Dec. 26, 1961 A. L. HERRMANN 3,014,360

VERTICAL ACCELERATOR FOR MISSILE COMPONENTS

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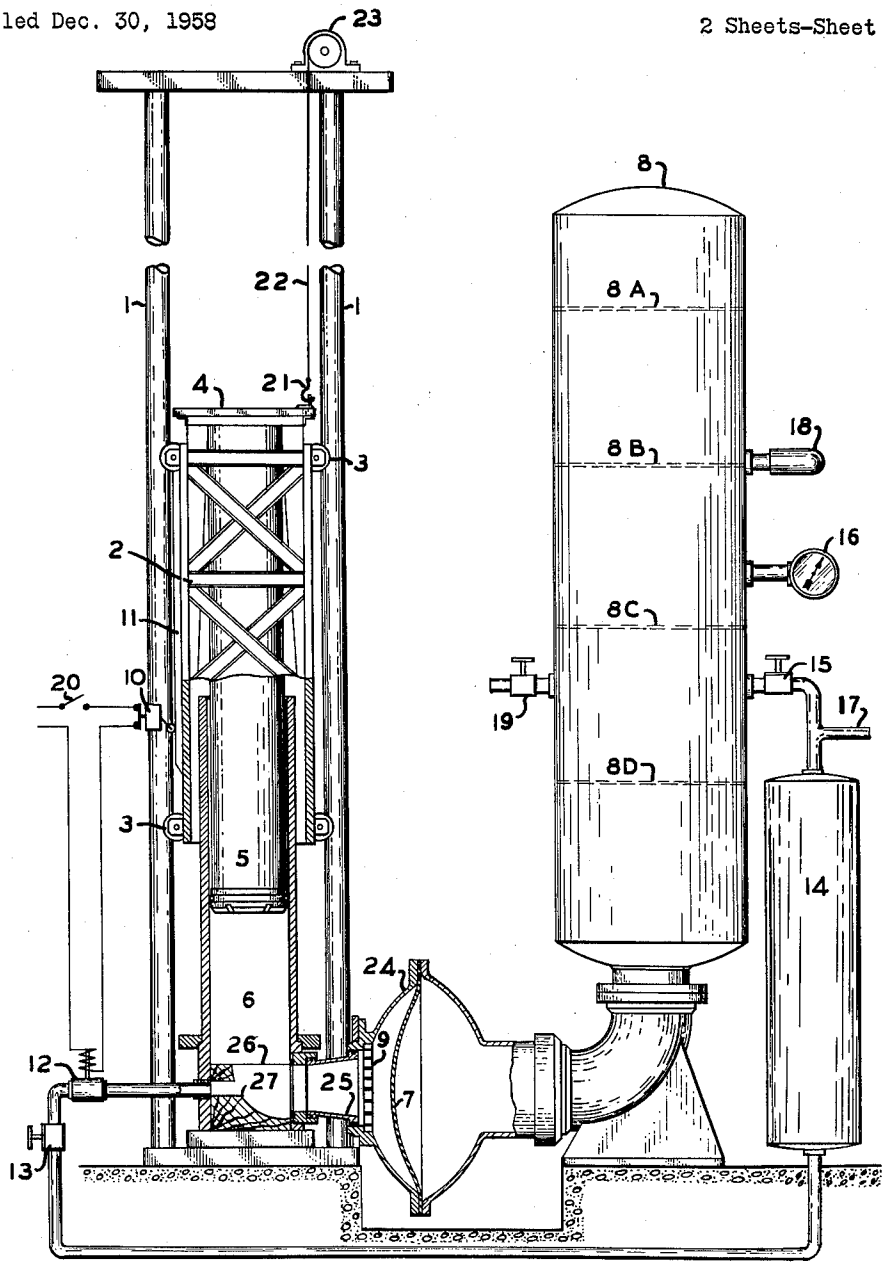


FIG. 1

ADOLF L. HERRMANN,
INVENTOR.

BY S. J. Rotondi,
A. T. Dupont,
H. M. Snyder,
Arvin E. Moore,
ATTORNEYS

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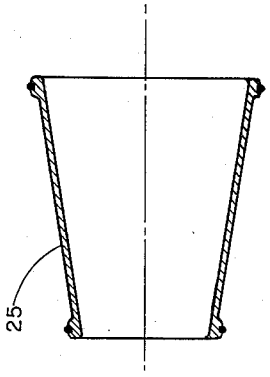


FIG. 2

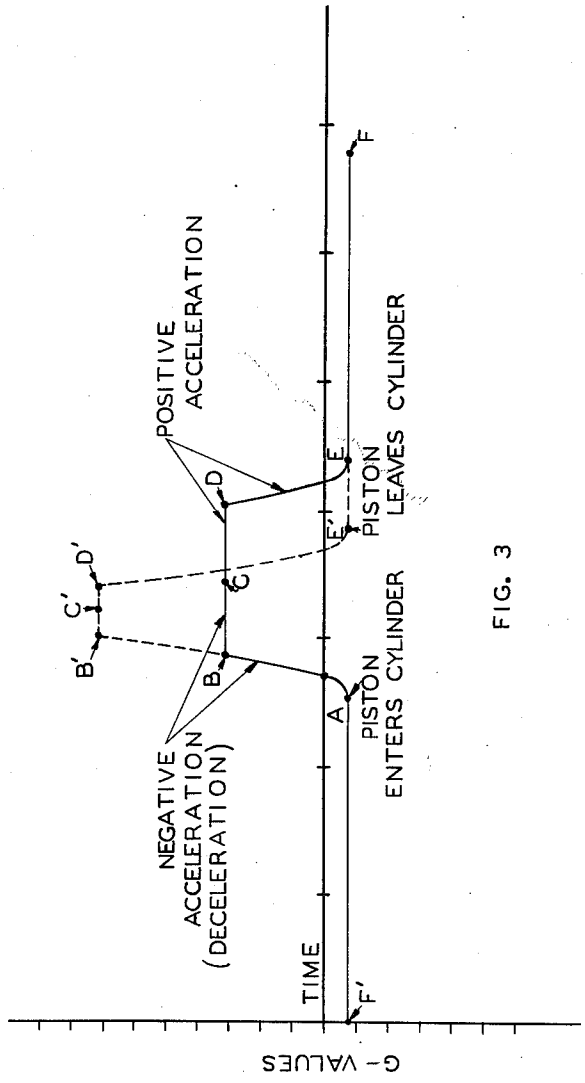


FIG. 3

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VERTICAL ACCELERATOR FOR MISSILE COMPONENTS

Adolf L. Herrmann, Huntsville, Ala., assignor to the United States of America as represented by the Secretary of the Army

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The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment of any royalty thereon.

This invention relates to a vertical accelerator for missile components. An efficient accelerator of this type that will simulate the accelerations to which missiles are subjected in flight is of prime importance to designers and manufacturers of guidance and control equipment of missile systems. When a missile is fired vertically, it is subject to a linear acceleration, which continues to act on the missile until the time that the power is cut off or the rocket motor burns out. At this time the vehicle goes into free flight and its components become weightless. Since all the accelerations during this period of propulsion are vertical, or have substantial vertical components, the types of accelerators that do not operate in a vertical, linear direction—such as vibration tables, centrifuges, and rocket-driven vehicles on rails—are not satisfactory aids in the acceleration-testing of guidance and control equipment.

In view of these facts, an object of this invention is to provide a vertical accelerator that simulates actual missile flight conditions.

Another object of the invention is to provide a pneumatic accelerator that cyclically will subject a test table, which supports instruments or other missile components, to vertical linear acceleration for a period during each cycle, and after this period will provide simulated free-flight conditions for further testing of the instruments during each cycle.

A further object is to provide a cyclic, vertical accelerator that is capable of reproducing the desired g loading on equipment that is being tested for a long and controllable period of time, and that comprises an automatic means for replacing pressure fluid that escapes from the device.

The foregoing and other objects of the invention will become more fully apparent from the following detailed description of exemplary structure embodying the invention and from the accompanying drawings, in which:

FIGURE 1 is an elevational view, partly in section, of an accelerator embodying the invention.

FIGURE 2 is a detail view, in section, of an accelerator part.

FIGURE 3 is a diagram showing acceleration curves for the instrument-supporting table when it is subjected to two different g values.

With reference to the drawings, the invention comprises: two or more vertical guide rails **1**; a vertically reciprocable carriage, having an outer frame **2**, rollers or equivalent sliding shoes **3** that are carried by the frame and move on rails **1**, and an instrument-supporting table **4** that is fixed to the upper end of frame **2**; a pneumatic motor for reciprocating the carriage, having a piston **5**, which may be of aluminum alloy, fixed at its upper end to table **4**, and a cylinder **6**, in which the piston is reciprocated; a source of compressed air or other gaseous motive fluid **8**, **15**; and means to provide, for a period during each cycle of the motor, a substantially constant pressure in the cylinder (and therefore substantially constant acceleration and deceleration of the piston and instrument table).

The means for providing periods of substantially constant acceleration and deceleration, during a cycle and during successive cycles, comprises a flexible diaphragm **7**, a grille **9** for limiting the pressure-equalizing movement of the diaphragm as piston **5** moves upward, and a cam-operated switch **10** that is urged toward open position by a spring and that comprises a cam follower of the roller type. The roller is actuated by a cam **11** that is on frame **2** soon after the piston enters the cylinder **6** on its downward stroke, and the switch remains in the closed position shown in FIG. 1 until just before the piston is forced out of the cylinder on its upward stroke.

The means for constant acceleration further comprises a solenoid-operated valve **12** that is opened when switch **10** is closed, allowing air under pressure to flow thru hand-operated regulating valve **13** from auxiliary air tank **14**. This tank is at all times in communication with main air line **17**; and the pressure in tank **8** is lower than that in line **17**, due to closure of valve **15** before the tank and line are at equal pressure. Thus a supply of cool compressed air is in contact with the heated air of the cylinder during nearly all the time that the piston is in the cylinder.

Guide rails **1** extend a distance above cylinder **6** that is greater than the height of the carriage and piston assembly. This distance may be, for example, about three times the height of the piston's length, or as much as sixteen to twenty times the height of the piston, depending on the desired g loadings and air pressures that are utilized.

The pressure in tank **8**, which is the major factor in controlling the acceleration and deceleration of the piston and instrument table, is adjustable by means of the hand-operated regulating valve **15**, which receives air under pressure from the main air line **17**. When the pressure, as indicated by gauge **16**, is at the level necessary for the desired accelerations and decelerations, but below the pressure in line **17** and tank **14**, valve **15** is closed. An example of a satisfactory maximum pressure in tank **8**, which is maintained by safety valve **18**, may be set at about 120 pounds per square inch. If after making a test of an instrument under large accelerations and decelerations another test is to be made, under lower pressure, the pressure in tank **8** may be lowered by opening bleed valve **19** until the gauge registers the required reading.

Tank **8**, optionally, may have baffle plates **8A**, **8B**, **8C**, and **8D**. These plates preferably are perforated, with each upper plate having larger perforations than the plate below it. However, any known type of baffles may be used in lieu of the perforated plates. The purpose of the baffles is to damp movement of the air and thus reduce the pressure-disturbing effect on the system of the shock waves that are set up by the moving diaphragm.

The diaphragm chamber **24** and cylinder **6** are detachably connected by means of sleeve **25**. This sleeve has self-aligning ends, which may be spherically curved, and which have seals, for example the O-rings that are shown in FIG. 1 and FIG. 2.

In the lower part of cylinder **6** there may be optionally provided a removable shock absorbing element **26**, made of wood, rubber or like material. This block serves the dual purpose of absorbing the shock of the piston's last downward movement when the machine is stopped, and also as a means for varying the effective length of cylinder **6**, thereby shortening the period of application of pressure on the piston and the consequent periods of constant accelerations during each cycle. With block **26** in place, an increase in the pressure in tank **8** increases the g loading for the said shortened periods of constant accelerations. The block is perforated for the

passage of air from tank **14**, and is grooved at **27** to provide for non-turbulent flow of air to or from diaphragm chamber **24**.

Block **26** may be removed and replaced by a higher or lower block, thereby shortening or lengthening the period of application of pressure on the piston.

The pressure supplied to cylinder **6** from auxiliary tank **14** is maintained at a level higher than the pressure in tank **8** by means of regulating valve **13**.

Tank **14** is an equalizing or surge tank. Since its volume is large relative to the volume of cylinder **6**, no significant pressure drop occurs in the make-up air system while the solenoid valve **12** is open.

Acceleration and deceleration curves for the piston and table or platform at two different *g* valves are shown in FIGURE 3. Curve F'—A—B—C—D—E—F represents a cycle of negative and positive accelerations while the piston moves from its top position to and from its low position under the influence of a certain pressure in tank **8** and the diaphragm chamber; and curve

F'—A—B'—C'—D'—E'—F

represents a cycle of greatly increased accelerations while the piston is under the influence of a greatly increased pressure in the tank and diaphragm chamber.

Operation

After the missile instrument or other component to be tested is secured to platform **4**, and for the first cycle of the accelerator's operation, the platform, carriage and piston are elevated under manual control. Since the first elevation may be mechanical, as set forth below, the acceleration curve F'—B—D—F in FIGURE 3 is shown as beginning (at F') with the piston's first downward stroke. Repetitive simulation of missile-flight conditions may be said to begin at the upper part of this downward stroke, irrespective of the manner in which the piston is initially lifted. After this first downward stroke is completed the accelerator repetitively simulates complete missile flights, with the booster phase of each complete flight commencing with the piston's being pneumatically forced upward—from the position indicated by C in the diagram.

The first elevation of the piston may be accomplished by opening valve **13** and closing switch **20**, whereby valve **12** is opened, and pressurized air forces the piston upward. Or, alternatively, the schematically indicated hook **21**, which is of a quickly releasable type, cable **22** and electric motor and pulley **23** may be utilized for the first elevation of the piston. If the cable and hook are utilized the hook is quickly released at the top of its movement. In any event, the piston and table **4** fall from their topmost position, simulating weightless free flight. At this time valve **12** is closed and the pressure in cylinder **6** is atmospheric, and is substantially lower than that in tank **8**. Consequently, diaphragm **7** has been forced to the left, as viewed in FIGURE 1, and is against grille **9**. The diaphragm remains in this position until the pressure in cylinder **6** is built up to a level above that in tank **8**.

When the piston re-enters cylinder **6** at point A (FIG. 3), while diaphragm **7** is against grille **9**, there begins a period of increasing deceleration that is indicated by the line A—B. During this period, cam **11** closes switch **10**, and air under pressure greater than the pressure in tank **8** is admitted to cylinder **6**. This action increases the rate of deceleration of piston **5** and shortens the period of the increasing deceleration, which ends at point B, when the pressure in cylinder **6** equals the pressure that is in tank **8** and in the part of the diaphragm chamber **24** that is adjacent to tank **8**. At this equalized-pressure point, B, diaphragm **7** begins moving from grille **9** toward the reservoir. As the kinetic energy of the piston has not been exhausted the piston continues to move downward; and the slowly moving diaphragm adjusts the volume of air below the descending piston so that the volume remains substantially constant; and the upward, decelerating pressure of the air on the bottom of the piston also is maintained substantially constant. It is true that the total volume of the whole air-containing system of the cylinder, diaphragm chamber, tank **8** and connecting conduits is slightly changed by the descent of the piston, but the amount of the change in the volume of cylinder **6** that is below the piston is so small in comparison with the pressure-absorbing volume of the tank and the remainder of the system that the total volume and the resulting pressure and deceleration remain substantially constant, while the diaphragm is in motion and the piston moves on downward from point B to point C.

When the carriage's kinetic energy is exhausted, the piston reaches the bottom of its stroke, at point C, and immediately begins its upward stroke, changing from deceleration (negative acceleration) to positive acceleration. Since the rate of change of the piston's velocity continues the same (due to the substantially constant pressure against the bottom of the piston) the acceleration line from the piston's low point C is a continuation of the straight line B—C to the point D, while the piston is rising and the diaphragm is slowly moving back toward cylinder **6**.

Point D is the end of the period of substantially constant acceleration. At this point the diaphragm is back against grille **9**, and the pressure in cylinder **6** begins to drop, as the piston goes on upward to the point E, where it leaves the cylinder.

Just before point E cam **11** clears the cam follower on switch **10**, and allows the spring to open the switch, causing valve **12** to be closed.

From the point E to the point F, at the top of the piston's movement, the carriage simulates free missile flight. Point F is the same as point F'. From point F' to point A, during the descent of the piston toward the top of the cylinder, the piston and table continue to have nearly zero acceleration and to simulate free flight.

If during the upward stroke of the piston the valve **13** is either closed or only slightly opened the carriage will rise only a part of the distance that it fell during the preceding downward stroke, with consequent different accelerations for the two strokes. This difference is due to energy losses in friction and heat, and may be reduced by increasing the pressure of the additional supply of air that goes to the cylinder thru automatic valve **12** and hand-operated valve **13**. Therefore, to obtain a desired constant acceleration, for each stroke, and during successive cycles over a certain period of time, the oprator would adjust valve **13** until the piston, frame and table rise to the same height during succeeding strokes. Calibration of one of the rails might be utilized as an aid in measuring the height of the strokes. Such equal reciprocations, producing a series of constant and equal accelerations, are of considerable value in the sustained testing of instruments and missile components under scientifically and accurately determined conditions.

Within the scope of the subjoined claims, the invention comprehends various obvious changes in the example of specific structure that is herein illustrated. For instance, the guide rails and valve **12** could be eliminated and the piston limited to travel within the cylinder **6**.

The following invention is claimed:

1. A vertical accelerator for testing elements under various conditions of flight comprising: a base; a set of elongated guide elements supported by said base and extending upwardly therefrom for a substantial distance; a vertically reciprocable carriage for supporting an element to be tested, guided in its vertical movement by said guide elements; a pneumatic motor, positioned between said guide elements at a distance below the top of said elements that exceeds the vertical extent of said carriage, comprising a piston that is connected to the carriage and a cylinder in which said piston reciprocates, said cylinder having an upper opening that communicates with the

atmosphere and has a cross-sectional area of substantially the same size as that of said piston, whereby on each upward stroke of the piston it moves outside of the cylinder and to a point substantially above the cylinder; a source of air pressure that is flow-connected to said cylinder, said source comprising a chamber open to said cylinder and having a yieldable wall; a compressed air reservoir sealingly connected to the side of said yieldable wall that is opposite from said motor; means connected to said cylinder for automatically adding extra air to said cylinder during each stroke of said piston; and a regulating valve for adjusting the quantity of said extra air to the amount necessary to compensate for the energy losses due to friction and heat, whereby said carriage may be subjected to a series of substantially constant and equal cycles of accelerations, conditions simulating the free flight of missiles, and decelerations.

2. A device for testing elements under various conditions of flight comprising: a vertically reciprocable support comprising a platform for supporting elements to be tested; guide means extending a substantial distance above said support for constraining said support to move vertically in its reciprocation; a pneumatic motor comprising a piston that is drivably connected to said support and a cylinder in which said piston reciprocates, said cylinder being vertically arranged below said platform and having an upper opening of a cross-sectional area that is substantially equal to that of the piston, said piston being free to move thru said opening and out of said cylinder as it moves upward; an air chamber flow-connected to the bottom of said cylinder, said chamber having a yieldable wall; a source of pressurized motive fluid sealingly connected to the side of said yieldable wall that is opposite from said motor; means for elevating said support, platform and piston until the bottom of said piston is a substantial distance above said cylinder, comprising mechanism for allowing said piston to fall from said substantial distance above said cylinder; said piston, cylinder and chamber being constructed and arranged to compress air below said piston after it re-enters the cylinder and as it further descends under the force of gravity, whereby the piston is bounced back out of the cylinder, and said platform is subjected to cycles of accelerations, conditions simulating the free flight of missiles, and decelerations.

3. A device as set forth in claim 2, in which said yieldable wall is a flexible diaphragm.

4. A device as set forth in claim 2, in which said source of pressurized motive fluid comprises a reservoir, means

connected thereto for supplying a controllable amount of fluid under pressure, a pressure gauge on said reservoir, and means for bleeding part of the fluid from said reservoir.

5. A device as set forth in claim 4, in which said motive fluid is compressed air and in which a safety valve is mounted on said reservoir.

6. A device as set forth in claim 2, in which said guide means comprises vertical rails, and in which said support comprises rollers in contact with said rails.

7. A device as set forth in claim 2, which further comprises means connected to said cylinder for automatically adding extra motive fluid to said cylinder during each stroke of said piston; and a regulating valve for adjusting the quantity of said extra fluid to the amount necessary to compensate for the energy losses due to friction and heat, whereby said carriage may be subjected to a series of substantially constant and equal accelerations.

8. A device as set forth in claim 7, in which said means for automatically adding extra fluid comprises a valve, a solenoid connected thereto, a source of electric current, a switch between said source and said solenoid, a cam follower connected to said switch, and a cam connected to said reciprocable support, for actuating said follower and switch.

9. A device as set forth in claim 2, in which said means for elevating said support comprises a source of compressed air, a conduit flow-connecting said source of compressed air and the bottom of said cylinder, a valve in the conduit, means for actuating said valve, and means operated by said support as it reciprocates for influencing said valve-actuating means to close said valve when the piston is outside the cylinder and to open the valve when the piston is inside the cylinder.

10. A device as set forth in claim 2 in which said means for elevating said support comprises a motor, a line drivably connected to said motor, and a detachable connection between said line and said platform.

References Cited in the file of this patent

UNITED STATES PATENTS

1,575,519	Amsler	Mar. 2, 1926
2,740,286	De Vost et al.	Apr. 3, 1956
2,931,218	Ottestad	Apr. 5, 1960

OTHER REFERENCES

Publication: "Hyge Shock Tester," Consolidated Electrodynamics Corp., Rochester, February 1957, pages 1–11.