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NATIONAL BUREAU OF STANDARDS

Quarterly Progress Report No. 3
For Period Ending June 30, 1947
on Project

ATI No 9781

KINGFISHER

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DEPARTMENT OF COMMERCE
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NATIONAL BUREAU OF STANDARDS

Quarterly Progress Report No. 3
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KINGFISHER

DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

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U. S. DEPARTMENT OF COMMERCE
W. Averell Harriman, Secretary

NATIONAL BUREAU OF STANDARDS
E. U. Condon, Director

NATIONAL BUREAU OF STANDARDS
Quarterly Progress Report No. 3
For Period Ending June 30.1947
on Project

KINGFISHER

Submitted to
Bureau of Ordnance
and
Bureau of Aeronautics
NAVY DEPARTMENT

Approved for the National Bureau of Standards
A.V. Astin, Chief of Project
E.U. Condon, Director

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I. INTRODUCTION

KINGFISHER weapons are radar-controlled, subsonic, medium-range, jet-powered missiles intended to deliver an explosive charge below the waterline against marine targets. Four KINGFISHER models are under development, their distinguishing characteristics are as follows:

Model C: A self-homing aircraft-launched missile of about 4000 lbs. total weight and a maxiumum low-altitude range of about 20 miles. This model is being designed for release from currently available aircraft and to carry currently available torpedoes, in particular the Mark 13 and Mark 25. It is expected that the acoustic homing torpedo Mark 21 (now under development) could also be carried with minor modifications to the missile structure. It is intended that this model be released from aircraft at low altitude near maximum range of radar visibility against a ship target. The torpedo, which has an explosive charge of about 350 lbs., is to be released from the missile within a few hundred yards of the target and is to complete its run under water.

The Model C KINGFISHER is considered primarily as an interim test missile to be used for the development of various components which are ultimately to be employed in other KINGFISHER Models.

Model D: A self-homing aircraft-launched missile of about 3000 lbs. total weight and a maximum low altitude range of about 20 miles. The Model D differs from the Model C primarily in size and payload. The latter is to be a homing torpedo with a jet propulsion engine built into the torpedo body (probably a modified Mark 40). The explosive charge will be between 200 and 400 lbs.

Model E: A command-guided, ship-launched missile of about 3000 lbs. total weight and 20-mile maximum range. After launching, the missile will maintain an altitude of several hundred feet. The warhead is to be the Mark 35 deep-diving sonic-homing torpedo now under development. The primary targets are submerged submarines at ranges from maximum to within a few hundred yards. It is expected that the missiles will also be effective against surface craft.

Model F: A homing, aircraft-launched missile of about 1300 lbs. total weight and range of about 40 miles. The warhead is to be a 500-lb. (approx.) plunge-bomb, now under development. The plunge-bomb, which is non-homing and non-powered, moved under water along a continuation of the air trajectory and is intended to strike ship targets below the water line. Proper fuzing will also cause effective damage when the charge is detonated near the ship hull. The homing system for this missile will probably consist of two stages: full action homing for the latter part of the missile trajectory and passive homing with auxiliary target illumination for initial part.

A common feature of all KINGFISHER missiles(other than those indicated above) is that they will approach the target at very low altitude (about 200 ft.) in order to lessen the probability of detection by radar, and interception by anti-aircraft fire. Another common feature is that all models release the payload from the airframe just prior to or at the instant of water entry.

The development of KINGFISHER weapons is the responsibility of the Bureau of Ordnance, U. S. Navy Department. During the current quarter the KINGFISHER program has been revised and adjusted to include the requirements of other service agencies. For example, the operational requirements of the Model F KINGFISHER have been expanded to meet the needs of the Army Air Forces, and one of the latter's development facilities has been enlisted in the KINGFISHER program. In addition, developments from other guided missile projects are being utilized in so far as possible for KINGFISHER missiles. For example, the guidance-intelligence system under development by the Naval Research Laboratory for project HORNET is being adapted for use with Model E KINGFISHER, and the liquid-fuel rocket developed for project LARK is under investigation as an interim power plant for Model C KINGFISHER.

Responsibility for technical direction of the KINGFISHER developmental program has been assigned by the Bureau of Ordnance to the National Bureau of Standards. Work is centered in the Ordnance Development Division of the latter agency. Other agencies involved with the development of major phases or components of the KINGFISHER weapons are as follows:

Bureau of Aeronautics: Power plant development and advisor on aerodynamic problems.

Army Air Forces: Advisor on operational requirements and aerodynamics, participation in field test program.

Naval Ordnance Test Station - Chincoteague, Va.: Field testing.
Naval Research Laboratory: Development of guidance-intelligence for Model E.
Westinghouse Electric & Mfg. Co. - Engineering for pilot production of Models C and D.
Goodyear Aircraft Co. - Model E KINGFISHER.
McDonnell Aircraft Co.- Model F KINGFISHER.
Fairchild - Power plant for Model C.

Committees to aid in co-ordinating the work of the above-mentioned agencies are now being set up and the structure of these will be shown in the next progress report.

The major development effort thus far has been on Model C KINGFISHER. Since this model is the only KINGFISHER missile using a currently available warhead, concentration of effort on Model C provides an expedient means of proving in by flight test various important components for all KINGFISHER models. An additional approximation to ultimate objectives is in the use of glider-type airframes. Powered missiles even of an interim design are not expected before 1948, but in the meantime much valuable information on navigation methods and stabilization and control systems is being obtained with gliders.

In the following sections of this report, the current progress and status of development are presented under the headings Airframe, Navigation, Intelligence, Stabilization and Control, Propulsion, Electrical power supply, and Instrumentation. Under each heading is a brief summary of overall status followed by a more detailed resume of current progress.

II. AIRFRAME

A. STATUS OF DEVELOPMENT

There are three types of KINGFISHER airframes now under development. (No work is in progress on the Model D airframe because the warhead development is not sufficiently advanced to fix dimensional requirements for the airframe).

1. Model C (formerly Type C).

The design configuration of the Model C KINGFISHER has been fixed after extensive tests on a 1/6 scale model in the National Bureau of Standards' six-foot wind tunnel.

Since the design configuration was determined from aerodynamic tests on a 1/6 scale model, it is planned to supplement these data with tests on larger scale models. To this end a full-scale model is now being built in the shops of the National Bureau of Standards. It is now about 80% complete; date for completion is August 1, 1947. Facilities for tests on the full-scale model are to be arranged by the Bureau of Aeronautics, Navy Department. At present these facilities are not available because of other test programs; therefore, the Bureau of Aeronautics has made arrangements to make tests of a 1/2 scale Model C KINGFISHER in the David Taylor Model Basin. The David Taylor Model Basin will construct the model for test purposes. In addition to determining the aerodynamic flight characterisitcs, it is hoped to make some preliminary investigation as to the optimum shape of the inlet ducts for the proposed Fairchild turbo-jet engine.

Photographs of the 1/6 scale model were shown in Progress Report No. 2.

Mark 15 glider airframes (the initial airframe for the now obsolete Model A KINGFISHER) are being used to flight test various components.

2. Model E.

The development of this type is in the early study stage by the Goodyear Aircraft Corporation. Several configurations have been presented for consideration.

3. Model F.

The development of the Model F airframe has been recently assigned to the McDonnell Aircraft Corporation.

and they have completed preliminary estimates of overall weight for two types of propulsion. (See Part V.)

Design configurations for the Model F, from which drawings are being prepared for a wind tunnel model, were made at National Bureau of Standards.

B. CURRENT PROGRESS

Airframes - With the completion of the wind tunnel tests on the 1/6 scale model of Model C KINGFISHER, described in the last progress report, the dimensional specifications for the airframe were fixed. (See bibliographical reference No. 2). These were transmitted to the Goodyear Aircraft Corporation and the latter is now making engineering drawings for fabricating this airframe in metal. It is expected that 50 of these airframes will be manufactured for use in field tests.

Prior to tunnel test with the Model C airframe mentioned in Paragraph II A (1), mock-up installation of various components will be made to determine clearances and optimum wiring lay-out.

Because of the split wings on the Model C airframe, it is planned to have one umbilical cord connector located in each wing root. This arrangement is being tried to obtain a reduction in size of the connector.

Provision is being made to increase the capacity of the fuel tank in the wings from 25 gallons to 35 gallons in order to allow for adequate range in case the turbojet's fuel consumption is larger than predicted.

It has been decided that the altimeter antennae for use on Model C KINGFISHER cannot be mounted within the wing because of interference with the wing's structure. Consideration is being given to the use of two dipoles mounted on the lower edges of the two vertical stabilizers. If this is suitable electrically, a slight change in the shape of these stabilizers will have to be made. The change will not appreciably affect the aerodynamic characteristics.

Torpedo Release Tests - Two field tests were made in May at Warren Grove, N.J. to test the release systems for separating the wings and nose section from the torpedo. (Flights K-28 and K-29). Details of the tests follow.

On May 20th, two units using SWOD Mark 15 airframes (numbers 9 and 10) with SWOD (Radar) Mark 2 (BAT) were dropped against a corner reflector. On both units, the wing and nose section release mechanisms were provided. These were actuated by a range switch in the radar equipment, set to operate 1000 feet from the target. The tail sections of both units remained fixed to the torpedo in an attempt to aid in the stabilization of the torpedo in free flight.

Both units made very good flights and had very little azimuth error, and both appeared to be heading slightly short of the target at the time the range switch operated. The records obtained from the cameras in the units compared very well with records of previous tests made with identical equipment.

A bomb shackle release system was used on units 9 and 10 to release the wings. The nose sections were released from the torpedo by two methods. On Unit 9, the nose section (containing homing equipment) was arranged to be released by the operation of latches actuated by electrical solenoids. On Unit 10, the nose section was arranged to be released by a cable connecting it to the wings which, as they separate from the torpedo, mechanically operate a special latch on the nose.

From a study of 16 mm pictures taken of the operating of the release systems, it was found that on both tests the wings failed to separate from the torpedo except for a quarter of a second period, immediately after the firing of the radar range switch, when the trailing edge of the wings lifted about two feet above the torpedo. The leading edges of the wings did not lift from the torpedo.

This wing action was apparently caused by the elevons being in a strong glide position, which made a sufficient shift of the center of lift of the wings toward the rear to cause the trailing edge to lift up, decreasing the angle of the wings and holding the leading edges of the wing down on the torpedo.

The nose section on unit 9 appeared to operate satisfactorily, as it was completely separate from the torpedo at the time of landing.

The nose section on unit 10 did not separate from the torpedo because the wings failed to lift far enough off the torpedo to operate the cable release mechanism.

III. NAVIGATION

A. STATUS OF DEVELOPMENT

Progress reported under this heading includes overall system studies involving interrelated features of the airframe, the guidance-intelligence and methods of stabilization and control. Currently most work pertaining to general navigation problems is being done on the flight simulator. This instrument has been described in earlier reports. Work done to date is applicable primarily to KINGFISHER Model C but is important also to Models D and F.

General analytical studies have led to the conclusion that, to obtain accurate homing on moving targets, lead computation is desirable. However, flight tests and simulator studies have shown that the errors with lead computation may exceed the errors of a pursuit course unless the missile is extremely well stabilized. An optimum system may include pursuit homing over most of the flight path with lead computation applied only near the end of the flight.

As described in preceding reports, the KINGFISHER Flight Simulator is essentially a device for solving the equations of motion of a missile and it reproduces in the laboratory the behavior of the missile in flight. Many actual missile components such as gyros and servos are included as components of the simulator when any given missile performance is tested. Many studies such as the comparison of the effect of different control systems used in the BAT* missile on homing accuracy have been completed. As tests have progressed, numerous details of the simulator have been modified to improve the accuracy of simulation. It is now felt that simulator results compare very well with those that would be obtained in field tests.

B. CURRENT PROGRESS

Progress has been made with the KINGFISHER Flight Simulator in finding out the effect of adding lead navigation to the homing path of missiles of the KINGFISHER type.

Tests with the simulator have conclusively demonstrated that, before the pursuit type of homing can be altered with very much advantage by automatic lead computing devices, the stabilization must be such that there is no tendency for the homing path to exhibit an oscillation. Any oscillation in the missile path will be accentuated by the lead device. Then, even though the average value for the misses will be smaller,

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* The KINGFISHER project is in many respects based on earlier work on the BAT project. (See prior progress reports). BAT missiles and homing equipment have been and still are being used to assist in the testing of components for KINGFISHER missiles.

the increased dispersion of the misses about the target will have made the addition of lead undesirable.

With the flight simulator adjusted so as to represent the BAT airframe, (SWOD (Air Stabilizer) MK 13), many stabilization configurations were tried. Most systems tested did not have enough margin of "course stability" to make the addition of lead desirable.

The best results using a lead computer were obtained with a modified BAT servo (SWOD (Control System) Mark 18). After the servo was modified so as to remove a long integrating time constant in the homing intelligence circuits, the missile homing path obtained from the simulator proved to be very smooth with no evidence of oscillation. When a random error was introduced in the target position, the missile would correct its path with no overshoot. The value of adding lead navigation was tested with a simulated missile velocity of 350 miles per hour and simulated target velocities of both 15 miles per hour and 30 miles per hour at right angles to the missile path. With a target velocity of 15 miles per hour, the average miss was about 80 feet behind the target for a navigational lead factor of 1 (pursuit course); with a lead factor of 2, the average miss was about 5 feet behind the target; and with a lead factor of 4, the missile overshot, making the average miss about 5 feet ahead of the target. For target velocities of 30 miles per hour, the average miss for a lead factor of 1 was about 200 feet behind the target; with a lead factor of 2, the average miss was about 10 feet behind the target; and with a lead factor of 4, the average miss was about 0 feet. The navigation lead factor may be defined as the ratio of the angle turned through by the missile to the angle turned through by the antenna when the missile changes its course. For all of the above tests, the dispersion of the misses was very small. When a navigation factor of infinity was tried, which is the case where the antennae always point in the same direction in space, a violent homing oscillation developed upon the slightest disturbance. For all of these tests the homing intelligence adjustments were the same.

IV. GUIDANCE - INTELLIGENCE

A. STATUS OF DEVELOPMENT

The intelligence system under development for Models C and D KINGFISHERS is an X-band radar providing homing signals for azimuth with supplemental altitude control. The equipment developed to date is based on earlier work on the now abandoned Model A KINGFISHER, a glider missile. The intelligence system for the Model A provided homing in both azimuth and pitch and has been described in detail in previous progress reports. The antenna was a four-horn array with sequential, electronic switching. In the Model C the antenna is a polyrod array.

For the Model E KINGFISHER a command system based on the HORNET development by the Naval Research Laboratory will be used, altitude being controlled by an altimeter.

B. CURRENT PROGRESS

1. R. F. Development

New Antenna System for Azimuth Only Scan. - It has been found by further experiment with the polyrod array mentioned in the last quarterly progress report, that suitable radiapatterns with good gain can be procured with this antenna. A photograph of a prototype array is shown in Fig. 1. It is anticipated that more than twice the gain of the present antenna can be packed into the same or a smaller space, due primarily to using all the aperture for both beams, rather than using portions of the aperture alternately. The antenna proper is considerably smaller, but can no longer house the magnetron, the klystron and the mixer assembly, thus reducing the net space gain. Scanning is again accomplished with switch tubes, by changing the point of feed and thus the phase relations between the elements of the array. The plumbing problems involved in getting the correct amplitude and phase distribution across the array from both feed points are now being worked out.

Switch Tube Status. - New switch tubes with reduced water vapor content have been found to have approximately the same characteristics as the old, at reduced control currents. Recovery time is, of course, an exception; the reduced water vapor content lengthens the recovery time to approximately 20 microseconds (compared to 4 microseconds for the older type). No life tests have been made, but the first three tubes installed in the unit have shown no failures in approximately 12 hours of operation. On the other hand, the firing voltage has shown a gradual rise

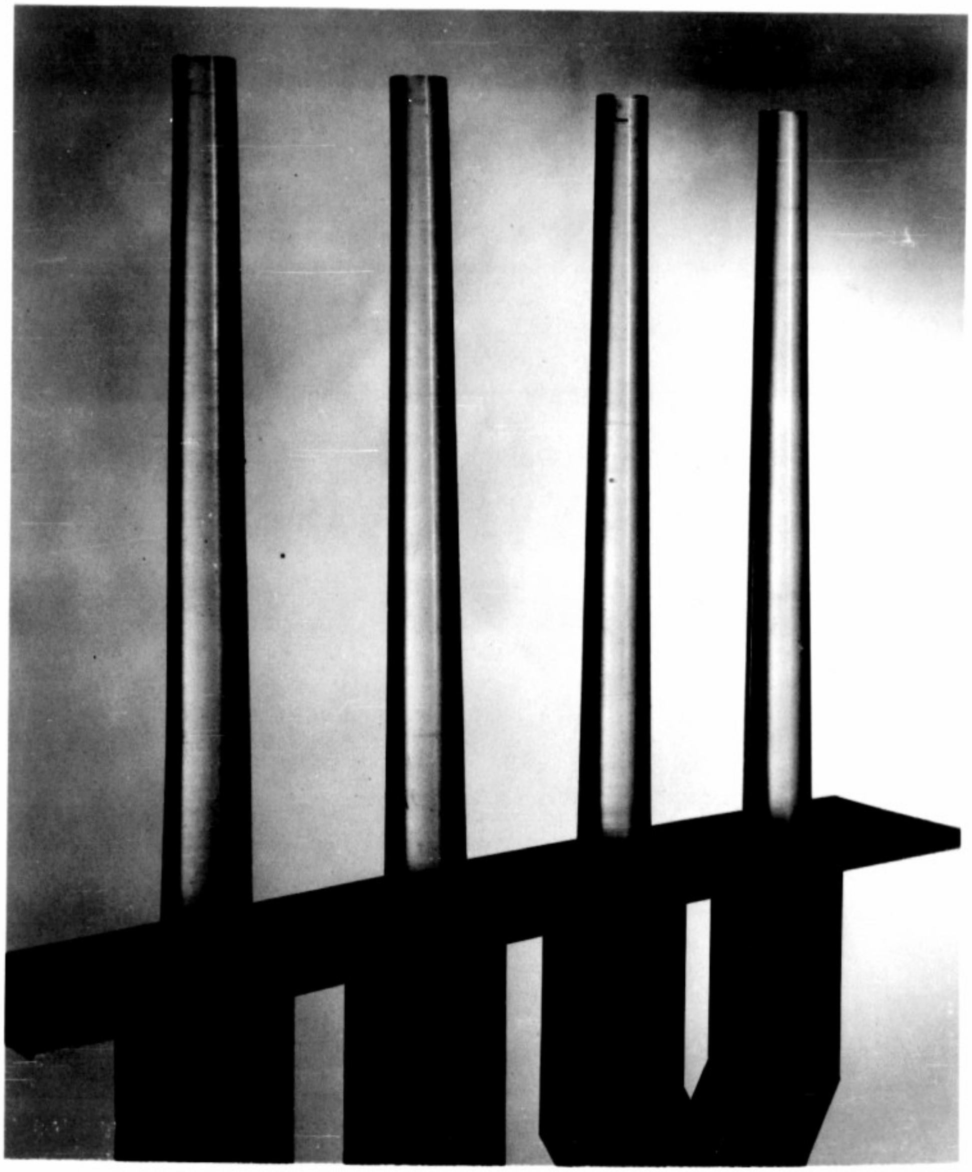

FIGURE 1

ONE BANK OF POLYROD ANTENNA ARRAY FOR MODEL C KINGFISHER

Complete antenna will consist of four banks forming an approximately square array.

in this period, which may make necessary a further increase of the voltages in the gating circuit, which are already inconveniently high.

Development of other switch tubes is being observed. One type, under the direction of NRL, is designed for very high r-f breakdown voltage, so that transmitter power can also be scanned with this tube; such a tube would be a convenience in certain problems. Under the direction of National Bureau of Standards, a second approach to the low-power tube is being explored, which will contain no resonant elements, and which will operate on low control voltages. Such a tube would eliminate three tuning adjustments and simplify gating problems.

Other R. F. Developments. - The untuned mixer will be ready for test shortly.

Further investigation of the transmitter-receiver coupling in the multi-horn type antenna for the Model C radar has been made. The coupling was considerably reduced by improving the local oscillator shielding. The remaining coupling is so weak that rudimentary or possibly no blanking circuits will suffice for good minimum range operation; the decision depends in part on radome properties. Various radome materials are now under investigation.

2. Circuit Development

I.F. Amplifier - Experience with the twelve available i-f amplifiers built under contract shows that elimination of all, or possibly all but one, tuning adjustments is feasible. A great deal of work was necessary, however, to eliminate feedback from the commercially made sets by a common scheme which would work on each amplifier of the twelve. Absorption in this task has limited further development of miniature amplifiers, but the task is now completed.

Video and Control Circuits - It has been found that the rigid coaxial cable, used extensively for filament wiring in the six commercial video units, has insulation subject to several objections. Due to the center conductor moving slowly through the insulation by cold-flow of the latter, shorts eventually develop at bends. Types of cable using fiberglass rather than plastic insulation are being investigated.

Further experience with the automatic range tracking circuits has now been gained, especially since a roof set-up affording natural targets with fluctuating echo strengths has become available. A brief summary of the status of this portion of the development follows.

The first step in the development was to build a tracking circuit similar to that used in the BAT, with the T5½ size tubes, and with constants modified for 0.25-microsecond pulses rather than 0.7-microsecond pulses. This circuit used a delay multivibrator to set the spacing between main bang and range gate, with a double cathode follower memory circuit, into which information was introduced through neon tubes. This circuit could not be made to track 0.25 microsecond pulses.

Two different circuits were then developed, either of which would give good tracking and memory. The first employed two crystal oscillators, whose relative phase and phase rate determined gate position and velocity. The second was a delay multivibrator circuit, with a single cathode follower memory circuit having special bias feedback features so that the tube always operated in a low grid current region. This second circuit was chosen for the first experimental models, for reasons of economy. It was found necessary to use d-c on the multivibrator filament to eliminate the last traces of gate jitter. In using the multivibrator circuit, the number of counter stages required to get down to the repetition rate when using a crystal stabilized oscillator was reduced. Sufficiently low frequency crystals are not available to avoid counter stages.

Experience now shows, however, that presently available T5½ tubes for the memory circuit may not be adequate. If, in place of the usual criteria, one selects excessive grid current as the life test endpoint, tube types tested to date have short lives. Grid current in the memory tube biases the velocity memory strongly. This same difficulty was experienced in the Bat development, even with the looser requirements made possible by the longer pulse. A tube (6SU7FTY) which was adequate was eventually developed in that case. At present, the situation is further aggravated by the unavailability of tubes made to JAN specifications, only "commercial" grades being available on the market.

Several appraoches to this problem are being explored:

a. Tests on further T5½, T3, and T7 tube types.

b. Circuit developments to reduce requirements on memory tube.

c. Simpler counting circuits for the dual-oscillator scheme. This circuit also requires a memory circuit, but qualitative analysis indicates that input impedance requirements may not be so stringent.

The tracking gate system has been altered for the purpose of eliminating an adjustment. Previously, two thyratron delay line circuits were used to generate the early and late gates. The thyratron grids were triggered together by a sawtooth wave form, and the gate spacing adjusted by controlling the bias on one thyratron. Development of a compact, high quality delay line has made possible the eleimination of one thyratron and of the bias adjustment, the late gate being formed by simply delaying the early gate. The line occasions almost no deformation in gate wave form, despite the narrowness (1/8 microsecond) of the latter.

3. Power Supply (Electronic); and Other Developments.

Experience of the contractor assigned the responsibility for packaging the 400-cycle power supply is such as to indicate that the power supply will go into the space allotted. Thus the dimensions in the mockup photographs in the previous quarterly report.will be those of the radar.

A new monitor design, allowing for expanded sweep presentation of the data, has been completed. Five units, and power supplies for same, are being constructed by an associated contractor.

The Bureau of Ships is placing a contract for the development of a modulator thyratron, with specifications ample for KINGFISHER use, and to be smaller than the 4C35. This latter is now, by a considerable margin, the largest tube in the set. However, space has been allotted for it in the present design.

4. Altimeter Development.

The altimeter for KINGFISHER is now under development at Emerson Radio & Phonograph Corporation. Agreement has been reached on general specifications regarding operational requirements, antennae type and size, mounting of antennae and physical size of altimeter.

The altimeter will be of the FM type operating on 250 megacycles with a deviation of 15 megacycles. Output of the transmitter will be approximately 1 watt. Altitude information from the altimeter is a positive voltage which

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will be proportional to altitude.

Range in altitude will be covered in two ranges; namely 25 to 500 feet and 500 to 2500 feet with automatic switch-over from one range to the other. A saturated condition above 2500 feet will exist causing output signal always to read 2500 feet when the vehicle is above that altitude.

Standard dipole antennae mounted under wing surfaces and parallel to axis of vehicle will be used on Model C KINGFISHER. Another possible arrangement would mount the antennae on the edges of the rear vertical stabilizers.

The altimeter under development should be satisfactory for KINGFISHER Models E and F, small revisions being necessary for each model.

The contractor feels that one experimental altimeter model can be delivered in October 1947 for preliminary tests.

5. Other Basic Systems.

The progress reported in previous sections has referred largely to work on the radar for Model C. This is the same basic system as will be employed in Model D; different systems are required for Model E and Model F.

Model E is to be a command set, with command guidance all the way, since there is no radar-visible target to home on. . Investigation (not yet complete) has been made of the status of systems already in advanced stages of development elsewhere. A variant of the HORNET system, employing modulation of the pulse repetition rate of a tracking radar, at present looks simplest. Although only three channels are required, it has been requested that a five-channel system be designed.

Model F has recently had a considerable extension of its required homing range, in order to include Army Air Force requirements. This alters the original plan to use a miniaturized Model C radar; it does not seem likely that any active system of size and weight appropriate to Model F dimensions will deliver the range required. Preset guidance plus active homing is also unattractive; the homing head would then require complicated target acquisition circuits. The possibilities and limitations of a passive homing head, with target illumination furnished by the mother plane, are now being studied.

6. Field Test Results on First Prototypes.

A variety of flight tests in the special experimental plane have been made. Results were limited on two scores; the inverter, converting the 24V dc airplane supply to 800-cycle a-c was found to be faulty; and the electronic power supply converting the 800-cycle a-c into the radar voltages had insufficient regulation.

The first fault was eliminated by replacing the inverter. The second was due to the transformers used; these were 60-cycle transformers. It was found that the correct d-c voltages were delivered with an 800-cycle primary supply; what was not noted until later was that this was achieved by the regulating system although transformer voltages were considerably out of line. The regulating tubes had short life and gave poor regulation under these circumstances. A new power supply with 400-cycle transformers is now at hand.

No completely satisfactory runs were made. However, experiments were completed showing that none could be expected in the plane with its present radome. The phenomenon of distortion of the radar width curve by the radome was observed to take place with the airplane randome, as was feared. Steps are being taken to find a supplier for a new radome for the airplane. In the meantime, it has been found that certain of the BAT radomes are satisfactory. Consequently, preparations are being made for further tests with the radar suspended outside the airplane in a modified BAT airframe. The preparations are nearly complete and early resumption of flight testing is foreseen.

V. PROPULSION

A. STATUS OF DEVELOPMENT

It is estimated that a propulsion unit having about an 800-lb net thrust will be required for KINGFISHER missiles. Major consideration is being given to a turbo jet for the Model C. Development of this item will be supervised by BuAer. Final power plants will probably not be available before late in 1948 and consideration is being given to interim power plants in order to provide powered missiles for test flights of other components. For this latter purpose, consideration is being given to the acid-aniline rocket motors developed for Project LARK and to the liquid oxygen-alcohol motors under development for Project METEOR.

Preliminary design studies of configurations for the Model F KINGFISHER were made by McDonnell Aircraft Corporation. Calculations indicate that when using an acid and aniline motor of the LARK type it would be necessary to exceed the specified maximum weight for Model F (1300 lbs.) by at least 100 lbs. in order to obtain the performance required. For this reason and because of the undesirable characteristics of acid and an aniline from the standpoint of safety and logistics, it was decided to study missile configurations employing pulsejet propulsion. Preliminary indications are that if an 11-inch-diameter partially-submerged pulsejet is used and the missile is designed structurally and aerodynamically for speeds of 500 knots, a level-flight speed above the specified minimum of 300 knots can be assured. Although a speed of 500 knots cannot be assured at this time because of the present lack of test data or adequate theory on pulsejet performance at high speeds, indications are that this speed is feasible. Preliminary studies indicate that the missile would weigh between 1100 and 1200 lbs.

VI. STABILIZATION AND CONTROL

A. STATUS OF DEVELOPMENT

Two methods for stabilizing KINGFISHER missiles are under investigation and components for each are under development. One method stabilizes the missile in pitch and roll through use of a gyro vertical. The position of the reference axes will be controlled by radar error signals. A second method is to stabilize in pitch and yaw by means of a free gyro spinning on the axis of roll and to stabilize in roll by means of an angular accelerometer.

The radar antenna will be stabilized along the line of sight to the target. Stabilization to within 1/4° without hunt is desired. A mockup of the Model A antenna has been stabilized in the laboratory.

B. CURRENT PROGRESS

1. Flight Tests of Fast Elevon Control.

On May 21, 1947, two SWOD Mark 9 Mod 1 units Nos. 1209 and 1133 were tested against a corner reflector to determine the effects of a slower elevon motion on the flight characteristics of a SWOD Mark 9 Mod 1 (Flights K-30 and K-31).

Both units were standard test units with Mark 18 Mod 1 servos except for a slower elevon motion. Unit 1206 was adjusted to operate at 13.5 degrees per second and unit 1133 was set for 25.9 degrees per second. These speeds are respectively approximately 1/5 and 1/3 of the normal speed.

Both flights appeared to observers to be no different than flights made by standard units. A 32-mile-per-hour cross wind caused the gliders to turn sharply as they neared the reflector.

Unit 1206 was perfect in range, being only 3 feet long in range while passing 125 feet to the right of the reflector.

Unit 1133 approached the reflector a little higher than unit 1206; and while passing only 45 feet to the right of the reflector, it landed 205 feet long in range.

The cameras in the glider 1206 were accidently run before the time of release and no records were obtained of the flight. Records were obtained on the test of 1133 and no great differences are noticeable except in the curves showing elevon motion, when compared with records of tests made with standard Mark 18 servos.

2. Antenna Stabilization

The clutch-operated servo systems being developed by Raymond Engineering Laboratories, Inc., and by F. H. Shepard are in the final assembly stages. Both clutch mechanisms have been bench tested, and show frequency response and output torques which are much better than required. Mock-ups of both systems have been built and studied for space economy, accessibility, and provision for radar mounting and adjustment. It has been found possible to use a common aluminum gimbal casting for all three systems, and the problem of an interchangeable mount is now being studied

The reversing-motor-operated system being developed at National Bureau of Standards is now in operation on a full sized dummy antenna and mount, with the gyro mounted on the antenna. Preliminary tests show a maximum stability error of from 1/6 to 1/4 degree for rates of pitch and yaw in excess of any anticipated for the KINGFISHER. There is no apparent interaction between the pitch and yaw sensing and controls. Either motion can take place separately or both can occur simultaneously without disturbing the direction of the antenna. The system also appears to be independent of roll. However, more tests are needed to confirm these results.

A slow drift has been noted when a constant torque is applied. This is due to the self-erecting properties of the Mark 18 Gunsight Gyro. Whether this effect is more objectionable than the random drift of a true free gyro is to be determined by test.

Figures 2 and 3 show two different views of the test setup. The dummy antenna is mounted in a gimbal which in turn is mounted in the tubular steel forward frame as shown in Figure 17 of the Quarterly Progress Report No. 2. The servo motors are mounted on this and the whole assembly is mounted for test purposes in large gimbals as shown.

The gyro and its associated pick-ups can be seen protruding through the ring type gimbal bearing in Figure 2. In Figure 3 the two servo motors and their associated gear trains can be seen; the elevation control being attached to the antenna gimbal, and the azimuth control mounted on the frame to the rear of the antenna. Both channels of the

Figure 2
Stabilized antenna mount,
showing gyro and pick-ups.

Figure 3
Stabilized antenna mount, showing
servo motors and associated gear trains.

servo amplifier are contained in the small chassis sitting on the test stand base board.

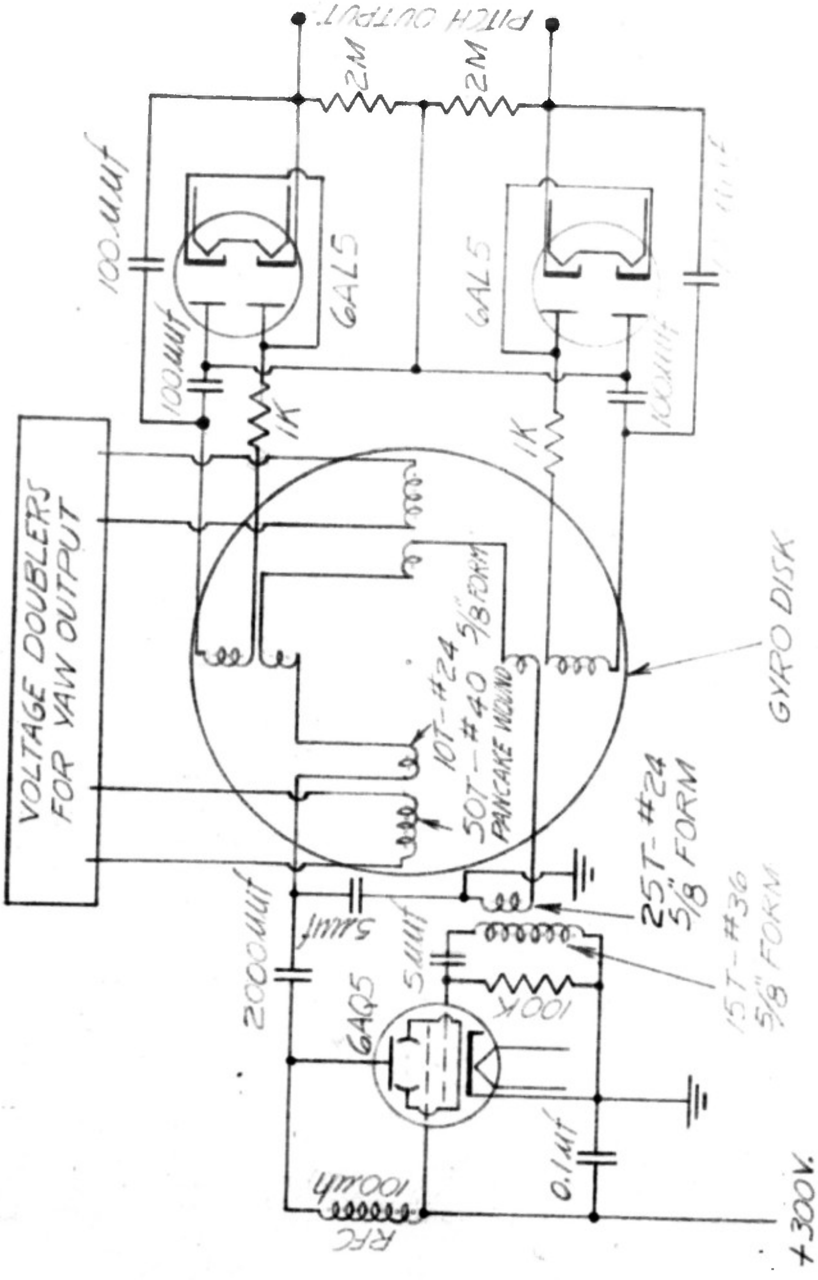
Probably the most interesting feature of this system is the pick-up employed on the gyro unit. The photoelectric pick-ups described and shown in Figure 18 of the previous report were satisfactory for short periods, but proved to have very poor long-term stability. As a result, new pick-ups have been devised utilizing the change in coupling of high frequency coils. The principle was first employed at National Bureau of Standards in a sensitive micrometer circuit. A schematic circuit diagram of the pick-ups is given in Figure 4.

The sensitivity of this circuit is excellent. The unit now in use has a sensitivity of approximately 80 volts per degree when connected to a 1/2-megohm load. No creep or drift of the pick-ups has been noted, and changes in sensitivity from day to day are very slight.

The great sensitivity and high voltage output of these pick-ups have made possible a greatly simplified servo amplifier. The push-pull signal from the rf pick-ups is fed directly to the grids of a single stage of d-c amplification employing push-pull 6AQ5's. These, in turn, control the saturation current in magnetic amplifiers which are coupled to the control phases of two-phase, low inertia servo motors. The anti-hunt is derived from a resistance-capacitance network directly across the pick-up, amplified by 6J6's and fed to the screen grids of the 6AQ5 d-c amplifier tubes. A circuit diagram of the experimental set-up is shown in Fig. 5.

A setup is being completed for determining the frequency response and stability of the overall servo system. Such tests are in progress on the National Bureau of Standards and Raymond systems, and are contemplated for the Shepard system.

Because the self-aligning properties of the Mark 18 (Gunsight) gyro lead to a steady creep when cable torque is applied to the antenna, two free gyros are now under development. Both consist of small motors and flywheels mounted in gimbals, with provision for magnetic precession in response to signals from the radar. In the one being developed by Raymond, the signal is derived from voltages induced in crossed coils surrounding a permanently magnetized flywheel. The one being designed at National Bureau of Standards employs the r-f pick-ups described earlier.



OSC. FREQ. 5MC

FIGURE 4 - CIRCUIT DIAGRAM OF R.F. PICKUP FOR GYRO

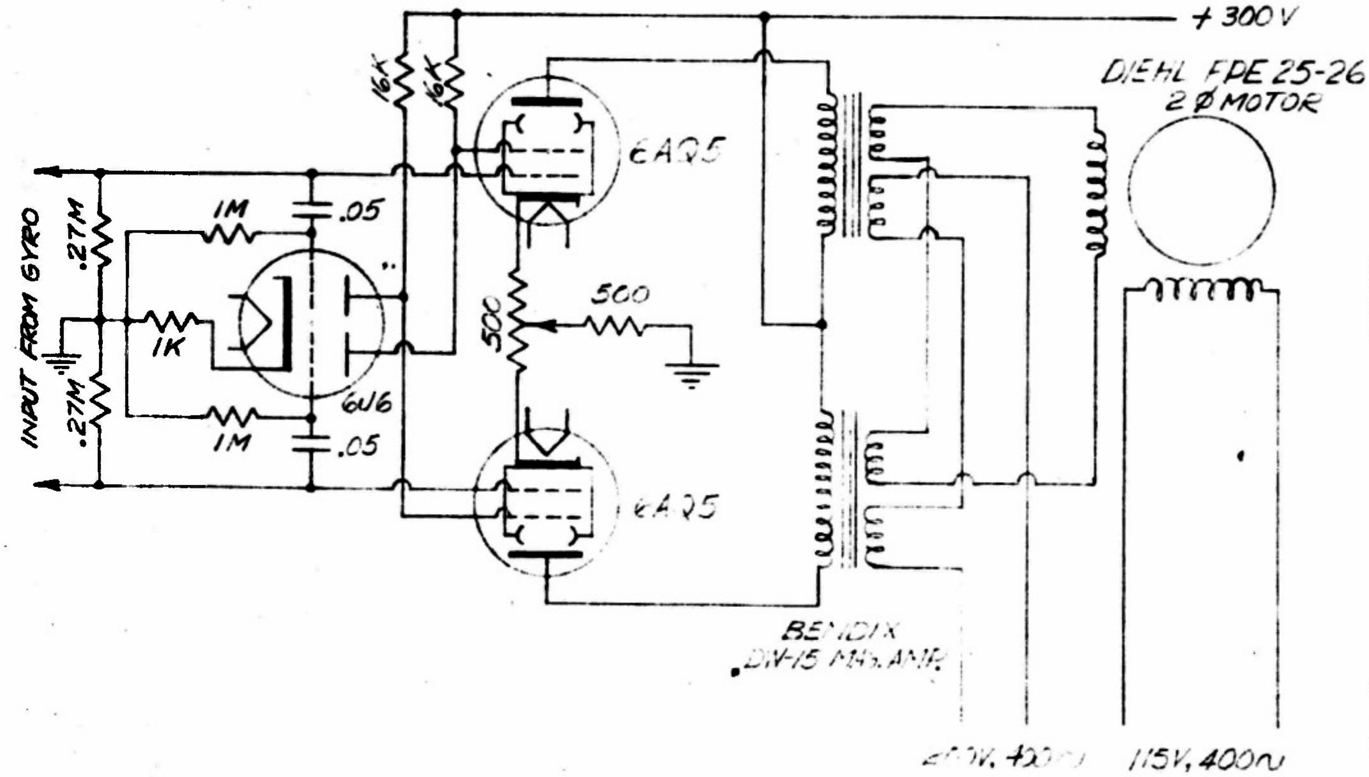


FIGURE 5 — ONE CHANNEL OF ANTENNA SERVO AMPLIFIER

3. Main Control Servo

The wedge-gear clutch described in Quarterly Progress Report No. 2 is now nearing completion. It is hoped that performance tests on this type can be started in the near future.

The Raymond Engineering Laboratories have under construction two main servo units, one a motor driven in-the-wing type and one an externally attached wind-driven type. Both utilize a new and more easily constructed version of the differential clutch described previously. National Bureau of Standards is developing the air-driven turbine for this application. F. H. Shepard is also building a packaged-unit servo for the main controls. It employs two opposing magnetic clutches. A small model of this clutch has been demonstrated successfully.

VII. ELECTRICAL POWER SUPPLY

A. STATUS OF DEVELOPMENT

Major consideration is being given to air-driven electrical generators to supply the power necessary for operating the radar and stabilization and control systems. A constant-speed windmill has been developed and tested in the laboratory with satisfactory results. A contract has been let for the construction of fifty of these windmill generators for flight tests.

Experimental work has also been started on a speed-regulated turbine which would permit mounting of the power supply and drive inside the airframe with appropriate ducts. Preliminary calculations and experiment indicate that this procedure will be practicable and more generally acceptable than the use of the externally mounted windmill.

VIII. INSTRUMENTATION

A. STATUS OF DEVELOPMENT

The instrument system developed for BAT, with some improvements, is being used for flight tests. This system includes two recording cameras within the missile and two ground stations for obtaining trajectory data by optical methods. The cameras within the missile are enclosed in rugged cases to preserve the records from damage caused by impact. One camera photographs an instrument panel and the other the view directly ahead of the missile. (See bibliographical reference No. 1).

Telemetering systems are under investigation for future flight tests. In conformance with the general service policy of reducing the number of telemetering receiving and recording systems required at Proving Grounds, work on an original telemetering system for KINGFISHER has been abandoned. Consideration is being given to the FM sub-carrier system of APL and the pulse-position modulated system of Raytheon. A conclusion has not yet been reached as to which system will be most suitable for KINGFISHER.

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The distribution of this report is in conformance with Parts A, B, and C of AN-GM Mailing List No. 3, dated May 1947.

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ATI FORM C (13 MAR 47)

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DIVISION: Guided Missiles (1)
SECTION: Design and Description (12)
CROSS REFERENCES: Missiles, Guided - Development (62920); Kingfisher (62920)

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Robert Storer
Chief, Records and Declassification Division

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