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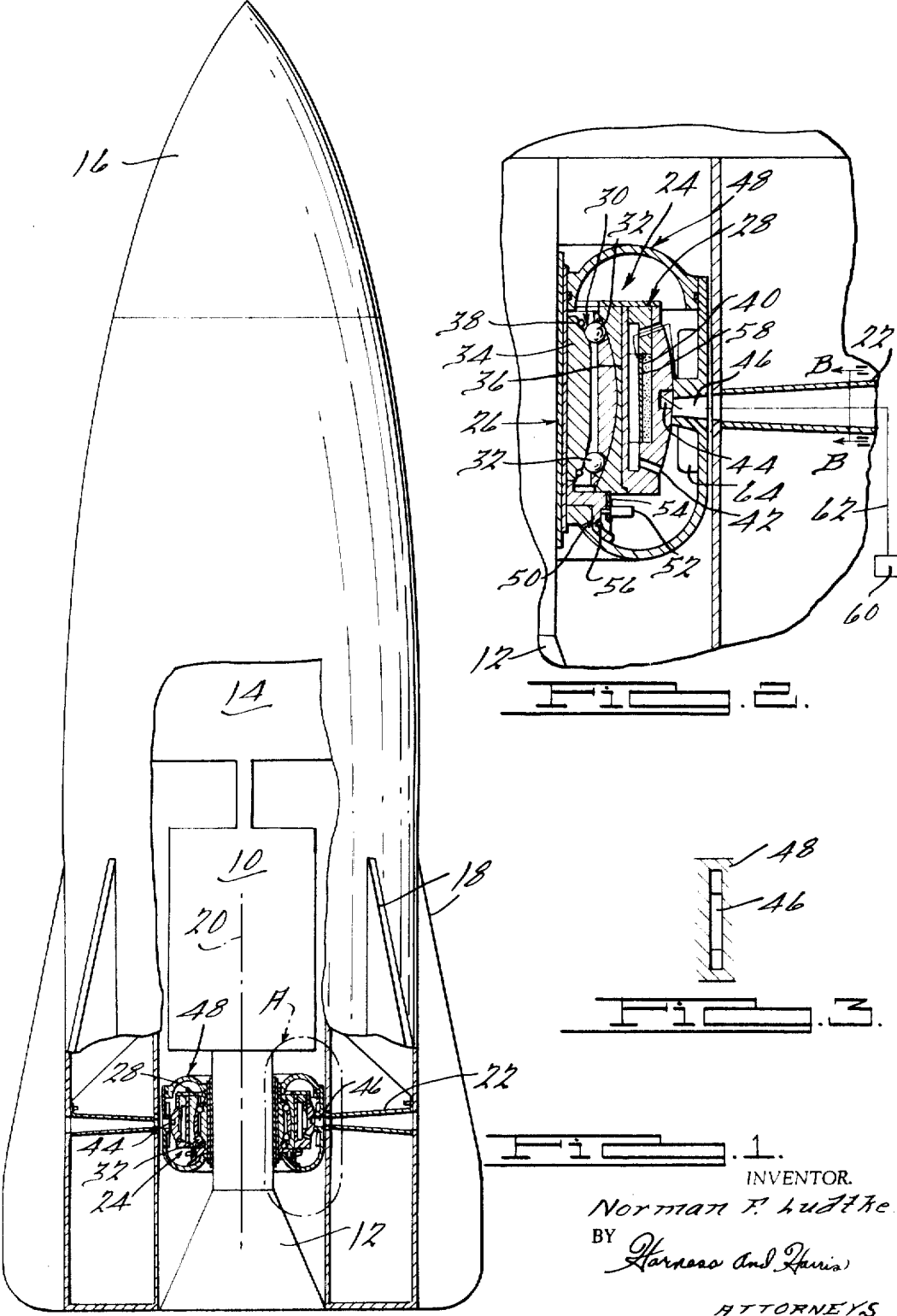
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3,304,029

MISSILE DIRECTIONAL CONTROL SYSTEM

Filed Dec. 20, 1963

2 Sheets-Sheet 1



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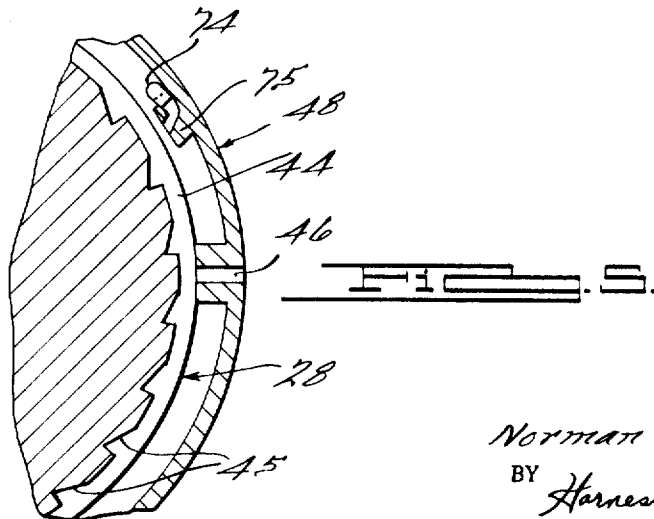
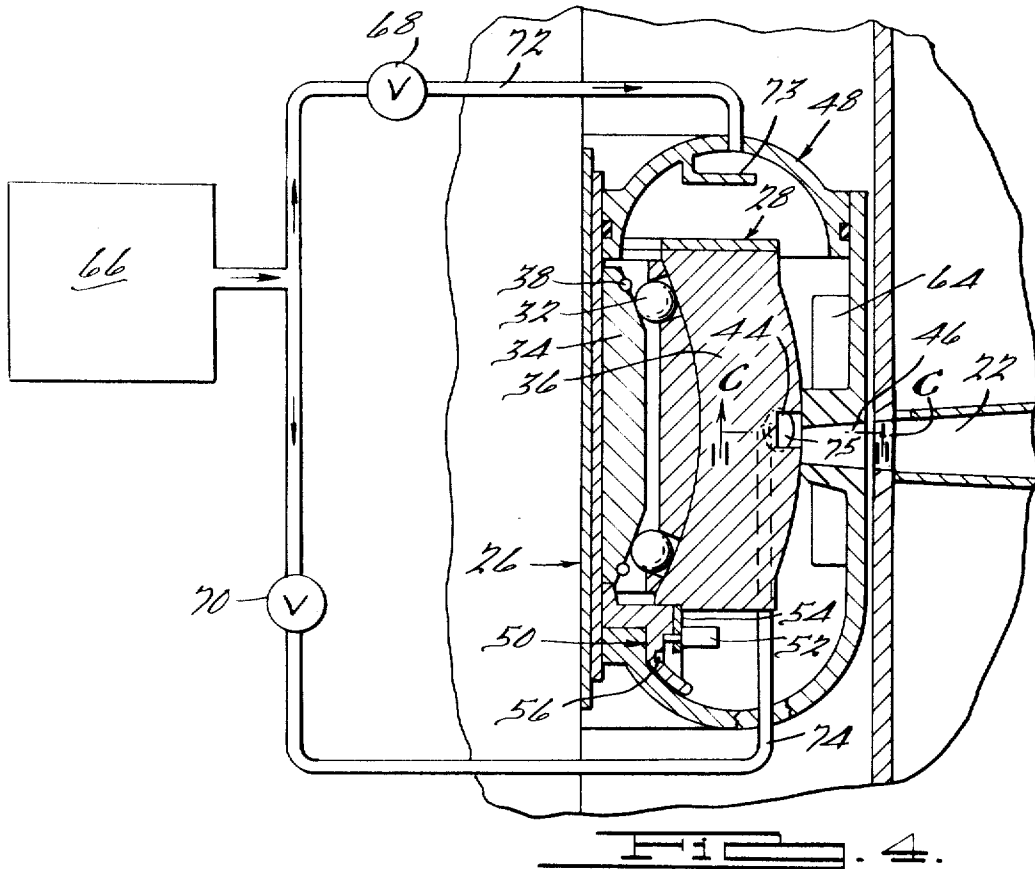
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MISSILE DIRECTIONAL CONTROL SYSTEM
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This invention relates generally to missiles and, more particularly, to an improved directional control system therefor.

The directional control of a missile or similar vehicle is accomplished by a system that balances the forces acting on the missile normal to the flight path during the boost phase of flight. These forces are thrust, drag, aerodynamic normal forces, and control forces. If these forces are in balance, ignoring gravity, the missile will fly a straight line to a target comprising any object or point in space.

Directional control systems for missiles and similar type vehicles currently known and in use employ a great variety of relatively complex electronic, mechanical, and pneumatic systems to accomplish the guidance and control function. Such systems are not justified in relatively short range missiles, particularly of the small artillery type. Prior to launching, such a missile is aimed with its longitudinal axis accurately aligned with its target or along its predetermined path. After launching, the missile is subjected to wind and other disturbing forces normal to its predetermined path causing the missile to pitch or yaw about its center of gravity and to deviate from the desired attitude. It is necessary to sense the occurrence of this deviation and to provide a balancing force promptly to maintain the missile on its predetermined path.

It is an object of this invention to provide a directional control system for a missile in which a single gyroscope element is utilized both to sense and to directly initiate and control the balancing forces required.

It is a further object of this invention to provide a directional control system for a missile in which a single energy source is utilized to provide gyroscope spin and to provide and maintain a constant pressure source for initiating and maintaining corrective force application.

It is a still further object of this invention to provide an improved missile directional control system in which the deviating movement of the missile itself from its launch predetermined path serves to generate a counterbalancing force by corrective jets without the intervening necessity for transducers.

The foregoing objects and others will become apparent from the following discussion and description of illustrative forms of my invention. In the drawings accompanying the description, in which reference characters have been used to designate like parts referred to in the description:

FIGURE 1 is a view of a missile incorporating the present invention with parts broken away and in partial cross section to better illustrate its placement and mode of operation;

FIGURE 2 is a sectional view to greatly enlarged scale of a portion A of FIGURE 1;

FIGURE 3 is a section taken along the line B—B of FIGURE 2;

FIGURE 4 is a view similar to FIGURE 2 showing an alternate embodiment of the present invention; and

FIGURE 5 is a section taken along the line C—C of FIGURE 4.

The invention is embodied in the missile illustrated in FIGURE 1 of the drawings. The numeral 10 designates the motor for the missile with motor nozzle 12. A suitable fuel for the rocket motor is indicated in chamber

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14 forward of the motor. A warhead 16 is shown mounted in the missile. Fins 18 are mounted on the aft portion of the missile to provide aerodynamic stability in flight. The directional control system which forms the subject matter of the present invention is shown with its operating elements mounted about the longitudinal axis 20 of the missile and around rocket motor nozzle 12. The directional control system alternately may be positioned in a like manner but forwardly of the missile center of gravity. A plurality of nozzles 22 are bodily fixed to the missile and oriented to provide corrective jet forces thereto to maintain the missile on its predetermined path in accordance with the present invention. A two degree of freedom gyro 24 is mounted on the missile with its spin axis coincident with the axis of the missile. Stator 26 is mounted about the motor nozzle 12 as shown in FIG. 2. Rotor 28 is mounted for rotation about stator 26 on a double ball bearing raceway 30. Included in raceway 30 are balls 32, an inner race 34 attached to stator 26, an outer race 36 attached to rotor 28, and a snap ring 38 for retaining the balls in place. A solid propellant 40 is contained in rotor 28 for rotating it at a desired rate. To that end, a plurality of spin orifices 42 arranged in two spaced and concentric rings are provided through the rotor 28. Spin orifices 42 are aligned to provide tangential forces to provide a balanced rotation of rotor 28 responsive to burning of the propellant 40. It will further be seen that pressure emitted through spin orifices 42 is communicated to plenum chamber 48 to provide a source of operating pressure therefor. Rotor 28 further is provided on its outer periphery with a peripheral groove 44, positionable in correspondence with the inlet portion 46 of each of the nozzles 22. In the practice of the present invention, at least three nozzles 22 are required, equally spaced about the missile. In the preferred embodiment here employed, four nozzles are utilized, two in the pitch plane and two in the yaw plane of the missile. Plenum chamber 48 is bodily fixed to the missile and mounted on stator 26 enclosing rotor 28 with a chamber adapted to be pressurized to provide fluid for corrective force jets. Plenum chamber 48 further acts as a valve operating means by reason of the operation of its nozzle inlet portions 46 in cooperation with grooved portion 44 of rotor 28 in a manner to be explained in the section "Description of Operation" hereinafter.

FIGURE 2 is further illustrative of the detail of the directional control system elements. A number of caging systems could be utilized. In the present system an inertial caging system 50 is incorporated which includes spring loaded plunger 52, locking pin 54, and locking groove 56. The gyro is shown in its caged, pre-launch position. Solid propellant 40 comprises a propellant of the cool burning type i.e. of a type combustible at about 2,000° F. A layer of readily ignitable material 58 is utilized to promote uniform and instantaneous ignition of propellant 40. To initiate the firing of the propellant, a source of electrical potential 60 is utilized. An extremely light and frangible grounded conductor 62 is threaded through nozzle 22, inlet portion 46, groove 44 and one of the spin orifices 42 to provide an electrical impulse to fire the solid propellant. The interior of plenum chamber 48 is further provided with a plurality of baffle plates 64 which are circumferentially and equally spaced about the chamber intermediate inlet portions 46 in the manner shown. It is the function of baffle plates 64 to reduce the fluid velocity in the plenum chamber in the area of the inlet portions 46. This serves to promote more uniform and less turbulent flow from the nozzles 22 and to minimize undesirable torque on the rotor 28 near its groove portion 44.

FIGURE 3 shows a section taken along the line B—B in FIGURE 2 and illustrates the cross-sectional config-

uration of inlet portions 46. These inlet portions are of a rectangular cross-section to promote linearity of operation as the inlet portions 46 carried by plenum chamber 48 are rotated about the groove portion 44 of rotor 28.

FIGURE 4 illustrates an alternate embodiment of the present invention in which an external source of pressurized fluid 66 is utilized both to pressurize plenum chamber 48 and to provide a rotative torque to spin rotor 28 up to the required angular rate. Valves 68 and 70 are provided in the supply lines from source 66 to provide the required flow rates in conduits 72 and 74, respectively, to achieve these purposes. Conduit 72 extends through the wall of plenum chamber 48 through its upper end. A baffle 73 is mounted across the outlet from conduit 72 to prevent direct impingement of the gas on rotor 28. Conduit 74 extends through the lower end of plenum chamber 48 and terminates in an outlet nozzle 75 fixed to the inner surface of chamber 48. Nozzle 75 is directed to apply a fluid jet against a series of notches 45 formed in the bottom of groove 44 as best shown in FIGURE 5. Each notch 45 extends across the bottom of groove 44 and is so formed that the impingement of the jet from nozzle 75 rotates rotor 28 about its spin axis in a manner well known in the art.

Description of operation

After acquisition of a target, the missile is positioned with its axis 20 in alignment with the target by a line-of-sight aiming procedure. With reference to FIGURE 2, an electrical impulse from source 60 is furnished through lead 62 to ignite igniter layer 58 and solid propellant 40. It should be noted that propellant 40 is of a sufficient quantity to burn for the entire length of the missile flight. Responsive to the burning of propellant 40, gas is expelled from the two rows of spin orifices 42. The center line of each orifice is in a plane that passes through the center of motion of the gyro. By setting the center line of each orifice at an angle so that it passes the center of motion at a predetermined distance, the required rotative torque is applied to spin the rotor 28. As soon as rotation of rotor 28 begins, frangible lead 62 is broken loose and is spun loose by the rotation of rotor 28. To obtain the desired r.p.m., the propellant is ignited prior to the launch of the missile. It will be seen that by suitable alteration of the geometry of the burning surface of propellant 40, adjustment may be made of the length of the spin-up time. During spin-up time, the gas pressure from orifices 42 is communicated to plenum chamber 48 thereby pressurizing the chamber. In the caged condition of the gyro prior to launch, the rotor 28 is maintained by inertial caging system 50 in the position illustrated in FIGURE 2. In the caged position of rotor 28, its groove 44 is positioned with its lower edge portion centered in the plurality of inlet portions 46 formed in plenum chamber 48. Thus, one half of each nozzle inlet portion 46 is covered by the rotor 28 and the other half is exposed by groove 44. Accordingly, the flow supplied in the caged condition is the same for each nozzle inlet portion 46 and its corresponding jet nozzle 22. The width of the groove 44 is further sized so that at the expected maximum angular rotation of the missile the throat area uncovered of an inlet portion 46 in that direction is fully open.

When sufficient time has elapsed to spin the gyro at the desired rate and to pressurize plenum chamber 48, the missile is launched by firing rocket motor 10. Inertial caging system 50 operates to move plunger 52 rearwardly to lock plunger 52 in groove 56 whereby relative movement between plenum chamber 48 and rotor 28 is allowed and the directional control system becomes operative. Plenum chamber 48 is bodily fixed and rotates with the missile. During flight the missile is caused to change its attitude from its predetermined line of flight by aerodynamic disturbance. This motion serves to decrease or increase the throat area provided by inlet portions 46

and consequently decrease or increase the jet forces applied through jet nozzles 22. With four equally spaced nozzles, the motion of the missile caused by the action of plenum chamber 48 increases in flow from one jet nozzle 22 and decreases the flow from the opposite nozzle. The difference between the two forces applied results in a net corrective force in the required direction to provide a balance of forces that will maintain the missile on its predetermined path. By proper sizing of the nozzles and adjustment of plenum chamber pressure, the required control forces for directional control of the missile may be achieved. It should be noted that the end chambers of the plenum chamber are sized so that they extend well beyond the edges of the grooves 44 on both sides. The air gap between the nozzle inlet portions 46 and the peripheral surface of rotor 28 is held to a minimum. This serves to minimize gas flow into the nozzles normal to the direction of spin. Inlet portions 46 further protrude into plenum chamber individually and are not part of a concentric ring. This permits the pressurized gas to feed into groove 44 between nozzle inlet portions 46. Gas flow through nozzle inlet portions 46 is permitted only in the direction parallel to rotor spin. This serves to eliminate torque in rotor 28 due to cross flows through the throats of nozzle inlet portions 46. The system is characterized by a self filtering feature due to the expulsion of gas by spinning rotor 28 through orifices 42. This motion imparts a centrifugal force on the gas thereby forcing the heavier particles to the outer face of the plenum chamber.

FIGURES 4 and 5 illustrate an alternate embodiment of the present invention in which an external source of constant pressure 66 is selectively connected both to provide rotor spin and to provide the required operating pressure for plenum chamber 48. A further embodiment of the present invention might incorporate a solid propellant 40 after the manner of FIGURE 2 to provide gyro spin and an external pressure source applied after the manner of FIGURE 4 to supplement in the pressurizing of plenum chamber 48.

It will be seen that I have provided a directional control system which is characterized by its simplicity and improved mode of operation and readily applicable to a great variety of missiles or, indeed, to any body thrust propelled in a medium that allows two degrees of freedom motion.

I claim:

1. A directional control system for maintaining a missile on a launch predetermined path comprising a gyroscope mounted with its spin axis and rotor aligned with the longitudinal axis of the missile at launch, said missile movable transaxially relative to said rotor, at least three substantially equally spaced and radially aligned jet nozzles mounted on the missile, a source of pressurized fluid operatively connectible to said nozzles, said gyroscope having said rotor operatively connected between said source and said nozzles for providing a variable fluid flow therethrough to provide balancing forces to the missile responsive to its movement relative to said rotor.

2. The combination as set forth in claim 1 in which said source of pressurized fluid comprises a plenum chamber fixed to said missile, mounted about and enclosing said rotor and operatively connected to a source of positive pressure, said chamber defining a plurality of variable passageways with the periphery of said rotor, each of said passages cooperable with a different one of said nozzles.

3. The combination as set forth in claim 2 in which a solid propellant is contained in said rotor and a plurality of circumferentially disposed spin orifices are provided through said rotor for rotating it at a predetermined rate responsive to ignition of said propellant, said orifices communicating with said plenum chamber for providing a source of positive pressure thereto.

4. The combination as set forth in claim 1 in which

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said nozzles include a passage of a selected cross-sectional configuration to provide a desired flow rate.

5. The combination as set forth in claim 4 in which said passage is of a rectangular cross section to provide linearity of operation.

6. The combination as set forth in claim 2 in which said rotor includes a plurality of notched portions circumferentially extending about its periphery, and a nozzle is connected to said source and directed toward said notched portions to provide a tangential force in a plane substantially normal to said spin axis for spinning said rotor at a predetermined rate.

7. The combination as set forth in claim 2 in which a plurality of baffle plates are mounted radially about the inner surface of said plenum chamber intermediate said nozzles.

8. A directional control system for maintaining a missile on a launch predetermined path comprising a two degree of freedom gyroscope mounted with its spin axis and rotor aligned with the longitudinal axis of the missile at launch, said missile movable transaxially relative to said rotor at least three equally spaced and radially aligned jet nozzles mounted on the missile, a pressurized plenum chamber fixed to the missile and enclosing the rotor of said gyroscope, said rotor having a peripheral grooved portion normally concentric with each of said nozzles and providing a variable flow to said nozzles from said chamber responsive to displacement of the missile relative to said rotor.

9. The combination as set forth in claim 8 in which said nozzles comprise a pair of oppositely directed nozzles in the pitch plane of the missile and a pair of oppositely disposed nozzles in the yaw plane of the missile.

10. The combination as set forth in claim 8 in which said rotor includes a plurality of notched portions circumferentially extending in a ring about its periphery and a spin nozzle is connected to a source of pressurized fluid and oriented toward said notched portions for rotating said rotor at a predetermined rate.

11. The combination as set forth in claim 10 in which said notched portions are formed on the periphery of said rotor within said grooved portion and said spin nozzle extends through said plenum chamber from said source of pressurized fluid.

12. A directional control system for maintaining a missile on a launch predetermined path comprising a two degree of freedom gyroscope mounted with its spin axis aligned with the longitudinal axis of the missile at launch, at least three equally spaced and radially aligned jet nozzles mounted on the missile, a pressurized plenum chamber fixed to the missile and enclosing the rotor of said gyroscope, said rotor having a peripheral groove portion alignable with each of said nozzles and providing a variable flow to said nozzles from said chamber responsive to displacement of the missile from its predetermined path, said rotor containing a solid propellant ignitable prior to launch and further including a plurality of spin orifices for providing rotation of said rotor at a predetermined rate, said spin orifices disposed in a pair of spaced concentric rings through the periphery of said

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rotor, each of said rings proximate a different end of said plenum chamber for providing a uniform pressurized state of said plenum chamber.

13. The combination as set forth in claim 12 in which a plurality of longitudinally aligned baffle plates are radially mounted about the inner surface of said plenum chamber in uniformly spaced groups intermediate said nozzles.

14. The combination as set forth in claim 12 in which said rotor is mounted for rotation about the stator of said gyroscope on a ball bearing raceway contained therebetween.

15. A directional control system for maintaining a missile on a launch predetermined path comprising a two degree of freedom gyro mounted with its spin axis and rotor aligned with the longitudinal axis of the missile at launch, said missile movable transaxially relative to said rotor, at least three substantially equally spaced and radially aligned jet nozzles mounted on the missile, a pressurized plenum chamber fixed to the missile and enclosing said rotor of said gyro, said rotor defining a plurality of passages, each of said passages normally concentric with a different one of said nozzles.

16. The combination as set forth in claim 15 in which said rotor of said gyro comprises a spherical surface portion, said portion mounted on a corresponding spherical surface portion of the gyrostator by a plurality of spherical bearing members.

17. The combination as set forth in claim 15 in which a common pressure source is operative connected to said plenum chamber for pressurizing it and in which a jet connected to said source is directed at said rotor to provide a tangential rotative force in a direction lying in a plane normal to its axis.

18. In a directional control system for a missile including a port varying system for providing balancing forces responsive to deviation of the missile from a predetermined path, a gyroscope having its stator fixed to said missile and its rotor cooperable with a plurality of lateral control ports, a spherical surface portion of said stator, a corresponding spherical surface portion of said rotor, and a plurality of spherical bearing members fixed therebetween for mounting said rotor on said stator.

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