

Aug. 25, 1964

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3,145,949

MISSILE GUIDANCE SYSTEM

Filed June 27, 1957

2 Sheets-Sheet 1

Fig. 1

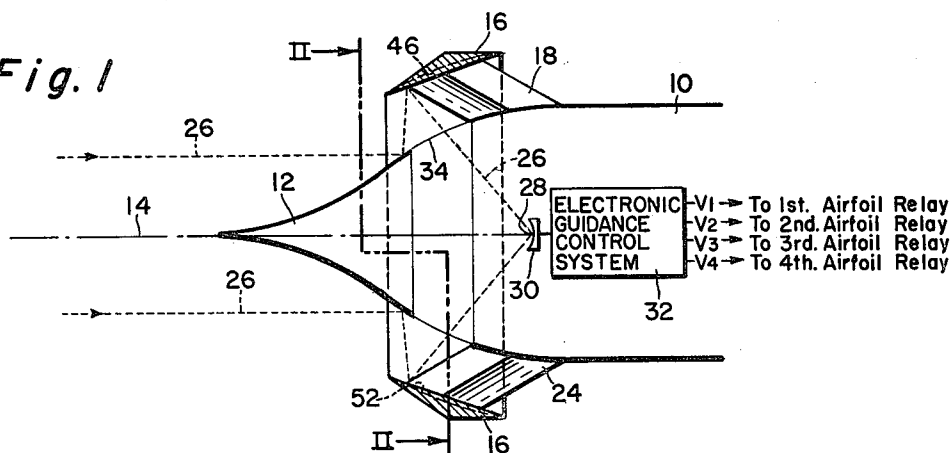
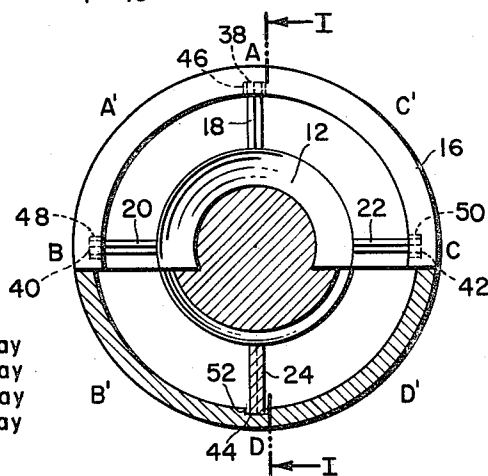
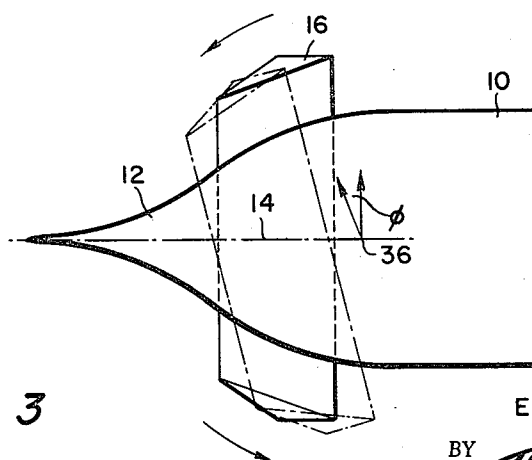


Fig. 2



A or A' = Location of 1st. Airfoil Relay
B or B' = Location of 2nd. Airfoil Relay
C or C' = Location of 3rd. Airfoil Relay
D or D' = Location of 4th. Airfoil Relay

Fig. 3



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Fig. 4

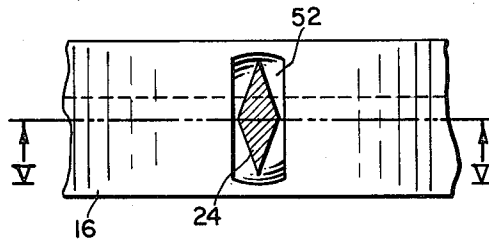


Fig. 5

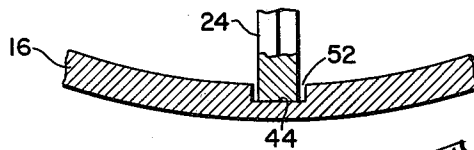


Fig. 6

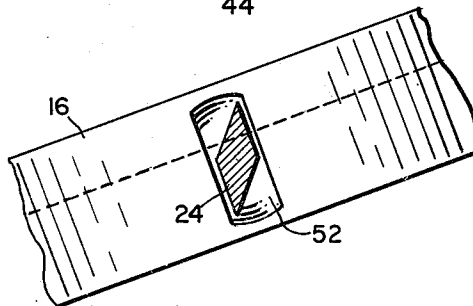


Fig. 7

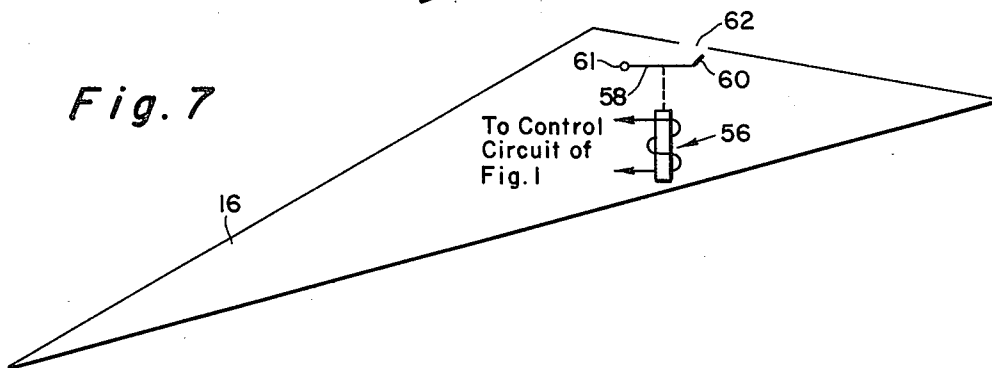
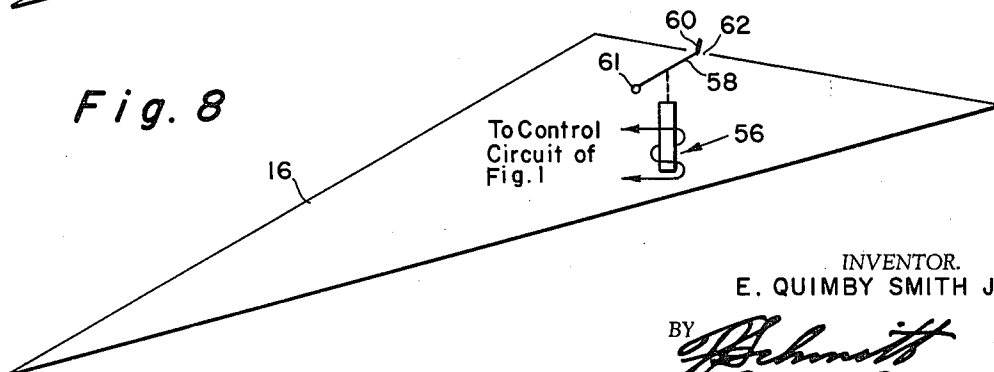


Fig. 8



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MISSILE GUIDANCE SYSTEM

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9 Claims. (Cl. 244-14)

(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 of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to missiles or projectiles incorporating some form of target-seeking, or homing, apparatus responsive to the reception of radiant energy emanating from the target itself, such apparatus operating to control the course of the missile in response to variations in the characteristics of the radiant energy received.

This application constitutes a further development of the concept set forth in application Serial No. 668,576, filed jointly by the present applicant and Willy A. Fiedler on June 27, 1957, now Patent No. 3,014,426.

In application Serial No. 668,576 there is disclosed a dual purpose air diffuser for jet engines having an annular air intake duct, or port, made up of an essentially tubular casing surrounding a central needle portion, or spike. The inner surface of this casing, as well as the outer surface of the spike, are configured for high aerodynamic efficiency as an air compressor, while at the same time acting (in one preferred embodiment) to sequentially reflect radiant energy rays emanating from the target to a common collection region located within the body of the missile. As an example, one surface of the diffuser unit may be of essentially elliptical form, while the remaining surface may define an inverted paraboloid of revolution.

Expressed differently, the invention of the prior joint application is direction to a combined air diffuser and radiant energy collector for missile engines of the ram-jet type, this unit being so designed that radiant energy from a target may be sequentially reflected from a plurality of diffuser surfaces and then brought to an approximate focal point on or near the missile axis.

That portion of the above concept which relates to the collection of radiant energy by a projectile has proven to be of considerable value in eliminating many of the problems heretofore present in so-called "seeker" systems. However, the prior invention is restricted to missile designs in which a ram-jet engine is employed, and in which air for the jet engine enter through an annular intake region or port.

It has now been found that the basic "optic" collection principle disclosed in the mentioned joint application may be adapted to other forms of projectiles, such for example as missiles which do not require for their operation a source of air under compression. In these circumstances, it is necessary to provide other means for performing the reflecting function which, in the prior application, is carried out by the inner surface of the tubular cowl surrounding the inner nose-cone or spike. In other words, it is necessary to again reflect inwardly to a common focal region those radiant energy rays which have initially been outwardly reflected from the surface of the missile nose-cone.

The above objective may be accomplished, in a preferred embodiment of the present concept, by providing an aerodynamic direction control surface in the form of a rotary-symmetrical air vane, mounted on the forward portion of the projectile body and spaced radially therefrom. The surface of this air vane is adjustable relative to the surface of the missile in response to control forces developed as a function of changes in the characteristics

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of the received energy from the target. There is a particular inter-relationship of missile axis, air vane position, and target which, when the air vane is in proper alignment, enables the latter to provide a continuously-active aerodynamic force on the missile in the direction of the target.

The inner surface of the air vane is made of a highly polished material, and is so configured as to direct to a common focal region those radiant energy rays reflected to it from the outer surface of the missile nose-cone section. Since the air vane is maintained in alignment with the target by means of the guidance system carried by the missile, it retains a substantially constant angular relationship with the arriving energy rays, which results in the latter being directed to a common collection region regardless of minor deviations in missile trajectory.

One object of the present invention, therefore, is to provide a radiant energy collector for projectiles of the "seeker" or homing class.

Another object of the invention is to provide an assembly for target-seeking missiles whereby radiant energy emanating from such target will be sequentially reflected from a plurality of "optically" complementary surfaces prior to collection and utilization, one of such surfaces acting as a missile flight-control member.

A further object of the invention is to provide a radiant energy collection system for "seeker" missiles in which a high signal-to-noise ratio may be established and maintained.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIGS. 1 and 2 are partly schematic side and front views, respectively, of the fore-part of a rocket-type projectile incorporating a preferred form of the present invention, certain portions of the projectile being shown by cross sections taken along the lines I—I and II—II;

FIG. 3 illustrates the operation of the flight control airfoil of FIGS. 1 and 2;

FIGS. 4, 5, and 6 are detailed showings of the construction and operation of certain of the components of FIGS. 1 and 2; and

FIGS. 7 and 8 illustrate one form of aerodynamic control mechanism which is suitable for use with the projectile of FIGS. 1 and 2.

Referring now to FIGS. 1 and 2, there is illustrated the fore section of a projectile of the rocket type, this projectile incorporating a radiant-energy collector designed in accordance with the principles of the present invention. The projectile includes a body 10, of generally cylindrical configuration, having a tapered or pointed nose section 12. The latter defines a surface of revolution relative to the longitudinal axis 14 of the projectile. Rocket 10 is provided with some suitable form of solid or liquid propellant which is carried in its after section (not shown). However, the details of this portion of the projectile, including the combustion chamber and exhaust nozzle, form no part of the present invention, and hence have been omitted from the drawings for the sake of clarity.

A missile on which the apparatus of the present invention is installed is intended to seek out a source of radiant energy. Accordingly, the missile must be able to intercept incident energy from such a target or source, and to convert variations in this received energy into flight control information.

The above considerations, therefore, dictate a radiant energy collector which is of such dimensions, in a plane normal to the longitudinal axis of the missile, that a sizeable "bundle" of energy radiations are intercepted and

directed to some form of transducer for conversion into control information. In general, the greater the cross-sectional area of this "bundle" of rays, the higher will be the signal-to-noise ratio of the developed error voltage.

In the mentioned application Serial No. 668,576 it has been disclosed how the forward nose section of a projectile can serve as a portion of a radiant energy collection system. In accordance with the arrangement therein set forth, the incident energy is doubly-reflected, once from the forward nose section of the missile to the under-surface of an annular shell or cowl, and thence from the latter to a common focal point lying on or near the missile axis. This shell, or cowl, in the mentioned application, actually forms the exterior casing or cover of the missile, and the spacing between this shell and the inner body member constitutes an air compressor unit for the jet engine by which the missile is propelled.

Since a rocket motor needs no source of air under compression, a dual purpose design such as set forth in the mentioned disclosure is inapplicable. However, the advantages of the "optic-collection" principle per se can be obtained in a manner to be set forth below.

Referring again to FIGS. 1 and 2, the projectile 10 is provided with an annular air vane 16 (also termed a "canard") mounted adjacent to, and concentric with, its forward nose section 12 by means of four radially-extending support fins 18, 20, 22, and 24 which are rigidly affixed to the body of the projectile. The air vane 16 is of rotary-symmetrical design and preferably of triangular cross-section (FIG. 1), although its particular cross-sectional contour has been selected primarily to provide structural rigidity and may be modified within aerodynamic limits as may be necessary or desirable. It is essential, however, that the inner surface of this air vane 16 be of frusto-conical configuration, and possess satisfactory reflection characteristics for any radiant energy incident thereon. Such a material as highly-polished stainless steel has been found to be very suitable for this purpose.

In the mentioned application it has been disclosed that, if radiant energy rays arriving along parallel paths are sequentially reflected from two surfaces which are chosen to be optically complementary, then the reflected energy may be brought to a common focal point. It has been demonstrated in the mentioned application that if one of these two reflecting surfaces is of "inverted" parabolic configuration, the remaining surface may be either conical or ellipsoidal.

The nose section of the missile of FIGS. 1 and 2 possesses such an "inverted" parabolic surface. Hence, all energy rays 26 which are essentially parallel both to each other and to the projectile axis 14 will be reflected from this surface to what would be a virtual focal ring encircling the nose member 12 were it not for the presence of the air vane 16. The latter, as previously brought out, possesses a highly reflective inner surface, which serves to again reflect the rays 26 to a common focal region 28 lying on or adjacent to missile axis 14. A transducer 30 located in this focal region intercepts the energy rays 26. Variations in the amount of energy received by the transducer as a result of a departure of the missile axis 14 from parallelism with the energy rays 26 are utilized by an electronic guidance system 32 to control the flight course of the projectile through the creation of an unbalanced drag force on the airfoil 16 as a result of selective actuation of a plurality of electro-magnetic relays. The latter will be more fully described in connection with FIG. 7 of the drawings.

As in the invention of the mentioned application, an annular portion 34 of the wall of projectile 10 lying adjacent to the nose section 12 is so formed as to permit the passage therethrough of the doubly-reflected radiant energy rays 26. While this annular section 34 is preferably composed of some solid translucent material, it

may in certain cases be merely a ring-shaped air gap of sufficient width so as not to cut off any appreciable number of the energy rays reflected from the inner surface of airfoil 16.

In order to establish and/or maintain a flight course for the projectile which will bring it to the desired target, guidance system 32 must operate to selectively vary the position or alignment of airfoil 16 relative to the projectile body. In other words, the airfoil 16 constitutes at least a major part of the missile's aerodynamic steering apparatus. Hence, the latter must be not only mounted for selective movement relative to the projectile body, but this relative movement must be of a universal nature in order to provide omnidirectional flight control.

As stated, the airfoil 16 is of rotary-symmetrical design having an inner surface of frusto-conical configuration. To provide the desired control, it must be mounted for universal movement about a pivot point such as 36 (FIG. 3) lying on the missile axis 14. As above brought out, the airfoil is coaxially mounted about this axis as part of a unitary assembly which includes the spike or nose-cone 12. The precise location of pivot point 36 on axis 14 is determined by the desired aerodynamic relationship between the missile body and the airfoil 16. It is usually selected to minimize drag effects at high missile speeds.

Referring now to FIG. 3, and assuming that the nature of the energy received by transducer 30 is such as to dictate a revision in the missile's trajectory, the position of the airfoil 16 relative to the missile body 10 will be altered in the manner exemplified in the drawing—that is, it will be moved from one position as shown in solid lines to one such as shown in dotted outline. In other words, the airfoil will be displaced about the pivot point 36 through a certain angle ϕ . With a universal mounting for the airfoil, this angular deviation may occur in any quadrant depending upon the phase relationship of four output voltages V_1 , V_2 , V_3 , and V_4 developed by the guidance system of FIG. 1. Such error-voltage-generating systems and their operation are well known in the art to which this invention pertains.

To permit the airfoil 16 to have such universal freedom of movement through a limited range with respect to the body of the missile, the particular supporting arrangement best shown in FIGS. 2, 4, and 5 may be employed. As illustrated in these figures, each of the radially-extending support fins 18, 20, 22, and 24 is diamond-shaped in cross-section and is formed such that its furthest surface extremity (indicated by the reference numbers 38, 40, 42, and 44, respectively) is configured as a portion of a sphere. These spherically-shaped fin extremities are designed to be respectively seated within recesses 46, 48, 50, and 52 (of generally rectangular outline but of spherical cross-sectional configuration) formed in the frusto-conical inner surface of airfoil 16. Since the radius of curvature of both the spherical surfaces 38 through 44 and of the recesses 46 through 52 is chosen with reference to the pivot point 36 (FIG. 3), the airfoil 16 will be free to take any angular position (within a limited range set by the width of the rectangularly-shaped recesses) with respect to axis 14, and the flight of the missile will be governed in accordance therewith. For example, in FIG. 6 the airfoil 16 has assumed a different angular relationship with respect to the support fin 24 than is shown in FIGS. 4 and 5. It will be noted that the diamond-shaped cross-sectional contour of the fins 18, 20, 22, and 24 prevents an unseating of these fins from their respective recesses 46 through 52, since the sides of each fin selectively abut the sides of its associated recess after a limited angular movement. This ensures that each support fin will remain disposed within its respective recess in airfoil 16, while at the same time permitting sufficient angular movement of these elements to provide for proper guidance of the projectile.

From the above it will be apparent how the airfoil 16 is mounted for universal movement relative to the body of missile 10. The instantaneous position of the airfoil, however, is determined by the characteristics of the energy intercepted by the transducer 30. The procedure by which variations in intensity of the energy received by a projectile develop quadrature error voltages is well known to workers in the guided missile art, and since the details of such a system form no part of the present invention, the system has been illustrated schematically as one from four output voltages V_1 , V_2 , V_3 , and V_4 are available.

These four error voltages from the guidance system 32 of FIG. 1 are respectively applied to the windings of four electromagnetic relays, all of which may be similar to the one designated by the reference number 56 in FIG. 7. The four relays are located within airfoil 16 and circumferentially spaced 90° apart so as to occupy locations such as A, B, C, and D (FIG. 2), or, alternatively, A', B', C', and D'. Each relay 56 is electrically connected to the guidance control system 32 of FIG. 1 by suitable conductors (not shown) so as to be energized by one of the control voltages V_1 , V_2 , V_3 , and V_4 , respectively.

The armature 58 of each relay 56 is elongated and carries a tab 60 on the extremity thereof opposite to the pivot 61. When the relay is deenergized, tab 60 lies completely within the airfoil 16, as best shown in FIG. 7. As soon as the relay is energized by an error signal from the guidance system 32, the armature 58 is actuated (upwardly in the drawing) to raise tab 60 until it extends through an opening 62 in the surface of the airfoil (FIG. 8). The tab 60, entering the air stream at substantially right angles to the surface of the airfoil, creates an aerodynamic drag on that portion of the airfoil with which it is associated. An unbalanced force created by a selective energization of less than the total number of relays 56 causes the airfoil 16 to assume a different alignment relative to the body of the missile, and hence results in a revision of the flight course of the projectile in a direction dictated by the new airfoil position.

Although it might be assumed that any appreciable departure of the incident energy rays 26 from a parallel relationship with the missile axis 14 might result in a marked reduction in the amount of energy collected by the transducer 30, actual tests indicate that usable error information is available even though the arriving energy rays are considerably "off-axis." Thus the disclosed system is not likely to permit the target to be "lost," as has occasionally been the case with previously-known homing arrangements when the approach angle exceeds a predetermined maximum.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described. For example, the four radially-extending fins 18, 20, 22, and 24 have been described as being rigidly affixed to the body of the projectile so that they movably support the air vane 16. If desired, however, the vane 16 may be rigidly secured to each of these fins 18-24, and then the latter mounted for limited universal movement as a unit about a point on the missile axis 14. This could be accomplished, for example, by a ball-and-socket joint, one of the elements of which is secured in position relative to the missile body, and the other element of which carries the four support fins so that they extend radially through appropriately-located openings in the body of the projectile.

I claim:

1. In a target-seeking projectile assembly adapted to receive energy emanating from the target and to convert

such received energy into information by means of which the course of the projectile may be controlled, said projectile being in the form of an elongated body of revolution having a tapered nose-cone section symmetrical with respect to the longitudinal axis of the projectile: the combination which comprises an air vane of essentially rotary-symmetrical configuration acting as an aerodynamic direction control member, said air vane being spaced radially from, and mounted for universal movement with respect to, that forward portion of said projectile adjacent said nose-cone section, thereby defining an annular air passage between an inner surface of said air vane and an outer surface of the projectile body, the inner surface of said air vane being so configured as to reflect a substantial proportion of any radiant-energy rays which impinge thereon to a common focal region lying on or near the longitudinal axis of the projectile; and a radiant-energy-permeable member forming part of the body of said projectile and lying in the path of those radiant-energy rays which are reflected from the inner surface of said air vane toward said focal region.

2. The combination of claim 1, further comprising a transducer located within said projectile body and adapted to convert variations in the radiant-energy rays arriving at said focal region into a correspondingly-varying electrical characteristic.

3. The combination of claim 2, in which said air vane is mounted for limited rotary movement about the longitudinal axis of the projectile in response to variations in the said electrical characteristic to thereby control the course of said projectile.

4. In a target-seeking projectile of the type adapted to utilize radiant-energy rays emanating from said target for the purpose of providing information as to the location of the latter with respect to the flight course of the projectile, said projectile having at least one aerodynamic directional control member in the form of a rotary-symmetrical vane mounted exteriorly of the body of said projectile for universal movement with respect thereto and spaced radially therefrom so as to define an annular air passage therebetween, the inner surface of said vane being of such nature as to reflect radiant-energy rays reaching said surface to a common focal region within the body of said projectile.

5. A projectile according to claim 4, further comprising means for converting variations in the characteristics of the radiant energy reaching such focal region into information for controlling the flight course of said projectile.

6. A projectile according to claim 4 in which said radiant energy rays reach the inner surface of said vane after reflection from the body of said projectile.

7. A projectile according to claim 6, in which that portion of the projectile body from which said radiant energy rays are reflected is in the form of an inverted paraboloid of revolution,

8. A projectile according to claim 7, further comprising means for varying the relative position of said vane with respect to said projectile body as a function of variations in the characteristics of the radiant-energy rays reflected by said vane to said common focal region.

9. A projectile according to claim 8, in which said means for varying the relative position of said vane with respect to said projectile body comprises means for developing an unbalanced drag force on said vane, the direction and magnitude of such drag force being a function of variations in the characteristic of the radiant-energy rays reflected by said vane to said common focal region.

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