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RE-SET MEANS FOR ACCELERATION INTEGRATOR

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FIG. 1.

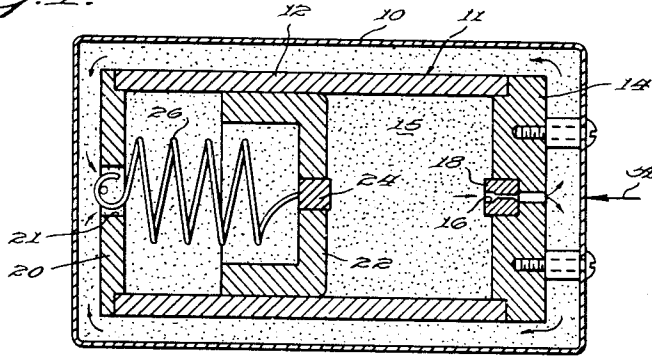


FIG. 2.

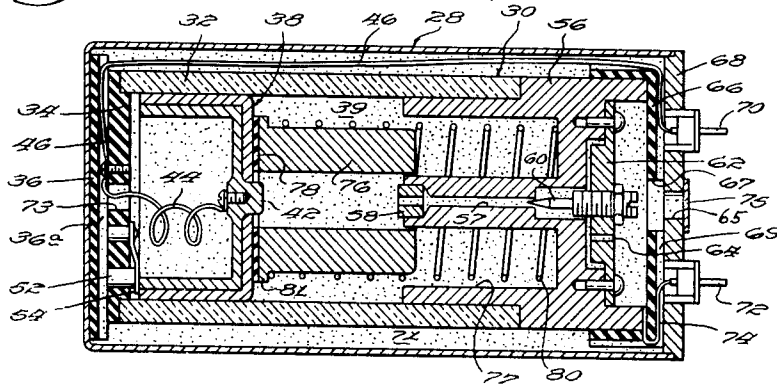
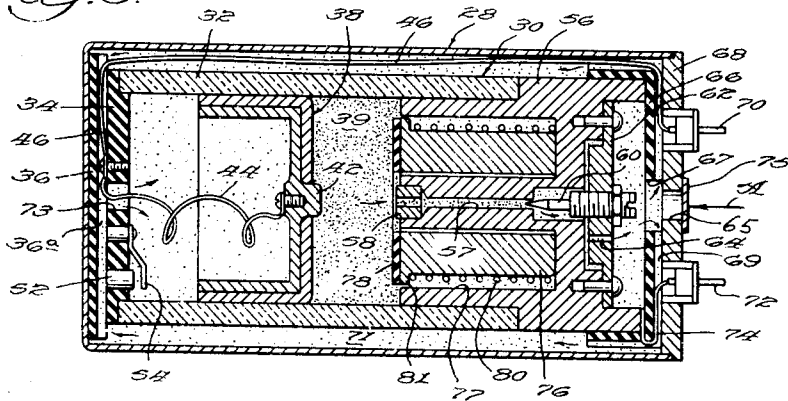


FIG. 3.



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RE-SET MEANS FOR ACCELERATION
INTEGRATOR

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4 Claims. (Cl. 73—503)

This invention relates to acceleration integrators which utilize, as a measure of the time integral of acceleration, the movement of a piston in a cylinder in which it is substantially free to move except for the opposition of a partially confined fluid medium.

More particularly, the invention provides improved holding and re-set means for returning the piston of such an acceleration integrator to its rest position following a cycle of operation, and for holding the piston reliably in that position until released in response to an applied acceleration.

In previous acceleration integrators of the described type, that holding and re-set function is performed by a spring which continuously urges the piston toward its rest position, and which therefore opposes the piston movement in response to acceleration. The action of such a spring during operation of an acceleration integrator tends to produce non-linearity of the response.

The present invention avoids such inaccuracies, which were inherent in many prior art devices, by providing a remarkably simple and reliable holding and re-set mechanism which completely releases the piston during normal operation of the device. That release is effected directly and automatically in response to an applied acceleration that exceeds a predetermined threshold value. The operation and advantages of the invention will be best understood in relation to the following description of an illustrative embodiment thereof, in connection with the attached drawings, in which:

Fig. 1 is a schematic axial section representing a prior art acceleration integrator during operation;

Fig. 2 is an axial section representing an illustrative embodiment of the invention in rest position; and

Fig. 3 is a section corresponding to Fig. 2, but representing the device during operation.

It will be helpful to discuss the operation of a typical prior art device in order to illustrate the operation and advantages of the invention. Referring to Fig. 1, a fluid, typically comprising an inert gas, is confined within the sealed container 10. A cylinder assembly 11 is mounted within the sealed container, the assembly comprising a cylinder wall 12, a closed end wall 14, and an open end wall 20. A freely movable piston 22 slidably engages the inside wall of the cylinder between the two ends. A chamber 15 of variable size is thus formed within cylinder 12 between piston 22 and end wall 14. A restricted orifice 16 in end wall 14 permits limited fluid flow between that chamber and the surrounding space within container 10. The piston is yieldingly urged toward the open wall 20 by a tension spring 26, and is normally held in a definite rest position defined by wall 20 when the device is not subject to an acceleration. When the device is accelerated bodily toward the end 20, that is, toward the left as shown, as indicated by the arrow A in Fig. 1, piston 22 tends to move in the opposite direction toward end 14, pressurizing the fluid in the chamber and forcing it through orifice 16 at a limited rate which increases with the magnitude of the

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acceleration. The fluid leaving orifice 16 travels around the outside of the cylinder walls, as indicated by the light arrows, and enters the cylinder behind the piston through an opening 21 in open end 20. When substantially all of the fluid has been forced through the orifice, the electrical contacts 18 and 24 close and complete a circuit between two external terminals on the container 10, which are not shown in the schematic illustration.

Assuming that piston 22 is always returned to the same rest position before acceleration is applied to the device, the time required for the contacts 24 and 18 to close after an acceleration is applied will depend on the amount of time required to force substantially all of the confined fluid through the orifice. Since the magnitude of the pressure differential across the orifice depends on the magnitude of the applied acceleration, the contacts will thus close for some relatively fixed value of the integral of acceleration with respect to time. The particular integral value is determined in part by the amount of obstruction offered by the orifice, which in practice may be adjustable.

In order for the device to be accurate it is necessary that the piston 22 always start from the same position when an acceleration is applied to the device. For this reason, spring means 26 are ordinarily attached between the piston and the end 20 of the cylinder to restore the piston to a uniform rest position and to hold it there until an acceleration is applied to the device. In practice the spring 26 usually must be strong enough to support the weight of the piston and to overcome the static friction of the piston. In addition, the spring must be strong enough to hold the piston 22 securely in its rest position against end wall 20 under the influence of normal vibration and jolts. Ordinarily a spring is used which exerts a force equivalent to at least from 1.5 to 2 times the weight of the piston.

A serious disadvantage of such prior art devices is the fact that the spring force acts not only prior to the application of acceleration, but also during such acceleration. Hence, the force exerted by the piston upon the fluid in chamber 15 is not accurately proportional to the value of the acceleration, but rather to the difference between that acceleration and a substantially fixed quantity due to the spring action. If the device is to be employed for integrating only accelerations having substantially a fixed value, that effect of the re-set spring can be fully compensated by suitable calibration of the device. But when employed to integrate variable accelerations, the spring action tends to produce an undesirable non-linearity of response. An important object of the present invention is to provide a means for dependably returning the piston to its rest position and holding it there against the force of gravity and normal vibration without the non-linearity of response inherent in previous re-set means of the type described.

Fig. 2 shows a section of an acceleration integrator utilizing one embodiment of the invention. A cylindrical container 28 with a hermetically sealed end cover 68 is filled with a suitable fluid, which will be considered for definiteness to comprise a gas such as nitrogen, for example. A cylinder assembly 30 is mounted within the container between the cover 68 of the container and a spacer 36 at the bottom of the container. The cylinder assembly comprises a cylindrical wall portion 32 and two end portions 34 and 56. The piston 38 is slidable axially within cylindrical wall 32, forming with that wall and end wall 56 a closed chamber 39. End portion 56 is provided with a restrictive orifice, shown as a coaxial bore 57 counterbored at its outer end to receive the valve-forming needle 60. Valve needle 60 is coaxially threaded in a mounting plate 62. Plate 62 is bored at 64 to allow unobstructed passage of gas.

therethrough. A cap 66 of electrically insulative material fits over the end portion 56 of the cylinder assembly and positions it in container 28. Cap 66 has a coaxial bore 67 and is radially channeled at 69 to permit unobstructed passage of gas from valve 60 to the annular chamber 71 outside of the cylinder structure. Channels 69 also permit passage of the electrical conductors 46 and 74, which communicate with the insulated terminals 70 and 72 in cover 68 of the container. Cover 68 has an axial opening 65 which provides access to the adjustment for needle 60, and also provides access for filling the container with gas. This opening is then hermetically sealed by a seal 75. Terminals 70 and 72 are also hermetically sealed. The other end 34 of the cylinder has an opening 73 in its central portion which communicates with radial channels 36a in spacer 36.

An electrical switch contact 42 is mounted on the inner face of the piston and is connected to terminal 70 by the flexible pigtail 44 and conductor 46. Pigtail 44 is highly flexible and exerts only negligible force on the piston. A second electrical switch contact 58 is fixedly mounted on cylinder end 56 in opposing alignment with contact 42. Contact 58 is connected through member 56, which is made of conducting material, and conductor 74 to terminal 72. Movement of piston 38 to the right on the drawing closes contacts 42 and 58, completing a circuit between terminals 70 and 72 on the end of the container. That circuit may be utilized in known manner to perform any desired indicating or control function.

Additional indicating means may be provided. For example, a fixed switch contact 52 and a spring-supported contact 54 are represented as mounted on end piece 34 in position to be closed in response to movement of the piston in its extreme left, or rest position. When the piston moves away from its rest position spring 54 moves away from contact 52, producing an electrical signal. The leads and terminals for this switch are not shown explicitly in the drawing, but may be similar to those already described.

The structure, as so far described, is functionally similar to the prior art device illustrated in Fig. 1, except for the absence of the tension spring 26. The functions performed by the spring 26 in the device of Fig. 1 are performed by the re-set structure now to be described. An annular re-set mass 76 is adapted to slide axially within the annular recess 77 formed in the inner face of the cylinder end 56. A compression spring 80 acts between the bottom of recess 77 and the peripheral flange 81 formed at the left end of the annular mass. A spacer 78 of resilient material is preferably mounted on the left end of mass 76 facing piston 38.

When the device is at rest or when the axial acceleration is below a predetermined threshold value, spring 80 presses mass 76 against the end of the piston 38, causing the latter to abut against cylinder end 34, as shown in Fig. 2. When an acceleration greater than that predetermined threshold value is applied to the device, as indicated in Fig. 3 by the arrow A, mass 76 compresses spring 80 and moves rapidly into recess 77, to the position shown in Fig. 3. At the same time, piston 38 moves away from its rest position, but that movement is rapidly checked by compression of the gas in chamber 39. Hence the piston is released from the action of spring 80 and acts as a free mass. The piston therefore presses against the confined gas with a force very closely proportional to the magnitude of the acceleration A, forcing the gas through the orifice and around the outside of the cylinder, as indicated by the light arrows. When substantially all of the confined gas has escaped from chamber 39 through the orifice, the contacts 42 and 58 close, thus providing a signal at a time when the integral of acceleration with respect to time reaches a predetermined value, in the manner

discussed in connection with the prior art device of Fig. 1. The indication obtained with the improved device, however, is more accurate and reliable than that of the prior art device, since all potential non-linearity and other inaccuracies due to spring 26 are eliminated without sacrificing accuracy in the starting position of the piston.

The weight of re-set mass 76 and the strength of spring 80 may be varied according to the type of service for which the device is intended. It is usually desirable that the piston be held securely in rest position against a disturbing force, which may be expressed as some multiple of the acceleration of gravity g , and which is typically at least about 1.5 g . For that purpose, spring 80 must exert a force corresponding to that multiple of g acting on both the piston and the re-set mass. It is usually desirable, further, that the threshold value of acceleration at which the piston is completely released be as close as possible to the defined disturbing force. We have discovered that this can be accomplished by making the re-set mass considerably heavier than the piston, typically from about 2 to about 5 times the weight of the piston. For example, if the weight of re-set mass 76 is 3 times that of piston 38, and if the strength of spring 80 is sufficient to hold the piston securely in rest position against a disturbing force corresponding to an acceleration of 1.5 g , then the threshold acceleration at which the piston is fully released is substantially 2 g . Or, as a further example, with the stated weight ratio, a spring force computed to release the piston fully at accelerations exceeded a threshold value of 5 g will hold the piston securely against disturbing forces up to 4 g .

It is also desirable that re-set mass 76 fit as closely as possible within recess 77, so that the volume of gas contained between the mass and the recess walls be kept relatively small. It is desirable for accuracy of the device that substantially all of the gas initially contained in chamber 39 be forced through the orifice before the switch contacts 42 and 58 close. This condition is desirable so that the operation of the contacts will be independent of the magnitude of the acceleration and depend only on its time integral. In this respect the annular design used in this embodiment has the advantage of minimizing the amount of gas remaining between the piston and its opposing cylinder and at the time that the contacts close.

An additional feature of the invention resides in its adaptability for use in calibration of the device. Acceleration integrators of this general type are ordinarily calibrated on a centrifugal table, which is brought up to a constant speed to provide a known acceleration input to the device. However, since the table must be first accelerated up to its chosen speed the piston must be artificially restrained from movement in some way so that the time at which the known acceleration becomes effective is accurately known. By forming the mass 76 wholly or partially of a magnetic material, and the walls of the cylinder and container of non-magnetic material, and by placing a solenoid over the end of the container near the rest position of the piston and passing an electric current therethrough, the piston may conveniently be held in its rest position until the chosen value of acceleration is reached on the accelerating table. The device may then be made to begin operation at a known time by breaking the circuit to the solenoid. Then the product of the known acceleration multiplied by the time required for the contacts to close gives an indication of the actual operation of the device, and if the actual operation is different from the desired operation the needle 60 may be appropriately adjusted to change the operation time to the required value.

It should also be noted that when mass 76 is responsive to magnetic fields it is possible to release the piston from spring action under control of an acceleration sensitive

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switch, rather than by the direct influence of acceleration alone upon mass 76. This may be accomplished, for example, by mounting a solenoid near the closed end of the cylinder, either within or outside of the container, and energizing the solenoid via an acceleration sensitive switch which closes whenever the selected threshold acceleration is exceeded. The re-set mass will then be drawn away from the piston due to the magnetic force of the solenoid. For such operation the piston and the cylinder walls must be non-magnetic and the re-set mass magnetic. Such use of a solenoid has certain advantages in that the mass of the member 76 may be made as small as desired by increasing the strength of the magnetic field. It may therefore be desirable in some embodiments of the invention to use the combination of a non-magnetic free piston with a magnetic member 76, non-magnetic walls 32, a solenoid around the end 56 of the cylinder assembly inside of the container, and an acceleration sensitive switch operable to energize the solenoid when acceleration exceeds the threshold value.

Although this invention has been described with reference to one specific embodiment thereof, it should be understood that the invention is by no means limited to that specific embodiment. Many modifications may be made in the specific structure disclosed without departing from the spirit of the invention. The invention includes all such modifications falling within the scope of the following claims.

We claim:

1. In combination with an acceleration integrator which comprises structure forming a cylinder closed at one end, piston means having a substantially flat inner axial face and movable inwardly in the cylinder in response to axial acceleration thereof, gaseous fluid means operable to limit

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the rate of piston movement, and abutment means adjacent the open cylinder end operable to limit outward piston movement; piston re-set means comprising a re-set mass of annular form normally positioned between the piston and the closed cylinder end, an annular recess formed in the closed cylinder end and adapted to receive the re-set mass, the outer axial face of the re-set mass being substantially aligned with the closed cylinder end when the re-set mass is received in said recess, and the re-set mass and annular recess so corresponding in size and shape as to minimize the volume of gas entrapped by inward movement of the piston to the closed cylinder end, and compression spring means acting between the re-set mass and the bottom of said recess.

2. The combination defined in claim 1, wherein the force exerted by said spring just exceeds the combined weight of the re-set mass and piston means.

3. The combination defined in claim 1, wherein the weight of the re-set mass is between about 2 and about 5 times the weight of the piston means.

4. The combination defined in claim 1, wherein the re-set mass comprises magnetic material, and the piston is free of magnetic material.

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