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(54) Piston and cylinder assembly control system.

(57) A piston and cylinder assembly control system is described which includes a piston (16a ; 18a) reciprocating in a cylinder (16b ; 18b) and connected to a part (12 ; 14) to be driven by the piston and cylinder assembly, a position sensor (34 ; 36) arranged to provide signals indicative of the position of the piston in the cylinder, a valve (20 ; 22) for controlling fluid flow to and from the cylinder, and a control unit (28). The control unit is arranged to : (i) receive the position dependent signals, (ii) determine the actual current speed of the piston in the cylinder, (iii) determine the maximum permitted speed of the piston at the current position from a predetermined relationship between maximum piston speed and current piston position, (iv) compare the maximum permitted speed with the actual speed, and (v) generate valve control signals to control the fluid flow to and from the cylinder such that the maximum permitted piston speed is never exceeded.

The piston and cylinder assembly may be double acting or single acting. If double acting it may comprise a double acting ram or two single acting rams.

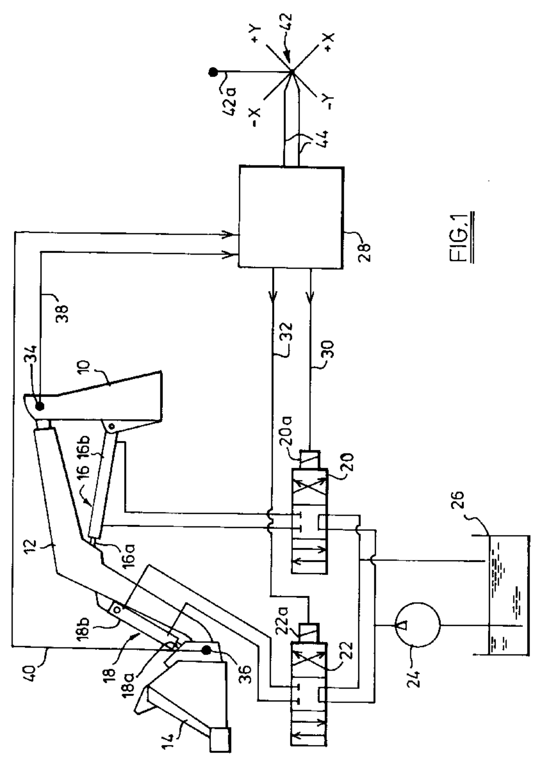

FIG.1

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This invention relates to a piston and cylinder assembly control system, in particular a system for controlling the speed of one or more pistons in a piston and cylinder assembly.

Systems for reducing the speed of a piston in a piston and cylinder assembly as the piston approaches the end of travel are known. One such system is described in EP 0022105 where for the majority of the piston's travel the fluid supply to the cylinder is proportional to the setting of the actuator but, as the piston approaches the end of the cylinder the fluid supply is reduced so that it is proportional to the distance to travel to the end of the cylinder. This prevents the piston hitting the end of the cylinder at high speed and thus prevents sudden high stresses to the piston and cylinder assembly and to the parts of a machine or vehicle moved by the assembly.

Such piston speed control systems are used, for example, in tractor mounted loader and digger operating systems.

It is an object of the invention to provide an improved piston and cylinder assembly control system.

The invention therefore provides a piston and cylinder assembly control system including:

- piston means reciprocating in cylinder means and connected to a part to be driven by the piston and cylinder assembly;
- position sensing means arranged to provide signals indicative of the position of the piston means in the cylinder means;
- valve means for controlling fluid flow to and from the cylinder means, and
- a control unit arranged to:
  - receive the position dependent signals;
  - determine the actual current speed of the piston means in the cylinder means;
  - determine the maximum permitted speed of the piston means at the current position from a predetermined relationship between maximum piston means speed and current piston means position;
  - compare the maximum permitted speed with the actual speed, and
  - generate valve control signals to control the fluid flow to and from the cylinder means such that the maximum permitted piston means speed is never exceeded.

The piston and cylinder assembly may be double acting or single acting. If double acting it may comprise a double acting ram or two opposed single acting rams. Thus the piston means may be a single piston reciprocating in a single cylinder or two pistons reciprocating in respective cylinders.

The invention provides the advantage that not only are very sudden stresses as a piston arrives at the end of a cylinder avoided but also stresses experienced by the assembly, and the part driven by the assembly, as the piston decelerates can be controlled. Such stresses can be kept to a minimum if, for the majority of the piston travel, the maximum permitted piston speed at any position reduces as a function of the square of the distance to the stopping position. However, to provide a jerk free piston halt, for the final portion of piston travel the maximum permitted piston speed may reduce as a function of the distance to the stopping position.

The system may determine the maximum permitted piston speed at any position by using a look-up table in the control unit, or by calculation according to a predetermined relationship. The actual piston speed at any point may be obtained by differentiation of the piston position signals or from separate speed sensor means.

The position sensing means providing signals indicative of the position of the piston within the cylinder may sense the position of the part driven by the piston and cylinder assembly and the control unit may be arranged appropriately such that the signals are converted to piston position signals. Alternatively the position sensing means may directly sense the position of the piston within the cylinder.

One embodiment of the invention, as applied to a tractor front loader, will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 schematically illustrates a tractor front loader incorporating a system according to the invention for controlling the speed of pistons in the bucket and beam cylinders of the loader;

Figure 2 graphically illustrates the curve of the maximum permitted piston speed versus distance to piston stopping point for (a) the loader beam when being raised and (b) the bucket when being crowded, and an example of actual speed during such use;

Figure 3 graphically illustrates the oil flow into and out of the respective cylinder during the example of Figure 2; and

Figure 4 graphically illustrates the curve of the maximum permitted piston speed versus distance to piston stopping point for (a) the loader beam when being lowered and (b) the bucket when being dumped.

Referring to Figure 1, a tractor front loader has a loader tower 10 supported on the chassis (not shown). A loader beam 12 is pivotally connected to the upper end of the loader tower 10 at one end and has a bucket 14 pivotally connected to its other end. The beam 12 and bucket 14 are moved about their respective pivot points by means of beam and bucket double acting hydraulic actuators 16 and 1 8 respectively. The actuators

16 and 18 each comprise a piston 16a, 18a and a cylinder 16b, 18b. The supply to and exhaust of hydraulic fluid from the actuators 16 and 18 is controlled by solenoid operated valves 20 and 22 respectively. The valves 20 and 22 receive pressurised fluid from pump 24 and exhaust fluid to reservoir 26. Valve operating solenoids 20a and 22a receive control signals from control unit 28 via lines 30 and 32.

Movements of the beam 12 and bucket 14 about their respective pivot points are monitored by beam and bucket position sensors 34 and 36 respectively in the form of rotary potentiometers. The sensors 34, 36 send position signals to the control unit 28 via lines 38 and 40. Although the sensors 34, 36 are shown located at the beam and bucket pivot points they may be located adjacent to the pivot points with appropriate links or struts to ensure they sense the movements correctly.

The control unit 28 is connected to control lever assembly 42 via lines 44. The control lever assembly 42 includes a manually operable control lever 42a mounted for pivotal movement about two perpendicular axes in the X and Y directions shown in Figure 1, the control lever 42a being located appropriately for operation by the right hand. The control unit 28 generates the control signals in response to signals received from the control lever assembly 42, representing movement of control lever 42a, and from the position sensors 34 and 36 as described later.

Pivotal movement of the control lever 42a to the left and right, i.e. in the X direction, commands pivotal movement of the bucket 14 with respect to the beam 12. Pivotal movement of the control lever 42a forwards and backwards, i.e. in the Y direction, commands pivotal movement of the beam 12 with respect to the tower 10.

When the beam 12 is, for instance, moved from some point in its possible range of movement to one end of its range of travel the system operates as follows. The lever 42a is pivotted in the Y direction to command movement of the beam 12. Initially the piston 1 6a accelerates towards a speed proportional to the pivot angle of the lever 42a. However, every 5ms the control unit 28 performs a calculation and checking routine to ascertain whether the speed commanded by the lever 42a should be modulated, and if modulation is necessary generates appropriately modulated control signals for the solenoid 20a.

The control unit 28 receives sensed angular position signals from the sensor 34 along line 38. The angular position signals are used in combination with the known end point of travel of the beam to calculate the angular distance to the end point. This angular distance is used as an input value for a maximum permitted piston speed look-up table in the control unit 28. Thus the angular distance is converted to a linear speed. The control unit 28 also calculates the actual speed of the piston 16a by conversion and differentiation of the angular position signals. The actual speed of the piston 16a is then compared with the maximum permitted piston speed for the distance to the end of travel and, if the maximum permitted speed is exceeded, the control unit 28 modulates the control signal for the solenoid 20a to reduce the fluid flow rate to and from the cylinder 1 6b such that the piston speed is reduced below the maximum permitted speed. As will be clear to a person skilled in the art of hydraulics the exact manner of control of the flow rate to and from the cylinder 16b depends on a number of factors including headside/rodside flow, gravity and inertia of the load.

Referring to Figure 2, solid curve 50 illustrates the maximum permitted piston speed versus distance to piston stopping point curve appropriate for the beam actuator 16 during raising of the beam 12 and for the bucket actuator 18 during crowding of the bucket 14. In region A the maximum permitted piston speed is proportional to the square of the distance to the stopping point. However, to prevent a jerk when the stopping point is reached the maximum permitted piston speed in region B is proportional to the distance to the stopping point. Dashed curve 52 illustrates an example of actual speed attained by the piston 16a or 18a. In portion A_1 of region A curve 52 is straight and below the curve 50 indicating that the speed commanded by the lever 42a is below the maximum permitted piston speed. At a distance S from the stopping position the dashed curve 52 joins the solid curve 50 indicating that at that point the speed commanded by the lever 42a has become the maximum permitted piston speed and the control unit has begun to modulate the control signals for the solenoid 20a or 22a and thus the oil flow to and from the cylinder 16b or 18b.

Referring to Figure 3, the change of oil flow into cylinder 16b or 18b with time for the above example is illustrated by curve 54. In portion P_1, corresponding to A_1 of Figure 2, the oil flow is constant, and the speed of the piston 16a or 18a is constant. in portion P_2, corresponding to A_2 of Figure 2, the oil flow reduces at a constant rate and the deceleration of the piston 16a or 18a is constant. In region Q the oil flow reduces exponentially to provide a no-jerk stop at the stopping position.

The regime described above is, however, not appropriate for the control of the respective actuators 16, 18 when the beam 12 is being lowered or when bucket 14 is being dumped. For the beam 12, when being lowered it is important that the beam reaches the physical end stop, that is the lowest possible point, and is not stopped short by an inaccurately set electronic end stop. For the bucket 14, when it is being dumped it is most advantageous to stop with a slight jerk in order to assist the loosening of the material in the bucket 14.

The maximum permitted piston speed curve in these cases is illustrated by the solid line 56 in Figure 4.

The curve 56 is the same as the curve 50 until at point T it falls to one third of the maximum permitted piston speed, as shown over portion C of the curve 56. No further slowing of the piston takes place, thus the remaining travel of the piston occurs at a constant speed, as shown over portion D of the curve 56. However, to prevent the operator continuing to operate the lever 42a and thus to waste power once the respective physical end stops have been reached time outs are imposed. At the same point as the control unit 28 ceases to modulate the flow of oil at point T it sets a time delay, for instance 0.5s or 1.0s, after which the flow of oil to the respective cylinder 16b or 18b is cut off completely.

Although the invention has been described above in connection with double acting actuators it may be used with pairs of opposed single acting actuators. In this case the system controls the flow of hydraulic fluid out of one actuator and the flow of fluid into the other actuator thus providing the same effect as controlling the flow of fluid into and out of a double acting actuator.

The system of the invention is not limited to use in tractor front loaders as described above. It is, for instance, particularly applicable for use on the backhoes of tractor digger loaders, to control piston speed during movement of the boom, dipper and bucket or other attachment.

The stopping position used by the system control unit in the calculation and checking routine need not be the end of the piston stroke. If the vehicle or machine to which the system is fitted also has a control system allowing other end stops to be set, for instance backhoe dig and dump positions, the piston may be slowed to a stop at these positions instead of at the end of the cylinder.

The system is not limited to the control of piston speed as the piston approaches a stopping point. Clearly the maximum permitted piston speed envelope can be of any form required for a particular application. There may, for instance, be applications where for safety reasons a piston must travel slowly during a mid portion of its travel as well as slowing to a stop at the ends.

Claims

1. A piston and cylinder assembly control system including:
   - piston means (16a; 18a) reciprocating in cylinder means (16b; 18b) and connected to a part (12; 14) to be driven by the piston and cylinder assembly (16; 18);
   - position sensing means (34; 36) arranged to provide signals indicative of the position of the piston means in the cylinder means, and
   - valve means (20; 22) for controlling fluid flow to and from the cylinder means,

   and characterised in that it also includes a control unit (28) arranged to:
   - receive the position dependent signals;
   - determine the actual current speed of the piston means in the cylinder means;
   - determine the maximum permitted speed of the piston means at the current position from a predetermined relationship between maximum piston means speed and current piston means position;
   - compare the maximum permitted speed with the actual speed, and
   - generate valve control signals to control the fluid flow to and from the cylinder means such that the maximum permitted piston means speed is never exceeded.

2. A system according to Claim 1 characterised in that the piston and cylinder assembly (16; 18) is double acting.

3. A system according to Claim 2 characterised in that the double acting piston piston and cylinder assembly comprises a double acting ram (16; 18).

4. A system according to Claim 2 characterised in that the double acting piston and cylinder assembly comprises two single acting rams.

5. A system according to any preceeding claim characterised in that the maximum permitted speed of the piston is determined by the control unit (28) by calculation according to a predetermined relationship.

6. A system according to any one of Claims 1 to 4 characterised in that the maximum permitted speed of the piston is determined by the control unit (28) from a stored look-up table.

7. A system according to any preceeding claim characterised in that the actual current speed of the piston means is obtained by differentiation of the position dependent signals.

8. A system according to any one of Claims 1 to 6 characterised in that the actual current speed of the piston means is obtained from speed sensing means arranged to provide signals indicative of the speed of the piston means within the cylinder means.

9. A system according to any preceeding claim characterised in that the position sensing means sense the position of the part to be driven and the control unit is further arranged to convert the signals to piston position signals.

10. A system according to any one of Claims 1 to 8 characterised in that the position sensing means directly senses the piston means position.

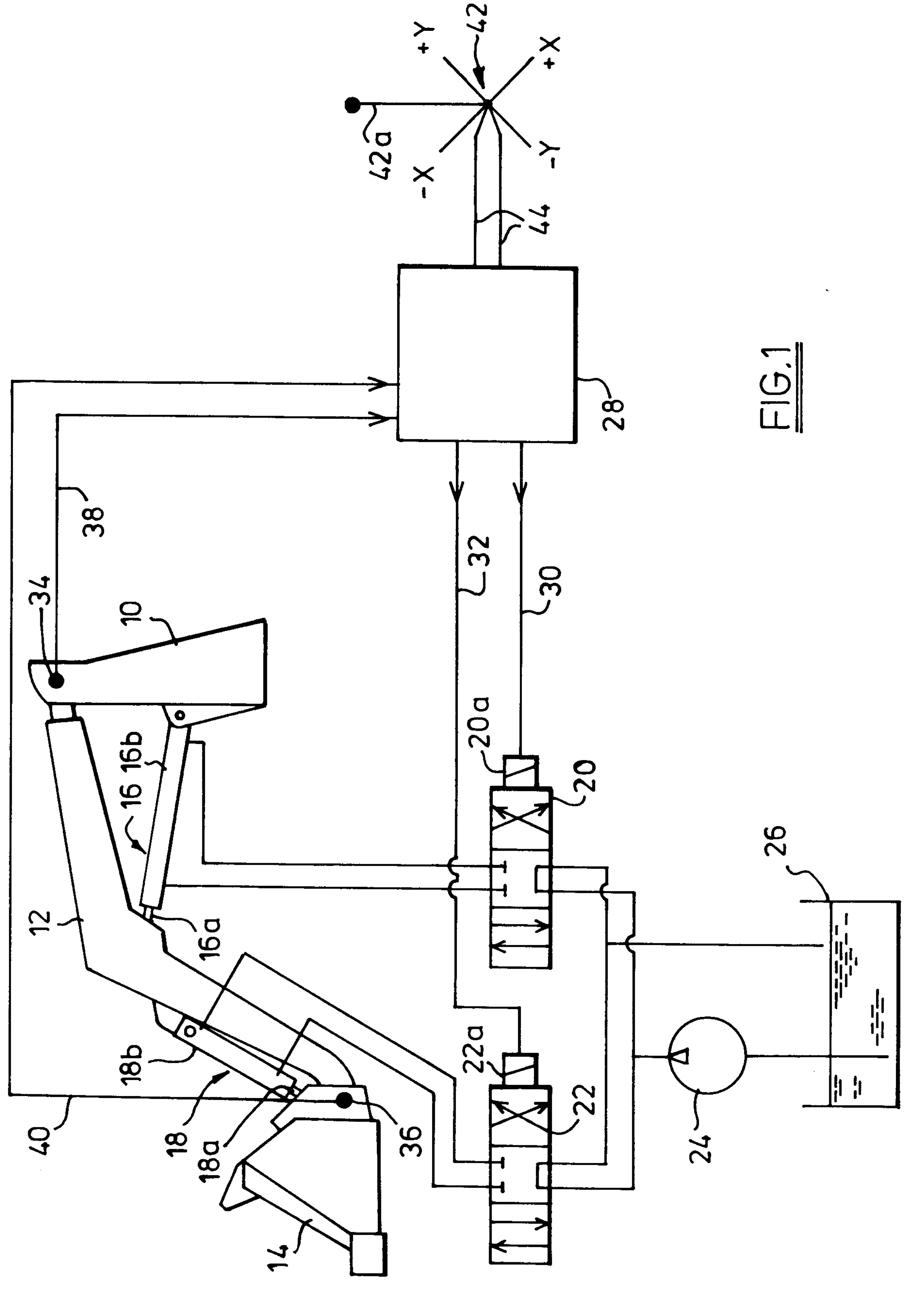
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FIG.1

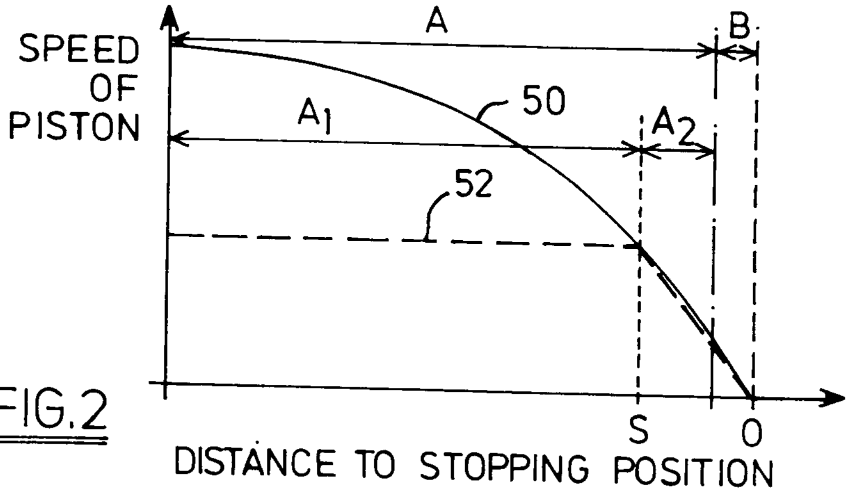

FIG.2

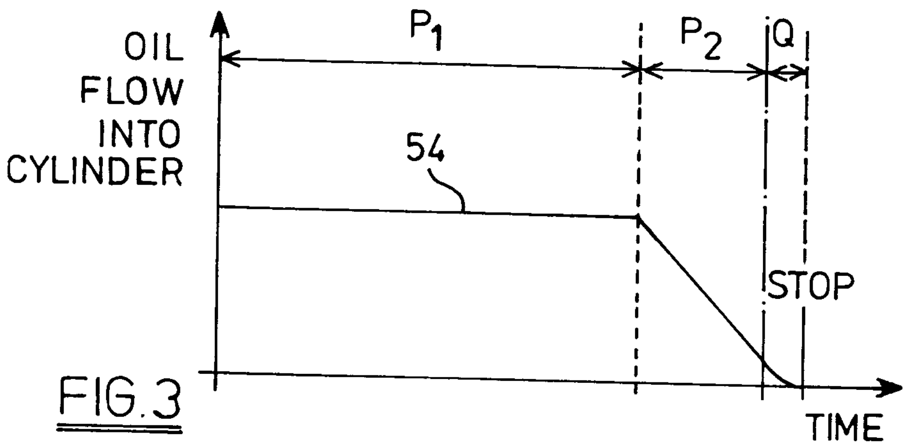

FIG.3

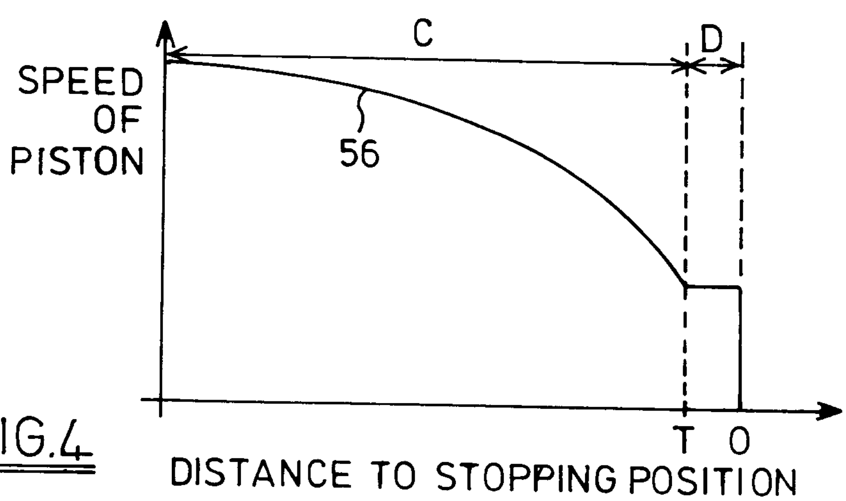

FIG.4

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EUROPEAN SEARCH REPORT

Application Number
EP 93 30 8912

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)
D,Y	EP-A-0 022 105 (AKERMANS VERKSTAD AB) * claim 1; figures 1-4 *	1-3,5,10	F15B11/04 G05D3/14
Y	DE-A-22 61 514 (THE RANK ORGANISATION) * page 4, paragraph 1 - page 5, paragraph 1 * * page 6, paragraph 5 * * page 9, paragraph 2 -paragraph 3 * * page 10, last paragraph - page 11, paragraph 1; claims 1-4; figures 1-3 *	1-3,5,10	
A	WO-A-87 04220 (AKERMANS VERKSTAD AB) * page 4, line 25 - line 29; claim 1; figures 1-3 *	1-3,9	
A	FR-A-2 125 982 (THE RANK ORGANISATION) * claims 1-3; figures 1-4 *	1	
A	FR-A-2 565 638 (NIPPON JOUCOMATIC) * claim 1; figures 1-8 *	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.5)

F15B
G05D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	16 February 1994	Thomas, C

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
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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
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