the dampers may be connected to hydraulic accumulators, so that energy which would otherwise be converted into heat can be stored as compressed nitrogen or in other suitable ways. The control system can then return this energy to the damper cylinders at suitable instants, so that the system becomes an active suspension system, but without the need for external power sources. This process assists in reduction of vehicle body movements at frequencies below the vehicle natural frequency, thus allowing stiffer springing to be used.

In a yet further embodiment, an external power pack can be used, if high rates of tilt, say, should be required, So far as the control system is concerned, it is in principle possible for at least one control system on the train to have sufficient memory for it to "learn the road" and predict future perturbations as a function of those which have already occurred.

Claims

1. A damping arrangement for use on a train of railway vehicles (1, 2, 3) for damping unwanted motion of a vehicle body (8) transmitted by a supporting bogie (5), the bogie (5) being subject to shock movement resulting from track irregularity, the arrangement comprising damping means (7) for coupling the vehicle body (8) to the bogie (5), said damping means (7) being controllable (12, 24) in dependence upon an indication of shock movement detected (23) at one or more points in said train foward of said bogie (5) to provide a changed damping resistance temporarily.

2. A damping arrangement according to Claim 1, wherein said one or more points comprise one or more bogies in said train forward of said bogie.

3. A damping arrangement according to Claim 2, wherein said one or more foward bogies comprises or includes another bogie supporting said vehicle body.

4. A damping arrangement according to Claim 2 or Claim 3, further comprising means (23) for detecting said shock movement and control means (24) for controlling said damping means (7) in response to the detected shock movement and to train speed (22).

5. A damping arrangement according to Claim 4, wherein said control means (24) is adapted to determine the average shock movement experienced by a number of forward bogies in said train.

6. A damping arrangement according to any one of the preceding claims, wherein said damping means (7) is controllable (12, 14, 15, 16, 17 - Figure 2; 12, 18, 19, 20, 21 - Figure 3) to provide two or more predetermined values of damping resistance.

7. A damping arrangement according to any one of Claims 1 to 5, wherein said damping means (7) is controllable to provide a continuously variable value of damping resistance.

8. A damping arrangement according to any one of the preceding claims, wherein said damping means comprises a hydraulic damper (7).

9. A damping arrangement according to Claim 8, as appendent to Claim 7, wherein said continuously variable value of damping resistance is provided by a fluid of controllable viscosity.

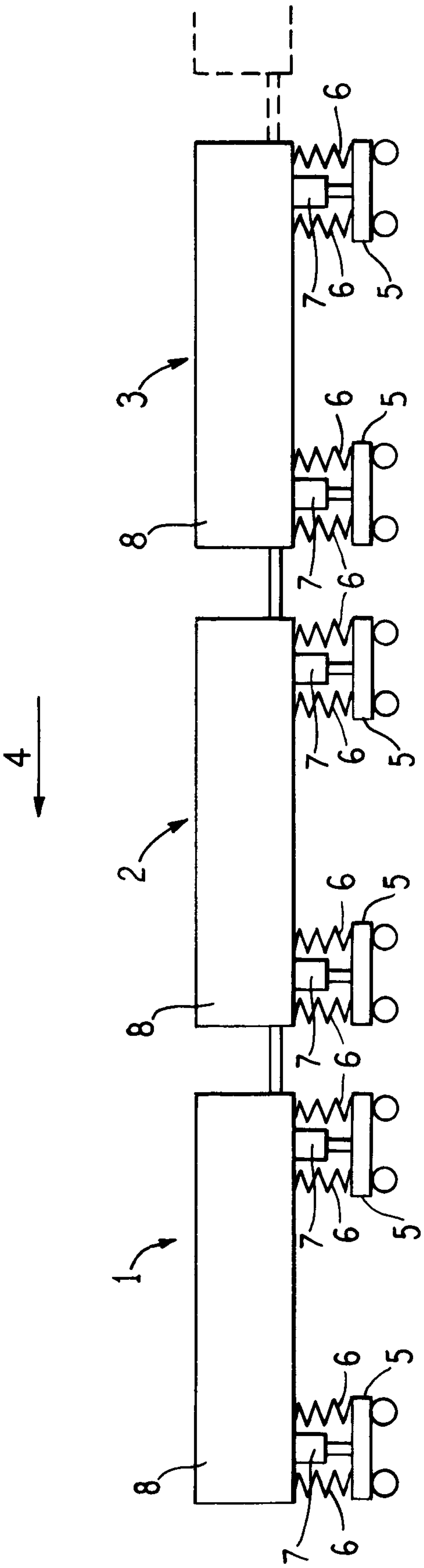

FIG.1

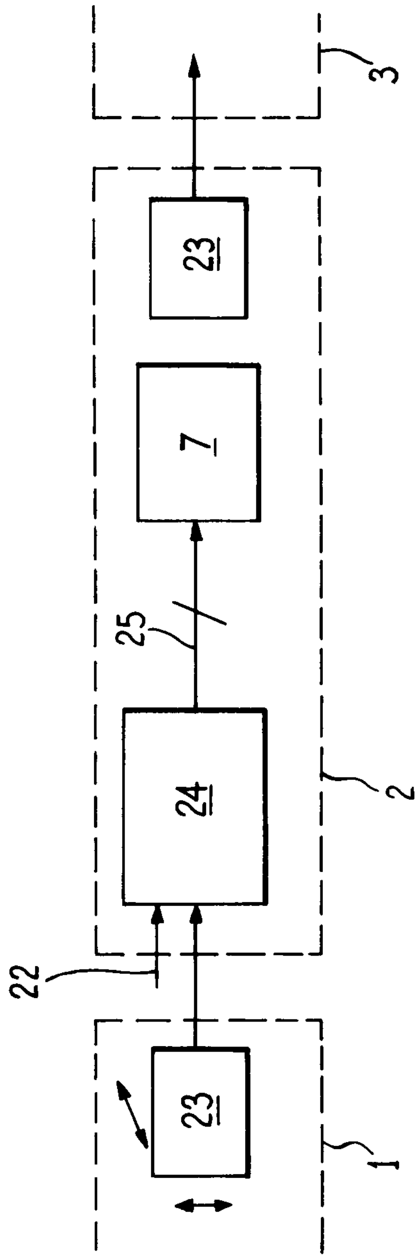

FIG.4

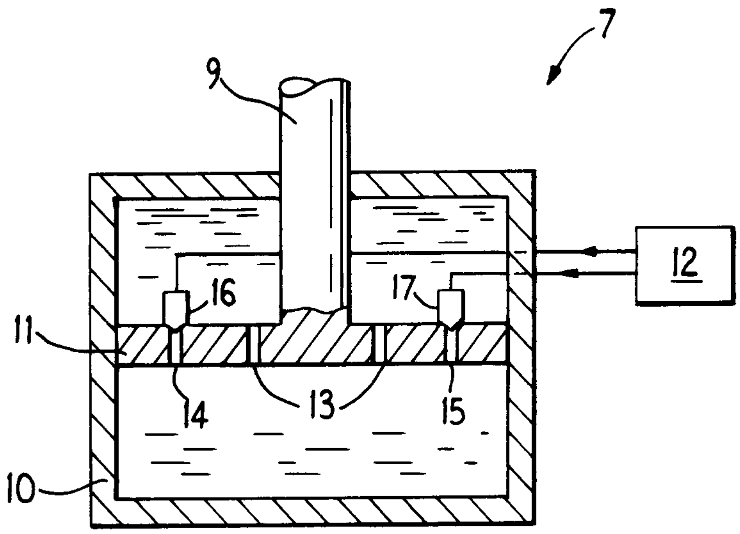

FIG. 2

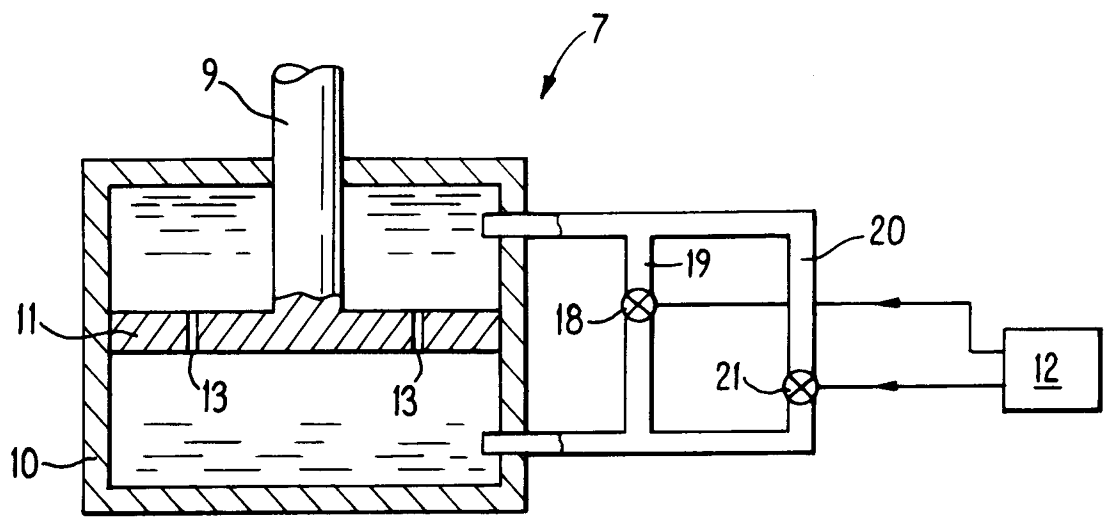

FIG. 3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 30 6208

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)
A	FR-A-2 312 402 (NICOLI) * Figure 1; claims 1-3 *	1-4	B 61 F 5/24
A	GB-A-2 015 954 (S.L.M.) * Abstract; claims 1-6 *	1	
A	GB-A-2 135 643 (KRUPP) * Abstract; figure 3; page 1, left-hand column *	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)
B 61 F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29-08-1991	SCHMAL R.

CATEGORY OF CITED DOCUMENTS

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