Jan. 24, 1950 R. D. WYCKOFF ET AL 2,495,304

DIRIGIBLE BOMB

Filed May 31, 1946 5 Sheets-Sheet 1

Fig. 1.

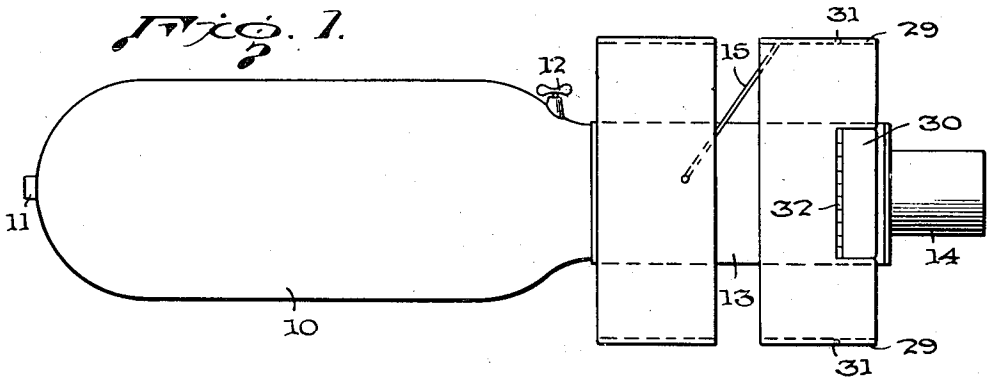
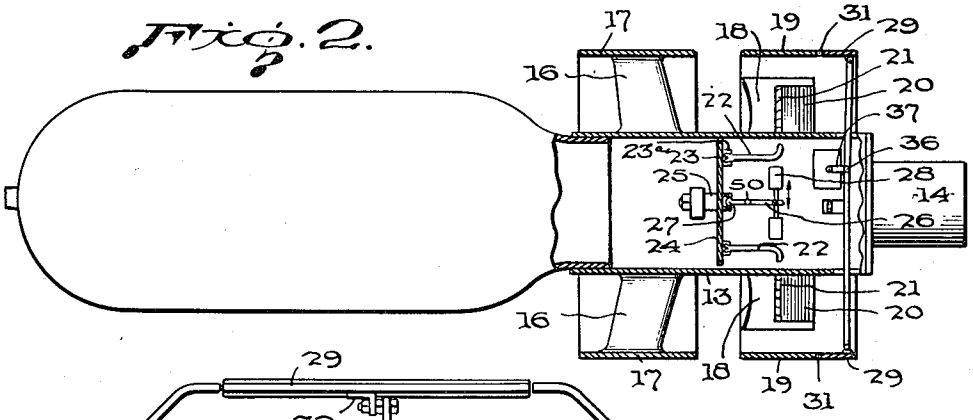


Fig. 2.



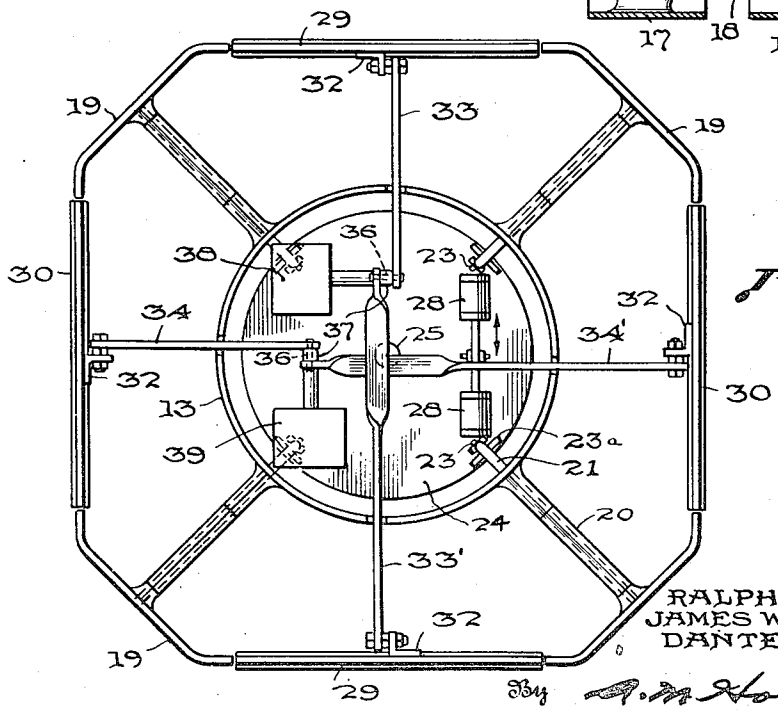


Fig. 3.

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DIRIGIBLE BOMB

Filed May 31, 1946 5 Sheets-Sheet 2

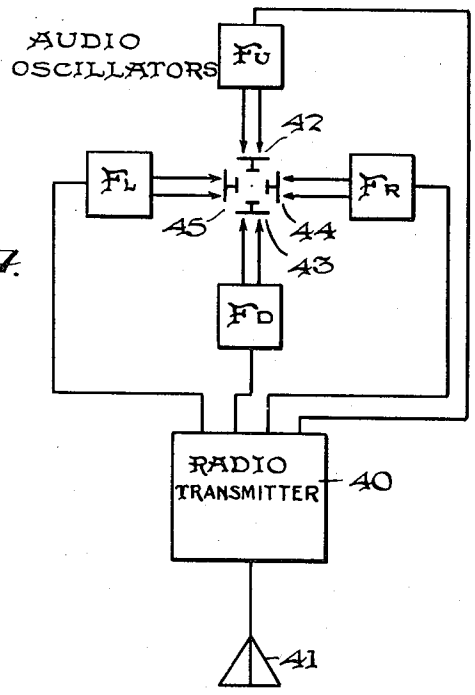


Fig. 4.

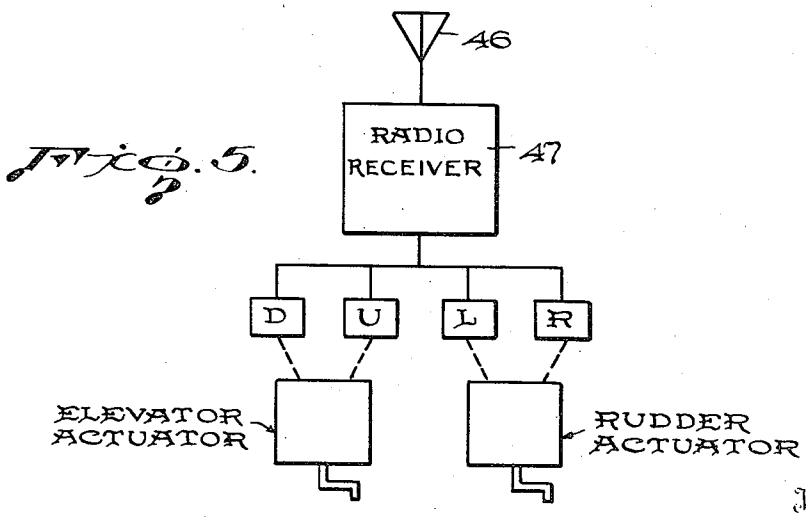


Fig. 5.

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DIRIGIBLE BOMB

Filed May 31, 1946 5 Sheets-Sheet 3

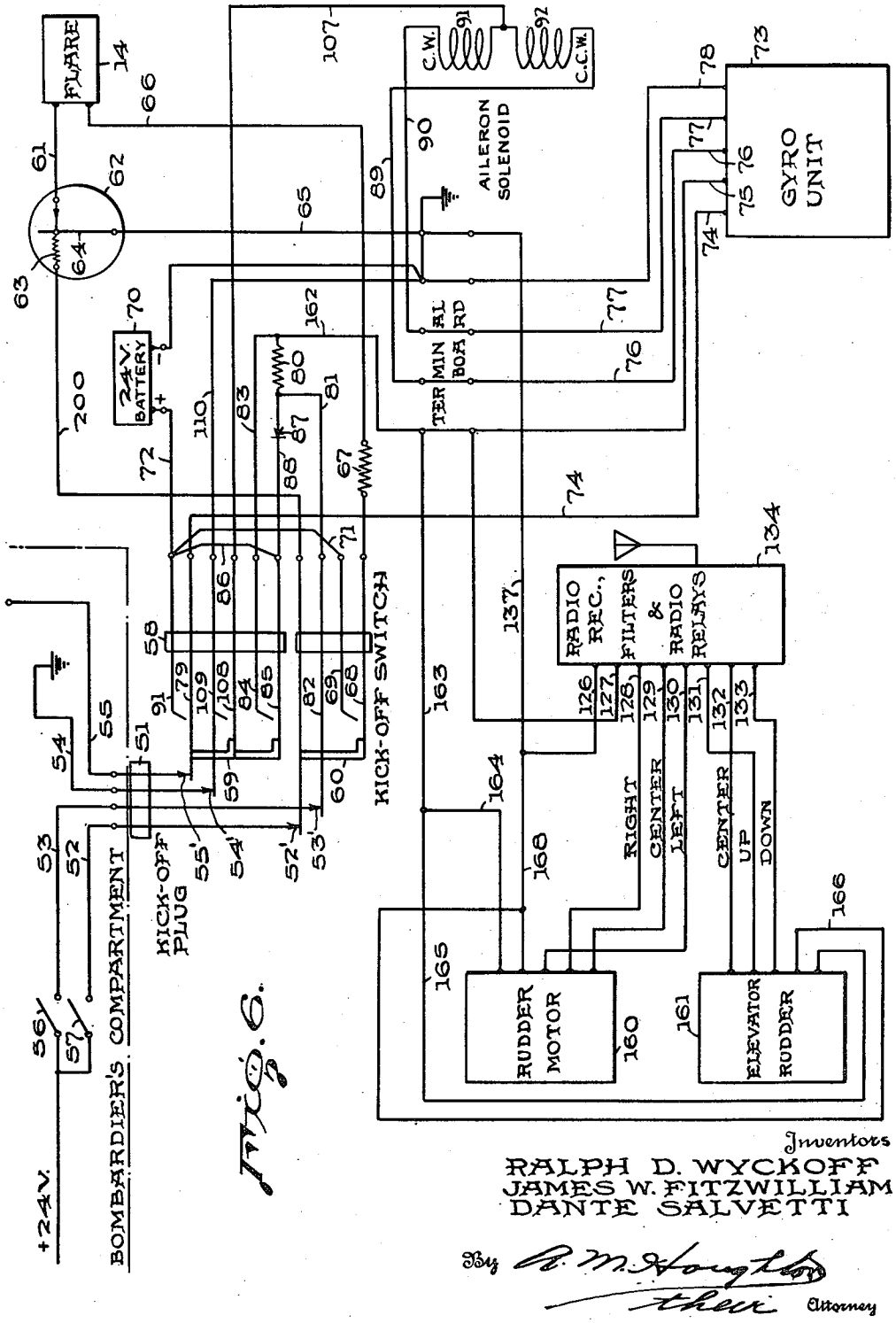


Fig. 6.

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DIRIGIBLE BOMB

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Fig. 7.

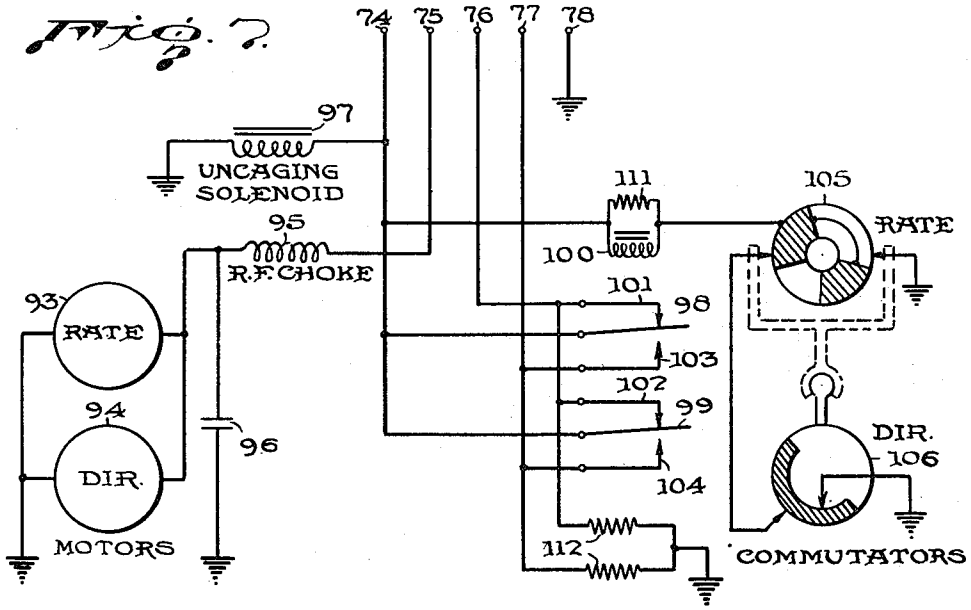
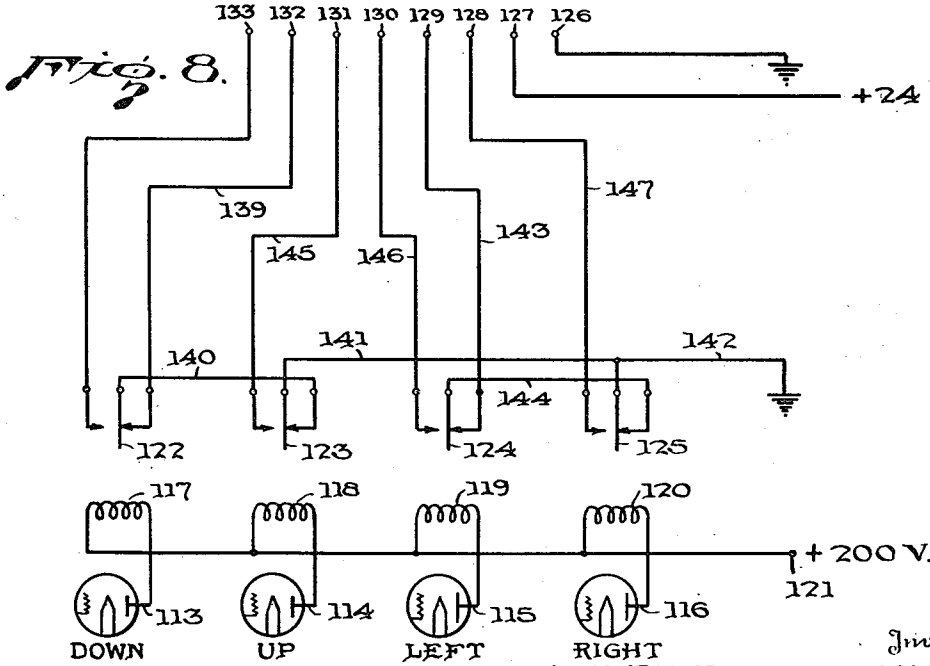


Fig. 8.



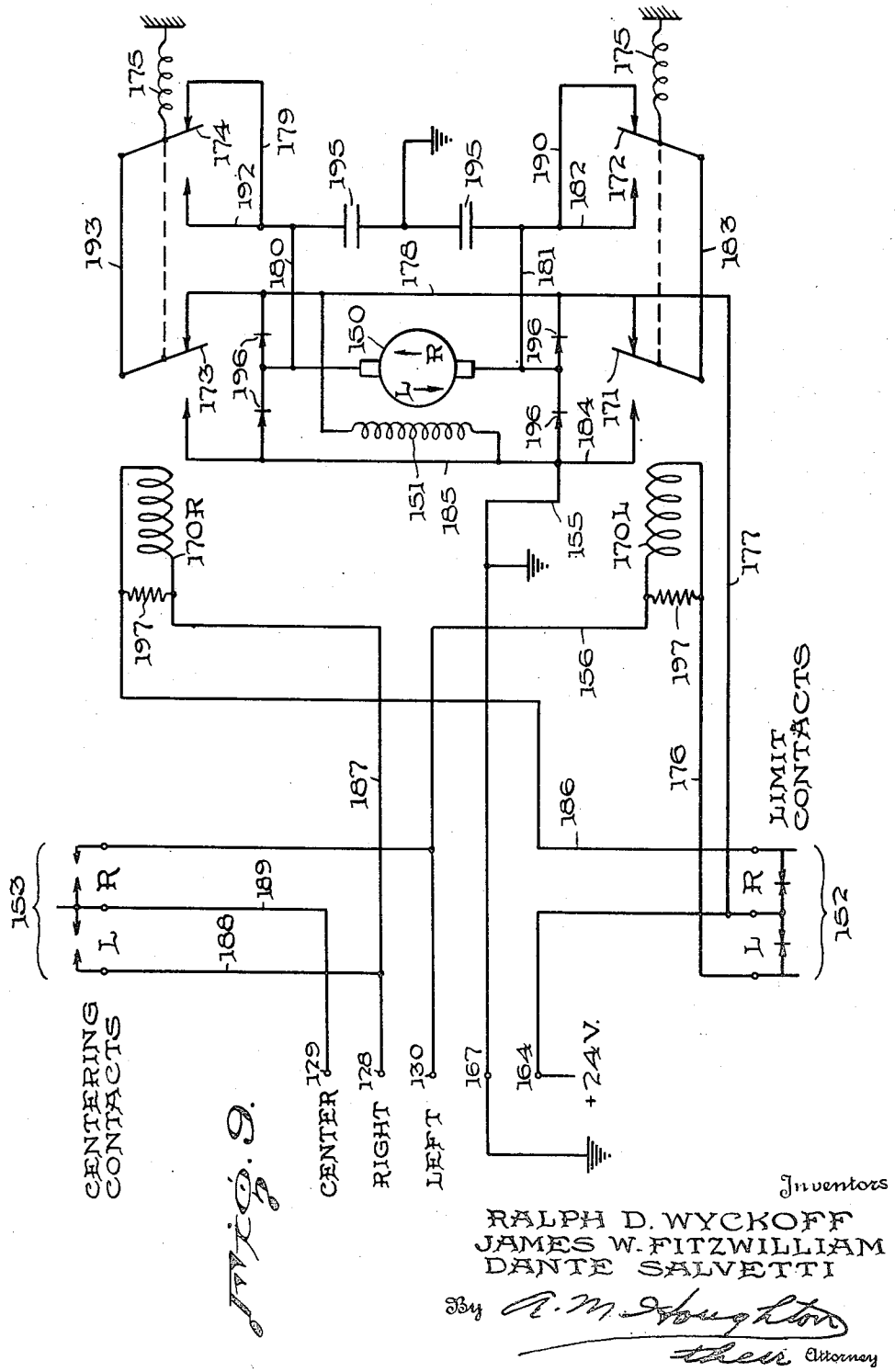
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UNITED STATES PATENT OFFICE

2,495,304

DIRIGIBLE BOMB

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Application May 31, 1946, Serial No. 673,372

11 Claims. (Cl. 102—3)

1

This invention relates to dirigible bombs and particularly to a remotely controlled high-angle bomb having a relatively steep trajectory bearing a general similarity to that of a freely falling bomb as distinguished from gliding bombs, for example, which approach the target at a low angle.

In order effectively to accomplish military bombing from aircraft, it is necessary to have a high percentage of target hits. Numerous aiming techniques have been employed to improve bombing accuracy, and at the present time this has reached a fairly high state of development. When a bomb is dropped so as to fall freely from the bombing plane, various factors are known to affect its trajectory. The magnitudes of these effects have been carefully determined and are customarily taken into consideration by the bombardier or by the automatic mechanism of his aiming apparatus or bomb-sight.

Freely falling bombs are customarily aimed by dropping them at an opportune moment which is indicated by a so-called bomb-sight. These bomb-sights make corrections for such factors as altitude of the plane, wind velocity, plane velocity, etc. However, in spite of careful consideration of the known factors involved, a certain amount of scattering occurs due to uncontrollable effects. Some of these effects are aerodynamic, some mechanical, some atmospheric.

It has been found desirable to steer an otherwise freely falling bomb so as to correct for inaccuracies in aiming and to correct for unforeseeable effects encountered by the bomb in flight. In spite of the relatively high terminal velocities attained by high-angle bombs, we have found that aerodynamic steering of a bomb in flight is both feasible and effective. Bombing accuracy has thereby been improved at least ten-fold.

This invention concerns a steerable bomb remotely controlled from the bombing plane by radio.

In the making of a steerable high-angle bomb, a number of factors must be taken into account. Means for producing deflecting or lift forces must be added in the form of aerodynamic surfaces. In addition, steering surfaces must be provided to maintain the desired angle of attack required for the production of deflecting forces. In order that steering controls be unambiguous, it is necessary to stabilize the bomb and control the space orientation of reference axes thereon. Dynamic stability in flight must be maintained to avoid undue oscillations and gyrations of the bomb. In addition, a number of practical considerations are involved; namely, structural strength must be sufficient to handle the aerodynamic forces required and space requirements should be kept within that permitted on military aircraft.

2

Strategic military requirements dictate a number of factors in the aerodynamic design of control and steering surfaces of a dirigible bomb. These concern principally maneuverability and accuracy. It has been found that a 1000-pound bomb, for example, must have an effective maneuverability of about 100 mils from 15,000 feet; that is, when dropped from 15,000 feet, such a dirigible bomb should be maneuverable over a ground area approximately 1,500 feet in radius. It must, of course, be capable of being accurately guided to the desired target within this area, such accuracy being as high as possible. The above maneuverability necessitates the use of aerodynamic surfaces which develop enough lift forces to produce the required path deflection; that is, it determines the aerodynamic lift that the bomb must generate when yawed at a preferred maximum trim angle with respect to its line of flight.

On the other hand, practical military requirements dictate factors which are not all compatible with the above aerodynamic requirements. Space available on military aircraft is limited and the bomb must be carried in the internal bomb bays of standard bombing planes. Furthermore, the fins and controlling mechanism should desirably be capable of attachment to standard bomb cases. It is obviously also desirable to make the control device as simple and inexpensive as more important requirements permit. These and other considerations have been so balanced in the embodiment of our invention that an operable device having many practical advantages is obtained.

It is an object of this invention to provide a remotely controlled high-angle bomb.

Another object is to provide a high-angle bomb having improved stability in flight.

Another object is to provide a unitary two-component control surface structure which may be readily attached to standard bombs for enabling the latter to be remotely steered in both azimuth and range.

Another object is to provide a two-component steerable bomb in which the control surfaces are disposed in spaced symmetrical relation about the bomb axis.

Another object is to provide a remotely controlled high-angle bomb in which the control sur-

face supports form leading edges for roll stabilizing ailerons.

Another object is to provide a bomb having a novel and advantageous aileron operating mechanism.

Another object is to provide a bomb having an auxiliary aerodynamic lift surface in advance of the control surface for increasing the effect of the latter upon the course of the bomb but which may be removed without appreciable change in trim yaw or pitch angle if the additional maneuverability due to the auxiliary surface is not required.

Another object is to provide a bomb having staggered shroud supports to improve roll stability.

These and other objects of the invention are attained by means of a tail structure having cylindrical symmetry and whose cylindrical lift surfaces are equipped with rudders and elevators remotely controlled by means of radio, the supports for such lift surfaces being equipped with ailerons which are gyro controlled to prevent roll.

Details of the invention are described in the following specification, of which the drawings form a part and in which

Fig. 1 is a side view of the dirigible bomb forming the subject of this invention;

Fig. 2 is a side view of the invention showing the tail structure in section;

Fig. 3 is a rear view of our bomb showing the means for controlling rudders and elevators;

Fig. 4 is a block diagram of the radio transmitting apparatus on the plane for controlling the course of the bomb;

Fig. 5 is a block diagram of the radio apparatus in the bomb responsive to the radio control signals;

Fig. 6 is a schematic electrical wiring diagram of the control apparatus on the bomb;

Fig. 7 is a schematic electrical wiring diagram of the gyro aileron control mechanism;

Fig. 8 is a schematic electrical wiring diagram of the radio relay circuit; and

Fig. 9 is a schematic electrical wiring diagram of a rudder or elevator actuating servo-mechanism.

Referring to Fig. 1, **10** represents the body or war head of a dirigible bomb. The case of the war head **10** and its explosive charge may be of any known type. A fuze mechanism **11** may be either contact or time controlled in known manner. Arming device **12** may be of known anemometer type or alternatively the bomb may be armed mechanically as it leaves the plane. A tail structure **13** is fastened to the end of the war head **10** and attached thereto are shrouds or control surfaces to be described. At the end of the tail structure **13** is attached a flare **14** usually started by a delayed action time fuse as it leaves the plane. The purpose of this flare is to permit the bombardier to easily observe the course of the bomb after it has left the plane. Tail structure **13** also contains radio control equipment for operating the rudders and elevators, such control equipment having exposed antenna **15**. Ailerons may be operated by means of automatic equipment also housed in tail **13**. The operation of these various components will be explained in detail later.

Inasmuch as war head **10**, fuze **11**, arming device **12**, and flare **14** are known devices, they will be omitted in discussion of subsequent figures.

Referring to Fig. 2, tail structure **13** is shown in section in order to more clearly illustrate the manner of operating ailerons and elevators. Fig. 3 is a rear view of the tail with the rear cover and flare removed. Radial supports **16** (Fig. 2) at the forward end of the tail structure support a cylindrical aerodynamic surface **17** whose function will be explained later. A second set of radial supports **18** support aerodynamic surface **19** and attached steering means. Mounted on the trailing edge of supports **18** are ailerons **20** pivoted on a radial torque rod **21** which passes through the interior of support **18**. Fastened to each aileron operating rod **21** is a crank arm **22**. Crank arms **22** may be bifurcated at their outer end and engage a radial pin **23** carried on an angle bracket **23a** welded to a circular plate **24** pivoted at **25** on the axis of the bomb. Thus, plate **24** mechanically ties all four ailerons together and at the same time rotation of plate **24** operates all ailerons simultaneously to cause rotation in the same direction about the axis of the bomb. Eccentric to the axis of plate **24** a rocker arm **26** engages plate **24** through ball and socket joint **27**. Rocker arm **26** may be supported at bearing **50**. The other end of the rocker arm engages the armature of a pair of opposed solenoids **28** so that deflection of plate **24** may be obtained, either clockwise or counterclockwise. The electric current in solenoids **28** is controlled by means of electric contacts mounted on a gyro mechanism housed in tail structure **13** such that upon rotation of the bomb about its axis, tilt of the gyro unit actuates the contact which energizes the appropriate one of solenoids **28** to cause proper deflection of the ailerons to restore roll orientation. Such a gyro unit is described in co-pending application Serial No. 543,168 by Molnar and Carnvale entitled "Gyro bomb stabilizer," and its operation will be described more fully later.

Under certain conditions, aerodynamic forces may act on the bomb which require considerable aileron effect to prevent rotation. Furthermore, in order to avoid increasing the size and capacity of aileron operating mechanism, the efficiency of aileron action should be maintained as high as possible. It is known that by providing ailerons with a leading surface, the aerodynamic efficiency of the ailerons is materially increased. Advantage is taken of this fact in our invention by making the radial supports **18** simultaneously also provide an effective leading surface ahead of the ailerons **20** to augment their lift or aileron effect. We have found that it is desirable to place the ailerons as far back in the stabilizer tail as possible. Ailerons ahead of the stabilizer lift surfaces may still serve as such but produce a backwash which impinges on the tail surface and causes an undesirable oscillation of the bomb. This is especially true when only a pair of ailerons are used forward of the tail surfaces. In our preferred embodiment four ailerons are used and mounted on the trailing edge of the radial struts used to support the rear cylindrical lift surfaces. However, two ailerons may be used if sufficient aileron surface is provided.

In a co-pending application, Serial No. 673,373, filed of even date herewith, by Ralph D. Wyckoff entitled "Aerodynamic surface for dirigible bomb," the advantages of substantially cylindrical control surfaces **17** and **19** are brought out. Inasmuch as radial supports **16** and **18** for the control surfaces **17** and **19**, respectively, represent non-cylindrical structure, there is an opportunity for the development of small rotational forces. These rotational forces may be materially reduced by staggering the rotational position of supports **16** and **18** about the axis of the

bomb. Thus one may use four supports 18, 90 degrees apart, each having an aileron 20 and use four supports 16, also 90 degrees apart, but staggered 45 degrees with respect to the position of supports 18.

When the bomb is in flight and moving in the wind stream in an attitude such as to give aerodynamic surface 19 an angle of attack, the surface 19 produces lift forces at right angles to the wind stream tending to deflect the path of the bomb. We have found that the addition of aerodynamic surface 17 augments the effectiveness of the surface in providing lift such that the maneuverability is materially increased. By proper location of the surfaces 17 and 19 with respect to the center of gravity of the bomb, one may alternatively remove surface 17 without appreciable change in the available trim yaw angle. This results in a reduction in maneuverability to about 60 per cent that of the double shroud arrangement, but under certain conditions this is permissible and the reduction in space required at the tail end of the bomb is ofttimes a compensating advantage. In the disposition of control surfaces on our bomb, the ability to add or subtract lift shroud 17 according to convenience without materially changing the aerodynamic stability of the bomb is an important advantage.

The proper trim angle of the control surface 19 is attained through the use of elevators 29 and rudders 30 (Fig. 1). These are hinged at 31 and 32 (Fig. 1), respectively.

The design of the aerodynamic surfaces 17 and 19 and of the steering surfaces 29 and 30 as well as of the ailerons 20, is governed by the military requirements previously stated. In view of these requirements, the most significant factors in the design of a high angle bomb are:

1. The lift-at-trim, or the lift that the bomb can generate at a preferred maximum trim pitch or yaw angle.
2. The roll torque suffered by the bomb when it is at a trim angle of attack caused by simultaneous deflection of the rudders and the elevators.
3. The weather-cock stability of the bomb over the range of pitch and/or yaw angle through which the bomb moves. One of the variables affecting the period of yaw or pitch oscillations is the stability, and the stability is the only quantity over which the designer has a large measure of control in the event he wishes to modify the period of oscillation.
4. The speed at which the rudders and elevators move when the bomb is being controlled in flight.
5. The size, shape and disposition of the aerodynamic surfaces.

Higher maneuverabilities or higher lifts-at-trim can be achieved by larger aerodynamic surfaces and/or by lower stabilities, whereas accurate steering when correcting small errors with simple "On-Off" control can best be done on a bomb of low maneuverability and high stability. Simple theory and wind tunnel tests show that the lift-at-trim of high-angle bombs increases with size of the aerodynamic surfaces, but decreases with increase in stability. With "On-Off" control, a low maneuverability permits small corrections to be made accurately and high stability permits the use of fast-moving rudders and elevators without the danger of large induced pitch and yaw oscillations and the consequent large roll torques.

Accurate steering of a high-angle bomb requires that the operator be able to effect a corrective deflection rapidly and to remove the control application quickly when the bomb is heading toward the target. Field experience has indicated that reasonably accurate steering can be done if the rudders and elevators move from the undeflected position to the deflected position in from 0.5 sec. to 2.0 secs., although more accurate steering can be done if the controls move even more rapidly. However, the speed of motion of the control surfaces affects the magnitudes of the pitch and yaw oscillations of the bomb, and to keep these amplitudes small it is necessary that the length of time it takes for the elevators or rudders to move from the undeflected position to the deflected position be approximately equal to or greater than the period of oscillation of the bomb in the latter part of its flight. Thus, the stability of the bomb must be adjusted to produce this period, a preferred range of values of which is from 0.3 sec. to 2 secs. for the period of oscillation.

Furthermore, field experiments have indicated that in the correction of large errors more accurate steering can be done if there is available more maneuverability than is necessary to barely correct 100-mill errors by steady and continuous application of control. This extra maneuverability is needed because the error to be corrected is not easily detected immediately after release, hence the operator must wait for about 10 or 15 seconds after release, at which time the aiming error becomes apparent, before he can intelligently direct the bomb. Thus, the maneuverability available in the first 10 seconds of flight is generally wasted. In addition, it is conducive to accurate steering to be able to guide the bomb so that it is headed for the target well before impact. Under this condition, since the aiming error is corrected before impact, it is apparent that the bomb requires more than the minimum maneuverability. Thus, it is desirable to be able to correct by steady application of control, errors whose mil value is two or three times greater than the minimum of 100 mils. We have found that this greater-than-minimum maneuverability requires a lift coefficient of 0.4 to 1.0 for a 1000-lb. bomb, the lift coefficient being defined by:

$$C_L = \frac{L}{qA}$$

where

L=lift force in lbs.

$q=\frac{1}{2}\rho V^2$=dynamic pressure of wind stream in lbs., ρ being the air density in slugs/ft.^{3} and V being the velocity in ft.

A=circular cross-sectional area of bomb body in ft.^{2}

In 1000-lb. bombs with large cylindrical tail cans (13—Figs. 1 and 2), and in order to obtain a stability great enough to produce periods of oscillation of approximately one second, it is necessary that the diameter of the lift and control octagons be greater than the diameter of the bomb body. In general, the greater the ring diameter, the greater the aerodynamic lift and stability. The maximum diameter of shroud ring is fixed by the dimensions of the bomb bay in which it will be carried. Space limitations in standard bomb bays, convenience in attaching the tails to the bombs in the bomb bay, and convenience in shipping the tail units to theaters

of combat make it desirable that the forward lift shroud 17 be attached to the tail cylinder 13, rather than to the war head 10, at the same time making the tail as compact as possible. The length, diameter, and position of the forward lift surface 17 may be adjusted to produce a lift coefficient which lies between 0.4 and 2.0 for a trim pitch or yaw angle of about 15°. We have found that the combination of the two surfaces results in a stability great enough to keep the period of pitch or yaw oscillation below one second during the latter portion of the flight. Further, the size and position of the two surfaces may be so adjusted that the stability and the controllability (defined by the trim yaw angle versus rudder angle relationship), remain approximately the same when the forward surface is removed. Thus, the only significant change in the bomb characteristics that is caused by the removal of the forward surface 17 is a lowering of the bomb lift-at-trim affecting its maneuverability. Without the forward lift surface 17 the bomb may be advantageously used where large error corrections do not have to be made.

We have found that the above aerodynamic characteristics may be attained by making either tail shroud length less than 30 per cent of the bomb length. The shroud length is defined as the dimension parallel to the axis of the bomb, this being the dimension which is commonly called the chord. The bomb length as here used includes the tail structure. We have further found that the sum of the chord lengths of the two tail shrouds should not exceed 50 per cent of the bomb length.

The use of two shrouds separated by an air gap as shown in Figs. 1 and 2 has been found to result in better aileron control and more effective roll stabilization. The two shrouds need not be of equal size. The space between the shrouds permits air flow by the ailerons which otherwise may be shielded. We have found that the space between the two tail shrouds should be greater than 10 per cent of the chord length of the smaller shroud.

In order to obtain effective steering of the bomb and to develop the trim angle of attack, it is necessary to keep within limits in the relation between flap area, flap deflection, and shroud area. We have found that for one component, the product of the total flap area in per cent of total shroud area by the maximum available flap deflection in degrees, should lie between 35 and 325 in order to attain the advantageous aerodynamic characteristics previously mentioned. A similar relationship applies to the ailerons. We have found that the total aileron moving area in per cent of the total shroud area multiplied by the maximum aileron deflection in degrees should lie between 20 and 200 in order to attain satisfactory roll stability.

In Fig. 3 we have shown an end view of the rear control surface 19 so as to illustrate the manner of operating rudders 29 and elevators 30. Each of the flaps 29 and 30 may have welded thereon a small angle bracket 32. Operating rods 33, 33', 34, 34' are hinged at the brackets 32 and extend from the flap inward to operating mechanism inside the tail 13. At the inner end rods 33 and 33' are engaged by a crank pin 36 mounted on the end of a crank arm 37 driven by means of servomotor 38. Servomotor 38, for actuating the elevators, is mounted somewhat off-center in order to give room for a similar servomotor 39 for actuating rods 34 and 34' to the rudders 30. Rods 33' and 34' may be of rectangular section and twisted through 90 degrees at the region where they cross in order to provide clearance between them. Thus, by proper control of servomotors 38 and 39, it is possible to actuate both of the elevators 29 or both of the rudders 30 in the same direction in order to bring lift surfaces 17 and 19 into the proper trim angle for providing the necessary path deflecting forces, these forces being set up through the operation of well-known aerodynamic principles.

Fig. 4 is a block diagram of the radio transmitting equipment carried in the bombing plane and for steering the bomb in its course by means of radio signals. The bombardier in the plane may observe the course of the bomb and from such observation easily determine the deviation required to bring the bomb on target. Signals are transmitted by radio from conventional transmitter 40 having a conventional antenna 41 on the plane. Various known methods of transmitting the necessary signals over such a radio channel may be used, and the one here described is by way of example. Four audio-oscillators F_u, F_d, F_r, F_l are provided, each modulating the radio transmitter 40 at a characteristic audio-frequency when its respective key is pressed. Thus, the bombardier has available four push buttons 42, 43, 44, and 45. If the bomb requires deviation to the right, he may push button 44, which causes oscillator F_r to modulate transmitter 40 at a predetermined frequency. The other oscillators operate at different audio-frequencies, each being controlled by its respective push button. The controlling radio wave, therefore, comprises a carrier frequency modulated by an audio-frequency appropriate to the direction of deviation which the bombardier desires to impart to the bomb. The four push buttons 42, 43, 44, 45 may be combined on a single-control stick as of the so-called "joy stick" variety. The radio circuits may be so arranged that both azimuth and range control may be applied simultaneously, the transmitter in this case being modulated by two audio-frequencies simultaneously and transmitting both of these to the bomb.

Fig. 5 is a block diagram of the radio receiving equipment carried in the bomb and used for responding to the steering signals from the plane. Here 46 represents the antenna, shown in Fig. 1 by numeral 15. Connected thereto is conventional radio receiver 47, including a demodulator which delivers audio signal to four filters, R, L, U, D. These are narrow band pass filters of known type and when an appropriate signal is received, it is passed on to rudder actuator 39 or elevator actuator 38 which in turn deflects the rudders or elevators in the proper sense. The type of control here described by way of example, is a simple On-Off type. In the absence of audio modulation of the radio signal received by 47, the rudder and elevator actuators return to neutral.

In the above embodiment of the radio control, if, for example, the bombardier desires to apply left rudder, he may close contact 45, Fig. 4, and thereby modulate the radio signal at a frequency F_L. The receiver 47 picks up this signal, and passes on a frequency F_L to the filters R, L, U, D. As this frequency may only pass through filter L, there is applied to the rudder actuator 39 a signal which causes the rudders 30 to move to their extreme left position. If none of the contacts 42, 43, 44, 45 are closed by the bombardier, no signal passes the filters D, U, L or R and the rudder and

elevator actuators automatically return to their neutral position by a control to be described later. This method of controlling the steering of the bomb has been found highly satisfactory, but alternatively other control channels or the use of so-called proportional controls may be devised by those skilled in the control art.

The bomb control apparatus will be now described with reference to Figs. 6, 7, 8 and 9 which are schematic wiring diagrams of the various components involved.

Referring to Fig. 6, the bomb is equipped with a so-called kick-off plug 51. All connections and components located below this kick-off plug are contained in the tail member 13 of the bomb. Connections above plug 51 are made on the ship, plug 51 being at the end of a short length of four-wire cable which pulls the plug 51 out after the bomb has moved away a few feet. The four wires 52, 53, 54, 55 serve certain purposes before the bomb is released. As the bomb drops away, the connections to these wires are severed and thereafter the bomb operates on its own as a self-contained unit. Wire 54 connects directly to the ship's ground and serves as an electrical ground before release. Wire 55 connects to the customary electrical bomb release mechanism on the ship and serves to uncage the directional gyro to be described later. An electrical impulse from the release mechanism is imparted at release through wire 55 to perform this function. Wire 53 is connected through switch 56 to +24 volt ship's power supply, this connection serving to supply power to various components of the bomb previous to its release so that all parts will be in operating condition when released. Switch 56 is normally closed a short time before release. Wire 52 connects through switch 57 to the 24 v. ship's power and serves the purpose of arming the tail flare 14 (Fig. 1). This is a safety mechanism to prevent premature operation of the flare. These four wires are severed at contacts 52', 53', 54' and 55' when the kick-off plug pulls out on release, and thereafter the springs of a kick-off switch indicated generally by numeral 58 make other connections as shown. Mechanical interconnections between contact springs are indicated by arms 59 and 60, these being made of insulating material.

Considering now the various components on the bomb itself, these will be described separately. Flare 14 connects through wire 61 to a thermal trip relay 62. The thermal release 63 is connected by the wire 200 to contact 52'. Movable contact 64 is grounded through wire 65. Wire 61 is thus seen to be open until the bombardier closes flare arming switch 57, whereupon thermal unit 63 burns out, permitting contact 64 to connect to wire 61, grounding one side of the flare. The other connection of the flare made through wire 66 connects through current limiting resistor 67 to spring 68 of the kick-off switch. When the kick-off plug pulls out on release, spring 68 connects to spring 69 and is thereby connected via wires 71 and 72 to the 24 v. battery 70 contained in the bomb. The negative terminal of battery 70 is grounded on the bomb. Thus the severing of the kick-off plug closes the above circuit and the battery power ignites the flare fuse. A time-delay fuse allows the bomb approximately eight seconds' drop before the flare ignites.

As previously stated, aileron control to maintain roll orientation of the bomb is obtained through the use of a free or directional gyro spinning in the plane of the trajectory. An auxiliary rate-of-turn gyro maintained in the same plane provides a rate-controlling mechanism. These two gyros properly coupled cooperate to prevent excessive roll oscillation of the bomb. The gyro unit itself forms the subject matter of co-pending application Serial No. 543,168 by Molnar and Carnvale and is indicated generally by numeral 73, and will be described in more detail later. Five wires 74, 75, 76, 77, and 78 are connected to the gyro unit. Wire 74 connects through spring 79 to contact 55' on the kick-off plug and via wire 55 to the bomb release mechanism. An electrical impulse from the release mechanism is transmitted to wire 74 to uncage the gyro at release. In order to make sure that the gyro does uncage properly, spring 79 connects with spring 91 when the kick-off plug is pulled and this serves to connect wire 74 through spring 79, spring 91, and wire 72 to the bomb's battery 70 to effectively actuate the gyro uncaging mechanism.

Wire 75 is seen to connect via wire 102 through current limiting resistor 80 to wire 81 and spring 82, thence through contact 53' and wire 53 to the bombardier's warm-up switch 56. Through this circuit the bombardier may, before release, set the gyros in motion. Subsequent to release; that is, when connection 53' has been broken, power to wire 75 is supplied through wire 83 and spring 84 connecting to spring 85, thence via wire 86 and wire 72 to the battery 70 on the bomb.

One may also note at this point that warm-up switch 56 leading through wire 53, contact 53', spring 82, wire 81, and rectifier 87, wire 88, wire 86, wire 72, supplies ship's power to maintain the 24 v. battery on the bomb fully charged.

Wires 76 and 77 from the gyro unit connect via wires 89 and 90 to aileron control solenoids 91 and 92 (shown also as 28, Fig. 2), the detailed mechanical operation of which has been described in connection with Fig. 2. Wire 78 serves as a ground for the gyro unit. Wire 107 serves as ground return for the aileron control solenoids via springs 108 and 109 and wire 110. Thus until the kick-off plug has been released the aileron solenoids cannot be energized.

Fig. 7 is a detailed schematic diagram of the gyro unit 73, connections 74, 75, 76, 77, and 78 being made to wires of the same number in Fig. 6. After the bomb has been released, connection 74 is made to the positive terminal of the bomb's battery, as previously described thus actuating the gyro uncaging solenoid 97. Terminal 75, after release, also connects to the bomb's battery as previously described, thus supplying power to the gyro motors 93 and 94 through radio-frequency choke 95 and condenser bypass 96 to ground. Choke 95 and condenser 96 serve as a filter to prevent commutator interference with other apparatus on the bomb.

Terminal 74 also supplies power to the center contacts 98 and 99 of a relay whose coil is shown at 100. Contacts 98 and 99 are biased to connect to springs 101 and 102 when coil 100 is not energized. When relay 100 is energized, contacts 98 and 99 connect to springs 103 and 104. Relay 100 is energized from connection 74 and controlled through contactors 105 and 106 mounted on the gyro gimbals in a manner described in the aforementioned Molnar and Carnvale application. When relay 100 is not energized, the contact springs 98 and 99 lead to contacts 101 and 102 and battery power from terminal 74 is supplied to terminal 76. Contactors 105 and 106 are so arranged that when the bomb rolls past neutral in the opposite direction and relay 100 is ener-

gized, contact springs 98 and 99 supply energy to terminal 77 through contacts 103 and 104. Relay coil 100 has resistor shunt 111 to prevent chattering and the relay contacts have shunts 112 to prevent sparking. The two sets of relay contacts 98 and 99 are provided to handle the aileron solenoid current without heating or sticking.

Returning to Fig. 6, it is seen that wire 76 connects to wire 89 and energizes counterclockwise solenoid 92, current returning to ground via wire 107, spring 108, spring 109, and wire 110. If terminal 77 is energized, wire 77 (Fig. 6) leads through wire 90 and clockwise solenoid coil 91 and to ground through wire 107, spring 108, spring 109, and wire 110. Thus, it is seen that the gyro unit controls the operation of either clockwise aileron solenoid 91 or counterclockwise aileron solenoid 92.

Details of gyro mechanism 105 and 106 are contained in the aforementioned Molnar and Carnvale application and do not form a part of this invention per se. It is sufficient to point out here that the contactor 106 coupled to the direction gyro opens the ground connection to the relay coil 100 on one side of the equilibrium position and closes it on the other. The ailerons are thus always at one extreme position or the other, producing slight roll of the bomb about the proper orientation. This roll is prevented from becoming excessive by the action of the rate gyro coupled to contactor 105. Contactor 105 opens the ground connection to relay 100 at a rate-of-roll exceeding about 5°–10° in one direction, and closes the ground to relay 100 at a rate-of-roll exceeding the same amount in the other direction (i. e., when contactor 105 is opening). In addition, the direction and rate-of-roll gyros described in the above-mentioned Molnar and Carnvale application are coupled together in such manner that zero position on the direction gyro varies with displacement of the rate gyro and hence with the rolling of the bomb. The effect of this coup'ing is to permit a speed of rotation proportional to the displacement of the bomb from its equilibrium position and this materially improves the roll stability attained by the gyro control.

Referring again to Fig. 6, the radio equipment on the bomb is shown generally by numeral 134 having terminals 126 to 133. Radio equipment 134 comprises a receiver, shown also as 47 in Fig. 5, and four filters shown in Fig. 5 as D, U, L, and R. Radio 134 receives its signals from antenna 138 which is shown also as 46 in Fig. 5 and 15 in Fig. 1. Terminal 126 is connected to ground through wire 137. The radio receives its power through terminal 127 supplied with 24 v. power through wires 162 and 83, springs 84 and 85, wires 86 and 72. However, prior to release of the bomb and before the kick-off plug is released, the radio receiver obtains warm-up power through wire 162, resistor 80, wire 81, spring 82, contact 53', wire 53 to the bombardier's warm-up switch 56. Terminals 128, 129, and 130 are connected to the rudder actuator while terminals 131, 132, and 133 are connected to the elevator actuator. The actuators themselves will be described in connection with Fig. 9, but the radio equipment serves by means of relays to apply a ground to the appropriate connection desired. In the absence of a control signal, terminals 129 and 132 are grounded and the elevators and rudders return to center position. Thus, for right rudder, the radio apparatus grounds terminal 128, at the same time opening the ground on centering terminal 129. Similarly, for left rudder, terminal 130 is grounded and the ground on 129 is opened. These connections are accomplished by a relay circuit shown in Fig. 8.

In Fig. 8, numerals 113, 114, 115, 116 represent the plate connection of the last tube of the previously mentioned audio filters D, U, L, and R, respectively, each of these plates being connected through relay coil 117, 118, 119, 120 to a common high potential terminal 121 leading to the radio plate power supply. Armature contact springs 122, 123, 124, 125 are normally connected to the right-hand contact. Upon energizing the relay coil, the center spring is drawn over to the left-hand contact. The diagram (Fig. 8) indicates how the contacts are connected to the terminals 128 to 133, these being the same terminals as those of the same numbers in Fig. 6. Thus, if no steering signal is applied, the relays will be in the position shown, and terminal 132 is connected to ground through wire 139, contact 122, wire 140, contact 123, and wires 141 and 142. Terminal 129 is also connected to ground through wire 143, contact 124, wire 144, contact 125, and wire 142. If the bombardier applies a signal of proper frequency to actuate the D (down) filter, relay 117 pulls contact 122 to the left. This grounds terminal 133 through left contact 122, wire 140, contact 123, wires 141 and 142. At the same time the ground on center connection 132 is broken at 122. For up elevator, relay 118 is actuated and spring 123 drawn to the left, which grounds terminal 131 through wire 145, left-hand contact 123, wires 141 and 142. At the same time the ground on center terminal 132 is opened at the right side of 123. For left rudder, relay 119 draws contact 124 to the left. This connects terminal 130 to ground via wire 146, left-hand contact 124, wire 144, contact 125, and wire 142. At the same time the ground on center terminal 129 is opened at the right side of 124. For right rudder, terminal 128 is grounded through wire 147, left-hand contact 125, and wire 142, at the same time opening the ground on center terminal 129 at the right side of 125. Keeping in mind that the application of steering signal merely grounds the appropriate terminal on the rudder or elevator actuator mechanism, we shall now describe these mechanisms by reference to Fig. 9.

The rudder and elevator actuating mechanisms are indicated in Fig. 6 by numerals 160 and 161. These mechanisms are both alike and are energized with 24 v. power from the bomb battery through a circuit as follows: wire 72, wire 88, spring 85, spring 84, wire 83, wire 162, wires 163 and 164 to the rudder actuator and 165 to the elevator actuator. A ground connection is obtained through wires 166, 168 and 137. The other three terminals on each of the actuating mechanisms go to radio terminals 128 to 133 previously referred to. Inasmuch as both actuating mechanisms are alike, only one will be described in detail.

Fig. 9 is a schematic wiring diagram of one of the actuating mechanisms for the steering surfaces. The mechanism consists of a shunt wound D.-C. motor whose field is indicated by 151 and armature by 150. This motor operates through a gear train to rotate arm 37 of Fig. 3. The principle of operation is that when left rudder signal is received, the actuating motor moves the rudders to the extreme left position. If no signal is received, the actuating motor automatically returns the rudder to the center position. Right rudder signal moves the rudder

to the extreme right position, etc. To assist in executing these movements, the arm 37 of Fig. 3 operates through appropriate cams to switches 152 and 153 (Fig. 9). Numeral 152 represents a limit switch mechanically so arranged that when the motor arm 37 reaches its extreme right position, contact 152R is mechanically opened. On the other hand, in the application of left rudder, when the motor arm reaches its extreme left position it mechanically opens contact 152L. In all intermediate positions of the arm, both contacts 152L and 152R are closed. Another cam on arm 37 operates a centering switch 153. Contacts on this switch are so arranged that they are both open only over a very small region at the center position. Contacts 153R and 153L are closed, respectively, when the arm 37 is off center to the right or left, respectively. A relay having coil 170R, when energized, moves contacts 173 and 174 to the left. Another relay 170L, when energized, moves contacts 171 and 172 to the left. Contacts 171, 172, 173, 174 are returned to the right-hand position by springs 175 when the relay coils are de-energized. Terminal 164 is connected to the 24 v. supply; terminal 167 is the ground connection; and terminals 128, 129, and 130 go to the corresponding connections on the radio (see Fig. 6). Bearing in mind the mechanical operation of switches 152 and 153 and of relays 170R and 170L, and the fact that radio control of Fig. 8 merely grounds the desired terminal 128, 129, or 130, we shall now describe the operation of the actuating mechanism of Fig. 9.

We shall assume for example that the rudders are originally in the center position so that contacts 153L and R are both open, contacts 152L and R are both closed, such being the situation when no signal is applied. Upon the application of left rudder signal, the radio relay 119 (Fig. 8) will ground terminal 130 (Fig. 9). Current then flows through the circuit as follows: 24 v. current enters through wire 164, contacts 152, wire 176, relay coil 170L, wire 156 to the ground on terminal 130. This pulls contacts 171 and 172 to the left and the current flows from wire 164, wire 177, wire 178, contact 173, wire 193, contact 174, wire 179, wire 180 downward through motor armature 150, wire 181, wire 182, contact 172 left, wire 183, contact 171 left, wires 184, 155 to ground. At the same time the current flows from 164 through 177 and 178 to the motor field 151, wire 185 and wire 155 to ground. The motor subsequently rotates to push the rudders to the left until the left limit is reached, whereupon arm 37 (Fig. 2) opens contact 152L, thereby releasing contacts 171 and 172 to cut off the motor. The motor will remain in this position as long as left rudder is being applied; namely, as long as terminal 130 is the only one grounded. If, however, the bombardier ceases to apply left rudder, then the radio relay (Fig. 8) opens the ground on 130 and automatically applies a ground on 129. The 24 v. power now flows as follows: through wire 164, contact 152R, wire 186, relay 170R, wire 187, wire 188, contact 153L, wire 189, to terminal 129. This energizes relay 170R, moving contacts 173 and 174 to the left. Current may now flow through the motor armature as follows: wire 164, wire 177, contact 171, wire 183, contact 172, wire 190, wire 181, upward through armature 150, wire 180, wire 192, contact 174 left, wire 193, contact 173 left, wire 185, and wire 155 to ground. This causes right-hand rotation of the motor until the center is reached, whereupon contact 153L opens. This breaks the circuit through relay 170R, releasing contacts 173 and 174 and shutting off the motor. The application of right rudder grounds terminal 128 and removes the ground from terminal 129 and the subsequent operation of the device is very similar to that when left rudder is applied except that direction of current flow in the armature is such as to produce right-hand rotation. If, after the application of right rudder, the steering signal is removed, the motor returns to center in essentially the same manner as above described. If the bombardier desires to do so, he may apply right rudder immediately after the application of left rudder or vice versa, in which case the motor does not stop at the center position but continues to the extreme of whichever position is desired. In order to eliminate commutator interference, condensers 195 are connected across the armature and grounded at their mid-point as indicated. Rectifiers 196 are connected as shown in order to further reduce commutator interference. Resistors 197 may be connected across relay coils 170R and 170L in order to reduce chattering. The elevator actuating mechanism is identical to that described above except that its motor actuates the elevator surfaces instead of rudder surfaces. Since the two actuating mechanisms are entirely independent, the bombardier may, if he desires, apply both rudder and elevator control simultaneously.

Having thus described our invention and its operating details it is apparent that various changes and modification may be made by one skilled in the art. Thus, while we have shown a simple form of On-Off control, both in the control of the ailerons and the rudders and elevators, a proportional type of control may be used as well. Other forms of control surfaces may be employed within the scope of our invention. Furthermore, our invention may be used with any type of dirigible bomb and may be used for bombing moving as well as stationary targets.

What we claim as our invention is:

1. A dirigible missile comprising a war head, a unitary tail structure, a substantially cylindrical aerodynamic control surface fixedly mounted on said tail structure, radial supports which attach said control surface to the tail structure, aerodynamic steering surfaces operably mounted on the trailing edge of said cylindrical control surface, means contained in said tail structure operating one alternate pair of steering surfaces as rudders which place the missile into an attitude of yaw so that the associated control surface may produce forces deflecting the path of the missile, means contained in said tail structure operating the other alternate pair of steering surfaces as elevators which place the missile in an attitude of pitch so that the associated control surface may produce forces deflecting the path of the missile, a radio antenna mounted on said tail structure and connected to means contained in said tail structure receiving and transducing a radio signal, means contained in said tail structure controlling said rudder operating means and said elevator operating means in response to the character of the radio signal received, ailerons operably mounted on the trailing edge of said radial supports, means contained in said tail structure operating said ailerons in unison tending to axially rotate the missile, and gyroscopic means contained in said tail structure controlling said aileron operating means so that resulting aileron action maintains

the missile's rotational orientation such that the rudder and elevator hinge axes lie in vertical and horizontal planes respectively.

2. A dirigible missile comprising a war head, a unitary tail structure, two substantially cylindrical aerodynamic control surfaces fixedly mounted on said tail structure, staggered radial supports which attach said control surfaces to the tail structure, aerodynamic steering surfaces operably mounted on the trailing edge of one of said cylindrical control surfaces, means contained in said tail structure operating one alternate pair of steering surfaces as rudders which place the missile into an attitude of yaw so that the associated control surface may produce forces deflecting the path of the missile, means contained in said tail structure operating the other alternate pair of steering surfaces as elevators which place the missile in an attitude of pitch so that the associated control surface may produce forces deflecting the path of the missile, a radio antenna mounted on said tail structure and connected to means contained in said tail structure receiving and transducing a radio signal, means contained in said tail structure controlling the rudder operating means and the elevator operating means in response to the character of the radio signal received, ailerons operably mounted on the trailing edge of diametrically opposite radial supports, said ailerons being mounted on torque rods having a bifurcated crank arm on their inner extremity, an axially pivoted plate having radial pins engaging the bifurcation of each aileron crank arm, solenoid means rotating said pivoted plate, gyroscopic means contained in said tail structure controlling said aileron operating solenoids so that resulting aileron action maintains the missile's rotational orientation such that the rudder and elevator hinge axes lie in vertical and horizontal planes respectively, a flare making visible the missile in its path, and means for igniting the flare and initiating operation of the aforesaid control means on release of the missile.

3. A dirigible missile comprising a war head, a unitary tail structure, substantially cylindrical aerodynamic control surfaces fixedly mounted on said tail structure, radial supports which attach said control surface to the tail structure, aerodynamic steering surfaces operably mounted on the trailing edge of said cylindrical control surface, means contained in said tail structure operating one alternate pair of steering surfaces as rudders which place the missile into an attitude of yaw so that the associated control surface may produce forces deflecting the path of the missile, means contained in said tail structure operating the other alternate pair of steering surfaces as elevators which place the missile in an attitude of pitch so that the associated control surface may produce forces deflecting the path of the missile, a radio antenna mounted on said tail structure, means contained in said tail structure receiving and transducing a radio signal, means contained in said tail structure controlling the rudder operating means in such manner that the rudders are urged into their extreme steering positions in response to a selected frequency of modulation of the received radio signal, means contained in said tail structure controlling the elevator operating means in such manner that the elevators are urged into their extreme steering position in response to a different selected frequency of modulation of the received radio signal, ailerons operably mounted on the trailing edge of diametrically opposite radial supports, means contained in said tail structure operating said ailerons in unison tending to axially rotate the missile, and gyroscopic means contained in said tail structure controlling said aileron operating means so that resulting aileron action maintains the missile's rotational orientation such that the rudder and elevator hinge axes lie in vertical and horizontal planes respectively.

4. A dirigible missile comprising a war head, a unitary tail structure, a substantially prismatic aerodynamic control surface fixedly mounted on said tail structure, a substantially prismatic aerodynamic control surface removably mounted on said tail surface at a location such that the missile remains stable on removal thereof, staggered radial supports which attach said control surfaces to the tail structure, aerodynamic steering surfaces operably mounted on a straight portion of the trailing edge of said fixed prismatic control surfaces, means contained in said tail structure operating one alternate pair of steering surfaces as rudders which place the missile into an attitude of yaw so that the associated control surface may produce forces deflecting the path of the missile, means contained in said tail structure operating the other alternate pair of steering surfaces as elevators which place the missile in an attitude of pitch so that the associated control surface may produce forces deflecting the path of the missile, a radio antenna mounted on said tail structure and connected to means contained in said tail structure receiving and transducing a radio signal, means contained in said tail structure controlling the rudder operating means and the elevator operating means in response to the character of the radio signal received, ailerons operably mounted on the trailing edge of said radial supports, means contained in said tail structure operating said ailerons in unison tending to axially rotate the missile, gyroscopic means contained in said tail structure controlling said aileron operating means so that resulting aileron action maintains the missile's rotational orientation such that the rudder and elevator hinge axes lie in vertical and horizontal planes respectively.

5. A dirigible missile comprising a war head, a unitary tail structure, a substantially cylindrical aerodynamic control surface fixedly mounted on said tail structure, said control surface being dimensioned to impart to the missile a period of oscillation of from 0.3 to 2 seconds, radial supports which attach said control surface to the tail structure, aerodynamic steering surfaces operably mounted on the trailing edge of said cylindrical control surface, means contained in said tail structure operating one alternate pair of steering surfaces as rudders which place the missile into an attitude of yaw so that the associated control surface may produce forces deflecting the path of the missile, means contained in said tail structure operating the other alternate pair of steering surfaces as elevators which place the missile in an attitude of pitch so that the associated control surface may produce forces deflecting the path of the missile, a radio antenna mounted on said tail structure and connected to means contained in said tail structure receiving and transducing a radio signal, means contained in said tail structure controlling the rudder operating means and the elevator operating means in response to the character of the radio signal received, ailerons operably mounted on the trailing edge of said radial supports, means contained in

said tail structure operating said ailerons in unison tending to axially rotate the missile, and gyroscopic means contained in said tail structure controlling said aileron operating means so that resulting aileron action maintains the missile's rotational orientation such that the rudder and elevator hinge axes lies in vertical and horizontal planes respectively.

6. A dirigible missile comprising a war head, a unitary tail structure, a substantially cylindrical aerodynamic control surface fixedly mounted on said tail structure, said control surface being dimensioned to impart a lift coefficient at maximum trim of from 0.4 to 2.0, radial supports which attach said control surface to the tail structure, aerodynamic steering surfaces operably mounted on the trailing edge of said cylindrical control surface, means contained in said tail structure operating one alternate pair of steering surfaces as rudders which place the missile into an attitude of yaw so that the associated control surface may produce forces deflecting the path of the missile, means contained in said tail structure operating the other alternate pair of steering surfaces as elevators which place the missile in an attitude of pitch so that the associated control surface may produce forces deflecting the path of the missile, a radio antenna mounted on said tail structure and connected to means contained in said tail structure receiving and transducing a radio signal, means contained in said tail structure controlling the rudder operating means and the elevator operating means in response to the character of the radio signal received, ailerons operably mounted on the trailing edge of said radial supports, means contained in said tail structure operating said ailerons in unison tending to axially rotate the missile and gyroscopic means contained in said tail structure controlling said aileron operating means so that resulting aileron action maintains the missile's rotational orientation such that the rudder and elevator hinge axes lie in vertical and horizontal planes respectively.

7. A dirigible missile comprising a war head, a unitary tail structure, a substantially cylindrical aerodynamic control surface fixedly mounted on said tail structure, said control surface having a length less than 30 per cent of the total length of the missile, radial supports which attach said control surfaces to the tail structure, aerodynamic steering surfaces operably mounted on the trailing edge of said cylindrical control surface, means contained in said tail structure operating one alternate pair of steering surfaces as rudders which place the missile into an attitude of yaw so that the associated control surface may produce forces deflecting the path of the missile, means contained in said tail structure operating the other alternate pair of steering surfaces as elevators which place the missile in an attitude of pitch so that the associated control surface may produce forces deflecting the path of the missile, a radio antenna mounted on said tail structure and connected to means contained in said tail structure receiving and transducing a radio signal, means contained in said tail structure controlling the rudder operating means and the elevator operating means in response to the character of the radio signal received, ailerons operably mounted on the trailing edge of said radial supports, means contained in said tail structure operating said ailerons in unison tending to axially rotate the missile, and gyroscopic means contained in said tail structure controlling said aileron operating means so that resulting aileron action maintains the missile's rotational orientation such that the rudder and elevator hinge axes lie in vertical and horizontal planes respectively.

8. A dirigible missile comprising a war head, a unitary tail structure, two substantially cylindrical aerodynamic control surfaces fixedly mounted on said tail structure, the sum of the chord lengths of said control surfaces being less than 50 per cent of the total length of the missile, radial supports which attach said control surfaces to the tail structure, aerodynamic steering surfaces operably mounted on the trailing edge of said cylindrical control surface, means contained in said tail structure operating one alternate pair of steering surfaces as rudders which place the missile into an attitude of yaw so that the associated control surface may produce forces deflecting the path of the missile, means contained in said tail structure operating the other alternate pair of steering surfaces as elevators which place the missile in an attitude of pitch so that the associated control surface may produce forces deflecting the path of the missile, a radio antenna mounted on said tail structure and means contained in said tail structure receiving and transducing a radio signal, means contained in said tail structure controlling the rudder operating means and the elevator operating means in response to the character of the radio signal received, ailerons operably mounted on the trailing edge of said radial supports, means contained in said tail structure operating said ailerons in unison tending to axially rotate the missile, and gyroscopic means contained in said tail structure controlling said aileron operating means so that resulting aileron action maintains the missile's rotational orientation such that the rudder and elevator hinge axes lie in vertical and horizontal planes respectively.

9. A dirigible missile comprising a war head, a unitary tail structure, two substantially cylindrical aerodynamic control surfaces fixedly mounted on said tail structure, said control surfaces being separated by a distance greater than 10 per cent of the chord length of the smaller surface, radial supports which attach said control surfaces to the tail structure, aerodynamic steering surfaces operably mounted on the trailing edge of said cylindrical control surface, means contained in said tail structure operating one alternate pair of steering surfaces as rudders which place the missile into an attitude of yaw so that the associated control surface may produce forces deflecting the path of the missile, means contained in said tail structure operating the other alternate pair of steering surfaces as elevators which place the missile in an attitude of pitch so that the associated control surface may produce forces deflecting the path of the missile, a radio antenna mounted on said tail structure and connected to means contained in said tail structure receiving and transducing a radio signal, means contained in said tail structure controlling the rudder operating means and the elevator operating means in response to the character of the radio signal received, ailerons operably mounted on the trailing edge of said radial supports, means contained in said tail structure operating said ailerons in unison tending to axially rotate the missile, and gyroscopic means contained in said tail structure controlling said aileron operating means so that resulting aileron action maintains the missile's rotational orientation such that the

rudder and elevator hinge axes lie in vertical and horizontal planes respectively.

10. A dirigible missile comprising a war head, a unitary tail structure, a substantially cylindrical aerodynamic control shroud fixedly mounted on said tail structure, radial supports which attach said control shroud to the tail structure, aerodynamic steering flaps operably mounted on the trailing edge of said cylindrical control shroud, said steering flaps being dimensioned so that the total flap area in per cent of total shroud area multiplied by the maximum available flap deflection in degrees lies between 35 and 325, means contained in said tail structure operating one alternate pair of steering surfaces as rudders which place the missile into an attitude of yaw so that the associated control surface may produce forces deflecting the path of the missile, means contained in said tail structure operating the other alternate pair of steering surfaces as elevators which place the missile in an attitude of pitch so that the associated control surface may produce forces deflecting the path of the missile, a radio antenna mounted on said tail structure and connected to means contained in said tail structure receiving and transducing a radio signal, means contained in said tail structure controlling the rudder operating means and the elevator operating means in response to the character of the radio signal received, ailerons operably mounted on the trailing edge of said radial supports, means contained in said tail structure operating said ailerons in unison tending to axially rotate the missile, and gyroscopic means contained in said tail structure controlling said aileron operating means so that resulting aileron action maintains the missile's rotational orientation such that the rudder and elevator hinge axes lie in vertical and horizontal planes respectively.

11. A dirigible missile comprising a war head, a unitary tail structure, a substantially cylindrical aerodynamic control shroud fixedly mounted on said tail structure, radial supports which attach said control shroud to the tail structure, aerodynamic steering surfaces operably mounted

on the trailing edge of said cylindrical control shroud, means contained in said tail structure operating one alternate pair of steering surfaces as rudders which place the missile into an attitude of yaw so that the associated control surface may produce forces deflecting the path of the missile, means contained in said tail structure operating the other alternate pair of steering surfaces as elevators which place the missile in an attitude of pitch so that the associated control surface may produce forces deflecting the path of the missile, a radio antenna mounted on said tail structure and connected to means contained in said tail structure receiving and transducing a radio signal, means contained in said tail structure controlling the rudder operating means and the elevator operating means in response to the character of the radio signal received, ailerons operably mounted on the trailing edge of said radial supports, said ailerons being dimensioned so that the total moving area thereof in per cent of the total shroud area multiplied by the maximum aileron deflection in degrees lies between 20 and 200, means contained in said tail structure operating said ailerons in unison, and gyroscopic means contained in said tail structure controlling said aileron operating means so that resulting aileron action maintains the missile's rotational orientation such that the rudder and elevator hinge axes lie in vertical and horizontal planes respectively.

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