June 30, 1964 E. D. GEISSLER ETAL 3,139,033

AERODYNAMICALLY STABLE MISSILE

Filed July 23, 1959 2 Sheets-Sheet 1

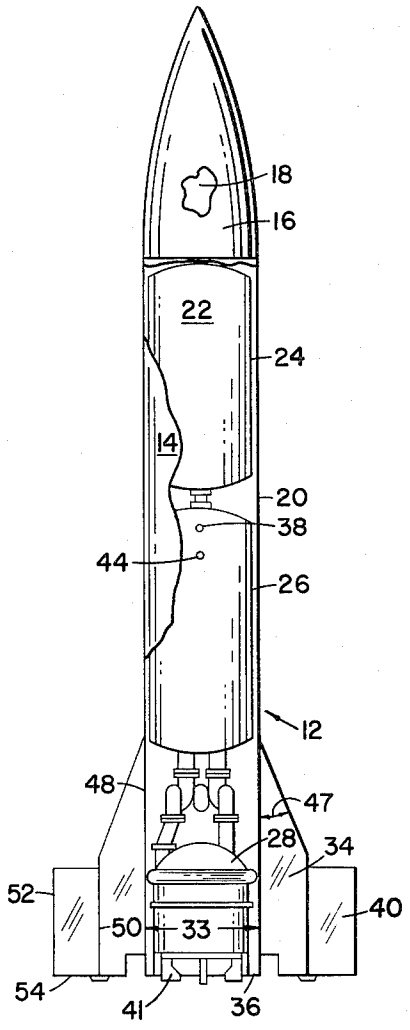


FIG. 1

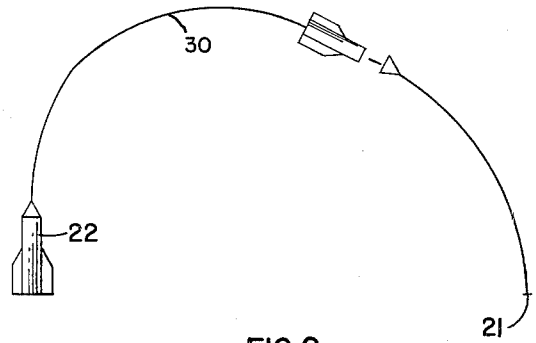


FIG. 2

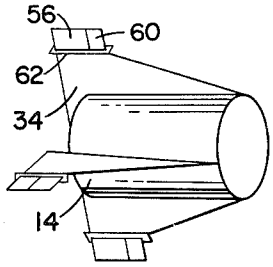


FIG. 4

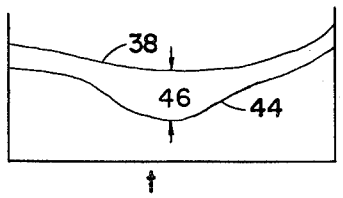


FIG. 3

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AERODYNAMICALLY STABLE MISSILE

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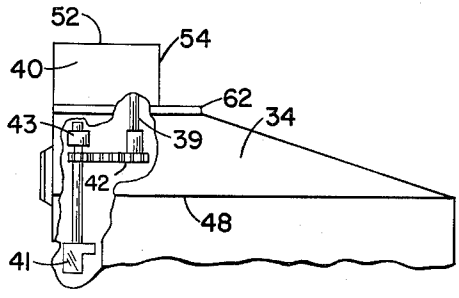


FIG. 5

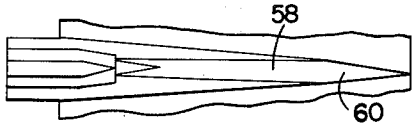


FIG. 6

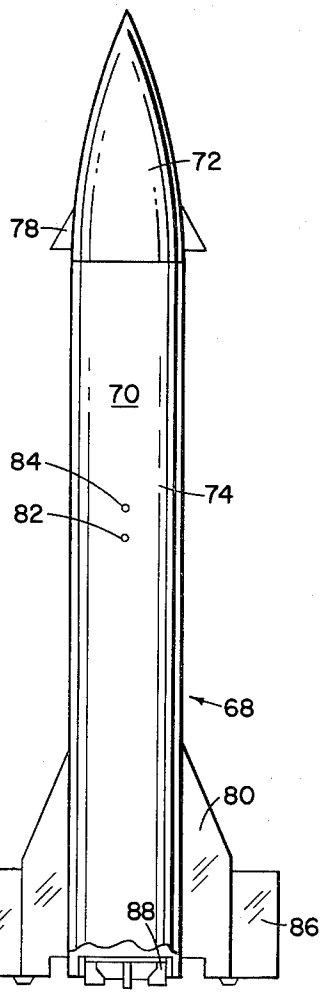


FIG. 7

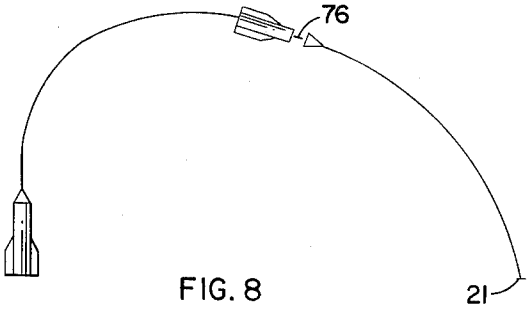


FIG. 8

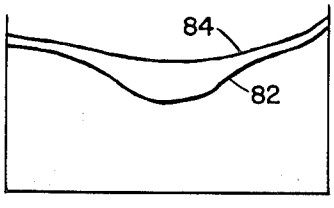


FIG. 9

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AERODYNAMICALLY STABLE MISSILE

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3 Claims. (Cl. 102—50)
(Granted under Title 35, U.S. Code (1952), sec. 266)

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

Our invention relates to missiles disposed for transportation of a payload to a target, and more particularly, to such missiles respectively provided with fins for aerodynamic stability and limitation of the restoring torques of the missiles.

Conventional missiles travel in predetermined trajectories to the targets usually including segments outside the atmosphere. Thrust for the entire trajectories is provided by combustion of fuel in the initial portions thereof and the missiles are directed in the trajectories by guidance and control devices.

The centers of gravity of the missiles shift considerably due to the consumption of the fuel, and the velocities of the missiles usually increase from zero at take off to a high maximum Mach number (in excess of 5 Mach) causing the centers of pressure of such missiles to move forward therein.

An object of our invention is to provide such a missile having inherent aerodynamic stability.

An added object of our invention is to limit the restoring torque and consequently limit the requirement of control of the missiles.

Another object of our invention is to provide such missiles with cruciform fins to provide such stability.

A further object of our invention is to provide such fins with planforms to limit the restoring torques of the missiles.

Other aims and objects of our invention will be evident from the following explanation.

In carrying out our invention, missiles provided with centers of gravity movable rearwardly and forwardly during the combustion period of the missiles are respectively provided with cruciform fins to provide the missiles with centers of pressure disposed in rearward serial relation with the centers of gravity for aerodynamic stability of the missiles to provide restoring torques thereto.

The planforms and dimensions of the fins are disposed to limit the spacing between the centers of gravity and pressure to the diameters of the respective missiles, and consequently limit the restoring torques thereof, for limitation of the guidance forces required to program the missiles in the predetermined trajectories.

For more complete understanding, reference is directed to the following description and the accompanying drawing, in which:

FIGURE 1 is an elevation, partly in section, of a missile incorporating an embodiment of our invention;

FIGURE 2 is a schematic view of a missile disposed at take-off in a trajectory;

FIGURE 3 is a graph of the relative positions of the centers of gravity and pressure during combustion;

FIGURE 4 is a partial perspective view of a missile with cruciform fins;

FIGURE 5 is a partial elevation of a missile with one of the fins and a corresponding airvane;

FIGURE 6 is a plan view of the fin and airvane;

FIGURE 7 is a modification of our invention including a reentry vehicle and a separable body secured thereto;

FIGURE 8 indicates the point of separation in the trajectory of the modification of FIGURE 7; and

FIGURE 9 is the corresponding graph of the centers of gravity and pressure of the modification shown in FIGURE 7.

Accordingly, a missile 12 is provided with a fuselage 14 including a nose 16 with a payload 18 therein, and a cylindrical booster 20 secured to the nose for transportation of payload 18 to a target 21.

The booster is provided with a power plant including a fuel reservoir 22 and an engine disposed in tandem relation and in communication therewith to provide thrust for the transportation.

The nose is provided with a fineness ratio of length to greatest diameter of substantially 2 and the fuselage is is provided with a slenderness ratio of length to diameter of substantially 11 to provide centers of pressure and gravity of the fuselage disposed in tandem relation.

In FIGURE 1 booster 20 includes a power plant with respective tanks 24 and 26 for alcohol and liquid oxygen disposed in tandem relation and in respective communication with an engine 28 for combustion of the propellants in the initial portion of a predetermined trajectory 30 to target 21 to provide the thrust required to propel the missile in the trajectory.

The center of gravity of the fuselage structure and the payload is fixed, and the centers of gravity of the fuels in tanks 24 and 26 move rearwwardly responsive to combustion of the fuels. The tanks are disposed in the fuselage for rearward and forward displacement of the center of gravity of the fueled fuselage as the tanks are emptied.

Fuselage 14 is provided with a diameter D, shown at 33. Fins 34 are secured to the fuselage to complete the missile, and the fins are secured to the booster adjacent rear end 36 thereof to apply maximum lift thereto. The added weight of the fins provides a center of gravity 38 of the completed missile slightly rearwardly of the center of gravity of the fueled fuselage and near the top of tank 26.

Quantities of fuel stored in tank 24 and the portion of tank 26 adjacent the top thereof are both above center of gravity 38. As engine 28 is operated, fuel flows from both of the quantities, and center of gravity 38 is displayed rearwardly in missile 12. As engine 28 continues to operate, fuel continues to flow from tank 24 at a continually decreasing distance above center of gravity 38 and flows from the remaining lower portion of the tank 26 at a continually increasing distance below the center of gravity.

When the products of flow times the distance above and below center of gravity 38 reach equality the rearward displacement ceases, and the center of gravity proceeds forwardly, responsive to further operation of engine 28.

Airvanes 40 are respectivley pivoted in fins 34 at 39 and missile 12 is provided with vanes 41 pivoted in the jet stream of engine 28 and disposed for simultaneous rotation with airvanes 40 through a chain drive 42 for application of forces thereto and consequent application of torque to missile 12 by an actuator 43 for guidance of the missile in the trajectory.

The fins are provided with such planforms that the areas of the assembled fins, when symmetrically arranged about the missile limits the relative location of the center of gravity and center of pressure of the missile to a predetermined spaced serial relation at the beginning of the trajectory. The air density decreases and the speed of the missile increases as the missile traverses the atmosphere to provide rearward and forward displacement of the center of pressure. The structural distribution of the fin areas, as defined by the hereinafter described plan-

form, limits the spacing **46** between centers **38** and **44** to a maximum distance of substantially the diameter **33** of the missile. By limiting the distance between the center of gravity and center of pressure to substantially 1 diameter, or less, the lever arm of the torque required to restore the missile to the desired attitude after deviation therefrom is held to a minimum.

To provide the missile with the structure necessary to obtain the above described desirable relationship between the center of gravity and center of pressure, fins **34** are cruciform clipped delta fins with half-apex angles **47** of substantially 17.5°, a root-chord length **48** of substantially 1.6D partly extending behind the booster, and a tip-chord length **50** of substantially 0.61D.

Airvanes **40** are rectangular and each includes a chord length **52** of substantially 0.43D and span **54** of substantially 0.27D. Vanes **40** include a flat plate portion **58** and a portion with an opening lead angle **60** of substantially 24°, extending rearwardly substantially 0.12D.

Gap effects due to deflections of the airvanes are compensated by end plates **62** disposed along the root chords of the air vanes and extending normally thereto to fence the boundary air layer from the fins.

A gear ratio of substantially 1:2.5 is disposed between the jet vanes and airvanes for maximum airvane deflection of substantially 11° to limit the hinge moments of airvanes **40**.

In the embodiment of FIGURE 7, a missile **68** is provided with a fuselage **70** including a reentry vehicle **72** enclosing a payload and a body **74** secured to the reentry vehicle and disposed for separation therefrom at a point **76** in the trajectory prior to reentry into the atmosphere. The nose of the reentry vehicle and the fuselage are provided with respective slenderness ratios of length to diameter of substantially two and eleven.

Body **74** includes tanks and an engine similar to missile **12** and the center of gravity of fuselage **70** similarly progresses rearwardly and forwardly responsive to fuel consumption.

Missile **68** includes fins **78** secured to reentry vehicle **72** and disposed for aerodynamic stability of the vehicle subsequent to the separation. Fins **80** of greater area than fins **34** are provided to space center of pressure **82** of missile **68** rearwardly of center of gravity **84** thereof and at a distance within diameter **33** therefrom.

Missile **68** also includes corresponding airvanes **86** and jet vanes **88** for guidance thereof.

While the foregoing is a description of the preferred embodiment, the following claims are intended to include those modifications and variations that are within the spirit and scope of our invention.

We claim:

1. An aerodynamically stable missile disposed for transportation of a payload to a target comprising:
   (*a*) a cylindrical booster;
   (*b*) a nose disposed on the top of said booster and in axial alignment with said booster;
   (*c*) said booster having a plurality of fuel tanks disposed in tandem relation therein;
   (*d*) a rocket engine disposed below said fuel tanks and at the base of said booster so that the jet stream from the engine will flow from the bottom of said booster;
   (*e*) a plurality of cruciform fins positioned on the outer surface of said booster;
   (*f*) said fins being provided with areas symmetrically disposed about the base of said booster and positioned thereon for locating the center of gravity and center of pressure of the missile in predetermined spaced serial arrangement and for limiting the spacing between the center of gravity and center of pressure to a maximum distance of substantially the diameter of the missile at various velocities and angles of attack of said missile;
   (*g*) airvanes rotatably disposed on each of said fins for aiding in the control of the flight of said missile through the atmosphere;
   (*h*) a plurality of jet vanes rotatably disposed in the jet stream of said engine for aiding in the control of the flight of said missile within the atmosphere of the earth and outside of the atmosphere of the earth; and
   (*i*) means for coupling said respective airvanes and said respective jet vanes together for simultaneous movement.

2. The device as set forth in claim 1 wherein said nose is a re-entry vehicle having fins disposed on its surface.

3. A missile as in claim 1 with said fins areas defined by a planform including a half-apex angle of 17.5°, a root-chord length of substantially 0.61D to limit the spacing between the center of gravity and center of pressure of the missile to a maximum distance of substantially the diameter of the missile at varying velocities and angles of attack of said missile and thus limit the force required on the vanes for retention of the missile in the desired altitude in the trajectory.

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