

April 5, 1949.

R. D. WYCKOFF ET AL

2,466,528

DIRIGIBLE BOMB

Filed May 31, 1946

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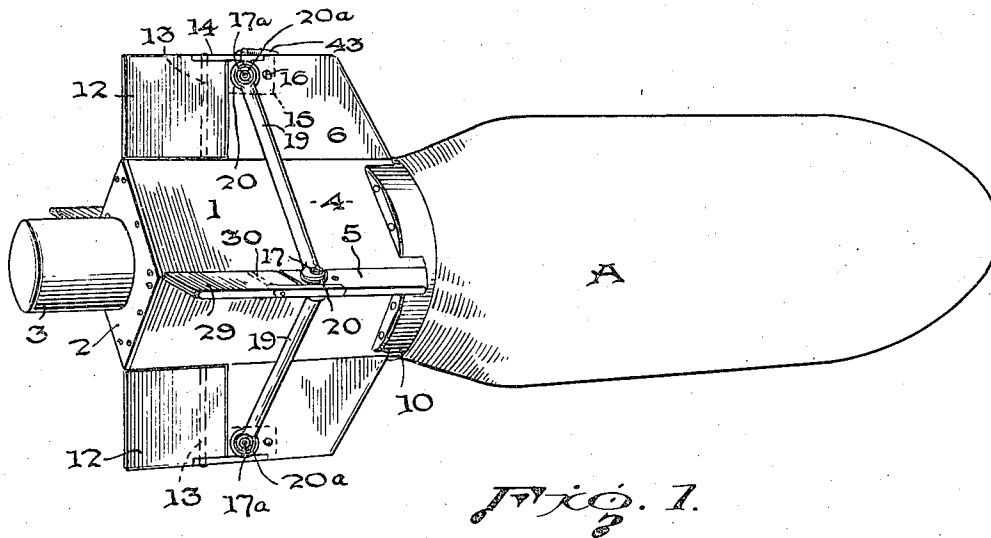


Fig. 1.

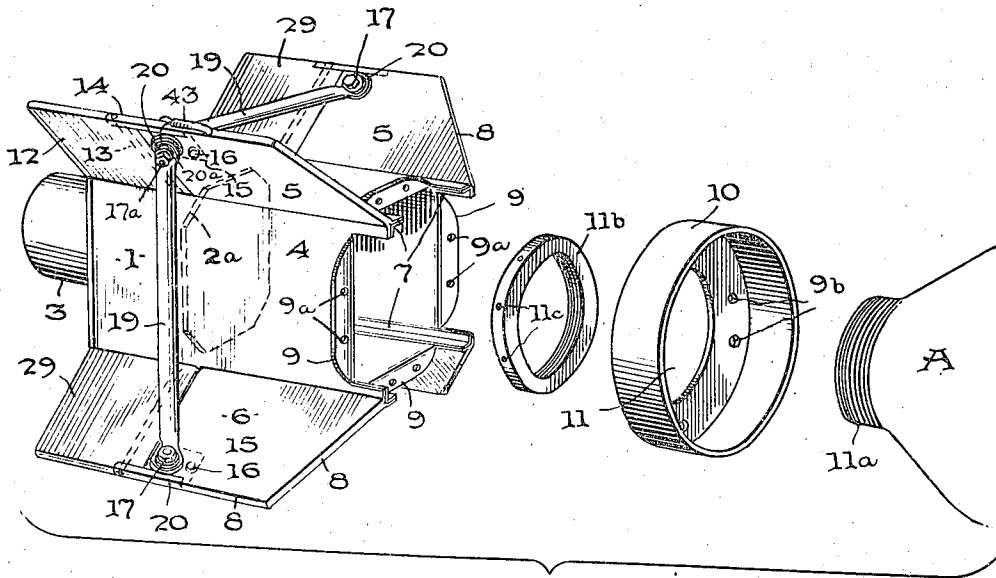


Fig. 2.

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8 Sheets-Sheet 2

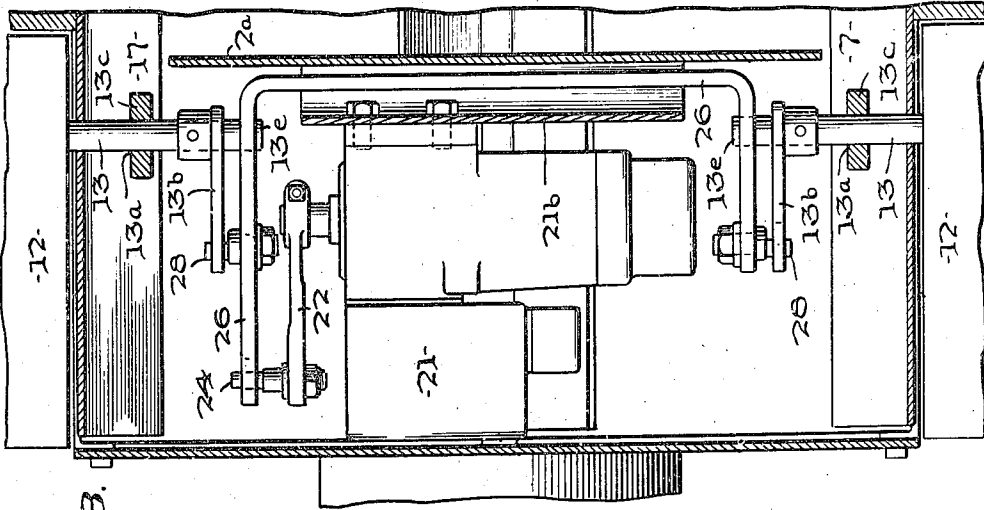


Fig. 3.

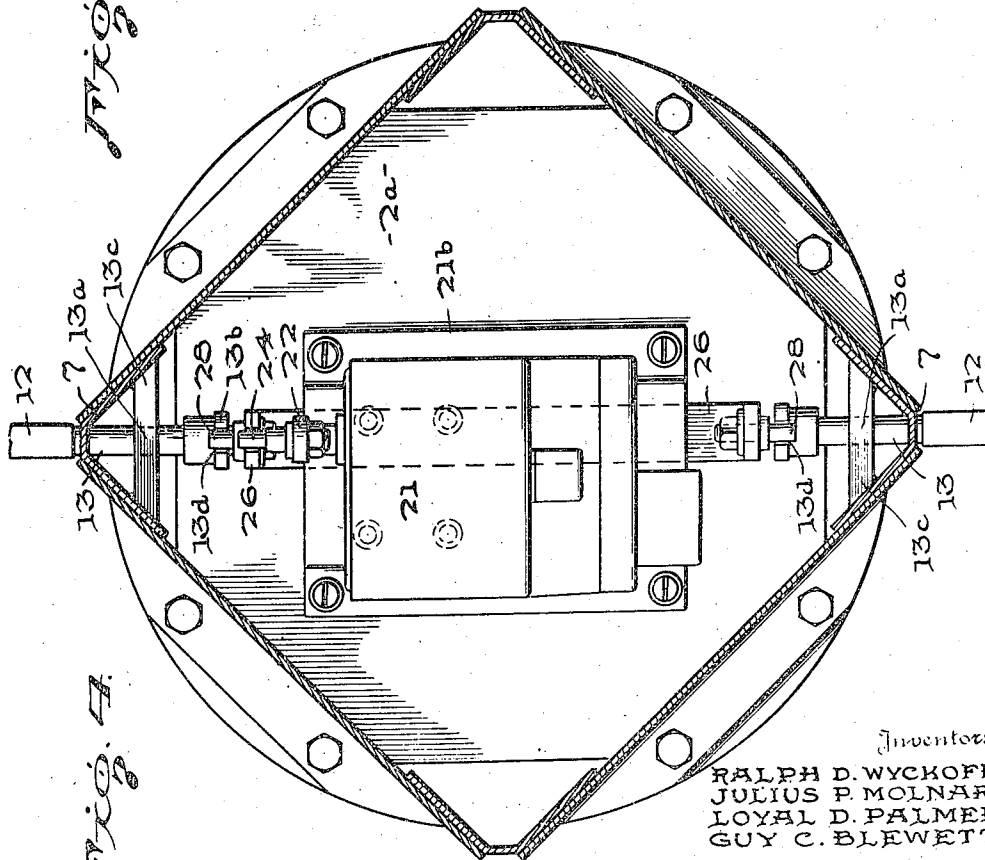


Fig. 4.

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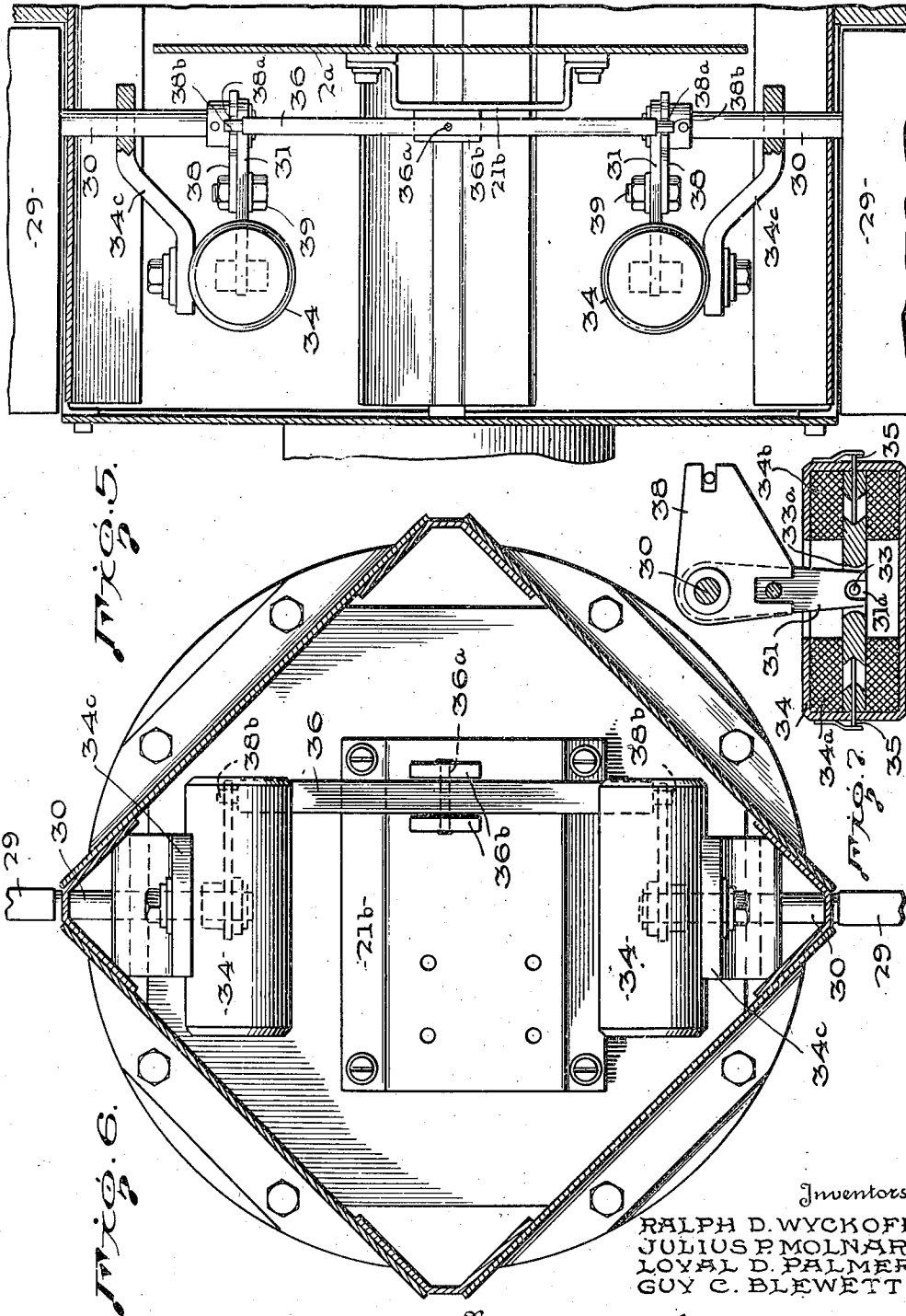
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Filed May 31, 1946

8 Sheets-Sheet 4

Fig. 11.

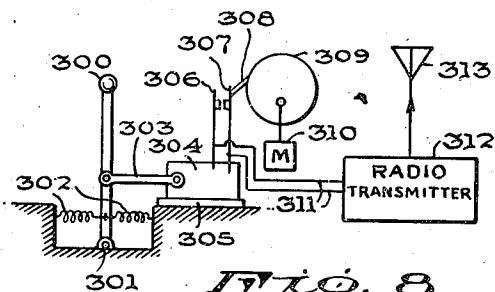
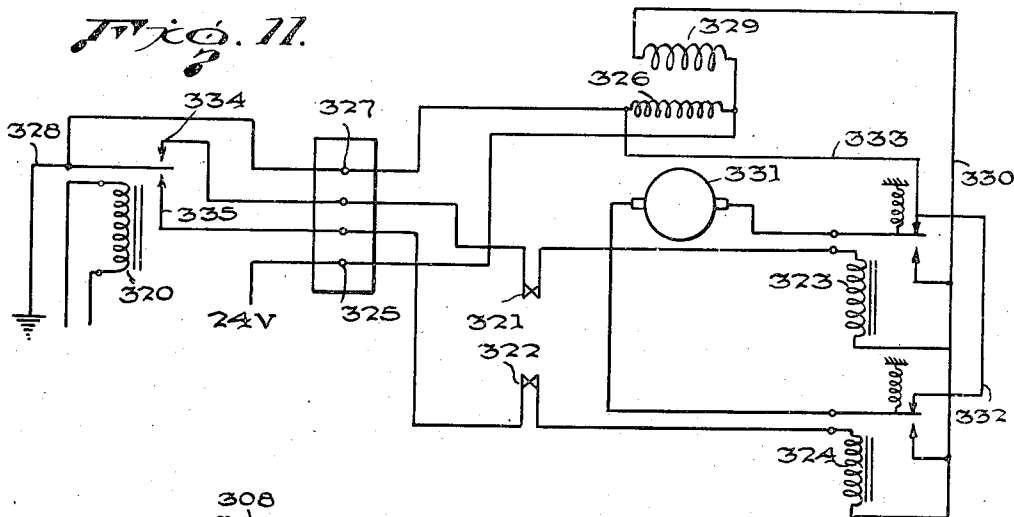


Fig. 8.

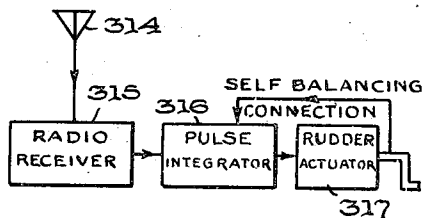


Fig. 9.

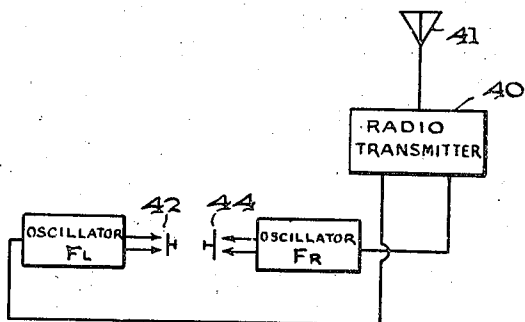


Fig. 12.

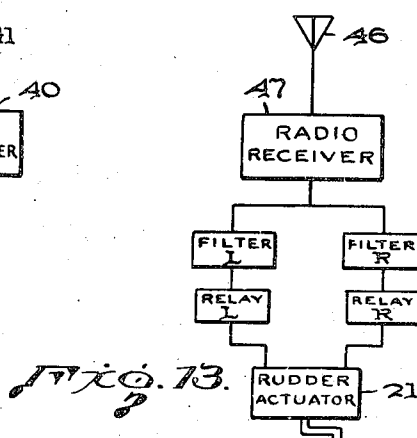


Fig. 13.

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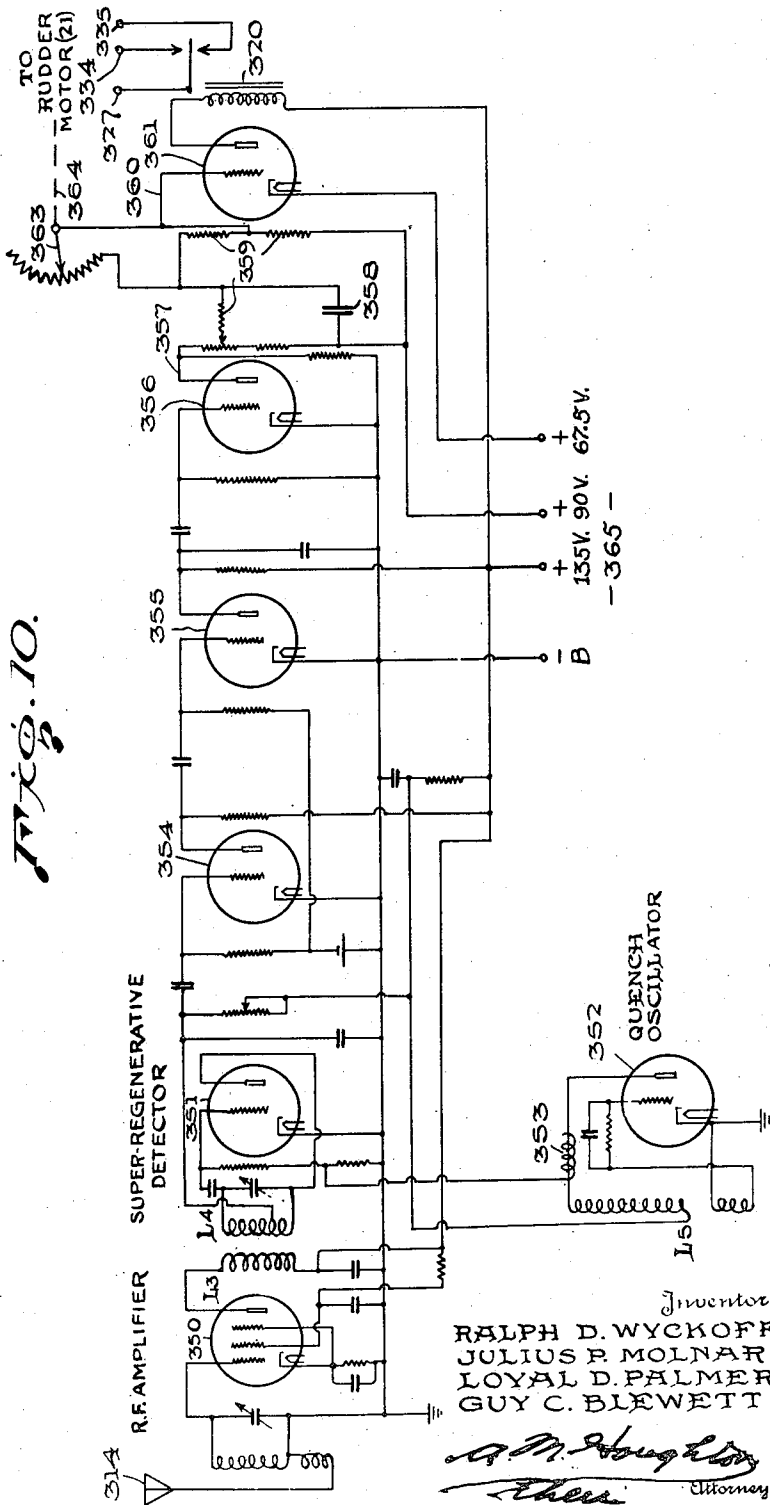
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Filed May 31, 1946

8 Sheets-Sheet 5.



April 5, 1949.

R. D. WYCKOFF ET AL

2,466,528

DIRIGIBLE BOMB

Filed May 31, 1946

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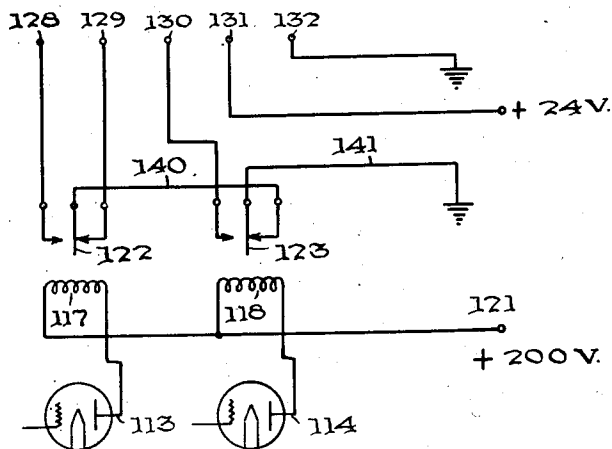
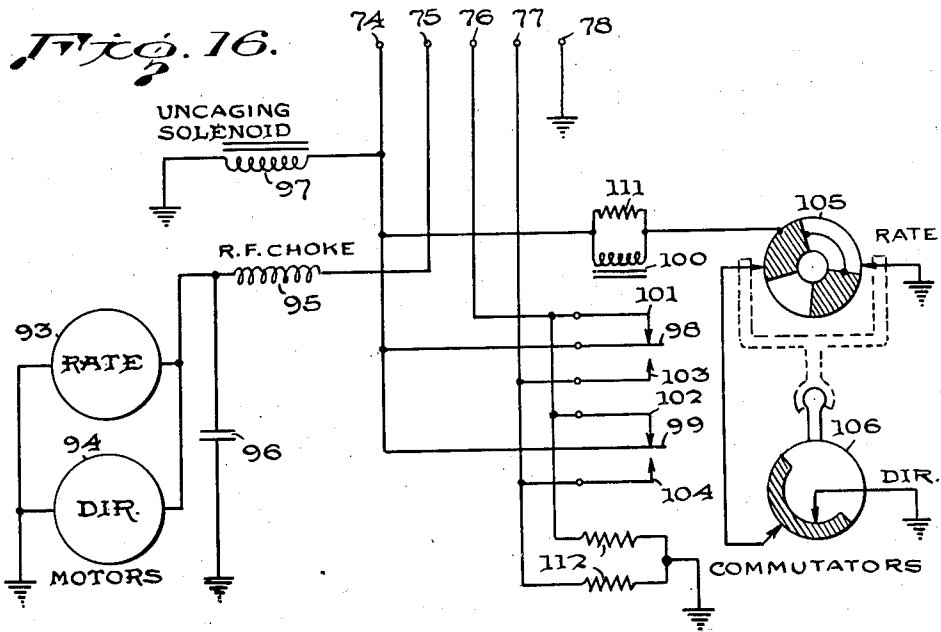


Fig. 14.

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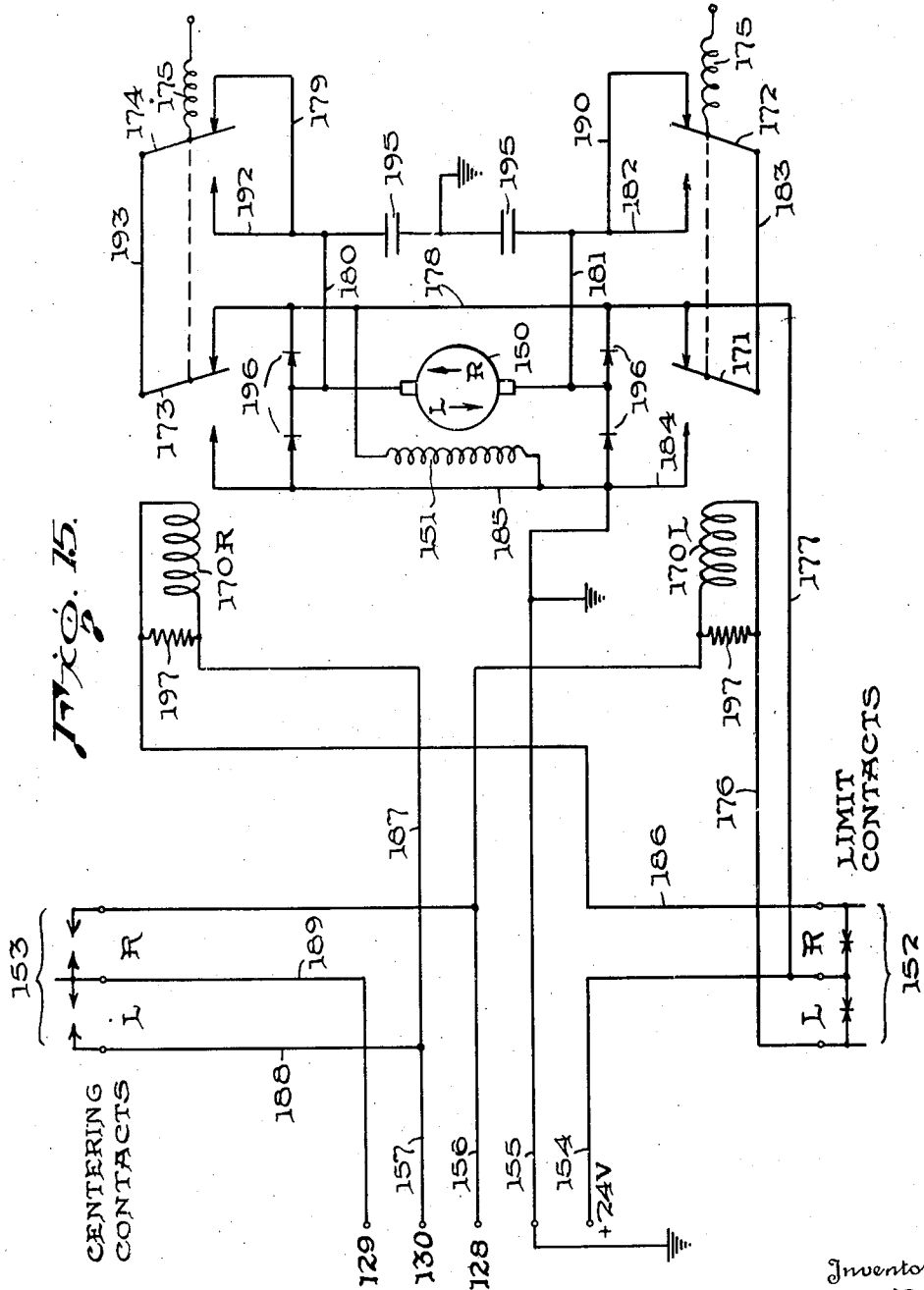
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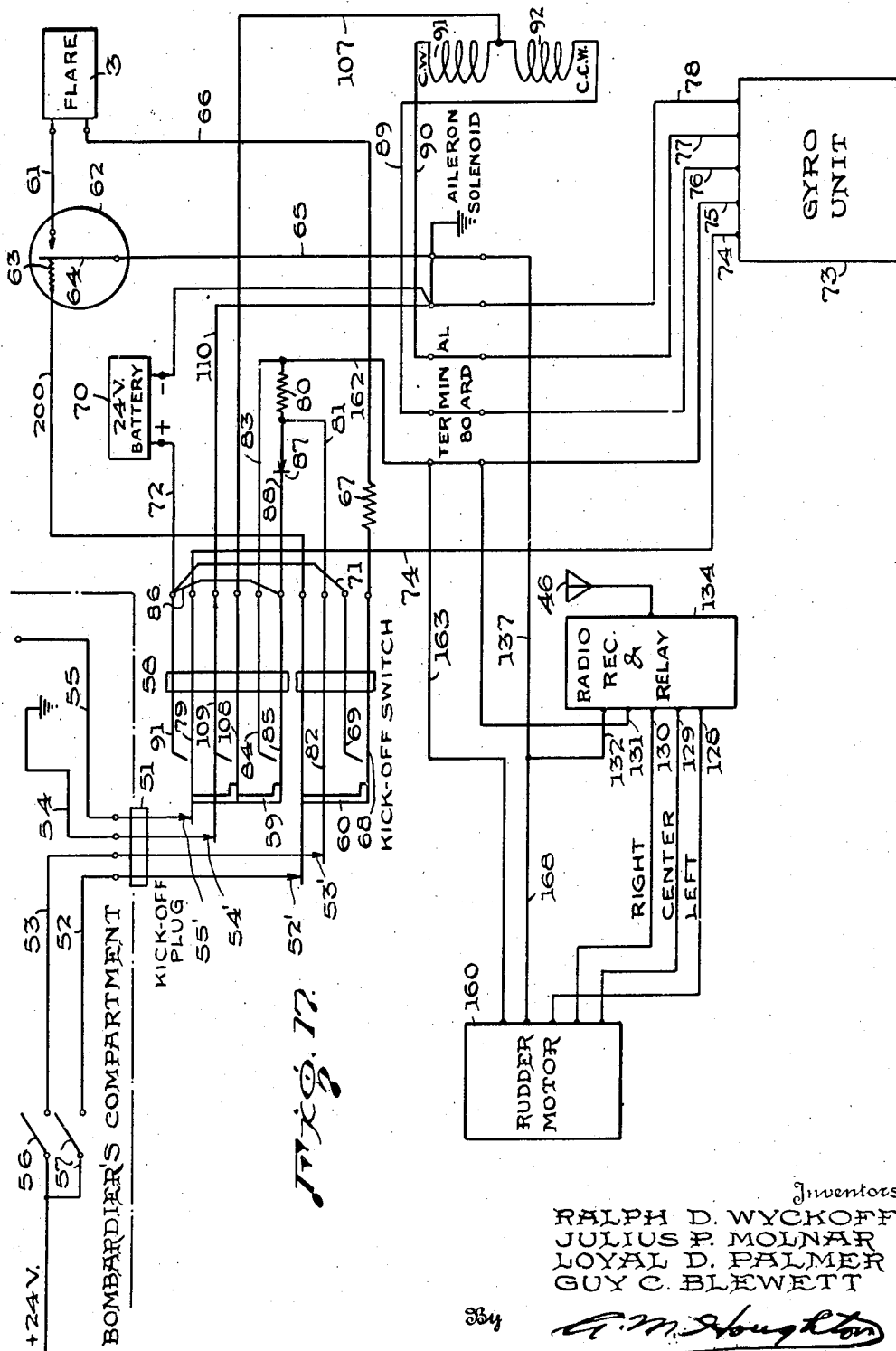
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UNITED STATES PATENT OFFICE

2,466,528

DIRIGIBLE BOMB

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Application May 31, 1946, Serial No. 673,374

2 Claims. (Cl. 102—3)

1

This invention relates to dirigible bombs and particularly to a remotely controlled so-called high angle bomb having a relatively stable 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 a plane, various factors are known to effect its trajectory. The magnitudes of these effects have been carefully determined and are 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 unpredictable and uncontrollable effects. Some of these effects are aerodynamic, some mechanical, and some atmospheric.

It has been found desirable to steer an otherwise freely falling bomb so as to correct for inaccuracy 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 such bombs in flight is both feasible and effective. Bombing accuracy has thereby been improved considerably.

This invention concerns a form of steerable bomb remotely controlled from the bombing plane by radio. Inasmuch as the bomb-sight is designed to automatically release the bomb at an instant such that its subsequent trajectory brings it on target in the direction of the bombing run, a highly effective steering control is obtained through remote control of azimuth only; that is, by the application of a steering effort either to the right or left as is required to bring the bomb on the line of target. Such azimuthal steering is also particularly valuable in bombing elongated targets, such as roads, railroads, bridges, etc., in which case the bombing run may be made in the long direction of the target and

2

a hit anywhere along the length of the target becomes effective.

In the making of a steerable high-angle bomb, a number of factors must be taken into account.

5 Means for producing aerodynamic deflecting forces must be added to the bomb in the form of aerodynamic lift surfaces. In addition, steering surfaces must be provided to maintain the angle of attack of these surfaces required for the production of deflecting forces. In order to maintain the effective direction of the steering controls, that is, to the right or left, it is necessary to stabilize the bomb against roll rotation. Furthermore, stability in flight must be maintained to avoid undue oscillation and gyration of the bomb. In addition, a number of practical considerations are involved; namely, structural strength must be sufficient to handle the aerodynamic forces required, the device must fit into already available component parts and preferably permit interchangeability, and in addition space requirements should be reduced to a minimum and kept within that permitted on military aircraft.

25 Military requirements dictate that the bomb must be capable of being accurately guided to the desired target, such accuracy being as high as possible. By means of our invention an error smaller than 10 ft. may be attained for 15,000 ft. altitude. This requires a degree of maneuverability which, in turn, demands that the aerodynamic surfaces develop sufficient lift forces to produce the required path deflection; that is, the maneuverability determines the lift which the bomb must generate when yawed at a preferred maximum trim angle with respect to its line of flight. The aerodynamic surfaces used to produce the required lift forces generally take the form of crossed tail fins. These may be provided with movable flaps or tabs which are controlled to set up the necessary attitude in flight.

40 Practical military requirements dictate factors which are not all compatible with the 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. In the dirigible bomb forming the subject of this invention, all the necessary components are contained in a tail assembly which is readily interchangeable with the ordinary tail assembly of a standard 1,000-pound bomb.

55 In order to obtain effective steering control,

the crossed-fin tail surfaces should be rotationally oriented in flight so that one pair of co-planar fin surfaces lies in the plane of the trajectory and the other pair of fin surfaces are at right angles thereto. Thus one may obtain right-left rudder control by applying rudders to the fins which lie in the plane of the trajectory. The other fins may conveniently be equipped with ailerons for maintaining roll orientation. If the bombs are carried in the bomb bay such that these surfaces have this orientation, the bombs take up a maximum of space; that is, they do not nest well in the bomb bay. In the device forming the subject of this invention, the bomb may be carried in the bomb bay in a position which is rotated at an angle of 45 degrees with the above, the bomb being automatically brought into proper roll orientation after it leaves the bombing plane. The effect of the improved nesting of the bombs in the bomb bay permits the plane to carry a larger number of bombs.

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

Another object of this invention is to provide a remotely controlled high-angle bomb steerable in azimuth after release.

Another object is to provide a remotely controlled high-angle bomb having a unitary remotely steerable tail structure which is interchangeable with the tail structure of standard non-steerable bombs.

Another object of this invention is to provide a remotely controlled high-angle bomb of great maneuverability which may be steered in azimuth by means of a rudder controlled in proportion to the desired degree of control.

Another object of this invention is to provide a remotely controlled high-angle stable bomb which may be steered in azimuth by means of a simple on-and-off rudder control.

Another object of this invention is to provide a remote azimuth controlled high-angle bomb having a cruciform tail structure and which may be nested in the bombing plane to take up a minimum of space.

These and other objects of the invention are attained through the design herein specified. Reference is made to the drawings forming a part of this specification, and in which

Fig. 1 is a perspective view of the bomb provided with the novel tail assembly comprising this invention;

Fig. 2 is a perspective view of the tail structure removed from the bomb and showing also the mode of mounting on the bomb and construction details of the housing;

Figs. 3 and 4 are side and rear views, respectively, of the tail structure showing for clarity only the rudder actuating mechanism;

Figs. 5 and 6 are side and rear views, respectively, of the tail structure showing for clarity only the aileron actuating mechanism;

Fig. 7 is a longitudinal section through one of the aileron actuating solenoids showing the manner in which the solenoid rotates the aileron torque rod;

Fig. 8 is a schematic diagram of one form of radio transmitting apparatus on the plane which may be used for proportional control of the rudders affecting the course of the bomb;

Fig. 9 is a block diagram of the radio receiving apparatus which may be used in the bomb to cooperate with the proportional control transmitting apparatus of Fig. 8;

Fig. 10 is a schematic electrical wiring diagram

of the proportional control radio receiving apparatus of Fig. 9 on the bomb;

Fig. 11 is a schematic electrical wiring diagram of the rudder actuating servo mechanism used for proportional control;

Fig. 12 is a block diagram of one form of radio transmitting apparatus on the plane which may be used for simple "on-off" control;

Fig. 13 is a block diagram of the radio receiving apparatus used in the bomb to cooperate with the "on-off" control transmitting apparatus of Fig. 12;

Fig. 14 is a schematic electrical wiring diagram of the radio relay circuit used for the "on-off" control;

Fig. 15 is a schematic electrical wiring diagram of the rudder actuating servo unit used for the "on-off" control;

Fig. 16 is a schematic electrical wiring diagram of a gyro-aileron control mechanism which may be used to set up and maintain the proper roll orientation of the bomb; and

Fig. 17 is a schematic electrical wiring diagram of the electrical equipment on the bomb showing the electrical relation of the various components.

Reference is made to Fig. 1 which shows the bomb in perspective view and to Fig. 2 which shows parts of the tail structure separated for purpose of clarifying the assembly. A war head A, which may for example, be a standard 1,000-pound demolition type bomb, has attached to it a box-like tail member 1 carrying the components used for controlling the flight path of the bomb. The front end of the box 1 is attached to the standard war head A through an adapter ring 10, this ring having a central aperture 11 (Fig. 2) which fits over the threaded extension 11a at the rear of the bomb and is held in place by a locking nut 11b in a conventional manner, nut 11b being tightened by a spanner wrench inserted in spanner holes 11c. The adapter ring 10 is thus attached to the tail end of the war head A in the same manner as the standard non-steerable tail fin. The outside diameter of nut 11b is smaller than the inside dimension of box 1, so that the latter may clear the nut when attached to adapter ring 10. The rectangular box 1 and its associated assembly is attached to the adapter ring 10 by means of screws passing through holes 9a in flanges 9 into threaded holes 9b in the ring 10. The entire assembly of box 1 is thus attached to a standard bomb in a simple manner.

The box 1 is preferably formed by suitably shaping four sheets of metal, the central portion 4 of each sheet forming a side of the box while the side portions 5 and 6 extend at angles of 45 degrees and together with the parallel adjacent portions of the proximate sheet form the cruciform tail fins. The sheets are held together to form the box 1 by means of angle strips 7 welded to the inside corners of the structure and external fillets 8 are secured by welding or soldering between each pair of adjacent side portions to produce a solid outside contour on the fins. The leading edge of the fins may slope rearward as shown, and as is customary in tail structures of this type.

Additional rigidity is imparted to the fin structure by the struts 19 which may be made from airplane tubing flattened and bent at 45 degrees at each end. These struts also form a radio antenna system in the form of a dipole by being electrically connected through their mounting bolts 17 and insulated from the body of the struc-

ture by insulating washers 20. The uppermost and the diametrically opposite corners of the dipole are left open-circuited by the use of additional insulating washers 20a under the bolt head 17a and the strut ends, thus forming the two sections of the dipole which are connected to a coaxial lead-in cable 43 passing through the uppermost fin to a radio receiver which will be described later and which is contained inside the box 1. Alternatively for a higher frequency carrier only two struts, 19, visible in Fig. 2 may form the complete dipole, or any or all struts may be connected as a simple T or L type antenna with the entire shell and bomb case acting as a ground member.

A transverse partition 2a is welded into the box 1 in approximately its middle and serves to impart additional rigidity to the box and also serves as a mounting for various actuating mechanisms and components to be described later. The rear end of box 1 is normally closed by a flat cover plate 2.

The rear cover plate 2 carries a flare 3. The purpose of the flare is to permit the bombardier to easily visually observe the course of the bomb after it is released. The war head A having a customary fuze (not shown) and arming devices (not shown), and the flare 3, are well-known devices and do not form a part of this invention per se.

Movably attached to the trailing edge of each fin surface is a control surface such as 12 and 29. These are made of spaced metal sheets continuously bonded by welded at their edges and pivotally mounted by means of torque rods 13 and 30 extending therethrough. The manner by which control surfaces 12 and 29 are actuated through torque rods 13 and 30 will be described later. Two of the control surfaces, such as 12, act as rudders and provide right and left steering control. The fins to which rudders 12 are attached are automatically oriented substantially in the plane of the trajectory during most of the bomb's fall, as will be described later. The other two control surfaces, such as 29, may serve as ailerons which provide roll orientation in a manner also to be described later. The rudder and ailerons are hinged along a line 25 per cent behind their leading edges in order to minimize the torques necessary to rotate them in a wind stream.

Rudders 12 are mounted on rods 13 journaled at the outer end in bearings formed in extension pieces 14, these being welded to blocks 15 which may be slipped in between the two sheets forming the fin and held in place by bolts 16 and 17. The inner mounting of rods 13 and its actuating mechanism is shown in Figs. 3 and 4. The inner end of the rod 13 extends through an aperture in the vertical corner brace 7 of the box and is aligned by bearing 13a formed in transverse plates 13c which are welded to angle strips 7. Connected to the inner end of each rod 13 is a crank arm 13b having a narrow open slot 13d at its outer end. A servo mechanism engaging the outer end of this crank arm controls the attitude of the rudder 12 attached to rod 13.

The manner by which the servo motor actuates the rudders 12 is illustrated in Figs. 3 and 4. A servo unit 21 having conventional step-down gearing with limiting and centering switches and crank 22, is suitably supported on a base 21b which may be bolted to the partition 2a inside box 1. The axis of crank 22 is substantially parallel to the axis of torque rods 13. The outer end of crank

22 is provided with stud 24 which engages a driving link 26. The driving link 26 serves as a coupling link to couple the two rudder cranks 13b together and with the servomotor in a manner which eliminates any binding due to slight misalignment. Driving link 26 may comprise a rectangular bar bent into a U-shape and having bearing holes on its legs close to the bends, these bearing holes fitting over the extensions 13e of of torque rods 13. Driving link 26 has at the outer end of its longer leg a narrow open slot engaged by stud 24 and at the outer end of its shorter leg a stud 28. The longer leg also carries a similar stud 28 similarly located, and studs 28 engage the open slot 13d of both crank arms 13b, these parts being disposed so that when movement takes place the difference in swing is taken up by the stud sliding slightly in the slot. Stud 28 are mounted on eccentric adjustments so that slight misalignments may be corrected. The angle of travel of the motor crank 22 from its neutral position is approximately $\pm 22^\circ$ while the corresponding angular travel of cranks 13b and hence of the rudders to which they are connected is an approximate $\pm 15^\circ$. Electrical actuation of the motor in servo unit 21 therefore will rotate both the rods 13 in unison and thereby deflect both the rudders 12 in the same direction. The electrical control of the motor and switches in unit 21 will be described later.

The ailerons 29 are identical in appearance and construction to the rudders 12 and are actuated in a manner illustrated in Figs. 5, 6 and 7, Fig. 7 showing a section through the actuating solenoid 34. Ailerons 29 are movable by means of torque rods 30 extending therethrough and into the control box 1 at alternate corners to those mounting the rudders 12, the outer and inner ends of rod 30 being journaled in a manner similar to rods 13 already described. The inner end of each rod 13 has secured thereto a crank 31 having an open terminal slot 31a. The crank arm 31 extends into an elongated opening in the case of solenoid 34, and the crank slot 31a straddles a transverse pin 33 maintained in an elongated clearance opening in the cylindrical solenoid core 33a. The solenoid is wound with independent coils 34a and 34b on each side of its central cross section so that selective energization will move the core longitudinally and hence cause rotation of the crank 31, rod 30, and aileron 29. Each solenoid is suitably mounted on a bracket 34c inside the control box 1. The ends of the solenoid cores are of customary conical shape and the core is returned to center by spring-pressed pins 35 located at each end of the solenoid casing.

To coordinate the operation of the two solenoids and to insure simultaneous operation of the individual ailerons regardless of any unbalanced aerodynamic torques on the two ailerons, the rods 30 are mechanically linked together. Each rod 30 has mounted thereon adjacent its crank arm 31 a bell crank 38, cranks 31 and 38 being secured together by a bolt and nut assembly 39, one member having an elongated hole whereby the angular relation between adjacent cranks 31 and 38 may be adjusted. Bell crank 38 has a slot 38a which engages a terminal pin 38b on a rectangular rocking beam 36, the beam 36 being mounted at its mid-point on transverse rocker pin 36a. Rocker pin 36a is supported in yoke 36b which is mounted on base 21b of the rudder servo unit. The edges of slot 38a are chamfered and made with clearance on pin 38b so that the resulting looseness permits the necessary tilting as the

beam 36 is rocked. The rocker beam 36 thus ties together the operation of the two ailerons so as to insure their simultaneous and coordinated operation. The solenoid coils are electrically so connected and their action mechanically linked by rocking beam 36 so that the ailerons operate in opposite directions in order to produce the necessary roll torque to bring the bomb into proper roll orientation.

Radio control

The bombardier in the plane may observe the course of the bomb after it is launched, the ignited tail flare 3, Figs. 1 and 2, being clearly discernible even in bright sunlight. It has been found that by visual observation, the bombardier may easily determine the direction of deviation required to bring the bomb on target. Various known methods of transmitting the necessary signals to the bomb from a radio channel may be used, two such methods being described here by way of example. The rudders for steering the bomb to left or right may be actuated by servomotor 21, as previously stated, the energization of this servomotor being controlled by the character of the radio signal received by the radio receiver within the bomb.

For best maneuverability it is desirable to provide a so-called proportional control system in which the angular displacement of the rudders on either side of their neutral position is correlated in proportional relation to the movement of the bombardier's control stick. In one embodiment to be described, the energization of the servomotor 21, which controls the attitude of the rudders, is controlled by the character of pulses transmitted from the plane and received by the radio receiver within the bomb. In this system regularly keyed pulses are transmitted over the radio channel, the bombardier's control stick varying the length of the carrier's pulses. Thus when the "on" time is equal (or of predetermined ratio) to the "off" time, neutral control is obtained. An increase in the "off" time and decrease in the "on" time effects control in one sense, whereas a decrease in the "off" time and increase in the "on" time effects control in the opposite sense.

One form of this system is described with reference to Figs. 8, 9, 10 and 11. The regularly keyed pulses transmitted over the radio channel are integrated in the radio receiver on the bomb. The carrier is keyed on and off, and when the time "on" is roughly equal to the "off" time the system is in its neutral position. Control is obtained by increasing or decreasing the "on" time relative to the "off" time. The manner in which the transmitter is keyed is illustrated diagrammatically in Fig. 8. Numeral 300 is a control stick pivoted at point 301 and returned to a center position by springs 302. Connected to control stick 300 is link 303 which moves insulating block 304 sliding horizontally in guides 305. Mounted on insulating block 304 are two contact springs 306 and 307, spring 307 being equipped with an insulating follower 308 which bears against eccentric disc 309. Eccentric 309 is driven by motor 310 at a nominal speed of about 1000 R. P. M. Adjustment of the contact points 306 and 307 is made such that the contact is closed approximately throughout half the revolution and open throughout approximately the other half of the revolution. The contacts are connected by wires 311 to the keying circuit of radio transmitter 312 whose signal is radiated

from antenna 313 on the bombing plane. By this means an interrupted carrier signal is transmitted, the relative length of "on" and "off" periods being under the control of lever 300 in the hand of the bombardier.

Fig. 9 shows the control equipment on the bomb. It comprises antenna 314 which may be the dipole made up of struts 19 (Fig. 1). Connected to the antenna is a conventional super-regenerative receiver 315 which together with pulse integrator 316 supervises the position of the rudder actuator 317 in a manner to be described. The rudder, actuated through a self balancing connection, finds its equilibrium position in a manner which will become evident by reference to Figs. 10 and 11.

Referring to Figs. 10 and 11, Fig. 10 shows a conventional super-regenerative circuit employing however an unusual manner of adjustment to avoid phase reversal in the square-topped output wave of the receiver. In the simplest type of super-regenerative circuit the oscillation of the detector produces the grid blocking which quenches the detector. This means that the detector grid is biased too near the cut off end of the characteristic curve of the tube. On strong signal the detector changes from grid detection to plate detection. Since these two types of detection are opposite in phase, a phase inversion of the received impulses results on changing from very strong signals to normal intensity. In applications of this circuit to remotely-controlled apparatus, as a radio-directed bomb, the latter must be operated over a range from a few feet to some thousands of feet from the transmitting antenna and the phase inversion described above would therefore impart a false movement to the control surfaces of the bomb. Consequently, a simple super-regenerative circuit cannot be employed.

Beginning at the left of Fig. 10, a conventional radio frequency amplifier using tube 350, which may for example be a type 9001, is connected to the receiving antenna and to the detector tube 351, for example a type 9002, through coils L₃ and L₄. The radio frequency stage is necessary due to the fact that the super-regenerative circuit is critical to antenna loading and hence must be isolated from the antenna. The radio frequency stage also provides some additional signal amplification and minimizes reradiation of the energy originating in the oscillating detector.

A separate "quench" oscillator utilizing tube 352, for example a type 655, and appropriate coils L₅ for the optimum "quench" frequency, (much lower than that of the detector circuit frequency) is connected to the detector 351 to "trigger" the latter into oscillation. The "quench" oscillator 352 is capacitatively coupled by adjustable capacity 353 to the grid circuit of detector 351 and operates to vary the detector grid voltage to cause the detector 351 to oscillate at a rate determined by the constants of the "quench" oscillator circuit. The adjustment of the detector circuit 351 is such that in the absence of energy from the local oscillator there is no oscillation of the detector at signal frequency.

Tubes 354 and 355 of Fig. 10 may be of the type 6SN7 and comprise an amplifier circuit of conventional resistance-coupled type but resistances and condensers having long-time constants are employed in order to preserve the square-topped wave-form for which the receiver is particularly designed. The wave-form is com-

posed of regularly-keyed voltage pulses, the length of which is varied by the operator of the transmitter, the length of pulse in the received signal being used to regulate an electric motor which moves the control surfaces on the bomb. The square-topped voltage pulses from the resistance-coupled amplifier are utilized as follows.

The amplified square-topped voltage pulses are applied to the grid of the first section 356 of a twin-triode vacuum tube. By using large input voltages the grid is driven between two limits, the negative cut-off and saturation, and so the average voltage at the plate 357 of this section is determined within limits, by the pulse length. The average plate voltage is filtered by the resistance-capacity circuit comprising condenser 358 and resistors 359 and is directly coupled to the grid 360 of the second section 361 of the twin-triode. The triodes 356 and 361 may together be a type 12SN7 tube for example. The second section 361 has included in its plate circuit the relay 320, the opening and closure of which depends upon the grid bias of tube 361, which in turn, depends on the pulse length applied to the input. In Fig. 10 the filament supply is conventional and is omitted for clarity. Terminals 365 are connected to voltages as shown on a conventional power supply.

When the relay is open, the motor 21 (Figs. 3 and 4) for moving the rudder surface runs in one direction, and when the relay closes, the motor goes in the opposite direction. Further details as to the operation of relay 320 will become apparent in the explanation of Fig. 11 to follow. In order that the rudders be held in an equilibrium position corresponding to the desired angle, i. e., pulse length, the motor 21 rotates a high resistance rheostat 363 (Fig. 10) which is connected to the grid circuit of the relay tube 360 and in so doing changes the bias on this tube. The rheostat 363 is mechanically coupled to motor 21 (Figs. 3 and 4) through connection 364 of Fig. 10. (This connection is conventional and is not shown on Figs. 3 and 4). Electrical terminals 327, 334, 335 connect to the rudder motor as shown in Fig. 11. Thus, the circuit responds essentially, as an automatically balancing potentiometer, which measures a voltage that can be controlled directly by varying the length of the pulses applied. By choosing the proper values for the circuit constants, the motor response can be made substantially a linear function of the pulse length over the range required.

The successful operation of this circuit depends on the existence of sufficient A.-C. ripple in the grid voltage applied to the second stage, so that the relay 320 in the plate circuit chatters near the balance point. In this way difficulties with relay hysteresis are eliminated. The amplitude of the A.-C. ripple can be controlled by the R. C. constant of the filter circuit. For optimum operation the amplitude should be limited to a value which permits relay chatter only when the motor is within a few degrees of the balance point. As will be evident, the ripple amplitude required depends on the difference between the pull-up and release threshold current of the relay.

Fig. 11 is a wiring diagram of the servomotor and reduction gear unit 21 which is connected to actuate the rudders. Devices of this character are well known, being used extensively in aircraft remote-control arrangements, for example. In Figs. 3 and 4 the motor 21 is connected through reduction gearing to a crank 22 which moves the rudders as previously described depending on the

direction of rotation of the motor. The latter in turn is governed by the energization of relay 320 (Figs. 10 and 11). Limit switches 321 and 322 are positioned to limit the maximum amplitude of rudder movement on either side of a central position.

In the motor circuit of Fig. 11, it is apparent that when power is applied to the terminal 325, it energizes shunt field 326, the circuit returning to the ground through terminal 327 and wire 328. The 24 v. power also energizes field coil 329 and wire 330 and it is apparent that energization of relay 323 will cause the motor armature 331 to rotate in one direction, while energization of relay 324 will cause the motor to rotate in the opposite direction through reversal of the current flow of the armature with respect to the field winding as is well known. The return current is via wire 332, 333 to 327 and ground. The energization of relays 323 and 324 is determined by the position of relay 320. When relay 320 is balanced so that it chatters between its contacts, the motor armature 331 remains at rest. However, if the relay 320 contacts 334, power flows from the 24 v. supply through field 329, wire 330, relay coil 323, limit switch 321, contact 334 to ground via wire 328. If relay 320 contacts 335, current flows in a similar way through relay 324 and limit switch 322 through contact 335 and wire 328 to ground. The limit switches 321 and 322 merely serve to open the relay circuit when an extreme position of the crank arm in either direction is reached. Attached to the crank arm 21 is rheostat 363 of Fig. 10, which balances the system, as explained in connection with Fig. 10.

While the above described system of control is advantageous for high maneuverability, a somewhat more reliable and for most purposes sufficiently effective system uses simple "on-off" control of the rudders. In this system the rudders are either full on or full off, and in the absence of control, return to neutral. The bombardier applies left rudder or right rudder as desired for a time which he estimates will correct the deviation of the bomb from the target line. It has been found that an experienced operator may do as well with this system as with a proportional control in bombing stationary targets.

An example of an "on-off" method of control, shown in Figs. 12 and 13, the transmitter 40 on the plane puts out a continuous carrier which may be modulated by either of two audio oscillators having frequencies F_L and F_R , each modulating the transmitter 40 at its characteristic audio frequency when its respective key 42 and 44 is pressed. The frequencies F_L and F_R may conveniently for example be 475 and 1000 cycles/sec. Thus the bombardier has two push buttons 42 and 44 which control the oscillators F_L and F_R to modulate the radio wave transmitted to the bomb. 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.

Fig. 13 is a block diagram of one form of radio receiving equipment carried on the bomb and used for responding to the steering signals from the plane. Here 46 represents the dipole or other type antenna made up of the struts 19 (Figs. 1 and 2). Connected to the ends of the dipole is the coaxial cable 43 (Fig. 1) leading to conventional radio receiver 47, including a demodulator which delivers audio signal to two filters L and R. These are narrow band-pass filters of known

type and when an appropriate signal is received, it is passed on by the agency of relays (which will be described later) to rudder actuator 21, which in turn deflects the rudders 12 in the proper sense. In the above form of control here described, only "on-off" control is obtained, the rudders returning to neutral in the absence of any audio signal. If the bombardier, for example, desires to apply left rudder he may close contact 42, Fig. 12, 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 L and R. As the frequency F_L may only pass through filter L, relay L is energized and there is applied to the rudder actuator power to drive it and the rudders into the leftwise position. If neither of the contacts 42 or 44 are closed by the bombardier, the rudder actuator automatically returns to its neutral position as described later.

The operation of relays L and R of Fig. 13 is shown by the wiring diagram of Fig. 14 in which numerals 113 and 114 represent the plate connection of the last tube in the audio filters L and R, respectively. Each of the plates 113, 114 are connected through a relay coil 117 and 118 to a common high potential terminal 121 leading to the radio plate power supply on the bomb. Armature contact springs 122 and 123 are normally connected to the righthand contact as shown in Fig. 14. Upon transmission of a signal through the audio filter the center spring of the relay is drawn over to the lefthand contact. Thus if no steering signal is applied the relays will be in the position shown in Fig. 14. The circuit diagram shows how the contacts and springs are connected to the terminals 128 to 132. Terminal 132 is connected to ground. Terminal 131 is connected to 24 v. power supply. If the bombardier applies a signal of a proper frequency to actuate the filter L (left), relay 117 pulls contact 122 to the left. This grounds terminal 128 through left contact 122, wire 140, right contact 123 and wire 141. At the same time the ground on center connection 129 is broken at 122. Similarly, if the bombardier applies a signal to actuate the filter R (right) relay 118 pulls contact 123 to the left. This grounds terminal 130 through left contact 123 and wire 141, while at the same time the ground on center connection 129 is broken at 123. Keeping in mind that the application of steering signal merely grounds the appropriate terminal on the rudder actuating mechanism, we shall now describe this mechanism.

Fig. 15 is a schematic wiring diagram of the rudder actuator 21 of Figs. 3 and 4. 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 22 of Figs. 3 and 4. 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 22 of Figs. 3 and 4 operates through appropriate cams to switches 152 and 153 of Fig. 15. Numeral 152 represents a limit switch mechanically so arranged that when the motor arm 22 reaches its extreme right position contact 152R is mechanically opened. On the other hand when the motor arm reaches its extreme left position contact 152L is opened. In all intermediate posi-

tions of the arm 22 both contacts 152L and 152R are closed. Another cam on arm 22 operates a centering switch 153. Contacts on this switch are so arranged that they are both open over a very small region at the center position. Contacts 153R and 153L are closed, respectively, when the arm 22 is off center to the right or left, respectively. Relay coils 170R and 170L when energized move contacts 171, 172, 173 and 174 to the left. Contacts 171, 172, 173 and 174 are returned to the right hand position by springs 175 when the relay coils are deenergized. Terminal 154 is connected to the 24 v. power supply. Terminal 155 is the ground connection and terminals 128, 129 and 130 go to the radio relay (Fig. 14) previously described. Bearing in mind the mechanical operation of switches 152 and 153 and of relays 170R and 170L, and the fact that radio control merely grounds the desired terminals 128, 129 or 130, we shall now describe the operation of the actuating mechanism of Fig. 15.

We shall assume that the rudders are in a center position so that the contacts 153L and 153R are both open, contacts 152L and 152R are both closed, such being the situation when no signal is applied. Upon the application of left rudder signal radio relay 117 (Fig. 14) will ground terminal 128 (Figs. 14 and 15). Current then flows through the circuit of Fig. 15 as follows: 24 v. current enters through wire 154, contacts 152L, wire 176, relay coil 170L to ground via wire 156. This holds contacts 171 and 172 to the left and the current flows from wire 154, wire 177, wire 178, contact 173, contact 174, wire 179, wire 180 downward through motor armature 150, wire 181, wire 182, contact 172L, wire 183, contact 171L, wire 184 and wire 155 to ground. At the same time the current flows from 154 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 22 (Figs. 3 and 4) 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 signal is being applied; namely as long as terminal 128 is the only one grounded. If, however, the bombardier ceases to apply that rudder signal then the radio relay (Fig. 14) opens the ground on 128 and automatically applies a ground on 129. Now 24 v. power flows as follows: through 154, contact 152R, wire 186, relay 170R, wire 187, wire 188, contact 153L, wire 189 to ground. This closes relay 170R moving contacts 173 and 174 to the left. Current may now flow through the motor armature as follows: wire 154, wire 177, contact 171, wire 183, contact 172, wire 190, wire 181, upward through armature 150, wire 180, wire 192, contact 174L, wire 193, contact 173L, 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 130 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 the 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 in Fig. 13. Rectifiers 196 are connected as shown in order to suppress sparking and eliminate consequent radio interference when contacts open the circuit of armature 150. Resistors 197 of relatively high resistance may be connected across relay coils 170R and 170L in order to reduce sparking and radio interference when contacts open the relay energizing current.

Roll stabilization

In order to maintain the bomb properly oriented so that the right and left rudder controls remain identified, it is necessary to provide a stabilizing mechanism actuating ailerons which maintain such roll orientation. Accidental rolling torques may be imparted to the bomb during its fall by accidental inequalities in the tail surfaces, or during launching, or may further develop due to inequalities in the steering effect of the rudders. A gyroscopic stabilizer is employed consisting of a directional gyro, so mounted that the plane of rotation of the gyro wheel is in a vertical plane of symmetry of the bomb corresponding also with the plane of the trajectory at launching. The gyro includes electrical connections to the aileron actuating solenoids so that if the bomb begins to roll in a clockwise direction, for example, the ailerons will be moved simultaneously in a direction to produce a counter-clockwise restoring torque on the bomb. A rate-of-turn gyro is simultaneously mounted to reverse the position of the ailerons if the rate of rolling exceeds 5 to 10° per second. The ailerons are thus always at one extreme position or the other, producing slight roll of the bomb about vertical orientation at a rate that never exceeds 10° per second.

The construction of the gyro wheels and their mountings, per se, do not form the subject matter of this application. Examples are described in a patent application, Serial No. 543,168, filed July 1, 1944, by J. P. Molnar and A. Carnvale, and also in an application, Serial No. 639,686, filed January 7, 1946, by B. E. Warren. It will suffice here to describe the electrical circuits controlled by the gyros, these being shown in Fig. 16. The direction and rate-of-turn gyros described in the above patent application of Molnar & Carnvale are coupled together in such manner that zero position on the direction gyro varies with the displacement of the rate gyro and hence with the rolling of the bomb. The effect of this coupling as explained in the above-mentioned application 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 control.

In order to permit the bombing plane to carry a maximum number of bombs, it is highly desirable that they be nested in the bomb bay with their tail fins 45° to the horizontal. The aileron controlling contactors therefore have their neutral position rotated through 45° as indicated in Fig. 16, so that there is initially applied to the bomb an aileron effect which remains until the bomb has rotated 45°, thus placing the rudders in the vertical plane, after which this roll orientation is maintained. Essentially, the function of

the contactor 106, Fig. 16, is to open the ground connection to relay coil 100 at the equilibrium position of the directional gyro. Contactor 105 opens the ground connection to relay 100 at an excessively large deviation of the rate gyro in one direction, and closes the ground to relay 100 at an excessively large deviation of the rate gyro in the other direction (i. e., when contactor 106 is open).

Fig. 16 is a detailed schematic diagram of the gyro unit, connections being made as shown. After the bomb has been released, terminals 74 and 75 connect to the positive terminal of the bomb's battery, as will be described later, thus supplying power to the gyro motors 93 and 94 through radio frequency choke 95 with condenser 96 bypass to ground. Choke 95 and condenser 96 serve as a filter to prevent commutator interference with other apparatus on the bomb. Uncaging solenoid 97 is powered from terminal 74, and is energized on launching the bomb, as will be described.

In Fig. 16, terminal 74 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, then contact springs 98 and 99 lead to contacts 101 and 102 and battery power from terminal 74 is supplied to terminal 76. When the contactors 105 and 106 allow the relay coil 100 to be energized, then contact springs 98 and 99 supply power to terminal 77 through contacts 103 and 104. Thus the gyro unit supplies power to the respective aileron solenoid connected to either terminal 76 or 77. The two sets of relay contacts 98 and 99 are provided to handle the aileron solenoid current without heating or sticking. Relay coil 100 has resistor shunt 111 to prevent sparking at the gyro contacts and the relay contacts have relatively high resistance shunts 112 to prevent sparking on opening of the aileron solenoid circuit. Wires 76 and 77 from the gyro unit connect to aileron control solenoids 34a and 34b shown in Fig. 7, the detailed operation of which has been described in connection with Figs. 5 and 6.

Bomb controls

Fig. 17 is a wiring diagram of the bomb and shows how the various components are interconnected. The components illustrated are those for "on-off" radio control, but the alternative proportional control may easily be substituted with obvious minor changes in the circuits to conform with the detailed diagrams previously explained.

Referring to Fig. 17, 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 1 (Figs. 1 and 2) of the bomb. Connections above plug 51 are on the bombing plane, 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 connections 52, 53, 54, 55 on the plane 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 when the bomb release mechanism is actuated by the bombardier. An electrical impulse from the release mechanism is imparted through wire 55 to perform this function as will be described later. 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 3 (Figs. 1 and 2). This is a safety mechanism to prevent premature operation of the flare. The four wires 52, 53, 54, 55 are severed at contacts 52', 53', 54', 55' when the kick-off plug pulls out on release of the bomb, 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 which are made of insulating material.

Considering now the operation of various components on the bomb itself, these will be described separately. Flare 3 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 there-by 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 bombardier may arm the flare previous to release, and on release 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 copending application Serial No. 543,168 by Molnar and Carnvale and is indicated generally by numeral 73. Five wires 74, 75, 76, 77 and 78 are connected to the gyro unit whose internal circuit is shown in Fig. 16. 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 thus transmitted to wire 74 to the uncaging solenoid 97 (Fig. 16) to uncage the gyro at release. In order to make sure that the gyro does uncage properly, spring 79 connects with spring 91 after 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 from the gyro motors (Fig. 16) is seen to connect through current limiting resistor 80 and wire 81 and spring 82, thence through contact 53' and wire 53 to the bombardier's warm-up switch 56. Thus 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 34a and 34b in Fig. 7, the detailed operation of which has been described in connection with Figs. 5, 6 and 7. Wire 78 serves as a ground for the gyro unit. Wire 107 serves as a ground return for the aileron control solenoids through springs 108 and 109 and wire 110 after the bomb is released. Thus the aileron control solenoids cannot be energized except after release from the bomb bay.

Returning to Fig. 17, it is seen that wire 76 connects to wire 89 and energizes solenoid 92, current returning to ground via wire 107, spring 108, spring 109, and wire 110. Wire 77 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, in accordance with the previously given explanation of Fig. 16.

Referring again to Fig. 17, the radio equipment on the bomb is shown generally by numeral 134 receiving its signals from antenna 46. Radio unit 134 comprises a receiver and the necessary rudder control relays. In the case of simple "on-off" control, unit 134 comprises a receiver 47, filter L, relay L, filter R and relay R all shown in Fig. 13, the operation of the relays having been explained in connection with Fig. 14. Thus connection 132 goes to ground via wire 137. For operating the radio after release of the bomb and consequent removal of the kick-off plug, terminal 131 is supplied with 24 v. power through wires 162 and 83, springs 84 and 85, wires 86 and 72. Prior to release and while the warm-up switch 56 is closed the radio receiver is supplied by ship's +24 v. power through wire 53, contact 53', spring 82, current limiting resistor 80, wires 162 and 103. The -24 volt side is via ground in the receiver to bomb case and via wire 110, spring 108, contact 54' and wire 54 to the aircraft ground connection. Thus the radio receiver is warmed up and in operating condition prior to release of the bomb. Terminals 128, 129, and 130 are connected to the rudder actuator. The actuator itself has been described in connection with Fig. 15, and the radio equipment serves by means of its relays to apply a ground to the appropriate connection desired. In the absence of a control signal, terminal 129 is grounded and rudders are in center position. Thus, for right rudder, the radio apparatus grounds terminal 130, at the same time opening the ground on centering terminal 129. Similarly, for left rudder, terminal 128 is grounded and the ground on 129 is opened. These connec-

tions are accomplished by the relay circuit already described in Figs. 14 and 15.

The rudder actuating mechanism is indicated in Fig. 17 by numerals 160. This mechanism is powered with 24 v. power from the bomb battery through a circuit as follows: starting from battery 70, through wire 72, wire 86, spring 85, spring 84, wire 83, wire 162, wire 163 to the rudder actuator. A ground connection is obtained through wire 168 and 137. The other three terminals of the actuating mechanism go to radio terminals 128, 129, 130 and the direction of rotation of the rudder actuating motor is controlled as previously explained with reference to Fig. 15.

Having thus described our invention in detail and the manner in which it accomplishes its objects, it is apparent that various changes and modifications in the details may be made by those skilled in the art and we do not mean to be limited in the controls to the particular embodiments illustrated. Furthermore, our invention may be applied to a dirigible bomb of any type or size and is not limited to the demolition-type bomb herein suggested. It may furthermore be used in the bombing of elongated targets which are 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, cruciform aerodynamic control surfaces fixedly mounted on said tail structure, electrically insulated struts extending between said control surfaces and serving as a radio antenna, aerodynamic steering surfaces operably mounted on the trailing edge of said control surfaces, means contained in said tail structure operating one pair of diametrically opposite steering surfaces as rudders which place the missile into an attitude of yaw so that the associated control surfaces may produce forces deflecting the path of the missile, means contained in said tail structure receiving and transducing a radio signal, means contained in said tail structure controlling the rudder deflection proportional to the deflection of the control stick in the controlling aircraft, means contained in said tail structure operating the other pair of diametrically opposite steering surfaces as ailerons tending to axially rotate the missile, and gyroscopic means in said tail structure controlling said aileron operating means so that resulting

aileron action maintains the missile's rotational orientation such that the rudders lie substantially in a vertical plane.

2. A dirigible missile comprising a war head, a unitary tail structure, cruciform aerodynamic control surfaces fixedly mounted on said tail structure, electrically insulated struts extending between said control surfaces and serving as a radio antenna, aerodynamic steering surfaces operably mounted on the trailing edge of said control surfaces, means contained in said tail structure operating one pair of diametrically opposite steering surfaces as rudders which place the missile into an attitude of yaw so that the associated control surfaces may produce forces deflecting the path of the missile, 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 the frequency of modulation of the received radio signal and are urged into neutral position upon the absence of modulation of the received radio signal, means contained in said tail structure operating the other pair of diametrically opposite steering surfaces as ailerons tending to axially rotate the missile, and gyroscopic means in said tail structure controlling said aileron operating means so that resulting aileron action maintains the missile's rotational orientation such that the rudders lie substantially in a vertical plane.

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