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Serial Number: 08/098,911

Date Filed: July 29, 1993

(NASA-Case-MSC-22111-1) MECHANICAL ENERGY ABSORBER Patent Application (NASA) 19 p

N94-15966

Unclas

G3/37 0190868

MECHANICAL ENERGY ABSORBER

The subject invention relates to an energy absorbing mechanism for providing a controlled feedback force relationship in response to a shock impact which occurs when a moving object is suddenly stopped so that the load on the system is within acceptable limits.

The energy absorbing system 11 includes a tubular housing member 13 slidably receiving a telescoping tubular shaft member 14. An internal spring 16 is provided for resiliently biasing the members in an extended condition. Frusto-conical diaphragm elements 35 frictionally engage a shaft 20 and are opposed by a force regulating set of disc springs 31. This provides a force feedback mechanism which serves to keep the stroking load at a controlled level notwithstanding a large increase in the friction coefficient. This force feedback mechanism also serves to desensitize the singular and combined effects of manufacturing tolerances, sliding surface wear, temperature changes, dynamic effects, and lubricity.

The novelty of the invention appears to lie in the particular configuration of elements of inherent simplicity which enable regulation of the dissipator load within tolerable limits under many variations of adverse operational environments and varying manufacturing parameters.

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MSC-22111-1
Serial No.: 08,098,911
Filed: 7/29/93

MSC-22111-1
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MECHANICAL ENERGY ABSORBER

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U.S.C. 2457).

FIELD OF THE INVENTION

This invention relates to an energy absorbing mechanism and more particularly, to an energy absorbing mechanism for providing a controlled feedback force relationship in response to a shock impact which occurs when a moving object is suddenly stopped so that the load on the system is within acceptable load limits.

BACKGROUND OF THE INVENTION

Energy absorbing mechanisms typically are either mechanical or hydraulic and sometimes a combination of hydraulic and mechanical systems. This invention concerns itself with mechanical energy absorbing means. Mechanical energy absorbing means typically utilize a basic spring mechanism and some sort of friction system to dampen or absorb the force effects caused by the spring. As a general rule, the mechanisms for controlling the spring rate are bulky or large and do not provide an effective control of shock forces in any simple manner. Nearly all of the existing mechanical energy absorbing systems have one or more of the following disadvantages:

- require close manufacturing tolerances;
- are sensitive to extreme temperature changes;
- mechanical types are sensitive to changes in the friction coefficient;
- production of a sharp load spike at the beginning of a stroke due to the initial breakaway friction coefficient;

Fluidic energy absorbing systems also include disadvantages of:

- sensitivity to stroking velocity;
- fluidic types are subject to leaks;

In addition, material deformation types of energy absorbers are limited to one-cycle or one time operations.

PRIOR ART PATENTS

U.S. Patent No. 3,828,893 (class 188/87) issued to T.R. Clark on August 13, 1974 relates to a linking device in a mechanism to adjust to a "fixed" position until released to move to another "fixed" position. The linking device employs sets of flat washers which are canted and located between a shaft and a housing and can be manipulated to seize and release the shaft as necessary.

U. S. Patent No. 3,176,590 (class 91/45) issued to H.R. Ubtenwoldt, et al, on April 6, 1965 relates a clamping device formed from a notched conically shaped discs which are utilized to lock a shaft in place.

U. S. Patent No. 2,707,108 (class 279/54) issued to H. Schottler on April 26, 1955 relates to a rotational coupling device which utilizes a conically shaped disc which has radially extruding slits extending to stress relief openings. When assembled on a shaft, the discs can be compressed to frictionally engage and grip a shaft for rotational purposes.

U.S. Patent No. 5,131,115 (class 16/82) issued to J.A. Sarto on July 21, 1992 relates to a positioning device where a shaft passes through elliptically shaped discs which are contained within a housing by opposing compression springs. An actuation can release the locking function of the discs to permit movement.

U. S. Patent No. 3,986,583 (Class 188/67) issued on October 19, 1976 to R.B. Kinzbach relates to use of springs and coupling devices.

U. S. Patent No. 4,007,815 (class 188/265) issued on February 15, 1977 to L. R. Acre relates to a locking device which utilizes a hydraulic system with a locking pawl and a spring.

U. S. Patent No. 3,843,159 (class 280/407) issued on October 22, 1974 to C. N. Hood relates to a latching device for a shaft which utilizes lock washers which can be locked and unlocked with respect to the shaft.

U. S. Patent 4,191,503 (class 414/401) issued on March 4, 1980 to R. O. Neff, et al, relates to a locking device which utilizes friction plates with holes where the friction plates when filled provide a locking function.

THE PRESENT INVENTION

The present invention is embodied in an energy absorbing means which has a tubular housing member slidably receiving a telescoping tubular shaft member where an internal spring is disposed between an internal end surface of the housing member and an internal end surface of the telescoping shaft member to resiliently bias the members to an extended condition. Because a spring alone can develop high load forces and will oscillate, it is desirable to have a primary energy absorbing means which dampens the oscillation effect and reduces the load forces. More importantly, in some instances it is desirable to regulate the load forces upon the object when the object is brought to a sudden stop so that impact forces on the moving object are controlled within a tolerable range.

Upon a load impact,the main spring of the mechanism is compressed with the movement of the housing member and telescoping shaft member toward a contracted condition. The movement occurs when one of the members is attached to a moving object and the other member contacts an immovable wall or barrier.

The telescoping shaft member has an outer hardened frictional surface which extends through a friction mechanism which provides a primary force controlling mechanism. The primary force controlling mechanism includes a plurality of frusto-conical, thin wall, diaphram members constructed from a resilient material which are received in a tubular housing portion of a housing member. The bores of the diaphram members are sized to frictionally engage the outer frictional surface of the shaft. The frusto-conical diaphram members, in an initial or first directional position, provide a mechanical frictional resistance when the outer frictional surface moves relative to the housing member toward a contracted condition. The friction resistance causes the frusto-conical diaphram members to be resiliently compressed radially or deflected during travel of the outer frictional surface relative to the housing member. This produces an increasing friction load on the shaft member until the diaphram members are deflected from a frusto conical configuration to a position normal to the axis of the shaft member. As this relative movement progresses, the inner base of the frusto-conical diaphram members engage a disc spring member(s) which provide an opposing resilient spring force on the diaphram members to maintain the frictional load on the shaft member. If the relative motion continues, the diaphram members pass through the position normal to the axis of the shaft member into a reversed position. In this displacement process, the forces exerted by the disc spring members are increasing but the friction force between the shaft and diaphram members also increase. When the impacting force reaches an equilibrium or balance of load with the resisting spring forces, the diaphram members continue to maintain a frictional load on the shaft member to absorb energy forces.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of a movable vehicle with an attached energy absorbing means to illustrate the application of the energy absorber;

FIG. 2 is a view in longitudinal cross-section through an energy absorbing means embodying the present invention;

FIG. 3 is a plan view of the configuration of a frusto-conical spring means of the present invention taken along line 3-3 of Fig. 2;

FIG. 4 is a view in an enlarged cross-section of the frusto-conical spring means in a static condition;

FIG. 5 is a view in enlarged cross-section of the frusto-conical spring means during a stroking motion;

FIG. 6 is a schematic illustration of the force relationships with the force control system of the present invention; and

FIG. 7 is a graph of force vs. the coefficient of friction.

Description Of The Invention

Referring now to the drawings, in FIG. 1 a vehicle or mobile conveyance 10 has an attached energy absorbing means 11 where the energy absorbing means 11 is adapted to engage a stop 12 and is intended to cushion and absorb the forces involved in a sudden or abrupt impact with the stop.

The energy absorbing means 11, as shown in FIG. 2, includes telescoping tubular members 13, 14 which are illustrated in an extended position. One of the tubular members 13 (sometimes called a housing member) has an internal and centrally located guide bar 15 which provides a central support for a helical spring 16 where the spring 16 is located between internal end surfaces 17, 18. The spring 16 serves to extend the tubular members 13, 14 to an extended condition relative to one another.

The other tubular member 14 (sometimes called a telescoping shaft member) has a outer surface 20 which is slidingly received in a bore 21 of the housing member 13. A stop shoulder or ring 19 is provided on the end of the shaft member 14 to limit relative extended travel of the members. At the other end of the shaft member 14 is an end cap 22 for engaging a stop. The spring 16 between the members 13 and 14 is shown in an extended position and is capable of being compressed when the members are moved toward a contracted position. These members are moved toward a contracted position in response to an impact force on the end cap 22 to provide a regular spring rate relationship in an energy absorbing fashion.

The housing member 13 has an enlarged hollow housing portion 23 located about the outer surface 20. The bore 25 of the housing portion 23 has three (3) lengthwise extending grooves 27 (see Fig. 3) located at 120° relative to one another about a central axis. As shown in Fig. 2, the upper end of the bore 25 is threaded to receive a retainer cap 29. In the bottom of the housing portion 23 is a metal belleville spring washer member 31. The inner bore of the washer member 31 has a slight annular clearance with respect to the outer surface 20 and the outer surface of the washer member has an annular clearance with respect to the bore 25. An annular metal spacer ring member 33 is located at the outer periphery of the washer member 31. Disposed on the spacer ring 33 in the housing portion 23 are a nested series of frusto-conically shaped, thin wall, resilient, friction diaphram members 35. The diaphram members 35 have an initial frusto-conical configuration where the frusto-conical surfaces are inclined toward the end cap 22 on the assembly.

The resilient diaphram members 35 each have cylindrically formed tab portions 37 (see Fig. 3) located at an angle of 120° from one another about a central axis where each tab portion 37 has a projection 39 which is slidably received in a groove 27. Each tab portion 37 is connected to an adjacent tab portion by an elongated tension portion 41. The members 35 are die cut to form the tension portions 41 and to form inwardly extending friction elements 43. Thus, there are three (3) friction elements 43 in each diaphram member which extend radially between a tab portion 37 and a semi-circular friction surface 45. The inner bore diameter of the semi-circular friction surface is sized smaller by several thousands of an inch than the O.D. of the shaft surface 20 so as to frictionally engage the outer shaft surface 20.

The outer edge surfaces of the tab portions 37 are spaced inwardly from inner bore 25 of the housing portion 23 to permit expansion (See Fig. 3). As shown in Fig. 3, the configuration of a diaphram member 35 thus includes three circumferentially spaced, segmental beam elements 35a, 35b and 35c each of which respectively have an inner curved surface 45 which lies on a bore diameter 47 for the semi-circular friction surfaces 45 of the beam elements. As noted, the bore diameter 47 has a significantly lesser diameter than the outer diameter of the outer surface 20. Each segmental element 35a, 35b and 35c has a major base portion with tapered side edges 48, 49 extending to a narrow connection with an outer connecting tension portion 41. The diaphram members 35 are made of material such as stainless steel, spring resistant material.

The housing member 23 has an outer threaded portion 50 for attachment to a wall 52 of a moving vehicle. The housing portion 23 engages the wall 52.

The friction diaphram members 35 are held in place by the retainer cap 29. The retainer cap 29 has an exterior threaded section 54 which provides for threaded attachment. The retainer cap 29 has an annular, inner flange which is adapted to contact the outer tab portions 37. When the retainer cap 29 is snugly in place, it is finally adjusted to align threaded bores 60 in the retainer cap 29 with openings in a retainer washer 62. The retainer washer 62 is sized to be received in the housing portion 23 and fits loosely on the shaft 14 but has alignment projections 64 which are slidably received by the grooves 27. Thus, cap screws 66 can attach the retainer washer 62 to the retainer cap 29 and lock the cap 29 in a fixed position. An "O" ring seal 68 can be disposed about the shaft 14 to eliminate debris problems.

As shown in Fig. 3, in the initial condition of the diaphram members 35, the nested diaphram members have inner bore surfaces disposed in frictional gripping contact with the outer surface 20 and the outer edge surfaces of the diaphram members 35 are disposed adjacent, but not touching the inner bore 25 of the housing portion 23. The belleville washer 31 disposed in the housing portion has an annular spacing between the shaft member and the housing portion and an annular spacing with respect to the bore surface of the housing portion. An annular spacer ring 33 is disposed between the base of the spring member 31 and the base of the diaphram members 35 and separates the sets of members from one another.

The outer surface 20 of the tubular member 14 has a hard surface coating or is made from hardenable material. There can be more than three segments or tabs in a diaphram member 35. With three tabs, the radial length of the beams can be quite long thus permitting a much larger radial displacement without overstressing the material. A larger displacement permits greater manufacturing tolerances.

In operation, when the device is assembled as shown in Fig. 2 and attached to a vehicle as shown in Fig. 1, engagement of the impact end cap 22 of the assembly will cause the member 14 to telescope into member 13 from the extended position toward a contracted position. The diaphram members 35 are in frictional engagement with the outer surface 20. The frictional engagement cause the diaphram members 35 to move radially or straighten out and "squeeze" the tubular shaft member 14 with increasing force as the shaft member is stroked relative to the housing. This movement or displacement results in the compression of the beam elements 35a, 35b, 35c and elongation of the tension elements 41. The diaphram members 35 absorb energy of the movement of the shaft member 14 and the load of the diaphram members on the shaft member increases which increases the friction force. Ultimately, the increase of the friction force causes the diaphram members 35 to pass from their initial configuration (see Fig. 4) to a position which is approximately normal relative to the axis of the shaft member 14. Thereafter, the belleville spring element 31 engages the diaphram members 35 and provide a resisting spring force on the diaphram members 35 which maintains the frictional load on the shaft and continues to absorb the energy load (see Fig. 5). If a lubricant such as Braycote 815Z oil is applied to the shaft surface 20, the wear factor is reduced and the unit has excellent recycling characteristics.

To aid in an understanding of the principles of this device, in Fig. 6, the diaphram members 35 can be schematically represented by a slanted rod 70 which is forced downwardly by a spring 72 onto a surface 74 on a moving member 76. The load on the surface 74 is a function of the element angle ϕ of the rod 70 and the spring force K of the diaphram members. As the rod 70 is moved past a perpendicular to the surface 74, the rod is acted on by the regulating spring 78. The output load P is a function of the spring rates of spring 72,28 as well as the slant angle ϕ and the friction coefficient μ.

As shown in Fig. 7, where there is no force control, the load output P is directly proportional to the friction coefficient as indicated by the curve O-A. With force regulation, the diaphram member and belleville springs control the load level as shown by the curve B-C.

This invention represents the inherent simplicity of a mechanical energy dissipator yet has simple innovative features which regulates the dissipator load to a tolerable limit under adverse environments or varying manufacturing variables. Specific advantages are as follows:

1. It does not leak fluid as the fluidic type does;

2. It will operate repeatedly for many load application cycles;

3. It is not sensitive to velocity and it will not give excessive initial stroking loads as the fluidic type does;

4. It minimizes environmental effects:

   a. of temperature extremes and

   b. of vacuum.

5. Minimizes the effect of manufacturing variables of:

   a. surface finishes;

   b. machining tolerances;

   c. surface hardness; and

   d. lubricity.

6. It will compensate for wear up to a reasonable limit.

It will be apparent to those skilled in the art that various changes may be made in the invention without departing from the spirit and scope thereof and therefore the invention is not limited by that which is disclosed in the drawings and specifications but only as indicated in the appended claims.

ABSTRACT

An energy absorbing system for controlling the force where a moving object engages a stationary stop and where the system utilized telescopic tubular members, energy absorbing diaphram elements, force regulating disc springs, and a return spring to return the telescoping member to its start position after stroking. The energy absorbing system has frusto-conical diaphram elements frictionally engaging the shaft and are opposed by a force regulating set of disc springs. In principle, this force feedback mechanism serves to keep the stroking load at a reasonable level even if the friction coefficient increases greatly. This force feedback device also services desensitize the singular and combined effects of manufacturing tolerances, sliding surface wear, temperature changes, dynamic effects, and lubricity.

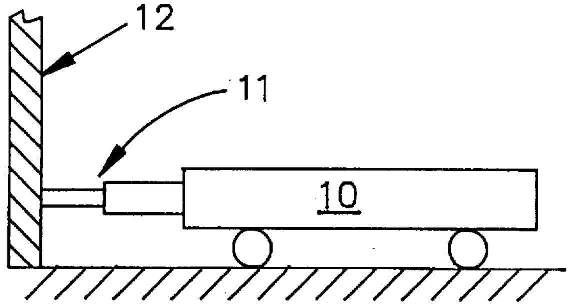

FIG. 1

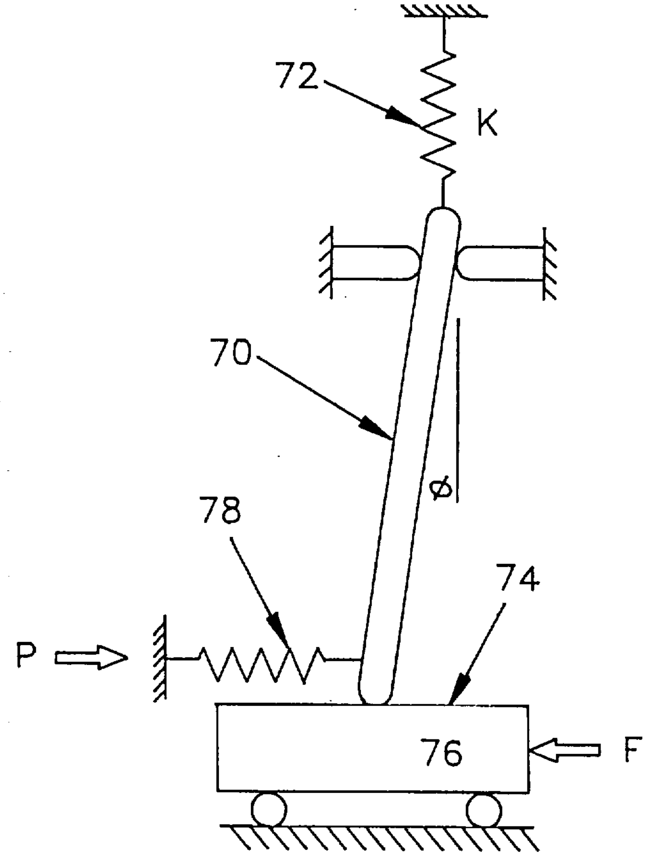

FIG. 6

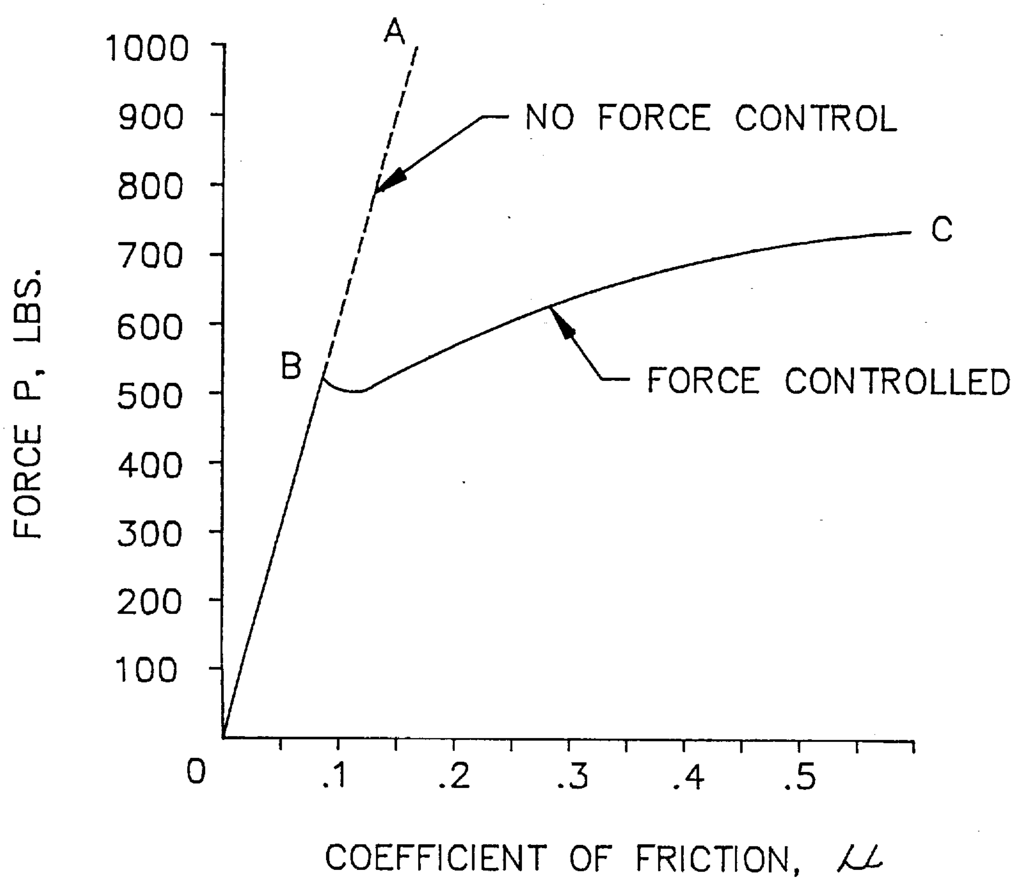

FIG. 7

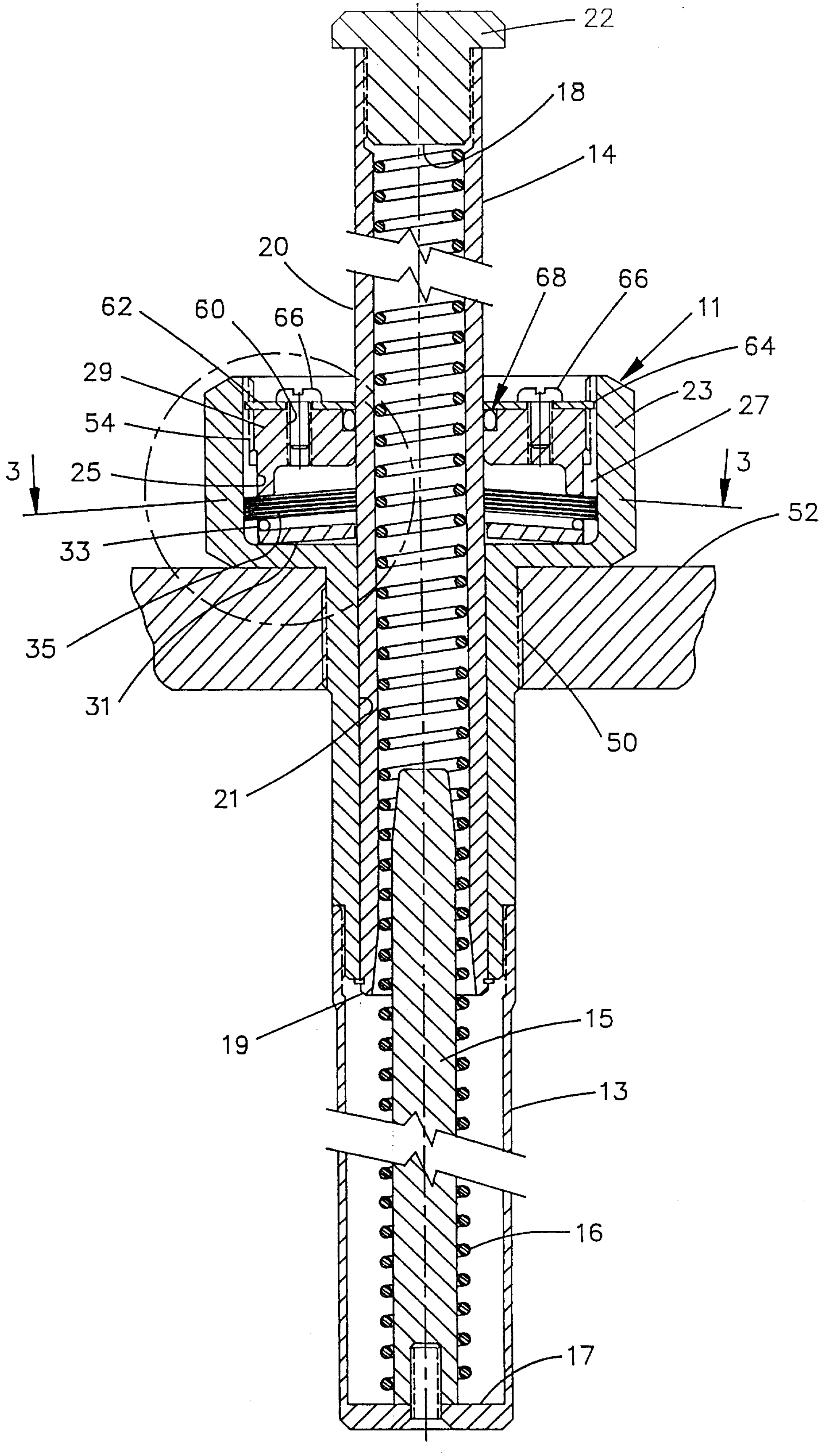
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FIG. 2

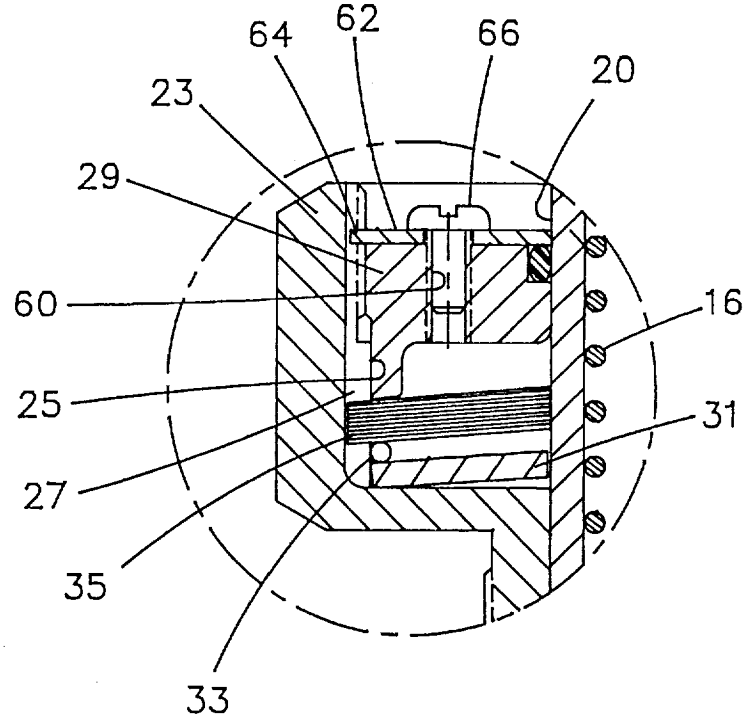

FIG. 4

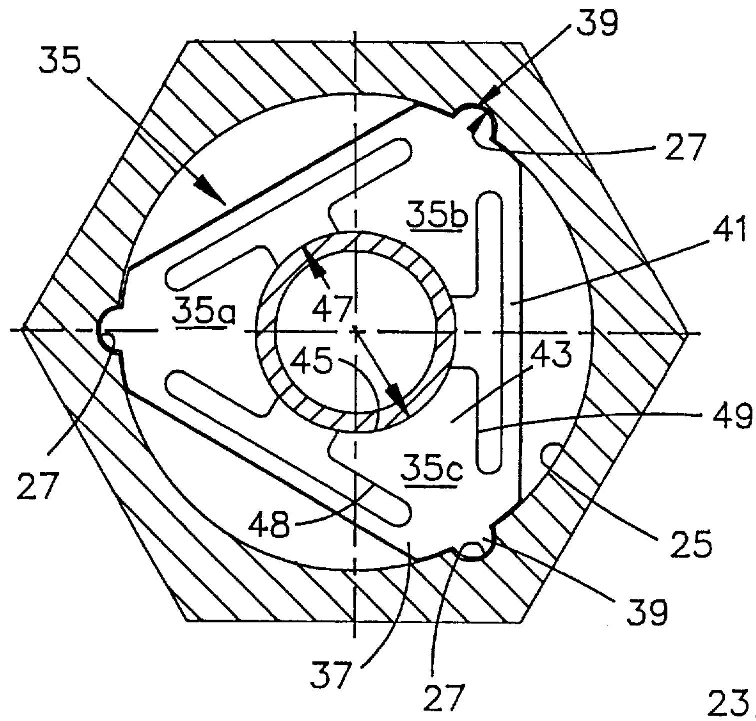

FIG. 3

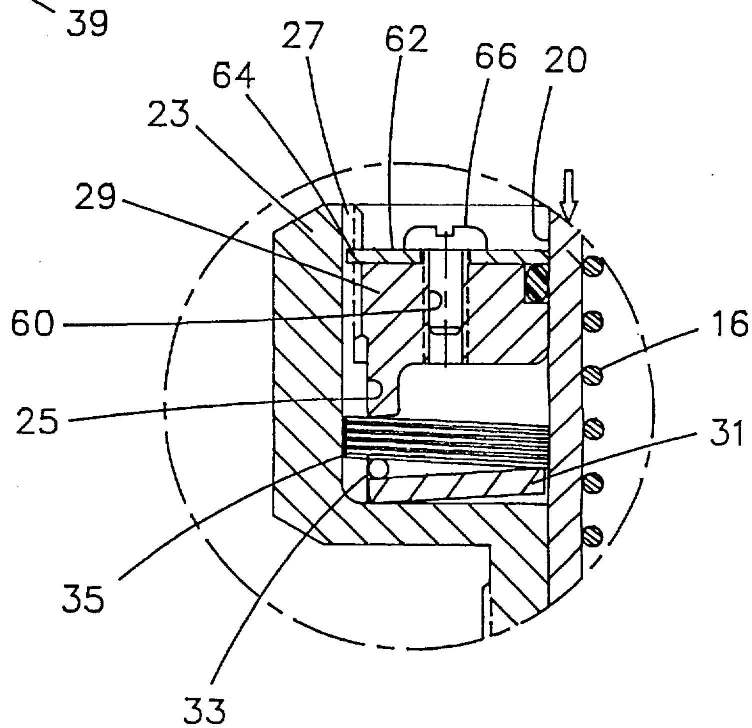

FIG. 5