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PROJECT RASCAL

PROJECT SHRIKE

Report No. ______ BMPR-32

Date __________ 31 MARCH 1953

Contract No.______ W33-038ac 14169

Project No. ______ MX 776 A & B

No. of Pages ______ 66

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RASCAL

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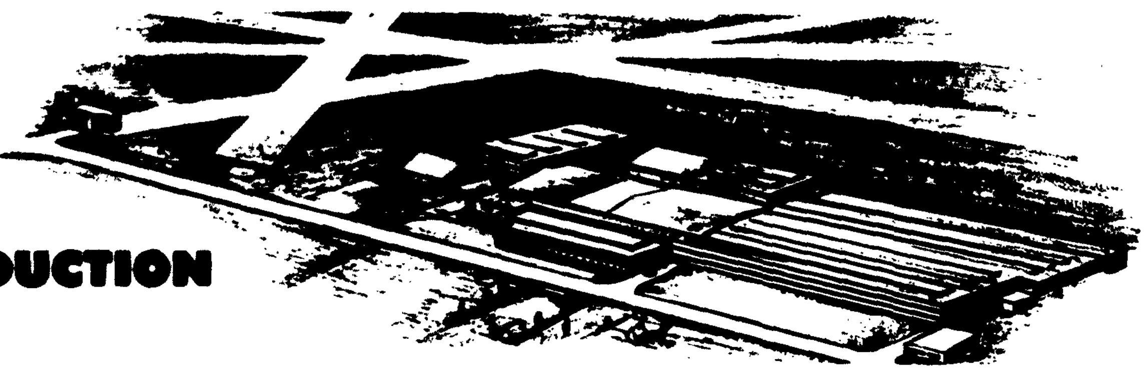


INTRODUCTION

1. DESCRIPTION OF WEAPON

a. RASCAL - Project MX-776B

RASCAL is a rocket-powered, supersonic, air-to-surface pilotless parasite bomber. Weighing 18,800 pounds, it carries a 2800-pound warhead (with provisions up to 5000 pounds) at speeds corresponding to Mach 1.5 to 2.5. Range is 75 nautical miles; accuracy — 50 per cent of the pilotless parasite bombers shall have a burst strike within 1500 feet of a vertical line through the target and at an altitude within plus or minus 500 feet of a predetermined altitude. Principal dimensions include: length 32 feet, diameter 4 feet, and maximum horizontal span 17 feet.

The B-47 has been designated the first priority director aircraft with the B-36 and B-52 following in order. For the present, only B-47s and B-36s will be considered. For R & D use, B-50s will be used as director aircraft.

A liquid rocket power plant (white fuming nitric acid and gasoline) supplies 12,000 pounds thrust for a short period to accelerate the pilotless parasite bomber to supersonic velocity and a smaller sustaining thrust, 4000 pounds, to maintain this velocity for the remainder of the flight.

Guidance of the pilotless parasite bomber is accomplished by a nonemanating guidance system and a radar relay and command system. The director aircraft proceeds to a predetermined launch point using its own long-range radar and computing system. Immediately prior to launch, information regarding aircraft velocity, range to target, etc., is fed into the RASCAL and serves as initial condition data for the nonemanating system. The pilotless parasite bomber is under the control of this system during the mid-course phase of the flight. At a predetermined range from target, the nonemanating system causes the RASCAL to assume a 30° dive angle. During the terminal dive, the radar in the nose of the pilotless parasite bomber illuminates the target, and the radar return is relayed to the director aircraft where it is displayed on indicators. An operator tracks the target echo, and sends guidance commands to the RASCAL via the microwave relay link.

The guidance system just described will be used on the final weapon system. As an interim measure for the early R & D pilotless parasite bombers, a radar midcourse guidance will be used in place of the nonemanating system.

b. SHRIKE - Project MX-776A

SHRIKE, a smaller missile of cruciform canard configuration, has been designed to test component designs and missile systems directly applicable to the larger RASCAL.

Length is 277 inches; diameter is 21 inches; wing span is 92 inches; gross weight is 3500 pounds; and the range is 50 miles at approximately Mach 2.0.

SHRIKE is powered by a rocket engine incorporating two 1500-pound, acid-gasoline thrust chambers. Track-command guidance equipment provides midcourse guidance.

2. STATUS OF FLIGHT TEST PROGRAM

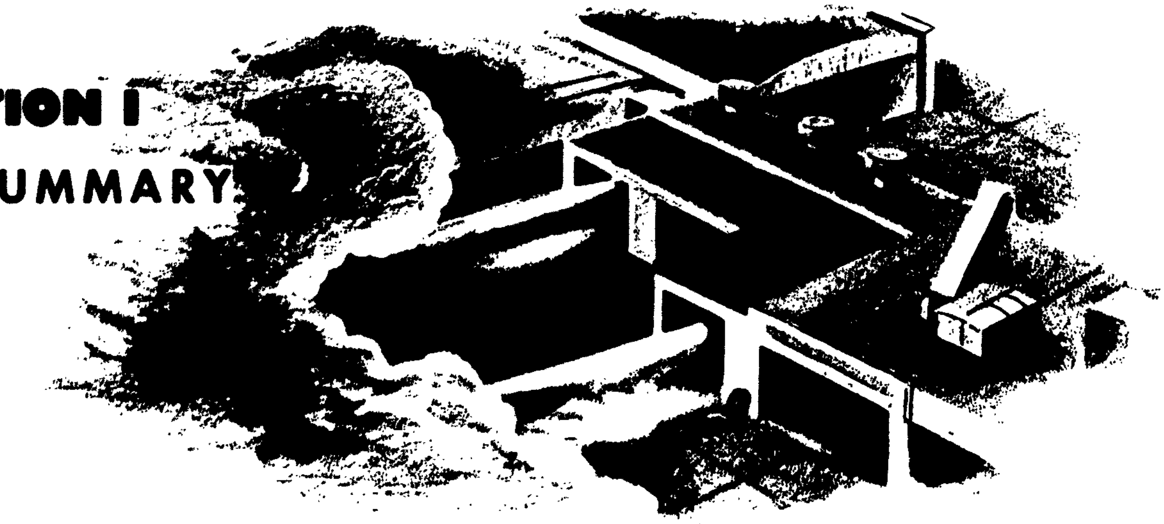
a. RASCAL

A series of RASCAL "glide" bombers has been launched to test launch gear operation, aerodynamics, stability, and recovery system. The second and third XB-63s were launched during this quarter. Flight testing details are reported in Section III.

b. SHRIKE

With the launching of two chemical warhead test vehicles, Missiles 2713 and 2812, on 20 and 23 January 1953, the SHRIKE flight testing program was brought to a close. The results of the chemical warhead tests are summarized in Section III.

SECTION I
SUMMARY



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In January 1948, Project MX-776 was divided into two concurrent programs:

MX-776A (SHRIKE) - Design, development, and fabrication were started on SHRIKE, a supersonic RASCAL test vehicle with a 50-mile range and design provisions for warheads up to 2000 pounds.

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In February 1952, the RASCAL program was reoriented to attain a B-63 for use by the military in 1955. The B-63 will be as proposed in the Bell Aircraft feasibility proposal, dated 10 January 1952, and shall be capable of being carried and launched by a B-47 airplane.

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Immediate objectives of Project MX-776 include the attainment of a complete weapon system consisting of a B-63 pilotless parasite bomber employing single-axis inertial guidance, X-band terminal guidance radar, an atomic warhead, a B-47 director aircraft equipped with a single-operator command-guidance system, and support equipment. Early in 1952, a complete nonemanating guidance system was established as a basic ultimate requirement for the RASCAL weapon. The program therefore, will progress from a single-axis radar-emanating guided weapon to a multiaxis nonemanating weapon. Additionally, a chemical warhead and a K_u-band search radar will be dovetailed into the weapon system.

In 1952, Project MX-776 progressed from the basic design phase to testing and evaluating pilotless parasite bombers, director aircraft, and ground support items. It was during this year that the first pilotless parasite bombers were subjected to intensive systems testing to ensure the attainment of system objectives.

Preliminary systems tests on a completed RASCAL are conducted in the Missile Laboratory at the Wheatfield facility where all RASCAL systems with the exception of the power plant are checked to insure proper operation. After a series of successful composite system tests are run, the RASCAL is shipped to AF Plant No. 38, where the 12,000-pound-thrust power plant is installed and all systems are again checked with the power plant in operation. After all systems have functioned successfully, the RASCAL is brought back to the Wheatfield Plant for preparation and shipment by ferry aircraft to the Holloman Air Development Center. At Holloman, the systems are again checked on the ground and in the air under operating environment during captive flights.

The first block of three XB-63s was committed to a flight testing program designed to evaluate: (1) the ability of the power plant to provide the thrust required to propel the RASCAL under actual flight conditions; (2) the ability of the servo-autopilot to maintain three-axis stabilized flight; and (3) to determine drag, lift, and other aerodynamic parameters and to evaluate the response of the servo-airframe combination to various pitch and yaw maneuvers.

This testing program on the first block was initiated on 30 September 1952, when XB-63 No. 0307 (round 3, airframe 7) was fired at Holloman, and completed on 13 March 1953 with the firing of No. 0510 — RASCAL 0409 was fired on 15 January 1953. (Flight test details are presented in Section III.)

As the major objectives of all these flights were attained successfully, it is now possible to conclude that:

(1) The thrust developed by the RASCAL power plant under actual conditions is essentially as predicted and will be adequate for its intended use.

(2) The servo-airframe combination has demonstrated its ability to maintain three-axis stabilized flight and to perform the maneuvers which have been required so far in the evaluation program.

(3) No evidence was disclosed that the RASCAL will not perform as expected.

This first group of three flights just described, whose primary mission was to evaluate power plant and servo-airframe operations, will be followed soon by the flights of Nos. 0613 and 0715 to evaluate the guidance system, and of Nos. 0811 and 0912 to evaluate the operation of the power plant in conjunction with the turbine-pump-fuel-feed system.

RASCAL No. 0613, the first guided XB-63, and its B-50 director aircraft are being prepared for their flight test. After exhaustive tests in the Missile Laboratory, RASCAL No. 0613 has demonstrated successful operation of all components and guidance and control systems. Two composite systems tests have been run and a third is scheduled for the next quarter. The director aircraft and its guidance equipment has been successfully checked out in flights with an F-80 (simulated RASCAL) and also in captive flights with an operating test vehicle (XB-63 mock-up No. 8).

RASCALS 0811 and 0912 are scheduled for turbine-pump evaluation flights. These XB-63s are out of manufacturing and largely through their systems checks in the Missile Laboratory. Concurrently, the power plants for these pilotless parasite bombers have been undergoing exhaustive tests, and Aerojet Engineering Corporation has been able to deliver power plant turbine pumps which have successfully passed the seven-cycle acceptance test. To date, four acceptance-tested turbine pumps have been delivered and over 60 runs on the turbine-pump-power-plant combination have been made at Bell Aircraft during January, February and March 1953 to establish the reliability and acceptability of this power plant.

While the progress already outlined was being made on the immediate flight test program, concurrent effort has resulted in significant advances towards the attainment of the final B-47/B-63 weapon system. A complete prototype of the Model 110 Single-Operator Terminal Guidance and Control Station, designed for installation in the B-47, has been installed in the laboratory and is currently being tested. The installation includes the automatic tracking relay antenna which has been developed to enable the B-47 director aircraft to maintain its receiving/transmitting antenna continuously directed at the XB-63 during its flight without the attention of the operator. (See Section II, Part C.) The initial tests on this piece of equipment have been successful. The unit has demonstrated its ability to track an F-80 carrying the RASCAL guidance equipment in actual flight. Both of these items are scheduled for early flight tests.

On oral authorization from WADC, active planning has been resumed for the design and fabrication of a chemical warhead test vehicle. This test vehicle, comprising mainly an airframe and a solid propellant power plant designed to simulate XB-63 trajectory, will be used to obtain impact patterns and detonation conditions for both BW and GB warheads. This work is being done for the Army Chemical Corps.

A training and provisioning conference was held at Bell Aircraft 10 through 13 March 1953. This conference was attended by representatives of TTAF, ATC, Hq. USAF, SAC, APG, WADC, AMC, ARDC, and other interested Air Force organizations. During the conference, preliminary evaluations were made on the numbers and types of personnel to be trained to support the Air Force Operational Suitability Testing program and to supply the required cadres of trained personnel.

With the basic operation of the power plant and the stability of the servo-airframe already established, the MX-776 weapons system evaluation program is now continuing with the following:

(1) The evaluation of guidance equipment in an F-80 aircraft used as a simulated RASCAL.

(2) The preparation for actual flight tests of a guided pilotless parasite bomber early in the summer of 1953.

(3) The evaluation, in actual XB-63 firings, scheduled for the summer of 1953, of an improved fuel feed system, incorporating a gas turbine drive, for the RASCAL Power Plant.

Shrike

FLIGHT TEST SUMMARY OF MODEL 59A

The Model 59A flight testing phase of the SHRIKE program was successfully concluded at Holloman Air Development Center on 23 January 1953. Three fundamental objectives were satisfactorily demonstrated: (1) three-axis stabilized supersonic flight; (2) effective guidance control during the launching, midcourse, and terminal dive phases; and (3) directing the missile to impact on a surface target.

Secondary objectives of benefit to the RASCAL and SHRIKE programs, were also accomplished successfully and included: (1) air launching of an acid/gasoline missile from a zero-length rail; (2) radar tracking and command destruction of the missile from the director aircraft as well as from the ground radar station; (3) surveys of ambient, equipment operating, and skin temperatures; (4) control of climb and altitude by means of a pressure-sensing altimeter in the pitch-servo system; and (5) determination of the dispersion pattern of a chemical warhead when separation occurs at specific velocity, altitude, and flight path angle. Additional data, as well as checks on systems and airframe design, were obtained for direct application to the RASCAL weapon.

SHRIKE 1601, the first of thirteen X-9 missiles in the Model 59A program, was primarily directed toward demonstrating the performance of missile systems. To permit a clear performance study of the systems, guidance commands were not transmitted to this missile. On the other hand, SHRIKE 1702 was subjected to a series of captive flight tests to investigate the problems of remotely coupling the guidance-servo link. Preliminary captive flight tests indicated that the guidance system and antenna patterns were satisfactory, and that commands could be transmitted up to a separation distance of 125 nautical miles. The final flight verified this as commands were received by the missile during midcourse and terminal dive. The performance of 1702 was not repeated with 1803 which was accidentally destroyed shortly after launch by a destruct frequency signal emanating from a malfunctioning ground tracking radar.

Missiles 1904, 2005, 2206, and 2307 were assigned the primary objective of demonstrating guidance control. SHRIKE 1904 provided an excellent demonstration of guidance control during the phases of prelaunch navigation, midcourse at high altitude, and terminal dive; impact was approximately 0.6 nautical miles from the target. Midcourse commands were not received by 2005 because of a mistuned command transmitter in the director aircraft, but both prelaunch and launch guidance operations were excellent. SHRIKE 2206 became unstable at launch and guidance control was not established. SHRIKE 2307 accepted commands during terminal dive and was guided to impact, 1646 feet from the target. An additional objective of Missiles 2005 and 2307 was to survey skin and equipment operating temperatures during high-altitude, high-velocity flight. The results obtained agreed reasonably well with both theoretical values and recorded values obtained from the flight testing of an earlier missile, No. 1006 of Model 59.

Missiles 2408, 2509, and 2610 provided an evaluation of SHRIKE as a low-level-attack vehicle. These missiles were launched at approximately 1500 feet above the terrain and flew in level flight at 3000 feet above the terrain. As each missile passed over a surface target, detonation was initiated by the guidance operator in the director aircraft. These missiles maintained three-axis stabilized flight at transonic Mach numbers for prolonged periods of time and also demonstrated successfully low-level attack.

The chemical warhead missiles, Nos. 2111, 2713, and 2812, demonstrated successfully the dispersion of warhead units and proved that structural design of the individual bombs deployed at Mach numbers ranging from 0.82 to 0.99 was satisfactory. The guidance-servo link adequately controlled Missiles 2111 and 2713 during the midcourse phase even though large angles of separation existed between the antennas of both the director aircraft and 2713. As SHRIKE 2812 was launched with an inoperative servo system, owing to loss of servo hydraulic pressure, attitude stabilization was not attained.

The various systems of SHRIKE — attitude stabilization, altitude control, guidance, power plant, and telemetering — were basically the same for all 13 missiles except for some changes in individual components. From the performance of these systems, the following general conclusions are drawn, with the understanding that these conclusions are based on a total of 13 firings, ten instrumented and three not completely instrumented, a profile of which is shown in Figure 1:

(1) Attitude Stabilization

Flight testing has indicated that the design of the servo system satisfactorily fulfills the requirements of three-axis stabilization. This system performed satisfactorily on seven of the thirteen missiles. Control of 1601 was lost owing to instability resulting from rudder and elevator oscillations which caused a severe drain on the hydraulic system. This condition was remedied on subsequent missiles by reducing the sensitivity of the servo loop in responding to the 30 cps vibration encountered on this flight. On Missiles 1702 and 1904, a failure of hydraulic pressure after 200 seconds of flight resulted in loss of control just prior to impact. It is suspected that a similar failure occurred during the nontelemetered flight of 2111. SHRIKE 2206 became unstable when the gains of the servo system were incorrectly set to compensate for the marginal stability of the missile (center of gravity was purposely changed). SHRIKE 2812 was launched with an inoperative servo; hydraulic pressure dropped below minimum as the missile was being launched.

In repeated instances, the stabilization system was able to control the attitude of the missile during the launching phase. The large-angle yaw-roll oscillations which occurred during most flights, except those of SHRIKE 2206, were quickly damped as well as the oscillations which occurred at reception of the terminal dive signal.

Three flights were made at low altitude and transonic velocity. Slight adjustments in the roll gains and the roll compensating networks provided excellent control for nearly 100 seconds of flight at Mach numbers ranging from 0.95 to 1.05.

The coupling of the servo system with the guidance system produced satisfactory servo response to guidance commands.

(2) Altitude Control

Of the missile systems, altitude control proved to be one of the most reliable. During four of the thirteen flight tests, there was no opportunity for this system to exercise altitude control because of failures in other systems. However, for the nine tests in which altitude control was established, the maximum

MISSILE NO.	LAUNCHING DATE
1601	4-16-52
1702	6-19-52
1803	7-1-52
1904	7-31-52
2005	9-9-52
2111	10-9-52
2206	10-23-52

MISSILE NO.	LAUNCHING DATE
2307	10-29-52
2408	11-26-52
2509	12-10-52
2610	12-16-52
2713	1-20-53
2812	1-23-53

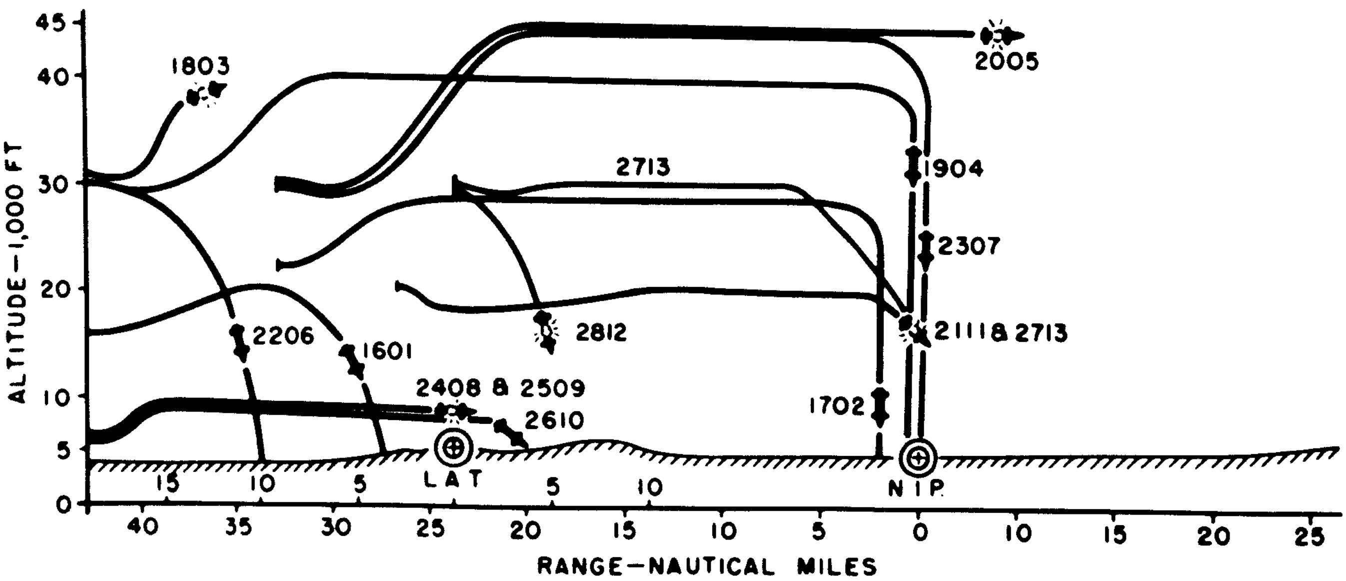

Figure 1. Profile of SHRIKE 59A Flights

deviation was only 1000 feet; and on six of these the error was only 200 to 400 feet. A Giannini wire-wound pickoff was used on four flights, and a No. 1597 Kollsman Synchrotel altitude transmitter was used on five. By using Kollsman instruments, a considerable portion of the noise normally induced on the pitch surfaces by Giannini instruments was eliminated.

(3) Guidance

Twelve missiles were equipped with a guidance system to test guidance with respect to prelaunch navigation and midcourse azimuth control. Of these, six were to be controlled in pitch and yaw during a vertical dive to a target, three low-level missiles were to be destroyed by a command signal in level flight over the target; and the remaining three, after completing an azimuth controlled flight (pursuit curve) to the terminal dive circle, were to enter a dive at a preset angle. During these tests, the launch point was satisfactorily determined by prelaunch navigation except for the two flights when aircraft heading was controlled from the ground radar station. Since the accuracy of the guidance system was somewhat contingent upon the experience level of the guidance operator, guidance accuracy increased directly with experience level. On the other hand, the average error in the launch-point-to-target distance computed by the guidance system was consistently two per cent.

Only nine of the twelve guided flights presented an opportunity for midcourse control, as three missiles did not establish level flight. Of the nine, the midcourse link was established on six, and three did not respond to midcourse commands for the following reasons: (1) Missile 2206 - mistuned command transmitter in the director aircraft; (2) Missile 2307 - erratic transmission of the computer in the "burst" mode; and (3) Missile 2408 - engine failure in the director aircraft caused a loss of power to the command transmitter. When the midcourse link was established, the missile responded quickly and accurately to the commands. Of the three low-level missiles, 2509 and 2610 were guided to miss distances of 0.52 and 0.45 nautical miles, respectively; the miss distance of 2408 without midcourse guidance was 1.5 nautical miles.

With the possible exception of 2713, operation of the guidance equipment was satisfactory on all twelve guided flights. Where the midcourse link was not established, the cause was due to equipment failure in the director aircraft, personnel procedure error, or to malfunction in a system other than guidance.

Three of the six missiles scheduled for a vertical dive responded to the dive entry signal and received commands, during the terminal dive phase, which altered the flight paths toward the target. Of the three which did not enter a dive, 1803 and 2206 should not be considered since their flights were interrupted shortly after launch, and 2005 reached the terminal dive circle but did not respond to the dive command. Missiles 1702, 1904, and 2307 responded to terminal dive commands; target miss-distances, Figure 2, were 1.8, 0.58, and 0.27 nautical miles, respectively.

(4) Power Plant

The rocket propulsion system proved to be the most reliable system in the SHRIKE missile. No component failures occurred and rated conditions of chamber pressures and thrust were maintained. Although telemetering was not used on the chemical warhead vehicles, the range, altitude, and velocity performances of these missiles indicated that rated thrust prevailed.

(5) Instrumentation

The telemetering system provided valid reducible data during the flights of ten missiles; three were not telemetered. The maximum noise level of the continuous channels was three per cent. It was found that the 10.5-kc channel, normally used as a continuous channel, could be commutated at five samples per second if an additional two to three per cent error could be tolerated.

Phototheodolite coverage was seldom complete during these flights, generally owing to a lack of tracking aids. Two station solutions were usually obtained during the initial post-launch period; the up-range stations were able to acquire the missile on only three occasions and this was accomplished when a smoke generator provided a suitable tracking aid.

Provision for smoke generation and adequate briefing of the theodolite operators are apparently fundamental requirements for complete flight coverage.

Radar tracking of the X-band beacon was successful on all but two occasions. Airborne radar was able to track all but one flight.

MISSILE NO.	LAUNCH-POINT-TO-TARGET DISTANCE (NAUT. MI.)	MISS DISTANCE (NAUT. MI.)	TRUE BEARING FROM TARGET
1702	30.0	1.8	111°
1904	42.8	0.58	108°
2307	33.5	0.27	043°
2408	19.6	1.75	024°
2509	19.4	0.52	065°
2610	18.4	0.41	041°

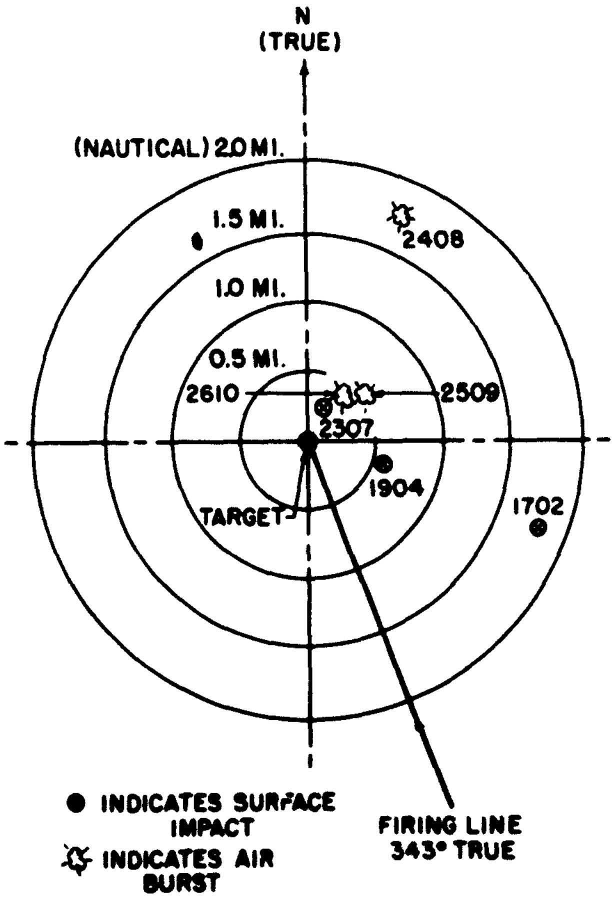

Figure 2. Miss Distances, SHRIKE 59A Missiles

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quarterly progress report

PROJECT RASCAL

PROJECT SHRIKE

Report No. _ _ _ _ _ BMPR-32

Date _ _ _ _ _ _ _ _ _ _ 31 MARCH 1953

Contract No. _ _ _ _ _ W33-038ac14169

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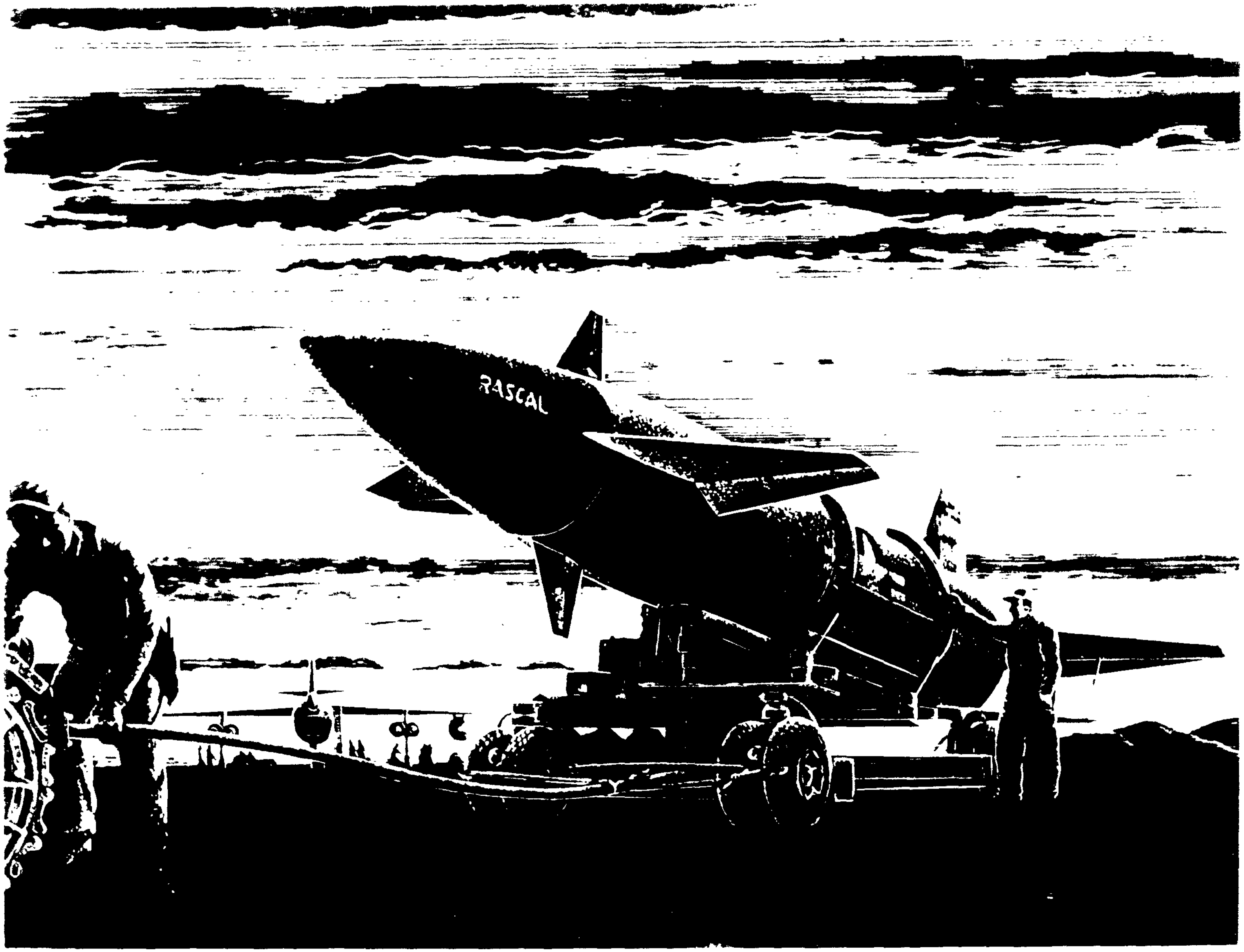
BELL Aircraft CORPORATION


RASCAL

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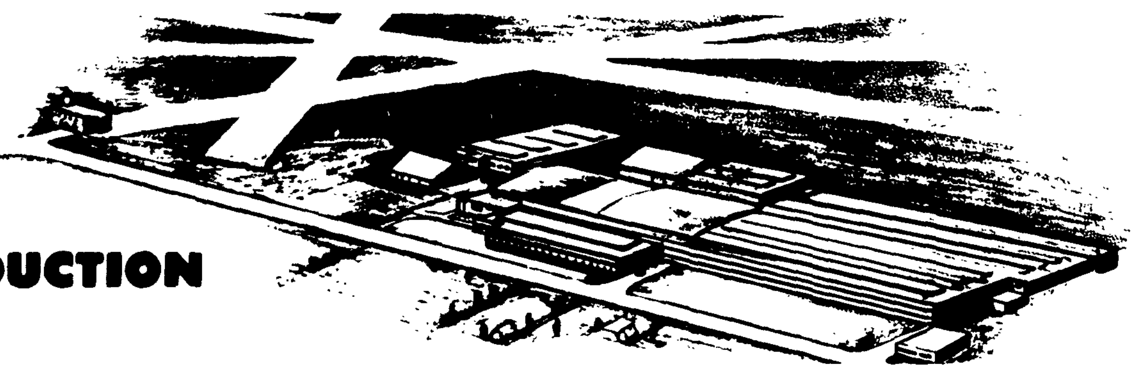

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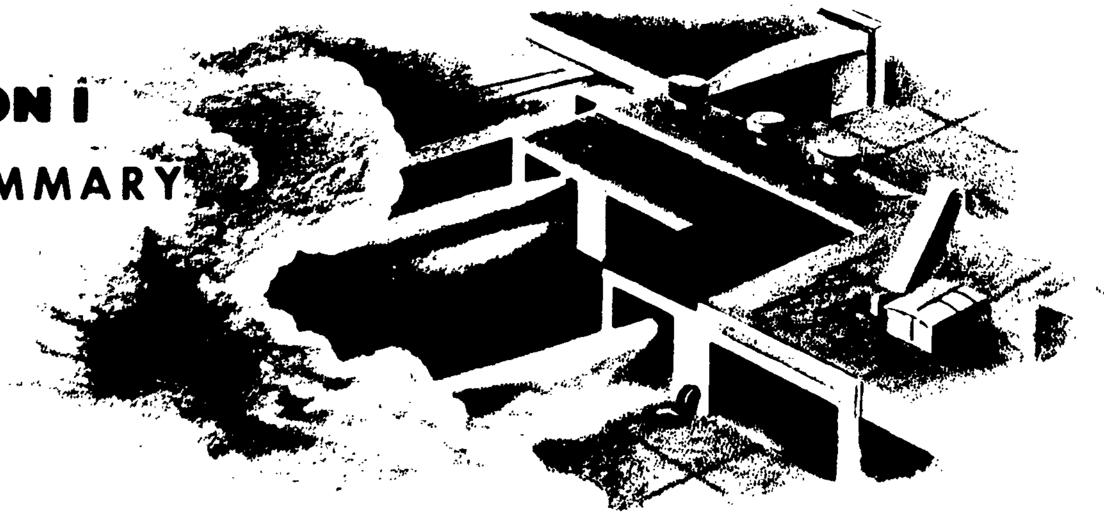

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In 1952, Project MX-776 progressed from the basic design phase to testing and evaluating pilotless parasite bombers, director aircraft, and ground support items. It was during this year that the first pilotless parasite bombers were subjected to intensive systems testing to ensure the attainment of system objectives.

Preliminary systems tests on a completed RASCAL are conducted in the Missile Laboratory at the Wheatfield facility where all RASCAL systems with the exception of the power plant are checked to insure proper operation. After a series of successful composite system tests are run, the RASCAL is shipped to AF Plant No. 38, where the 12,000-pound-thrust power plant is installed and all systems are again checked with the power plant in operation. After all systems have functioned successfully, the RASCAL is brought back to the Wheatfield Plant for preparation and shipment by ferry aircraft to the Holloman Air Development Center. At Holloman, the systems are again checked on the ground and in the air under operating environment during captive flights.

The first block of three XB-63s was committed to a flight testing program designed to evaluate: (1) the ability of the power plant to provide the thrust required to propel the RASCAL under actual flight conditions; (2) the ability of the servo-autopilot to maintain three-axis stabilized flight; and (3) to determine drag, lift, and other aerodynamic parameters and to evaluate the response of the servo-airframe combination to various pitch and yaw maneuvers.

This testing program on the first block was initiated on 30 September 1952, when XB-63 No. 0307 (round 3, airframe 7) was fired at Holloman, and completed on 13 March 1953 with the firing of No. 0510 – RASCAL 0409 was fired on 15 January 1953. (Flight test details are presented in Section III.)

As the major objectives of all these flights were attained successfully, it is now possible to conclude that:

(1) The thrust developed by the RASCAL power plant under actual conditions is essentially as predicted and will be adequate for its intended use.

(2) The servo-airframe combination has demonstrated its ability to maintain three-axis stabilized flight and to perform the maneuvers which have been required so far in the evaluation program.

(3) No evidence was disclosed that the RASCAL will not perform as expected.

This first group of three flights just described, whose primary mission was to evaluate power plant and servo-airframe operations, will be followed soon by the flights of Nos. 0613 and 0715 to evaluate the guidance system, and of Nos. 0811 and 0912 to evaluate the operation of the power plant in conjunction with the turbine-pump-fuel-feed system.

RASCAL No. 0613, the first guided XB-63, and its B-50 director aircraft are being prepared for their flight test. After exhaustive tests in the Missile Laboratory, RASCAL No. 0613 has demonstrated successful operation of all components and guidance and control systems. Two composite systems tests have been run and a third is scheduled for the next quarter. The director aircraft and its guidance equipment has been successfully checked out in flights with an F-80 (simulated RASCAL) and also in captive flights with an operating test vehicle (XB-63 mock-up No. 8).

RASCALS 0811 and 0912 are scheduled for turbine-pump evaluation flights. These XB-63s are out of manufacturing and largely through their systems checks in the Missile Laboratory. Concurrently, the power plants for these pilotless parasite bombers have been undergoing exhaustive tests, and Aerojet Engineering Corporation has been able to deliver power plant turbine pumps which have successfully passed the seven-cycle acceptance test. To date, four acceptance-tested turbine pumps have been delivered and over 60 runs on the turbine-pump-power-plant combination have been made at Bell Aircraft during January, February and March 1953 to establish the reliability and acceptability of this power plant.

While the progress already outlined was being made on the immediate flight test program, concurrent effort has resulted in significant advances towards the attainment of the final B-47 B-63 weapon system. A complete prototype of the Model 110 Single-Operator Terminal Guidance and Control Station, designed for installation in the B-47, has been installed in the laboratory and is currently being tested. The installation includes the automatic tracking relay antenna which has been developed to enable the B-47 director aircraft to maintain its receiving/transmitting antenna continuously directed at the XB-63 during its flight without the attention of the operator. (See Section II, Part C.) The initial tests on this piece of equipment have been successful. The unit has demonstrated its ability to track an F-80 carrying the RASCAL guidance equipment in actual flight. Both of these items are scheduled for early flight tests.

On oral authorization from WADC, active planning has been resumed for the design and fabrication of a chemical warhead test vehicle. This test vehicle, comprising mainly an airframe and a solid propellant power plant designed to simulate XB-63 trajectory, will be used to obtain impact patterns and detonation conditions for both BW and GB warheads. This work is being done for the Army Chemical Corps.

A training and provisioning conference was held at Bell Aircraft 10 through 13 March 1953. This conference was attended by representatives of TTAF, ATC, Hq. USAF, SAC, APG, WADC, AMC, ARDC, and other interested Air Force organizations. During the conference, preliminary evaluations were made on the numbers and types of personnel to be trained to support the Air Force Operational Suitability Testing program and to supply the required cadres of trained personnel.

With the basic operation of the power plant and the stability of the servo-airframe already established, the MX-776 weapons system evaluation program is now continuing with the following:

(1) The evaluation of guidance equipment in an F-80 aircraft used as a simulated RASCAL.

(2) The preparation for actual flight tests of a guided pilotless parasite bomber early in the summer of 1953.

(3) The evaluation, in actual XB-63 firings, scheduled for the summer of 1953, of an improved fuel feed system, incorporating a gas turbine drive, for the RASCAL Power Plant.

Shrike

FLIGHT TEST SUMMARY OF MODEL 59A

The Model 59A flight testing phase of the SHRIKE program was successfully concluded at Holloman Air Development Center on 23 January 1953. Three fundamental objectives were satisfactorily demonstrated: (1) three-axis stabilized supersonic flight, (2) effective guidance control during the launching, midcourse, and terminal dive phases; and (3) directing the missile to impact on a surface target.

Secondary objectives of benefit to the RASCAL and SHRIKE programs, were also accomplished successfully and included: (1) air launching of an acid gasoline missile from a zero-length rail; (2) radar tracking and command destruction of the missile from the director aircraft as well as from the ground radar station, (3) surveys of ambient, equipment operating, and skin temperatures, (4) control of climb and altitude by means of a pressure-sensing altimeter in the pitch-servo system, and (5) determination of the dispersion pattern of a chemical warhead when separation occurs at specific velocity, altitude, and flight path angle. Additional data, as well as checks on systems and airframe design, were obtained for direct application to the RASCAL weapon.

SHRIKE 1601, the first of thirteen X-9 missiles in the Model 59A program, was primarily directed toward demonstrating the performance of missile systems. To permit a clear performance study of the systems, guidance commands were not transmitted to this missile. On the other hand, SHRIKE 1702 was subjected to a series of captive flight tests to investigate the problems of remotely coupling the guidance-servo link. Preliminary captive flight tests indicated that the guidance system and antenna patterns were satisfactory, and that commands could be transmitted up to a separation distance of 125 nautical miles. The final flight verified this as commands were received by the missile during midcourse and terminal dive. The performance of 1702 was not repeated with 1803 which was accidentally destroyed shortly after launch by a destruct frequency signal emanating from a malfunctioning ground tracking radar.

Missiles 1904, 2005, 2206, and 2307 were assigned the primary objective of demonstrating guidance control. SHRIKE 1904 provided an excellent demonstration of guidance control during the phases of prelaunch navigation, midcourse at high altitude, and terminal dive; impact was approximately 0.6 nautical miles from the target. Midcourse commands were not received by 2005 because of a mistuned command transmitter in the director aircraft, but both prelaunch and launch guidance operations were excellent. SHRIKE 2206 became unstable at launch and guidance control was not established. SHRIKE 2307 accepted commands during terminal dive and was guided to impact, 1646 feet from the target. An additional objective of Missiles 2005 and 2307 was to survey skin and equipment operating temperatures during high-altitude, high-velocity flight. The results obtained agreed reasonably well with both theoretical values and recorded values obtained from the flight testing of an earlier missile, No. 1006 of Model 59.

Missiles 2408, 2509, and 2610 provided an evaluation of SHRIKE as a low-level-attack vehicle. These missiles were launched at approximately 1500 feet above the terrain and flew in level flight at 3000 feet above the terrain. As each missile passed over a surface target, detonation was initiated by the guidance operator in the director aircraft. These missiles maintained three-axis stabilized flight at transonic Mach numbers for prolonged periods of time and also demonstrated successfully low-level attack.

The chemical warhead missiles, Nos. 2111, 2713, and 2812, demonstrated successfully the dispersion of warhead units and proved that structural design of the individual bombs deployed at Mach numbers ranging from 0.82 to 0.99 was satisfactory. The guidance-servo link adequately controlled Missiles 2111 and 2713 during the midcourse phase even though large angles of separation existed between the antennas of both the director aircraft and 2713. As SHRIKE 2812 was launched with an inoperative servo system, owing to loss of servo hydraulic pressure, attitude stabilization was not attained.

The various systems of SHRIKE – attitude stabilization, altitude control, guidance, power plant, and telemetering – were basically the same for all 13 missiles except for some changes in individual components. From the performance of these systems, the following general conclusions are drawn, with the understanding that these conclusions are based on a total of 13 firings, ten instrumented and three not completely instrumented, a profile of which is shown in Figure 1:

(1) Attitude Stabilization

Flight testing has indicated that the design of the servo system satisfactorily fulfills the requirements of three-axis stabilization. This system performed satisfactorily on seven of the thirteen missiles. Control of 1601 was lost owing to instability resulting from rudder and elevator oscillations which caused a severe drain on the hydraulic system. This condition was remedied on subsequent missiles by reducing the sensitivity of the servo loop in responding to the 30 cps vibration encountered on this flight. On Missiles 1702 and 1904, a failure of hydraulic pressure after 200 seconds of flight resulted in loss of control just prior to impact. It is suspected that a similar failure occurred during the nontelemetered flight of 2111. SHRIKE 2206 became unstable when the gains of the servo system were incorrectly set to compensate for the marginal stability of the missile (center of gravity was purposely changed). SHRIKE 2812 was launched with an inoperative servo; hydraulic pressure dropped below minimum as the missile was being launched.

In repeated instances, the stabilization system was able to control the attitude of the missile during the launching phase. The large-angle yaw-roll oscillations which occurred during most flights, except those of SHRIKE 2206, were quickly damped as well as the oscillations which occurred at reception of the terminal dive signal.

Three flights were made at low altitude and transonic velocity. Slight adjustments in the roll gains and the roll compensating networks provided excellent control for nearly 100 seconds of flight at Mach numbers ranging from 0.95 to 1.05.

The coupling of the servo system with the guidance system produced satisfactory servo response to guidance commands.

(2) Altitude Control

Of the missile systems, altitude control proved to be one of the most reliable. During four of the thirteen flight tests, there was no opportunity for this system to exercise altitude control because of failures in other systems. However, for the nine tests in which altitude control was established, the maximum

MISSILE NO.	LAUNCHING DATE
1601	4-16-52
1702	6-19-52
1803	7-1-52
1904	7-31-52
2005	9-9-52
2111	10-9-52
2206	10-23-52

MISSILE NO.	LAUNCHING DATE
2307	10-29-52
2408	11-26-52
2509	12-10-52
2610	12-16-52
2713	1-20-53
2812	1-23-53

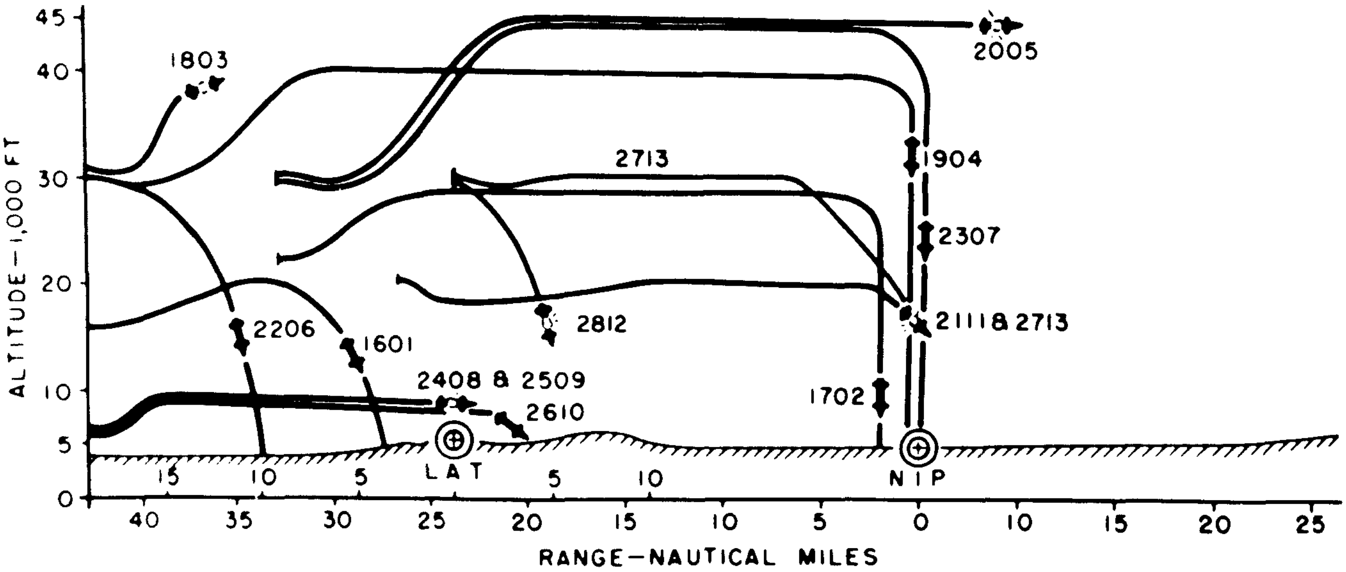


Figure 1. Profile of SHRIKE 59A Flights

deviation was only 1000 feet, and on six of these the error was only 200 to 400 feet. A Giannini wire-wound pickoff was used on four flights, and a No. 1597 Kollsman Synchrotel altitude transmitter was used on five. By using Kollsman instruments, a considerable portion of the noise normally induced on the pitch surfaces by Giannini instruments was eliminated.

3) Guidance

Twelve missiles were equipped with a guidance system to test guidance with respect to prelaunch navigation and midcourse azimuth control. Of these, six were to be controlled in pitch and yaw during a vertical dive to a target, three low-level missiles were to be destroyed by a command signal in level flight over the target, and the remaining three, after completing an azimuth controlled flight (pursuit curve) to the terminal dive circle, were to enter a dive at a preset angle. During these tests, the launch point was satisfactorily determined by prelaunch navigation except for the two flights when aircraft heading was controlled from the ground radar station. Since the accuracy of the guidance system was somewhat contingent upon the experience level of the guidance operator, guidance accuracy increased directly with experience level. On the other hand, the average error in the launch-point-to-target distance computed by the guidance system was consistently two per cent.

Only nine of the twelve guided flights presented an opportunity for midcourse control, as three missiles did not establish level flight. Of the nine, the midcourse link was established on six, and three did not respond to midcourse commands for the following reasons: (1) Missile 2206 - mistuned command transmitter in the director aircraft; (2) Missile 2307 - erratic transmission of the computer in the "burst" mode, and (3) Missile 2408 - engine failure in the director aircraft caused a loss of power to the command transmitter. When the midcourse link was established, the missile responded quickly and accurately to the commands. Of the three low-level missiles, 2509 and 2610 were guided to miss distances of 0.52 and 0.45 nautical miles, respectively; the miss distance of 2408 without midcourse guidance was 1.5 nautical miles.

With the possible exception of 2713, operation of the guidance equipment was satisfactory on all twelve guided flights. Where the midcourse link was not established, the cause was due to equipment failure in the director aircraft, personnel procedure error, or to malfunction in a system other than guidance.

Three of the six missiles scheduled for a vertical dive responded to the dive entry signal and received commands, during the terminal dive phase, which altered the flight paths toward the target. Of the three which did not enter a dive, 1803 and 2206 should not be considered since their flights were interrupted shortly after launch, and 2005 reached the terminal dive circle but did not respond to the dive command. Missiles 1702, 1904, and 2307 responded to terminal dive commands; target miss-distances, Figure 2, were 1.8, 0.58, and 0.27 nautical miles, respectively.

(4) Power Plant

The rocket propulsion system proved to be the most reliable system in the SHRIKE missile. No component failures occurred and rated conditions of chamber pressures and thrust were maintained. Although telemetering was not used on the chemical warhead vehicles, the range, altitude, and velocity performances of these missiles indicated that rated thrust prevailed.

(5) Instrumentation

The telemetering system provided valid reducible data during the flights of ten missiles; three were not telemetered. The maximum noise level of the continuous channels was three per cent. It was found that the 10.5-kc channel, normally used as a continuous channel, could be commutated at five samples per second if an additional two to three per cent error could be tolerated.

Phototheodolite coverage was seldom complete during these flights, generally owing to a lack of tracking aids. Two station solutions were usually obtained during the initial post-launch period; the up-range stations were able to acquire the missile on only three occasions and this was accomplished when a smoke generator provided a suitable tracking aid. Provision for smoke generation and adequate briefing of the theodolite operators are apparently fundamental requirements for complete flight coverage.

Radar tracking of the X-band beacon was successful on all but two occasions. Airborne radar was able to track all but one flight.

MISSILE NO.	LAUNCH-POINT-TO-TARGET DISTANCE (NAUT. MI.)	MISS DISTANCE (NAUT. MI.)	TRUE BEARING FROM TARGET
1702	30.0	1.8	111°
1904	42.8	0.58	108°
2307	33.5	0.27	043°
2408	19.6	1.75	024°
2509	19.4	0.52	065°
2610	18.4	0.41	041°

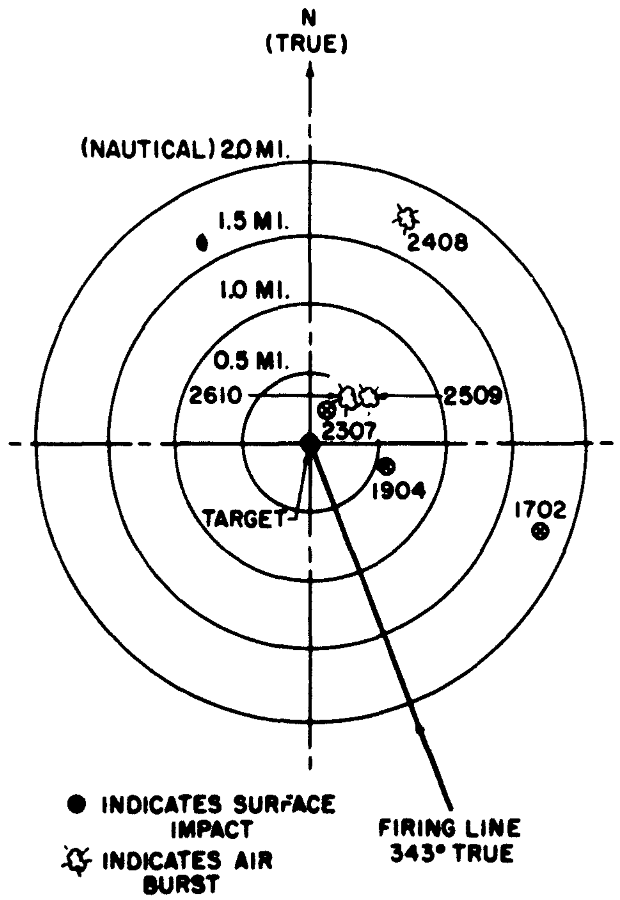


Figure 2. Miss Distances, SHRIKE 59A Missiles

C. Facilities

1. NIAGARA FRONTIER DIVISION

a. General

Facilities contract AF33-038ac18896 provides Bell Aircraft with a means for obtaining equipment to be used in fulfilling supply contracts of Project MX-776. In addition, Bell Aircraft is authorized to acquire and install machinery and equipment, and to make initial repairs to government-furnished equipment.

The Wheatfield Plant is the heart of the MX-776 Program. This plant and its auxiliaries fulfill the requirements for developing and manufacturing pilotless parasite bombers. Bell Aircraft, situated adjacent to the Niagara Falls Municipal Airport, is ideally located and provided with the means for extensive flight development testing of the XB-63 and related programs. In addition, rocket testing is being conducted constantly at the Wheatfield rocket test facility which consists of 13 test cells and associated control rooms, and is the principal installation for conducting rocket research and development. Each cell is equipped with a separate set of fuel and oxidizer systems ranging in capacity from 80 to 750 gallons. A centrally located instrumentation room records data from any one of 13 rocket test cells.

Support programs at the Niagara Frontier Division include:

(1) The design and modification of Director Aircraft.

(2) The design and fabrication of Ground Handling Equipment.

(3) The design of equipment and instrumentation for, and the modification of, the Trainer Aircraft.

(4) Training of military personnel and an XB-63 Training Program.

(5) Operational weapon support equipment studies.

b. Construction

In support of contracts of the MX-776 Project, many construction programs have been completed while others are partly complete.

Roofing-over of the 10,000-foot area between the main assembly and hangar buildings has been completed. This new floor space, designated Building No. 2A, and shown in Figure 3, provides additional working area for such functions as tool grinding, tool and fixture inspection, and tool dispersing.

Construction of the new Aerodynamics Shed located east of the Compressor Building is essentially complete, Figure 4. This structure, measuring 28 x 72 feet, houses the wind tunnel. After the remaining instrumentation has been procured and installed, the facility will be used for the probe testing of XB-63s. A work shop equipped with small hand tools and bench tools provides an area for the adjustment of models and for checking their workability.

As previously reported, the Gas Generating Plant is being transformed to accommodate high-pressure test work. This structure, Building No. 18, will be used for the high-pressure testing of XB-63 tanks and tube bundles after instrumentation has been completed.

The new foundry building, to be located adjacent to the northeast corner of the main assembly building, is rapidly progressing through the design stage. This structure, designated Building No. 2B, will provide the foundry with an additional working area measuring 200 x 50 feet. A fire-resistant steel

Figure 3. Building No. 2A, Wheatfield Plant

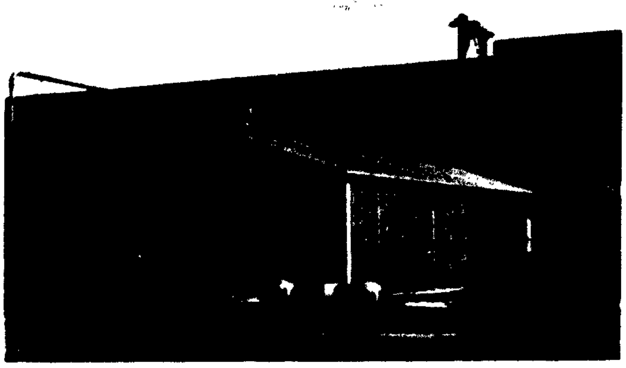


Figure 4. Aerodynamics Shed, Wheatfield Plant

and masonry construction will support a 10-ton traveling crane mounted on over-head rails extending the full length of the building. Building No. 2B will house the foundry ovens and furnaces, and some large metal-working machinery.

The following changes in Rocket Laboratory facilities were made during this quarter:

(1) Test cells A-2, B-1, C-1, C-2, C-3, D-2, D-3, and D-4 underwent a complete acid system inspection and hydrostatic testing of the acid tanks.

(2) Test cell D-1 was converted for RASCAL thrust chamber development testing.

(3) Two 100-gallon, 1000-psi pressure tanks were received for cell S-1 and installed for use in the Model 56 propellant valve flow test system.

(4) Test cell S-2 was modified to accommodate the Model 62 turbine pump flight approval test installation.

(5) A 15 lb sec, 350-psi, 2-stage Byron Jackson centrifugal pump was installed on the existing water flow stand to increase the flow capacity of the stand.

(6) A sand and dust environmental test chamber was designed and built to simulate desert conditions. This chamber can accommodate components or assemblies including the RASCAL power pack.

(7) A flow stand for production testing of Model 62 and 62A valves was designed, fabricated, and turned over to the test group.

(8) A portable fuel trailer was designed and built for servicing the test cells.

(9) A Sprague hydrostatic test cart to pressure-check propellant tanks was fabricated for use in the test cells.

(10) A steel barricade, floor flood, and safety showers were provided for safety purposes in the destruction test portion of the power plant safety program.

(11) The drum cleaning system was revised to promote greater efficiency in the cleaning of acid drums.

(12) A pressurized water flow test system was provided in the spray laboratory to permit water flow rates in excess of the flow attainable from the existing pump installation. This system permits simultaneous flow of the oxidizer and fuel in the study of injector flow patterns.

(13) A flow stand was provided for the individual water flowing of 3, 16-inch cooling tubes used in experimental aluminum thrust chambers.

(14) The instrument room was expanded to accommodate 30 additional recording instruments. New instruments are being installed as they are received.

(15) The drawings for a 12,000-square-foot addition to the Rocket Engineering Building were submitted for management approval. This area will house additional testing and engineering facilities plus a propellants research laboratory.

2. HOLLOMAN AIR DEVELOPMENT CENTER

a. General

The MX-776 flight testing program is being conducted at Holloman Air Development Center, New Mexico. This program includes specific types of flying such as captive and final flights of both SHRIKE and RASCAL. In addition, other flights are continually made to familiarize SAC and other Air Force agencies with the various aspects of the MX-776 Program.

The broad features of this program aim toward the development of a pilotless parasite bomber capable of controlled flight at supersonic speeds to surface targets up to 75 nautical miles from the point of release.

The facility at HADC consists of approximately 45,000 square feet of shop, laboratory, warehouse, assembly area, and floor space being utilized for the servicing of XB-63s. Askania cinetheodolites and a mobile relay telemetering station installed for instrumentation coverage of the final stages of XB-63 flights, facilitate research and development work on guidance, stability, and control. Instrumentation data, resulting from scheduled firings, are reduced and dispatched to development groups at the Niagara Frontier Division in an effort to integrate into the over-all program the data that may affect design adequacy, safety, reliability, and performance.

b. Construction

Facilities at the RASCAL hardstand are gradually progressing. However, some plumbing, wiring, and cement work is required before the facilities in the pit area are complete. Figure 5 shows a RASCAL in the loading pit.

The radar buildings, Figure 6, adjacent to the main RASCAL building have been completed except for adequate power facilities. The radar equipment will be installed after electrical installations have been completed.

3. AIR FORCE PLANT NO. 38

a. General

The Air Force Plant No. 38 is located in a remote and secluded area approximately 12 miles from Bell Aircraft Corporation. This area was formerly used for the manufacture and storage of TNT during World War II. With its 58 earth-covered concrete igloos, excellent drainage ditches, railroad sidings, surfaced roadways, and power lines, it is well suited for the development and testing of pilotless parasite bombers, missile power plants, and component parts.

The AF Plant No. 38 provides a facility having a fourfold purpose: the first is the development of the XB-63 power plant; the second and major purpose is the production acceptance testing of each power plant and the complete systems checking prior to shipping XB-63s to Holloman Air Development Center; the third is the proving of XB-63 ground handling equipment; and the fourth purpose is to obtain statistical data regarding the life expectancy and reliability of components.

b. Construction

The installation of fixed station test equipment for acceptance firings in test cell E-8 has been completed and will be used for the acceptance firing on XB-63 No. 0813. Figure 7 shows the installation of the console junction boxes and interconnecting cables in cell E-8. A similar fixed station, which is being placed in test cell E-9, is approximately 60 per cent complete. With this type of installation, all test equipment, except for the cables connected to the XB-63, is located inside the control room to prevent damage by acid fumes or explosions.

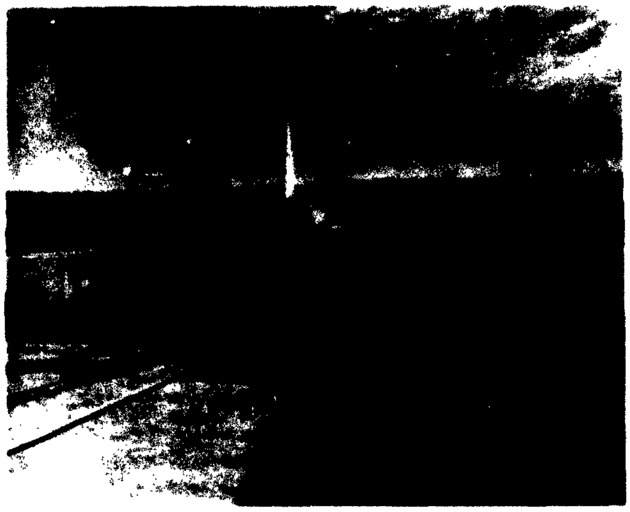


Figure 5. XB-63 No. 0409B in Loading Pit at HADC

Figure 6. RASCAL Radar Building, HADC

The interior ceiling insulation of the temperature-controlled test cell E-5 has been satisfactorily repaired, and work has started on the rocket engine test stand for the high- and low-temperature tests required for flight approval. Figure 8 shows the test stand installation with boiler plate protection to minimize test cell damage in event of explosion.

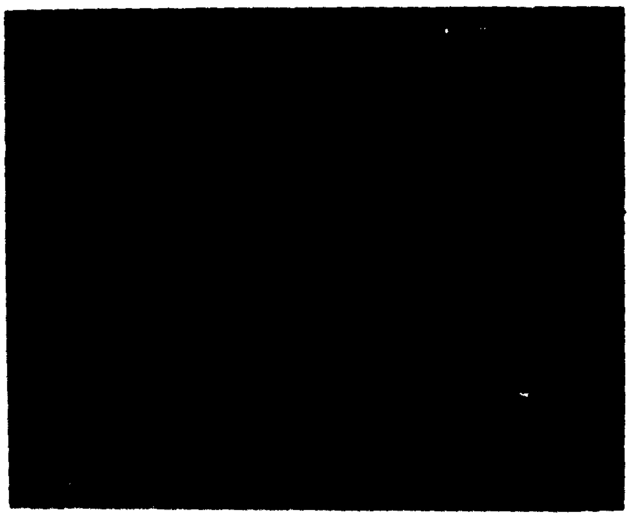


Figure 7. Console in Test Cell E-8, AF Plant No. 38

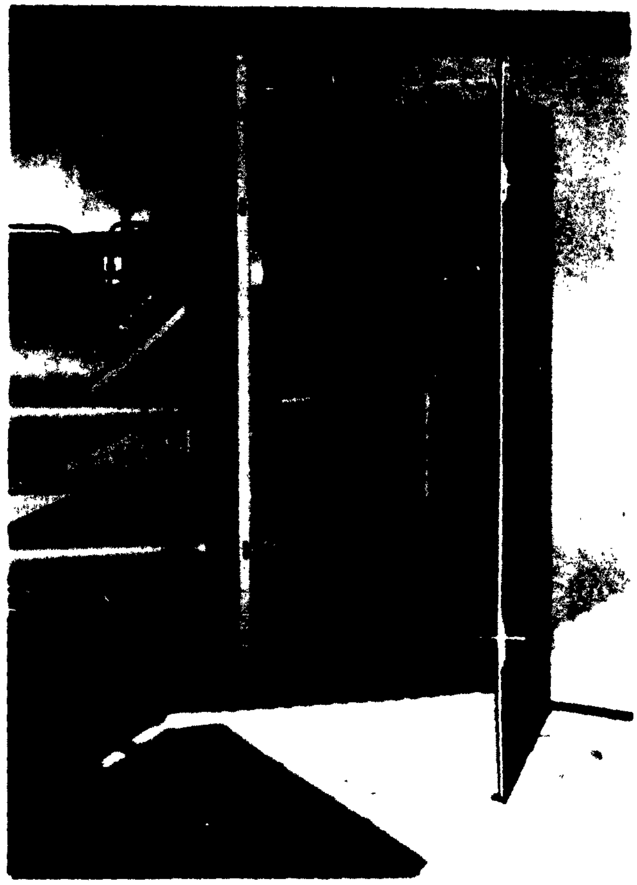
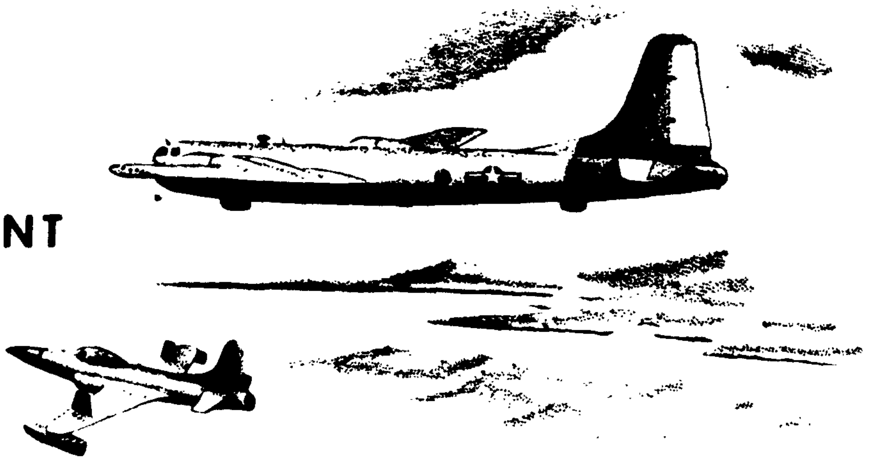


Figure 8. Test Stand Installation, Cell E-5 at AF Plant No. 38

SECTION II
RESEARCH and DEVELOPMENT PROGRAM



A. Servo

1. GENERAL

RASCAL servos provide stability of the search and relay antennas in pitch, and stability of the airframe in roll, pitch, and yaw. Another servo function is to maintain the search antenna at constant speed in space. In order to maintain radar contact with the director aircraft, the major axis of the relay antenna lobe must be oriented toward the aircraft. This orientation is in part accomplished by the servo system. In addition, provisions are made for accepting internal and external pitch and yaw guidance signals which direct the pilotless parasite bomber to its target.

Servo research and development is directed toward continuous improvement of operation and simplification of the system and components.

Advancements in inertial guidance are reported in the section on guidance.

2. SERVOPILOT SYSTEM

The single-axis hydraulic test table is being reworked and is expected to be completed early in the next quarter. This table will be used to simulate the actual airframe motion while analogue computer studies are made of the roll system using the vertical and rate gyro configuration actually employed in the XB-63. In addition, this table will be used for evaluating the present stable platform design and for designing the platform servo to be used with the single-axis inertial guidance system.

The new technique for aligning the pitch stable platform with the relay antenna was used on a number of XB-63s, and proved to be completely satisfactory.

One of the prototype pitch stable platforms of the type effective on No. 35 and subsequent XB-63s has been completed and is being evaluated. It is expected that the second platform will be available early in the next quarter.

Preliminary work has been started on the redesign of autopilot amplifiers and other electronic components, aiming toward simplification of circuitry and improved reliability. The guidance and autopilot systems have been successfully mated in XB-63 No. 13. This will be the first pilotless parasite bomber to be flight-tested with a guidance system.

Flight test results of XB-63s 0409B and 0510B indicate very good operation of the autopilot system. It is interesting to note the degree of stabilization of the roll system. With simultaneous angles of attack and sideslip of 12° and 3°, respectively, the roll angle was less than 1°. All other roll angles encountered during flight were much smaller.

Tests were run to show the agreement of the response obtained with the autopilot for servo mock-up No. 02, and the load stands used to develop the autopilot. The mock-up is being wired so that all test points and sequences will be available during the temperature testing of the unit.

The portion of the autosequencer used to develop the reference voltages for the exercising of the autopilot is being temperature-tested.

Review and release of specifications for servo components and systems for XB-63 Model 56F is continuing.

3. ANTENNA STABILIZATION SYSTEMS

a. XB-63 Search Antenna

Workshop Associates is now delivering search antennas in quantities which meet the requirements of XB-63 schedules.

The initial development work has been completed on the hydraulic spin drive system for the X-band antenna. The drive system was tested in the Servo Laboratory under conditions expected in XB-63 maneuvers. The response of the hydraulic drive system under laboratory conditions was found to be superior to that of the electric drive. Testing under environmental conditions will be started as soon as a prototype amplifier is available. An amplifier should be available within five weeks.

A complete X-band stabilization system utilizing an electric spin drive search antenna was tested in the Vibration Laboratory. These tests indicated that some changes are necessary in mounting the amplidyne and the antivibration weight. It is planned to test the spin drive with the vibration directly applied to the search antenna to clarify some of the results of the previous tests. Also, the present antenna system and the proposed hydraulic search antenna spin drive system will be tested with the vibration applied to the new cast shelf. Laboratory testing of the X-band search antenna pitch stabilization system using synchros has been completed and the results were satisfactory.

Work has been started on the pitch stabilization of the K_u-band antenna to adapt the pitch stabilization portion of the amplifier to the servo valves and to check the response of the system.

b. XB-63 Relay Antenna

The altimeter for the new relay antenna pitch controller was tested under environmental conditions. The test was apparently satisfactory except for vibration. As soon as a prototype pitch controller is complete, development testing will be carried to completion and environmental testing then started.

4. SERVO HYDRAULIC SYSTEM

Figure 9 is a schematic representation of the hydraulic system for the Model 56F XB-63s. By utilizing the reservoir in the XB-63, when external as well as internal hydraulic power is used, it has been possible to simplify the system by eliminating the hydraulic switching devices required on Models 56B, D, and E. Also, as a result of this change, the external hydraulic system in the director aircraft has also been simplified to the point where essentially all that is required is a pump and a disconnect.

Since high viscosity of the hydraulic fluid at low temperatures results in poor servo-response, a prelaunch heating system has been set up and analyzed. With this system, the oil is heated to a temperature of 70° to 100°F in an insulated reservoir and heat from heaters used to protect power plant equipment is supplied to all hydraulic lines and equipment in the aft compartment. Prior to servo checkout, the operator exercises the hydarulic system by pressurizing the system and releasing the fluid through the servo valves at a controlled rate. This action increases the temperature of the hydraulic fluid. To determine the optimum rate of flow, the following rough analysis was made:

(1) For an ambient temperature of -65°F, the average oil temperature in the system at start of exercising was determined. This average oil temperature was calculated as -13°F.

(2) The values of heat loss at -65°F ambient were plotted against the average oil temperature of the entire system (See Figure 10). It is assumed that the net loss of heat is zero because, as the result of initial mixing, the heat loss from the cold lines is balanced by the BTUs added by the heaters. Figure 11 shows the input rate of heat energy to the oil as the result of exercising at various flow rates.

(3) By utilizing the data from Figures 10 and 11 and the calculated total heat capacity of 77.6 BTU per degree Fahrenheit, an equation was established representing the variation of temperature with time for various exercising flow rates. This variation is shown in Figure 12.

(4) From the data in Figure 12, it was determined that an exercising flow rate of 4 gpm would be used as this increases the average temperature of the oil to the desired range of from 40° to 100°F. This average temperature can be attained within a reasonably short time without requiring an excessive amount of power.

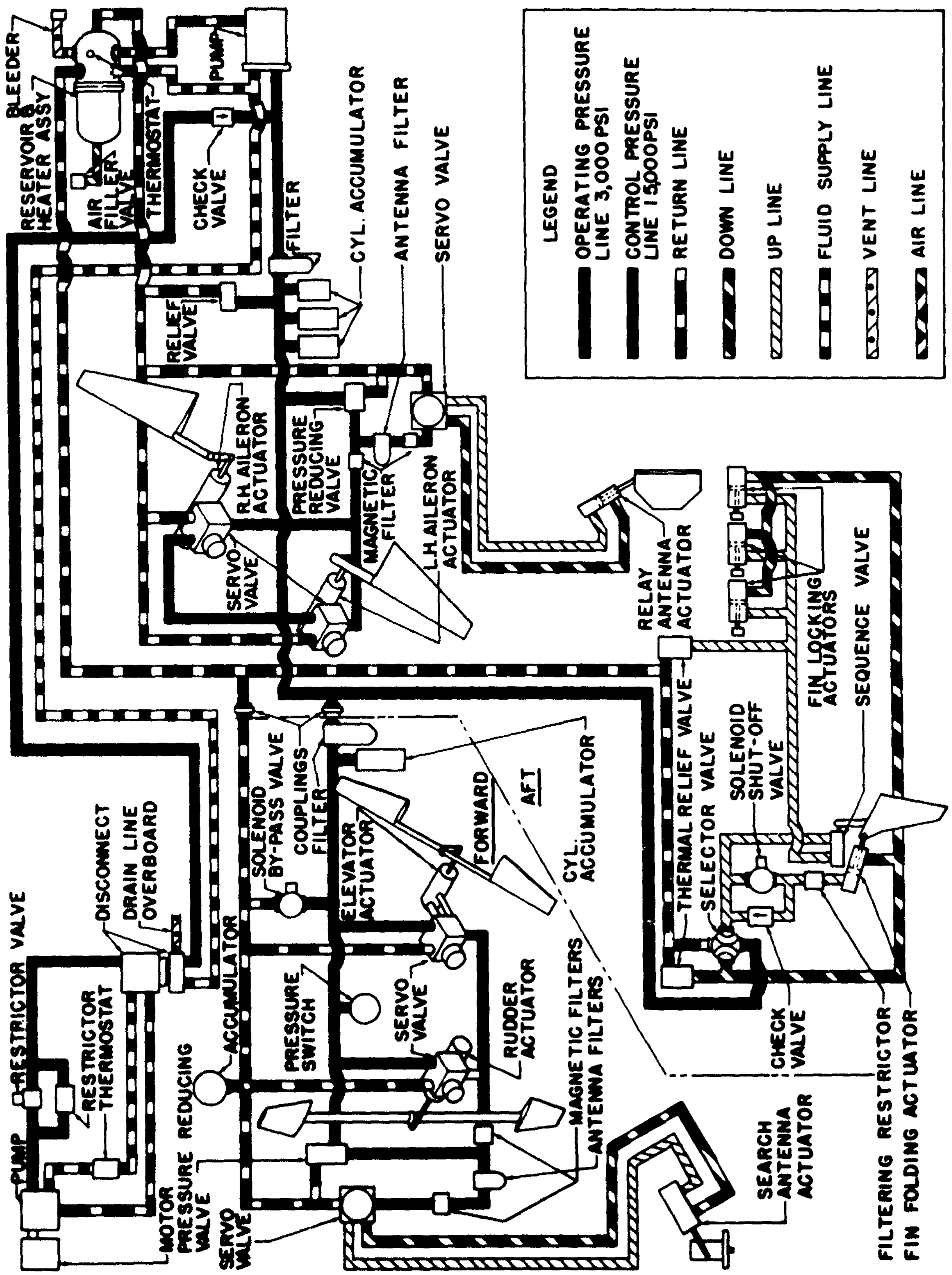


Figure 9. Servo Hydraulic System for Model 56F XB-63s

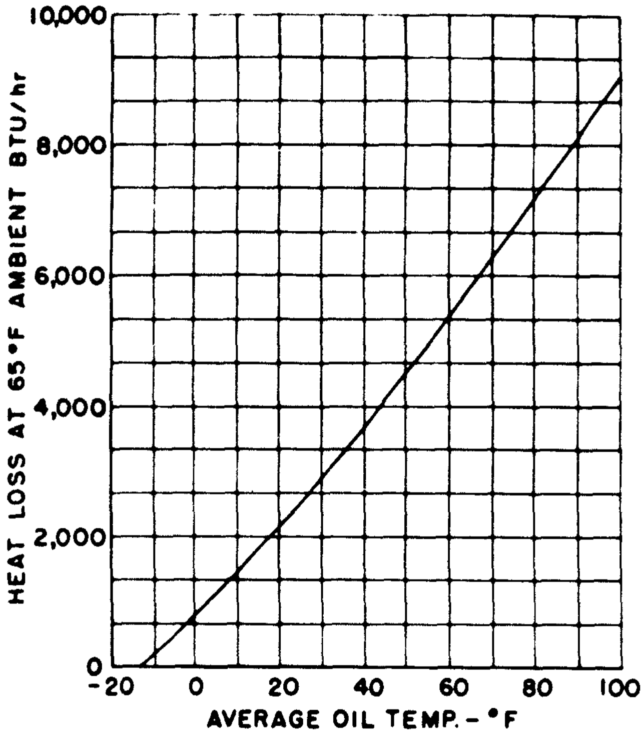


Figure 10. Hydraulic System Heat Loss vs. Average Oil Temperature

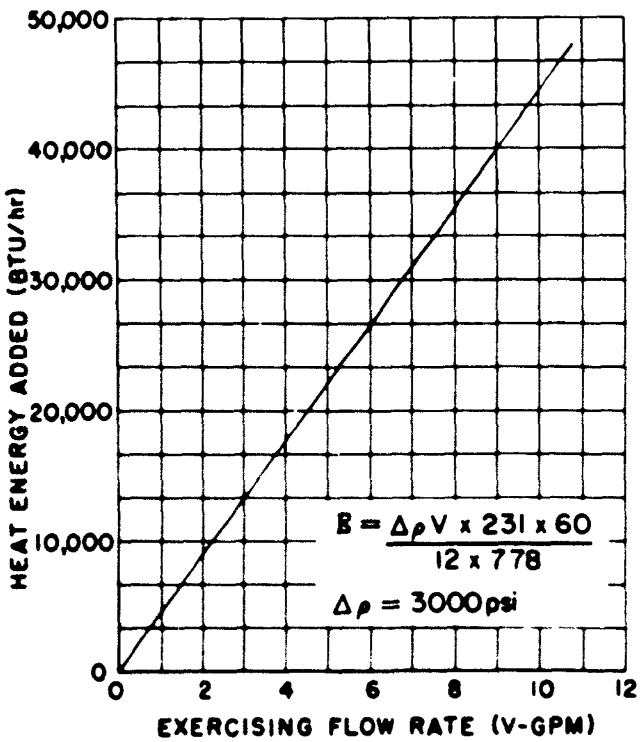


Figure 11. Heat Energy Input vs. Exercising Flow Rate

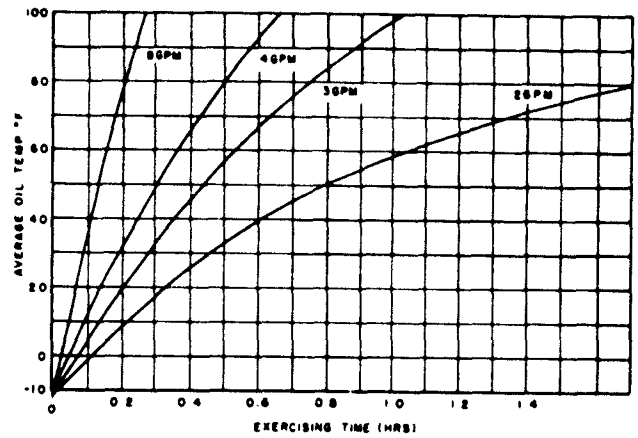


Figure 12. Average Oil Temperature vs. Time for Various Exercising Flow Rates

To prevent overheating the oil when the XB-63 is operated at ambient temperatures greater than -65°F, thermostats, controlling the exerciser, will be installed in the director aircraft portion of the hydraulic system.

The full-scale mock-up of the Model 56F hydraulic system will be completed in approximately six weeks, and tests will then be started.

Mechanical and hydraulic installations on the hydraulic load simulator to be used with the RCSS (RASCAL Comprehensive Simulation System, see Training Section) are complete. As electronic installations will be completed soon, testing will be started in the near future.

5. SERVO VALVES

Figure 13 is the SV-4 valve which is a prototype of the valves to be installed in the production B-63s, Model 62. (The valves of the SV-4 type are designated SV-6, -7, -9, and -11). Figures 14 and 15 compare the flow and regulating characteristics of this valve under widely varying line pressures. The results of an SV-4 frequency response test are shown in Figure 16.

Design release for production of the SV-6, -7, and -9 valves has been delayed somewhat, but should be completed during May. The SV-11 valve will also be released during the next quarter.

The development of an automatic flow checking stand, Figure 17, to speed up valve manufacture and inspection has been completed and details have been turned over to Production Testing. In using this equipment, the servo valve is clamped to the stand; the direction of flow through the valve is selected by means of push buttons; and the spool displacement and oil flow information are fed electrically into the X-Y recorder. With this method, the time necessary to determine spool overlap and clearance at the edges is five minutes, as compared with previous methods of one and one-half hour.

6. TERMINAL DIVE CONTROL

Studies of a simulated terminal dive in five degrees of freedom were started during this quarter. Actual components are used wherever possible. Circuitry which simulates the airframe and dive geometry has been improved to compute the drag and its effect on the velocity of the pilotless parasite bomber. These studies provide a preliminary estimate of the aptitude and training required of the operator to guide the pilotless parasite bomber in pitch and yaw simultaneously. The effects of other factors such as initial terminal dive velocity, initial angle, and boost or power dives are also being investigated.

Work is being continued on the Azimuth Offset Guidance Computer. The limits of the offset distance of the preliminary design have been determined and means of increasing this distance are now being investigated.

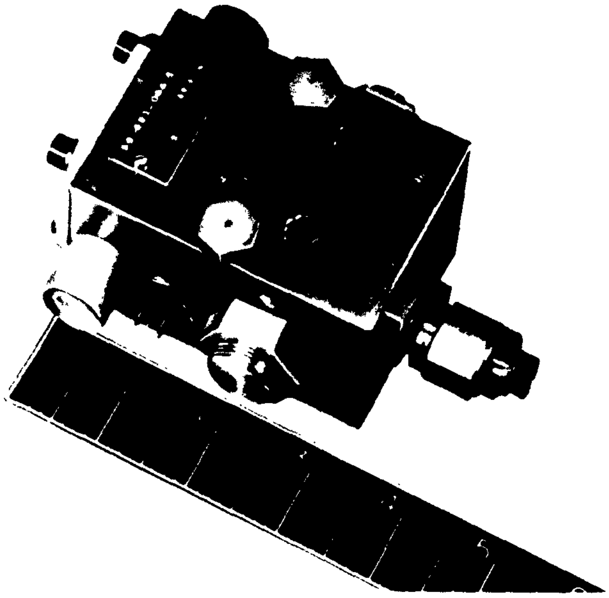


Figure 13. SV-4 Valve

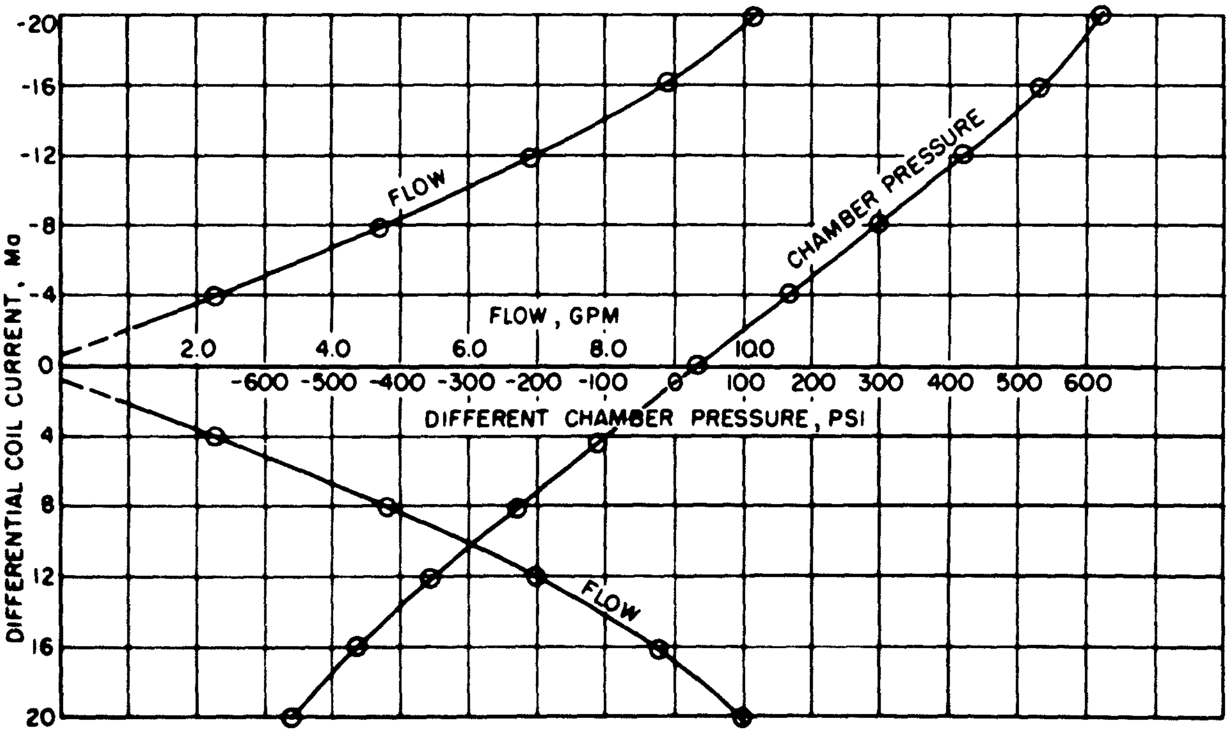


Figure 14. SV-4 Characteristics at 3000 psi Line Pressure

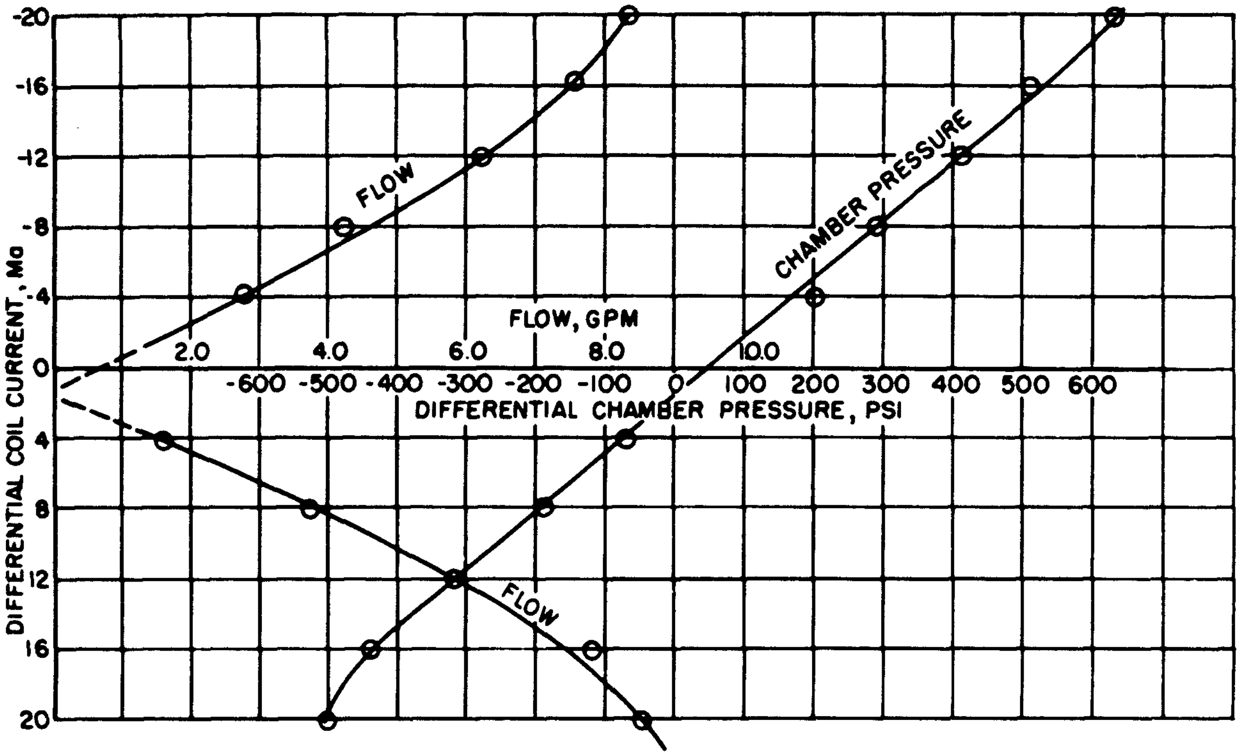


Figure 15. SV-4 Characteristics at 1750 psi Line Pressure

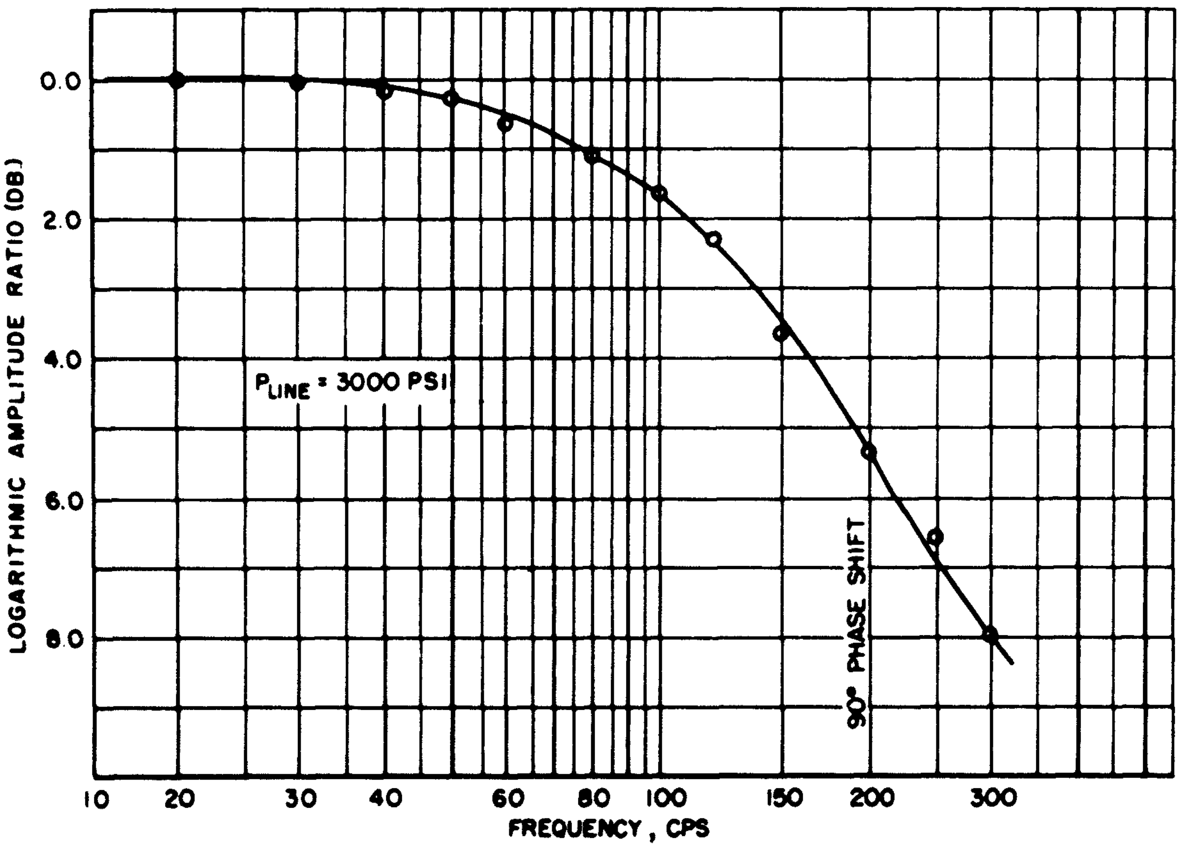


Figure 16. Frequency Response Characteristic of SV-4A Valve

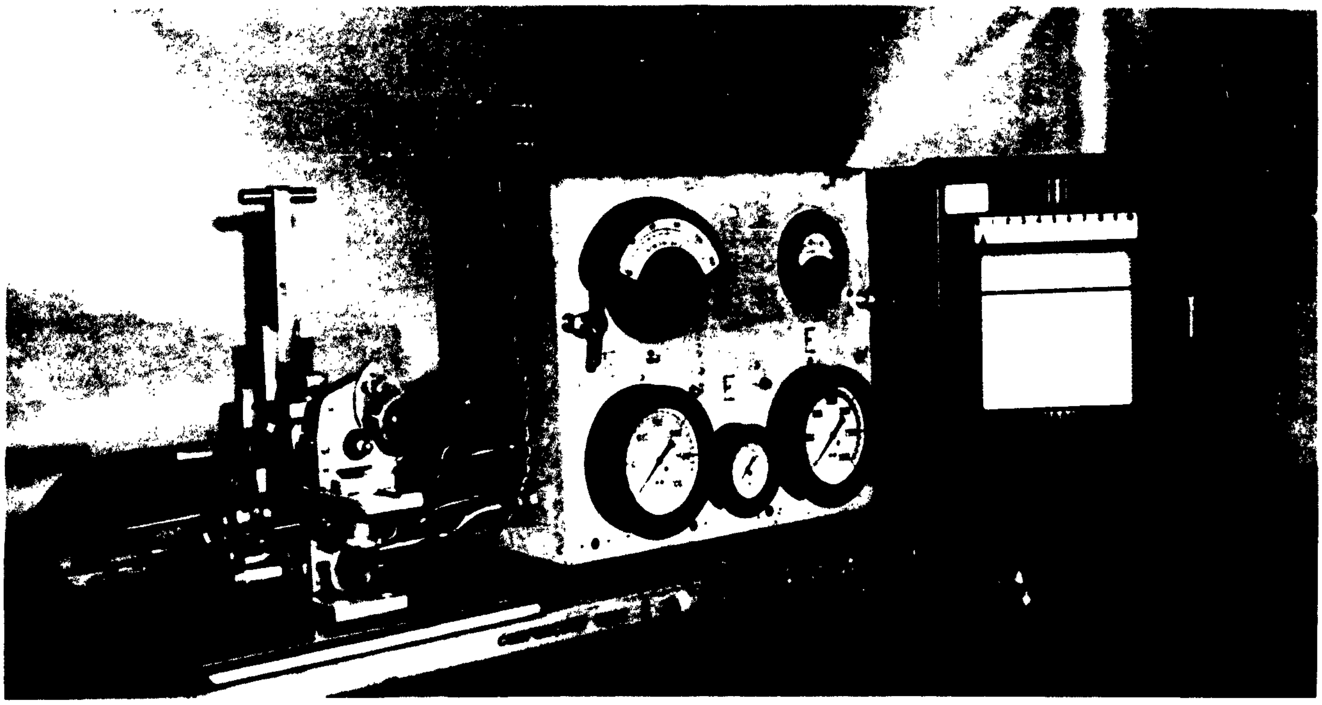


Figure 17. Automatic Flow Checking Stand

B. Propulsion

Rascal

1. POWER PLANT AND TURBINE PUMP INSTALLATION

a. At Bell Aircraft

Activities at AF Plant No. 38 were increased by operation on a full two-shift basis with a test program concerned primarily with the operation of complete power plants, turbine pumps, gas generators, and starters under various conditions to prove reliability and safety of operation. A large part of this program is devoted to malfunction testing where possible malfunctions are deliberately introduced and their effects upon safety observed.

In test cell E-4 the power plant compartment temperature survey program was completed using serial No. 9 turbine pump. Resulting data show that the temperatures encountered within the compartment under engine operating conditions are not excessively high.

Upon completion of this program, the facility was designated for acceptance testing of the power plant for pilotless parasite bomber No. 11 with serial No. 9 turbine pump being transferred to test cell E-7 for checking out tests.

During the run pilotless parasite bomber No. 11 power plant was partially destroyed by an explosion in the No. 1 thrust chamber resulting from a servicing error. A detailed report of the investigation of the explosion was prepared and transmitted to WADC as Bell Aircraft Report No. 56-982-018 entitled "Investigation of XLR-67-BA-1 Rocket Engine Explosion".

Test cells E-6 and E-7 were devoted almost entirely to malfunction tests, first of engine components and then complete power plants.

The success of Aerojet Engineering Corporation in producing a more reliable gas generator resulted in the discontinuance of the program of adapting the Bell Gas Generator to the Aerojet Turbine Pump, thus permitting initiation of the gas generator and starter malfunction tests in cell E-7. Shutdown characteristics were studied under abnormal operating conditions. Serial No. 9 turbine pump was then installed and a similar series of malfunction tests performed. However, each start test resulted in a malfunction shutdown without gas generator ignition occurring. The trouble is apparently due to excessive fuel lag to the starter. This problem is currently under investigation.

Serial No. 8 turbine pump was installed in cell E-6 and the malfunction test program started at this facility. Malfunctions were introduced by cutting electrical power during stabilized boost phase operation. As a result of these tests some simplification of the electrical system was made possible.

After changing the electrical system, two thrust chamber firings were then made to test the new configuration with both runs successfully completing all transitions.

Information on thrust chamber shutdown characteristics when electrical power or gas generator chamber pressure are lost during the thrust chamber start transient was next determined. In all runs a smooth shutdown was effected.

All malfunction tests in the cell E-6 series were made on essentially the same hardware without the necessity for repair. This consisted of 12 good runs during seven of which thrust chambers were operating.

All malfunction tests completed to date using specification WFNA will be repeated using 95 per cent acid. Test work on this program is continuing.

b. <u>At Aerojet</u>

At the Aerojet-General Corporation activity has centered upon the acceptance testing and delivery of turbine pump assemblies. Deliveries have been accelerated with the result that turbine pumps serial Nos. 11, 12, 18, 19, 20, and 21 completed acceptance tests and were shipped to Bell Aircraft this quarter. These turbine pumps are of the same configuration as serial No. 15X which successfully completed a seven-cycle duration test this quarter. It was agreed that serial No. 15X turbine pump assembly will be retained at Aerojet for further development work.

Current activity is concerned with investigations of the cause of pressure surges within the gas generator and of high frequency instability during gas generator firings. A reduction in the frequency and severity of the pressure surges may be effected by a postfire purge.

Of the several types of oxidizer pump shaft seals tested to date, the heavy wall Fulton-Sylphon bellows seal has proved to be the most durable. Additional investigation is being carried out on the Crane teflon wedge seal. The redesign of the oxidizer seal rotating ring was completed.

Five gas generators were received from Ryan Aircraft under an Aerojet production subcontract to Bell Aircraft, three of which exhibited high frequency instability during firings on the test stand. However, this instability has not been encountered to date when the generator is used to drive a turbine pump assembly.

Also under investigation on the turbine pump installation is the loss of rotor balance believed to be caused by stress relieving of the rotor during the first firing. A revision of the heat treat procedure for the rotor is being undertaken to correct this difficulty.

In addition, acceptance tests have been revised to include disassembly of the turbine pump after a full duration run, readjustment of clearances, and a half-duration run through all phases as a final test.

2. COMPONENT DEVELOPMENT

a. <u>4000-Pound Injectors</u>

Preliminary test firings were made on 24 production type injectors at the Rocket Laboratory with the performance and stability of all injectors being acceptable. Twenty-two of these injectors were returned to the shop for installation. The remaining two were retained for test purposes.

Eighteen unfuzzed impinging showerhead injectors were received at the Rocket Laboratory. These are prototype injectors for the 75L* thrust chamber. Sixteen of the injectors have a drilling configuration comprising 72 impinging pairs with the remaining two injectors drilled with 92 impinging pairs. The 92-pair injectors were patterned after a 2600-pound injector, developed at this facility, which delivers 97 per cent combustion efficiency in a 47L* thrust chamber. Thrust per impinging pair of orifices was used as the design criterion. Each injector was evaluated as received from the shop in a 75L* thrust chamber by several 5-second duration fire tests. All injectors completed this evaluation satisfactorily. The average value of C* obtained was 5000 ft per sec. This is in excess of 96 per cent of the theoretical combustion efficiency. Figure 18 shows test data obtained from a typical injector.

The injectors were then evaluated in a regeneratively cooled thrust chamber with the propellants at -30°F. Each of the 92-pair injectors functioned exceptionally well, but the 72-pair injectors functioned smoothly only after the oxidizer orifices were counterbored in such a manner that the orifice L/D was less than 1.3.

A program has also been initiated to develop an oxidizer manifold baffle plate in an effort to obtain complete combustion nearer the injector face which should minimize the required combustion volume and result in less effect of any possible combustion irregularities due to injector nonuniformity or propellant variation. It is hoped to fire a baffled injector during the next quarter.

A 72-pair uncounterbored injector was test fired in a 75L* uncooled start chamber to determine the lower limit of stability relative to chamber pressure and feed pressure. Figure 19 is a plot of feed pressures versus chamber pressure for the three sets of orifices used. A second injector of this configuration was counterbored and also subjected to the same test.

The "GO, NO-GO" type of test to detect localized high heat transfer areas in the convergent and throat section of the nozzle was continued, being conducted with a mild steel, unexpanded, water-cooled

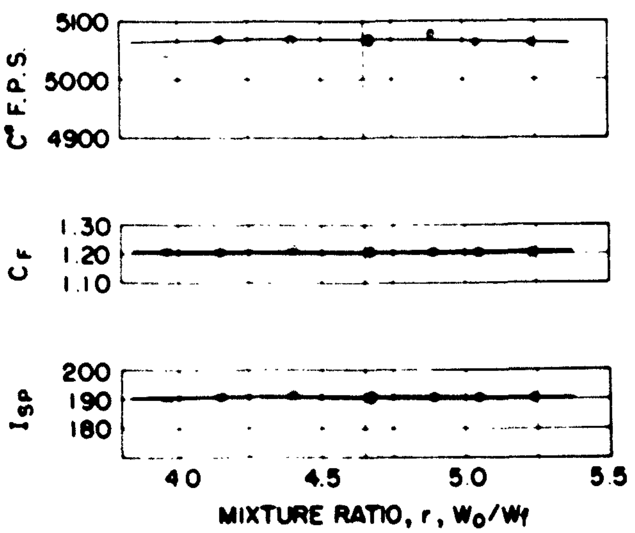


Figure 18. 72-Pair Injector R-52a in 75L* Chamber with Unexpanded Water-Cooled Nozzle

nozzle in order to more nearly duplicate inside wall temperatures of regenerative chambers. Four nozzle failures were recorded for approximately 350 fire tests with all failures taking place at high rates of water flow. Each of these nozzles had been subjected to relatively few firings before failure. After each failure the injector was successfully tested using a new nozzle. An attempt is being made to correlate these failures with propellant properties.

Because of the fact that several regenerative thrust chambers have failed at the throat during this quarter, the one-to-one correspondence of the "GO, NO-GO" type of test has been questioned.

An investigation was conducted to determine whether or not thermal equilibrium is reached at the throat of the mild steel nozzle in the normal five seconds of operation. All data obtained indicate the temperatures of both water and steel stabilize within three seconds. The temperatures obtained after stabilization took place were extremely low, probably indicating the temperature of a point in the water film rather than the steel wall temperature.

An effort is being made to develop test equipment which will permit long duration runs at low rates of nozzle coolant flow. This should show whether there is a change in the combustion process leading to some unexplained failures experienced during long duration runs.

The two-on-one unit type injector development discussed in previous reports was continued during this quarter. A redesign was made and is now being manufactured.

b. <u>4000-Pound Thrust Chamber</u>

Thirty-one 65L* thrust chambers were fired during this quarter. Twenty of them developed leaks during acceptance test firings. The remaining eleven thrust chambers completed the acceptance firings without damage, while of the twenty that leaked, nine were rejected because of excessive leakage and eleven were accepted after being repaired. Because of the high incidence of leakage, an extensive investigation was initiated to determine the cause of the failures. The failures could be attributed to one or all of the following causes: mechanical, chemical, and cooling. These types of failures are interrelated, and it is difficult to isolate one type in any specific instance.

Several of the rejected thrust chambers were sectioned and subjected to visual and metallurgical examination. One thrust chamber displayed evidence of mechanical failures with tubes burned out in regions all around the throat, and exhibiting various cross-sectional deformations. But other eroded tubes showed no apparent deformation irregularities. Hence, more than one type of failure was indicated.

To determine if the thrust chamber coolant tubes were restricted before firing, all tubes of several chambers were flowed prior to installation of the head manifolds. In some cases tubes were found to be completely blocked. As a result it was decided to investigate the manufacturing processes.

Using theoretical heat fluxes and coolant velocities, it was ascertained that the maximum permissible decrease in coolant velocity in a tube to prevent burnout was 10 per cent. To determine the actual throat velocities, 41 tubes were flowed at rated equivalent water flow and then sectioned at the throat. The velocities were accurately determined by measuring with a planimeter the cross-sectional area which had been magnified approximately 100 times. The plot of pressure drop versus velocity is shown in Figure 20. The scatter of the data is attributed to instrument error. As a result of this it was determined that the maximum permissible variation in pressure drop between tubes in an assembly was 10 psi.

To investigate the variation in tube pressure drop occurring in normal tube forming techniques, a sample of 568 tubes, manufactured to the established

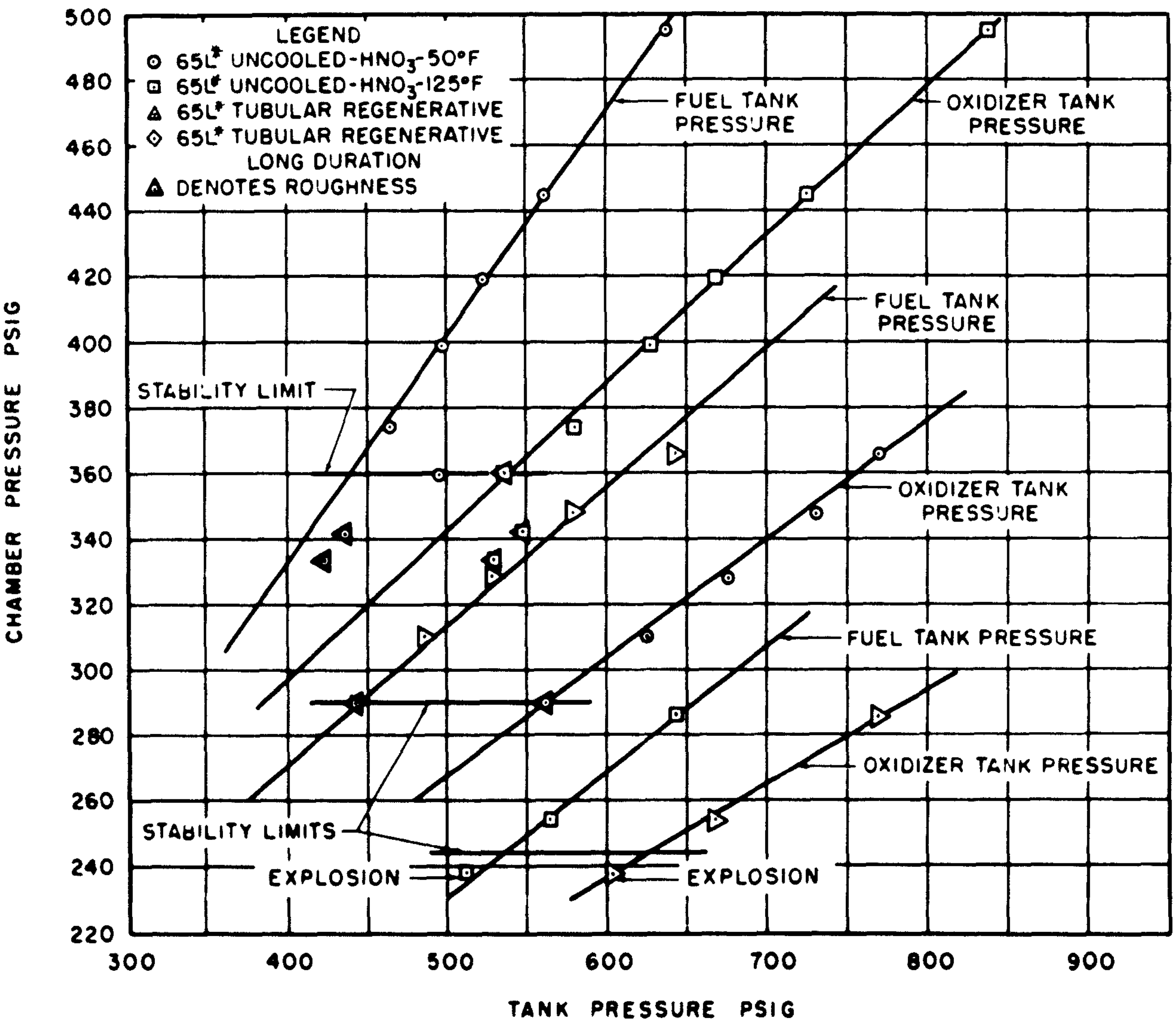


Figure 19. Effects of Tank Pressures on the Chamber Pressure Stability Limit with Injector R-52a

production tolerances, was water flowed. Approximately 94 per cent of the tubes had pressure drops from 38 to 48 psi. By dividing the tubes into groups, with 10 psi ranges, the rejections could be reduced to 2 per cent.

Extensive tests were made to minimize the occurrence of the "hour-glass" cross-sectional shape at the throat during the forming of the tubes. The procedure evolved resulted in annealing the tubes before and after the forming operation.

A series of "controlled" tube assemblies was then manufactured to determine the effect of each significant manufacturing process on the pressure drops.

It was soon apparent that the major variation in the pressure drops of tubes in an assembly was caused by weld penetration when assembling the throat retaining ring. Several methods were attempted to eliminate this difficulty. It was found that best results were obtained by using a low current welding arc.

A total of five "controlled" tube assemblies were fabricated and are ready for testing. Flow tests of individual tubes disclosed no change in pressure drop caused by any manufacturing process subsequent to welding. These "controlled" thrust chambers will be fired in the next quarter and the results evaluated.

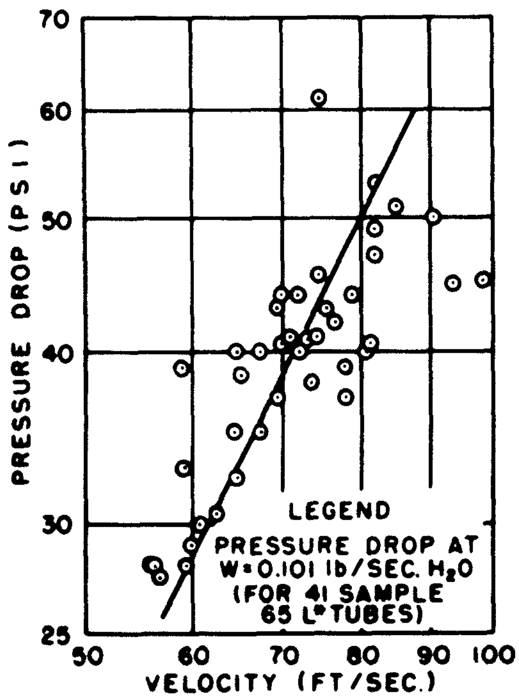


Figure 20. Pressure Drop vs. Velocity

To investigate the possiblity of chemical types of failure, the injectors which had been fired in the rejected thrust chamber were re-evaluated. In all cases satisfactory operation was obtained at water coolant rates of 3.5 pounds per second. These tests may be inconclusive since the surface of the gas side of the mild steel nozzle does not simulate the scalloped, irregular surface of the tube-walled thrust chamber. Preliminary results have indicated that at least an increase in combustion efficiency can be attributed to the surface conditions of the tube-walled chamber. Figure 21 shows C* values obtained from tests run with an uncooled test chamber at propellant temperatures of 50°F and 125°F. Also included are the results from tests with the same injector run in a tubular regenerative thrust chamber. The investigation of surface conditions will be continued in the next quarter.

Metallurgical examination of tubes from several rejected thrust chambers revealed grain growth, carbide precipitation in the grain boundaries, and intergranular corrosion. The precipitation and corrosion could occur either in the manufacturing or testing processes. From laboratory tests, it was determined that an incorrect annealing procedure during the fabricating process caused carbide precipitation. To eliminate this factor, the annealing procedure was modified. However, this cannot completely eliminate carbide precipitation.

Grain growth and carbide precipitation indicate temperatures well above those calculated using average heat rejection rates. In the combustion chamber region, carbide precipitation was apparent both around the tubes and in regions across the tube as is shown in Figures 22a and 22b, respectively. The heat transfer in this region is approximately one quarter that in the throat. The precipitation in Figure 22a apparently was caused during the annealing operation, the ceramic baking operation, or in the casting process. The precipitation shown in Figure 22b was probably caused by the excessive localized heat transfer during firing. The problem continues under investigation.

Chemical analysis of the propellants has not revealed any characteristic connected with the burnouts. A further evaluation of the failures is being made in an attempt to correlate the burnouts with propellant properties.

Study is also being made of the effect of applying ceramic to the irregular chamber wall of the tube-walled design in an effort to minimize the effects of this irregular surface in cooling failures.

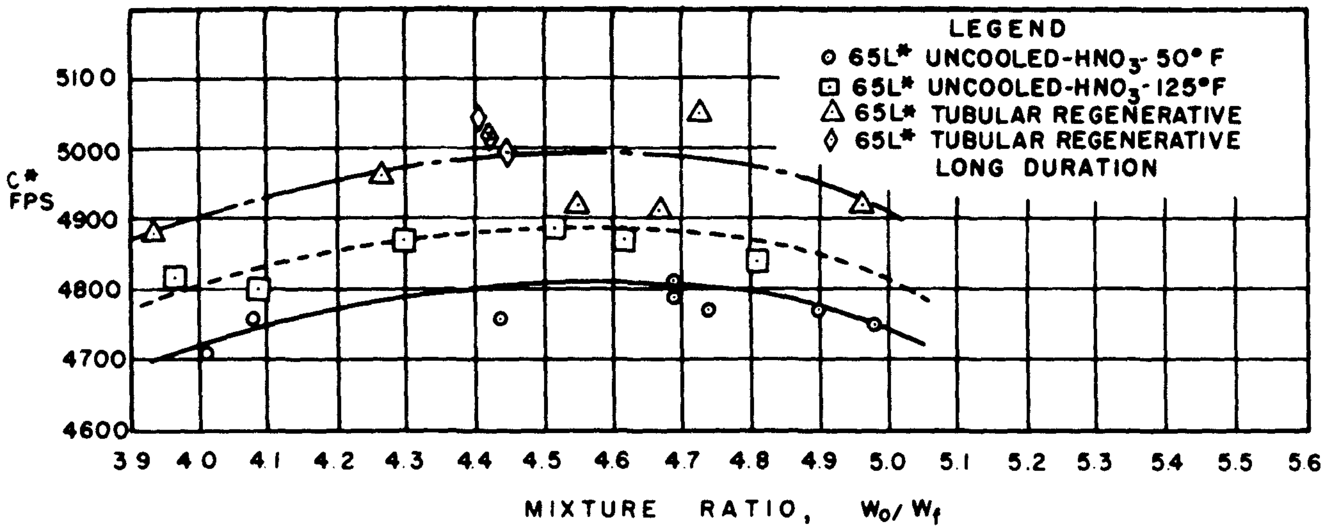


Figure 21. C* vs. Mixture Ratio, Injector RM-137

It will not be possible to reach any definite conclusions regarding the throat burnout problem until several of the previously mentioned "controlled" thrust chamber assemblies have been evaluated. However, the following results are indicated:

(1) Large fabrication variations, important from an engineering aspect, can exist in the tubular thrust chamber but can be reduced to a negligible effect.

(2) Although the "controlled" thrust chambers have not completed test firing, there are indications that mechanical difficulties are not the basic problem.

(3) The question of material suitability of the Type 304 stainless steel in this application has not been resolved, but should be determined in the next quarter.

The primary emphasis of future investigation will be on the following:

(1) Determination of combustion process irregularities caused by variations in propellant properties.

(2) Analysis of the thermal deformations or incidence of coolant tube restrictions occurring during test firing.

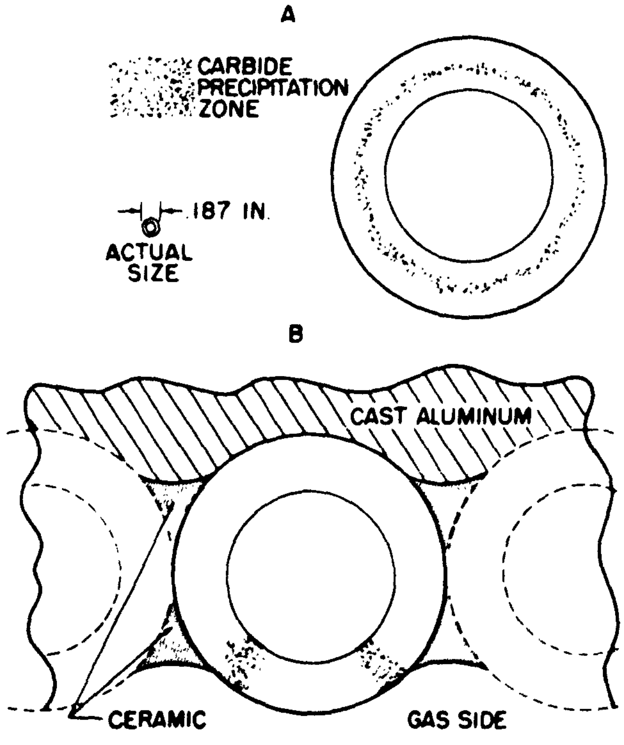


Figure 22. Sketch of Carbide Precipitation Zones of Type 304 Stainless Steel Tubing

(3) Investigation of the internal surface effects inherent in the tube-walled design.

(4) Further investigation and analysis of the injector.

All of these problems are currently being worked on and some results should be available in the next report.

The first two production type 75L* tubular thrust chambers were delivered for test firings. After developing many leaks during the course of five runs, thrust chamber P-1 was sectioned for use in the throat burnout investigation. Thrust chamber P-3 performed satisfactorily with only minor repairs needed. The testing of this chamber is continuing.

The 75L* tubular thrust chamber incorporates an uncooled divergent nozzle extension approximately 0.7 in. long. Both 75L* chambers incorporating this nozzle ran very well. Additional thrust chambers of this configuration will be tested.

The program to investigate the cause of the stainless steel insert erosion was continued this quarter. Two thrust chambers, 506-T and 507-T, were fitted with this insert, and 506-T was fired. It burned out after two short duration firings. The burnouts were attributed to an excessive heat transfer rate from turbulence caused by the abrupt change of section at the aluminum wall and the chamber tube junction. Erosion was evident on the downstream edge of the aluminum wall.

The oxidizer outlet manifold on thrust chamber 507-T was enlarged and fitted with a baffle to provide better cooling in the region where the aluminum wall met the tubes in the chamber. In addition, the aluminum wall was tapered to eliminate the abrupt step between the aluminum and the chamber tubes. Thrust chamber 507-T successfully completed eight firings totaling 938 seconds duration. To eliminate the need for the coolant manifold baffle, a new configuration will be made and tested.

The program to investigate the cause of the thrust chamber casting defects has been completed. Approximately 25 thrust chambers have been cast using the same method and all have been satisfactory.

The first prototype all-aluminum thrust chamber, E-1, having a partially expanded drilled coolant passage nozzle, was completed and tested, performing satisfactorily in all tests.

Several thrust chamber assemblies having no 3-S ceramic between the tubes and the casting are being manufactured. These chambers will be tested in an effort to find out if the ceramic is necessary. Thrust chambers of this configuration without the green milled enamel on the tubes will also be tested.

A multiple nozzle expanded to sea level was test fired during this period to determine the effect of this nozzle type on performance and flame length. The flame length of the multiple nozzle was less than one-half that of the conventional nozzle of similar performance.

c. Propellant Tanks and Bladders

The first set of 61ST propellant tanks received from the Benson Company was found to be unsatisfactory because of incomplete weld penetration and poor joint design of the forward dome enclosure.

The teflon oxidizer tank bellows was ordered changed to a shorter and thicker material since tests had shown that the material currently in use occasionally failed.

In addition, detail drawings were completed for the air separators to be used with Model 56F.

d. Valves and Controls

A revision of the effectivities of all valves and controls was completed during this report period, as were the development drawings for a universal type injector head shutoff valve.

Layouts were finished for an installation to be incorporated into all production injector heads.

Drawings for the 56-472-570 jettison valve were revised in order to attain an explosion proof unit, while drawings for the installation of chamber pressure switches and propellant valve microswitches were also completed.

The layout studies were completed for the installation of a tandem type low pressure jettison valve, and the necessary drawing revisions were made to enable the use of this part on Models 56D, 56E, and 56F.

3. RESEARCH

a. Heat Transfer Tests

During this quarter the transparent annular test section was utilized to obtain forced convection, nucleate boiling, and heat transfer data with JP-4 at low velocities of 3 to 8.5 ft per sec and at test section pressures of 50, 100, 300, and 5000 psia. The nonboiling data appear to correlate with the equation of Carpenter, Colburn, Schoenburn, and Wurster* for heating in an annulus.

$$Nu = 0.023(Re)^{0.8}(Pr)^{1/3}(\mu/\mu_w)^{0.14}$$

where Nu = Nussult number of bulk fluid

Re = Reynolds number of bulk fluid

Pr = Prandtl number of bulk fluid

μ = Viscosity evaluated at bulk fluid temperature

μ_w = Viscosity evaluated at wall temperature

No satisfactory correlation was found for nucleate boiling data. It was established, however, that the liquid film heat transfer coefficient in the nucleate boiling range is independent of the velocity; also, that the range of heat flux between the inception of nucleate boiling and burnout decreases as the pressure increases, and that the transition heat flux equals the burnout heat flux at approximately 550 psia.

A 16-mm motion picture camera loaded with color film was installed adjacent to the transparent test section to record the appearance of the tube during tests. The resultant movies vividly illustrated carbon formation and burnout. Carbon deposits began to appear when the tube wall reached a temperature of approximately 900°F and continued to build up as the temperature increased.

This phenomenon will be observed on all future tests.

During the next quarter additional heat transfer tests on JP-4 will be performed at velocities from 10 to 40 ft per sec.

b. Injector and Spray Studies

Research and development with the oxidizer (acid) cooled hollow tube flame holders, begun in the last quarter, was continued. Three RASCAL injectors, RM-26, RM-28, and RM-84 were modified by the addition of the hollow tube grids. In all three injectors an estimated liquid velocity of approximately 30 ft per sec was attained which was adequate for cooling purposes, as was shown by the lack of erosion after evaluation firings as long as 601 seconds with RM-26. The modified injectors also indicated some improvement in I_{sp} and C*.

A new series of tests on calibrated thrust stands with start chambers whose throat areas are readily measurable is to be initiated.

Injectors RM-26-1, 2, 3; RM-28-1, 2; RM-84; and RM-42 were dyed water flowed to find the spray distribution with and without flame holder grids. In general, addition of the grid improved mixing and distribution.

Several families of orifices were high pressure flowed at P_c = 0, 100, 200, 300, 400, and 490 psig. The orifice diameters ranged from 0.50 to 0.81 in. and length/diameter ratios from 1 to 53. Orifices representing RASCAL injector configurations were also flowed.

An intensive analysis of this latter data plus previously gathered data on orifices with L/D from 1 to 25 showed that:

(1) Width of hydraulic flip region increases as chamber pressure and L/D increase.

(2) Orifice differential pressure at which flip occurs increases as chamber pressure and L/D increase.

Injectors R-61, R-62, and R-63 were dyed water flowed during this period with R-61 and R-62 showing good mixing and distribution.

c. Variable Thrust Injectors

The test program of the variable thrust injector was continued during this quarter with evaluation of two 400-pound (formerly rated at 600 pounds) thrust units with the piston-operated, variable thrust injectors CV-1 and CV-2.

Thrust chamber of various L* values and diameters were used in tests of injector CV-1. WFNA and JP-4 were used as propellants with both hydrazine and mixed trialkyl trithiophosphites [$(RS)_3P$] used as igniter fluids. Performance curves are shown in Figure 23.

Leakage tests were made to determine the amount of propellant leakage with the piston in the closed position and the likelihood of ignition during the leakage period. Ignition is most likely to occur when the differential pressure between the piston bleed pressure and tank pressure is less than 100 psi.

* Carpenter, Colburn, Schoenburn, and Wurster: Trans. Am. Inst. Chem. Engrs. 42 165-187 (1947).

Ignition tests were performed to compare hydrazine and $(RS)_3P$ as starting fluids with $(RS)_3P$ giving the better results.

Injector CV-2 was also tested through various L* values and chamber diameters with stability results similar to injector CV-1, but considerably lower performance.

Testing was begun on the 4000-pound variable thrust injector VT-1 which was dyed water flowed over the full range of piston positions. Mixing was good in the full open position, but streakiness appeared in the partially open positions.

One firing was attempted resulting in an explosion which damaged one of the orifices in the injector. New, redesigned orifices are being prepared for water flow tests before further firings will be attempted.

d. Propellant Investigations

(1) Additives

A series of runs using a 4000-pound regeneratively cooled thrust chamber was made at ambient temperatures of +35°F to +45°F in order to determine the maximum water content in WFNA that could be tolerated before rough or destructive performance was encountered. Beginning with WFNA conforming to MIL-N-7254, water was added in increments of approximately 3 per cent by weight until, at a total water content of 13 per cent, the thrust chamber exploded during the run. The performance parameters measured are shown in Figure 24.

A second series of runs using the same type thrust chamber was made with the water content of the acid being decreased in increments of 3 per cent from the 13 per cent level and at successively lower temperatures until rough or explosive performance was encountered. One run at 0°F with 10 per cent water content resulted in an explosion. On another run with 7.5 per cent water content an oxidizer tank temperature of -40°F was attained, but rough runs were encountered. The performance parameters for the runs with WFNA containing 7.5 per cent water are shown in Figure 25.

The performance characteristics of WFNA modified with approximately 10 per cent by weight of ammonium nitrate as a freezing point depressant were obtained from runs at successively lower ambient temperatures from +55°F to an oxidizer tank temperature of -42°F. A run was made at -47°F, the lowest oxidizer tank temperature obtainable, with

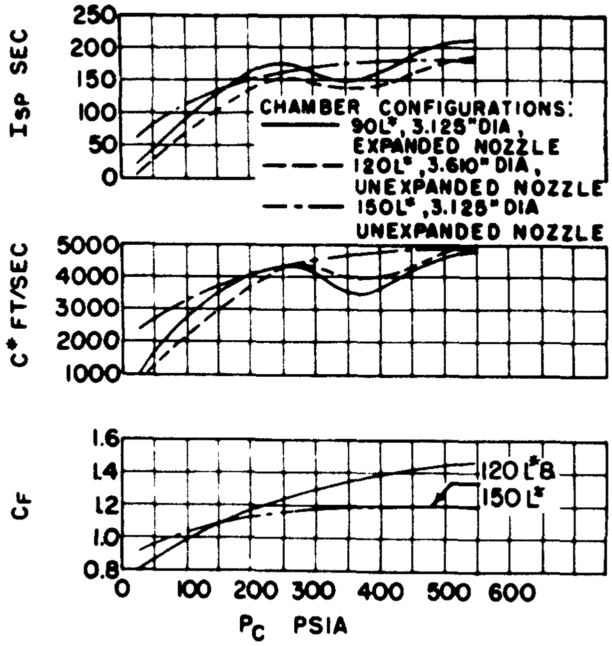


Figure 23. Performance Characteristics of Injector CV-1

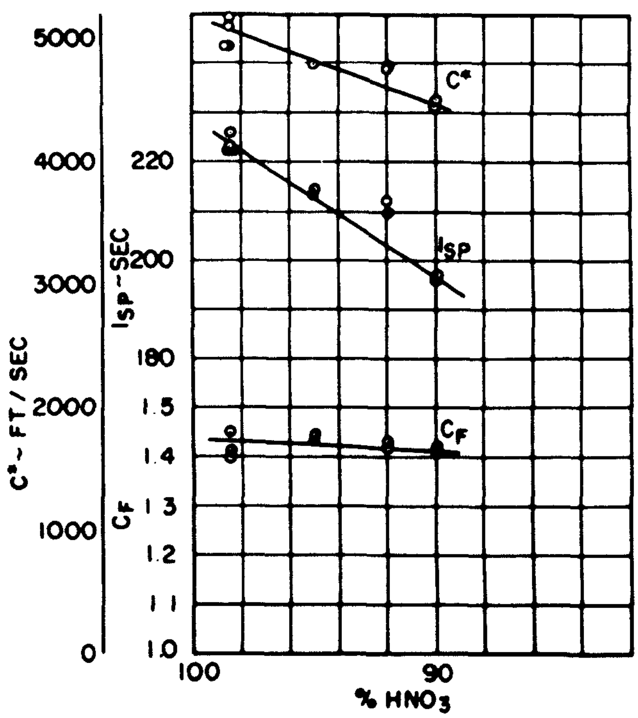


Figure 24. Thrust Chamber Performance for Various Percentages of Water Additive to WFNA

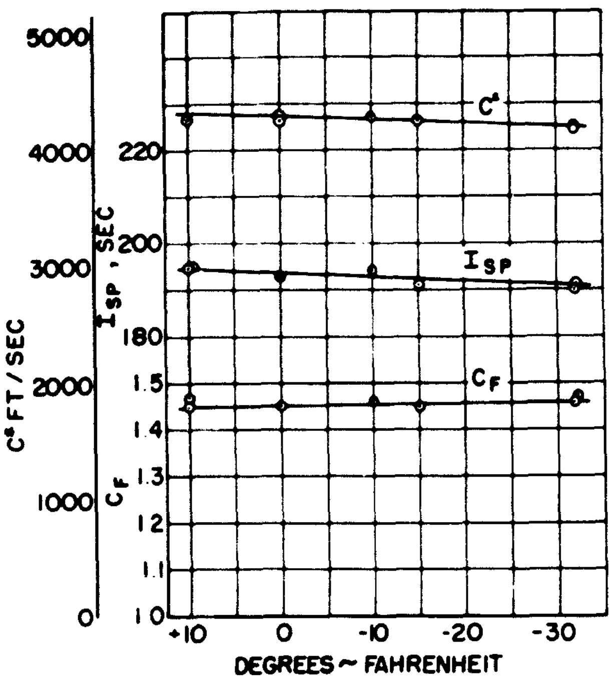


Figure 25. Thrust Chamber Performance for 7.5% Water Additive to WFNA at Various Propellant Temperatures

WFNA containing 9.24 per cent by weight ammonium nitrate. The performance parameters measured are shown in Figure 26.

(2) Ignition Lag

To check ignition delays of propellant combinations the California Research Corporation type cylindrical ignition delay tester was put into operation. The instrument was used in conjunction with a pulse amplifier and a General Electric time interval meter.

Propellant combinations checked by this instrument and instrumentation gave the following results for ignition lag at 50°F:

(a) WFNA/eutectic hydrazine – 20.5 msec
(b) WFNA/n-butyl mercaptan – 13 msec
(c) WFNA/$(RS)_3P$ – 6 msec

(3) Catalysts with Ammonium Nitrate

A number of catalysts are under consideration for incorporation into the WFNA-ammonium nitrate system. Motor testing is being held pending complete evaluation of the ammonium nitrate modified WFNA alone.

(4) Quality Control

A new proposed specification for WFNA was written.

Bell Aircraft Corporation began construction of a WFNA meter after the design by Dr. J. C. Clark of the Naval Air Rocket Test Station which will be used to obtain the percentages of NO_2 and water in WFNA.

(5) Spectrophotometric Studies

Absorption curves versus wavelength were determined for WFNA, JP-4, and certain samples of WFNA containing known amounts of metallic contaminants. The results obtained are in agreement with published values for WFNA and contaminated WFNA.

(6) Systems Safety

Tests were initiated to determine the maximum quantity of JP-4 that could safely be exploded in a RASCAL thrust chamber so that precautions could be taken to eliminate the possibility of greater quantities of JP-4 accumulating therein.

It was computed that if 0.05 pound of JP-4 and 0.25 pound of WFNA react together completely in a RASCAL thrust chamber so rapidly that none of the resulting gas escapes from the nozzle, then the total equilibrium pressure would be approximately 5000 psi.

A series of tests was performed to determine the best method of detonating a stoichiometric mixture of WFNA and JP-4. Of the various ignition methods tried, the most forceful explosion resulted from placing a blasting cap below the surface of the heated propellants. A mixture of 0.05 pound JP-4 and 0.25 pound WFNA, detonated in this fashion, completely demolished a RASCAL thrust chamber on two occasions.

e. Materials Evaluation

(1) Miscellaneous Material

A polyethylene lining in a steel pail completed 110 days exposure to nitric acid without noticeable damage. The iron pickup of the acid stored in the pail was quite low.

Du Pont acid-resisting paints, Nos. 279 and 280, were quickly penetrated by the acid and loosened from the metal.

Samples of a pure aluminum oxide coating flame sprayed on stainless steel and on aluminum were received from Norton Company. These samples showed excellent adhesion and temperature resistance. However, the process, which is still in the developmental stage, does not appear to be ready for use in items as large as a RASCAL thrust chamber.

An apparatus for stiffness tests on plastics in the cold box was designed and is being fabricated.

Several thread lubricants were tested for detonation after a week's storage in contact with hydrazine. No detonation was produced. The lubricants tested were:

Key Absolute	Cyl-seal
Parker Oxyseal	John Crane No. 2
Parker thread lube	Rectorseal
	Dow Corning No. 33 Silicone Grease

(2) Bladder Material

Efforts were continued to obtain suitable materials for fuel and oxidizer tank bladders. The SHRIKE fuel bladders of 0.013 in. material were considered of marginal strength for a bladder of the RASCAL size despite satisfactory tests on the oscillation tower up to 2g acceleration. A heavier bladder of 0.30 in. rubberized nylon was received for this purpose.

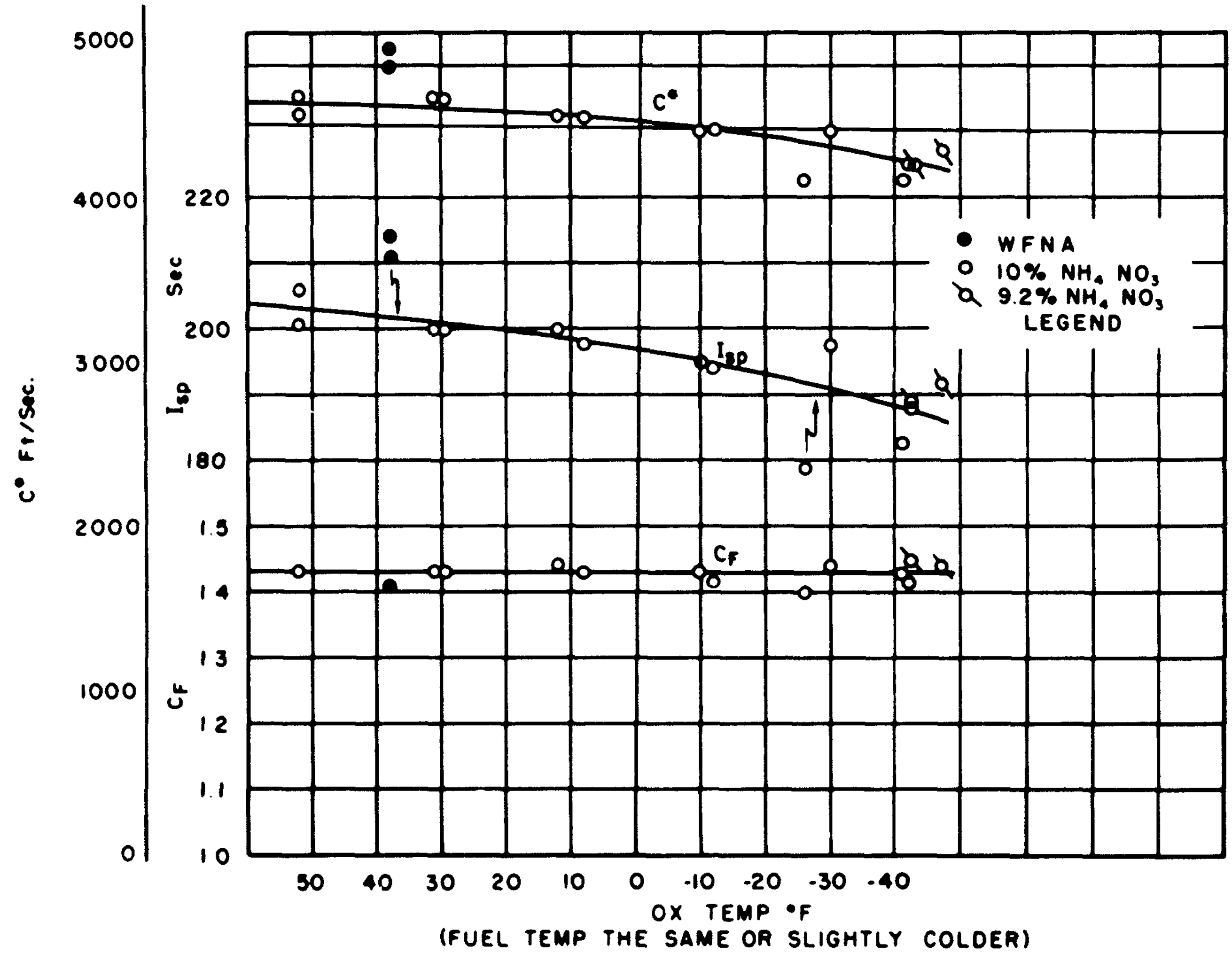


Figure 26. Thrust Chamber Performance for 10% NH_4NO_3 Additive to WFNA at Various Propellant Temperatures

A small teflon bladder received from the Minnesota Mining and Manufacturing Company for use as an oxidizer bladder was found to possess sufficiently strong seams. It was reported last quarter that seams in similar bladders were quite weak. Teflon bladders for WFNA now show promise of being satisfactory for unlimited storage time and for use over the entire required temperature range of -65°F to 160°F.

A sample of Hypalon X 39 was unable to withstand WFNA sufficiently for use as a bladder. A sample of Hypalon X 10 remains to be tested.

f. Corrosion Program

The status of the corrosion program is as follows:

Phase I - Bell Aircraft Corporation Report No. BLR-51-106, "Corrosion Effect of WFNA on Various Non-Ferrous and Stainless Steel Alloys at Ambient Temperature and 160°F" dated August 1952, was issued during this quarter. The purpose of this report was to present the data obtained after one year of preparation and exhaustive testing by Bell Aircraft to screen material for WFNA on Project MX-776.

The object of Phase II was to establish rates of corrosion of several selected alloys. Samples were exposed to WFNA at several temperatures (to 160°F maximum) and for various periods (to 90 days maximum). The experimental work has been completed and the report is being written.

Phase III is a continuation of Phase I. The experimental work has been completed and the report is being written.

Phase IV will start soon. Selected alloys will be exposed to WFNA containing additives being considered for freezing point depressants and combustion catalysts.

From curves taken in this program it appears that at the higher temperatures, the cumulative rate of corrosion decreases with time, while at the lower temperatures it increases somewhat with time.

g. New Type Thrust Chamber

This quarter development work on the cast aluminum tube walled thrust chamber was concentrated mainly on improvement of the production type. For the report see the 4000-lb thrust chamber section of this report.

A series of tests was made at various conditions on thrust chambers without a stainless steel protective sleeve over the aluminum skirt. The object was to investigate if the modifications on the production injectors of higher pressure drop in the oxidizer manifold and counterbored orifices result, in addition to improved combustion stability, in an improvement in skirt erosion.

Tests were continued on thrust chambers cooled with JP-4 to investigate temperature conditions at different mixture ratios.

h. Solid Propellant Gas Generator

Compatability tests were begun this quarter between JP-4 and the combustion product gases of the solid propellant, HES-5192, both in the presence and absence of a chemical diluent. As the tests continued, each run was made progressively more severe. In all tests the combustion product gases were passed over the JP-4, but in no case did reaction occur.

A final series of five runs was made to determine the reproducibility of flow rates when JP-4 is expelled from a tank under pressurization of the solid propellant and chemical diluent combustion product gases. However, the entire solid-propellant gas generator program was terminated before the tests could be completed.

i. Combustion Research

During this period a combustion research program was initiated with the following aims:

(1) To develop equipment for combustion delay measurements in liquid propellant rocket thrust chambers.

(2) To measure combustion delay of WFNA/JP-4 as a function of thrust chamber pressure and mixture ratio.

A fluid-pulse generating unit adaptable for installation in either fuel or acid line, was designed and assembled. It was installed in the acid line of a 400-lb thrust chamber and a series of evaluation runs was made. High frequency instrumentation in addition to standard instrumentation was also installed.

A report is in preparation presenting the combustion delay data, as obtained with the fluid pulse generating unit.

In addition, efforts to improve the high frequency pressure instrumentation are being continued.

4. DATA ANALYSIS

a. General

A Data Analysis Group was formed to assist the various groups in the analysis of data and preparation of reports. The group will also make recommendations as dictated by the results of the various investigations undertaken.

b. Hydrazine Ignition

The reliability of hydrazine as an igniter fluid has been demonstrated by the fact that, during the last three years, more than 5000 successful thrust chamber starts have been made.

A program was initiated to determine the minimum quantity of hydrazine which would start combustion in a 4000-lb RASCAL tubular thrust chamber. Tests indicated that for ambient temperature of +35°F, a minimum of 1.5 ounces of hydrazine was required, while for -30°F, a minimum of 2.5 ounces was required. Eight ounces are contained in the RASCAL thrust chamber starting system.

c. Power Plant Flight Test Analysis (XB-63)

The analyses of the power plant data for pilotless parasite bombers 0307 and 0409B were made and showed that during both flights power plant performances were normal throughout the firings and within specifications.

d. Cold Test Injector History

A study of the 140 cold tests made with 56 injector heads of latest configuration at propellant temperatures of -25°F to -40°F showed all runs except 7 (5 per cent) were smooth. Since the injectors on the rough run had performed satisfactorily on previous cold tests, it was believed that the system, rather than the injectors, was responsible. Cold tests will be discontinued until further injector configuration changes are made.

e. Rocket Engine Run Log

Bell Aircraft Corporation Report No. 56-982-017, "XLR-67-BA-1, Rocket Engine Run Log," was issued during this quarter with copies being sent to WADC. The report summarizes in the form of a running log the test runs being made on the RASCAL power plant.

f. Component Testing

During the quarter, the regulator pack for XB-63 No. 10 was serviced and test flowed. The regulator pack for XB-63 No. 13 was overhauled for suspected acid damage, while the fuel regulator of the pack for No. 15 was reworked after it "hung up" during the engine acceptance run. This pack will be reflowed early in the next quarter. An R & D pack was made into a production spare.

A new accumulator bladder was installed in XB-63 No. 15, and the hydraulic actuating circuit cleaned to eliminate malfunctioning of the prop valve on the bottom boost chamber.

Thrust chamber assembly 86RC replaced 77RC, the cruise chamber of XB-63 No. 13.

g. Engine Acceptance Tests

A penalty run was made on XB-63 No. 13 engine on the power plant mock-up at AF Plant No. 38 on 26 February. Although performance was not to specifications, a waiver was signed on this run, because the below-specification operation was due to the mock-up propellant feed system rather than the engine.

An acceptance firing was made on the No. 15 engine on 12 March. A penalty run will be made because of regulator malfunction.

h. Missile Testing

Satisfactory acceptance firing of XB-63 No. 10 was made at AF Plant No. 38 in January. RASCAL No. 10 was successfully flight tested at HADC on 13 March. RASCAL No. 13 is expected at AF Plant No. 38 for tests early in the next quarter.

Shrike

1. INSTALLATION

The flight test program of the 59A SHRIKE missiles was completed with the launching of the last two missiles, Nos. 2713 and 2813, at HADC on 20 and 23 January, respectively. Both missiles were of the chemical warhead series with no provisions for telemetering equipment. Power plant operation on both flights was satisfactory.

Missile 2713 veered off on a heading approximately 35° left immediately after launching. Otherwise the flight was satisfactory with normal detonation and warhead deployment.

Missile 2813 suffered an apparent loss of servo, guidance, and hydraulic power immediately prior to launch, but occurring too late to halt the launching, and resulting in an unplanned power dive. Warhead separation was successful, but occurred at Mach 0.86 rather than Mach 1.31 as planned.

Since no telemetering equipment was carried, no definite reason can be assigned for the malfunctions in the two flights.

Power plant operation on all thirteen flights of the 59A (WFNA/JP-4) series was satisfactory with no malfunctions occurring during flight or servicing, thus achieving the objectives of the 59A power plant program.

2. 1500-POUND THRUST CHAMBER

The spare rocket engine, mentioned in the last report, was tested, accepted, and shipped to HADC.

This completes the SHRIKE test program. No further SHRIKE power plant reports will be issued.

C. Guidance

1. GENERAL

The guidance system of the XB-63 pilotless parasite bomber consists of a single-axis inertial guidance system plus an unattended radar, a radar relay, and a command system, components of which are located both in the director aircraft and in the XB-63.

Briefly, the system operates as follows: The director aircraft is navigated to the launch point with the aid of a long-range search radar and computer. Immediately prior to launch, information regarding director aircraft velocity, range to target, and the difference between director aircraft drift angle and expected XB-63 drift angle is fed into the XB-63 inertial system. During the midcourse phase of flight, the pilotless parasite bomber is under the control of the inertial system. At a predetermined range from the target, the XB-63 assumes a 30° dive angle. Thus, the inertial system establishes the pilotless parasite bomber on its course for target impact within the accuracy limitations of launch information and accuracy capabilities of its components.

The radar system is incorporated in RASCAL to improve the accuracy of target acquisition. Prior to the initiation of dive, search radar equipment located in the nose of the pilotless parasite bomber is turned on. During the terminal dive phase, the target area is scanned by this search radar equipment, and video return information is transmitted to the director aircraft by means of a microwave relay link. This information is presented on a radar indicator in the director aircraft and enables a single guidance operator to make vernier corrections to the flight path established by the inertial system, thereby making possible a high degree of accuracy in target acquisition.

The foregoing guidance description applies to the XB-63 program only after the inertial guidance system is incorporated. Inertial guidance is scheduled for incorporation into the XB-63 program at pilotless parasite bomber No. 35E. Prior to the incorporation of the inertial guidance, the track-command midcourse guidance system described by Bell Aircraft Specification No. 56-947-001 is used.

2. GUIDANCE TESTING

a. Flight Testing

To aid in testing RASCAL guidance components, a B-17 Aircraft (AF-3439) is used equipped as a flying laboratory. A modified F-80 simulating the XB-63 in flight is used to check out the B-50 guidance equipment (in the B-17) as well as to investigate the unattended operation of the R&D XB-63 guidance system. From 1 January to 31 March, 1953, 19 test flights of the guidance system were made with these aircraft. Systems under test were: X-band Unattended Search Radar, K_u-band Unattended Search Radar, Model 3 Terminal Guidance, Model 4 Terminal Guidance, Automatic Tracking Relay Antenna, Model 5 XB-63 Relay Equipment, Model 4 Video Relay Receiver, and Model 5 Video Relay Receiver.

(1) X-band Radar

Flights made with the X-band radar system included tests to measure the dynamic range of the reflected RF signal strength, tests to evaluate the automatic gain control (AGC) circuits, and tests to establish system performance with several types of vertical radiation patterns of the antenna. Data collected during three flights showed that the dynamic range over cities varied from approximately 60 db at 3000 feet to approximately 37 db at 20,000 feet. The range was about 10 db less over open country. Automatic gain control data were obtained during six flights and this information made possible an accurate evaluation of the present AGC circuitry.

Photographs of the Radar PPI scope, taken during several flights, will be used as an aid in designing a radar simulator. Figures 27A and 27B show a typical radar return and the area scanned by the X-band radar on low PRF at 27,000 feet altitude and adjusted to display a maximum slant range of 12 nautical miles.

(2) Terminal Guidance System

During this period, Model 3 TGCS (Terminal Guidance Control System) was installed in the B-17 airplane, and a second system, Figure 28, was set up in the Electronics Laboratory. The equipment above the table top in Figure 28 is that which is mounted at the operator's position, and the equipment below table top is that contained within the guidance capsule in the bomb bay of the B-47. In tests, radar video was relayed to these systems and to TGCS Model 4. Flights are currently being made to evaluate and improve the altitude tracking circuits in the Model 3 system. These laboratory TGCS systems were also used in connection with F-80 relay flights.

(3) Video Relay (XB-63)

The XB-63 relay equipment was used only to test other systems. During these tests the video relay link was established on 14 occasions, and a satisfactory signal was received at the maximum range tested (158 nautical miles from air to ground).

(4) K_u-band Radar

Flight tests on the K_u-band unattended search radar (USR) were conducted to evaluate the automatic gain control circuits, and to collect radar target dynamic range data for evaluating the receiver compression circuit. After dynamic range data were collected and analyzed, it was found necessary to reduce the receiver video compression. More flights will be made to evaluate this modification. Tests of the AGC circuits have not been completed; thus, no conclusions have been made.

An F-80 aircraft (AF-8485) has been modified and is being used to simulate the XB-63 in flight. Flights were made to check the unattended operation of the XB-63 equipment and the results were satisfactory. The F-80 was also used to help test guidance equipment installed in the B-50 aircraft.

Information on the complete maintenance of all systems operated by the Flight Testing Unit has been collected and will be used in studying the reliability of systems to improve their dependability.

All equipment has been removed from the B-17 Aircraft (AF-3517) which will soon be returned to the Air Force.

Future flight testing plans include the installation of a recording system in B-17 AF-3439, additional evaluation testing of the X-band and K_u-band radar systems, continued use of the F-80 with the B-50 Program, system tests with Model 4 TGCS, evaluation of the ATRAS (Automatic Tracking Relay Antenna System) equipment in flight, and air-to-ground-laboratory flights to test both the video and the command systems in the F-80 aircraft.

b. Ground-Laboratory Testing

The second phase of the engineering tests utilizing XB-63 No. 08B was completed. This phase consisted of mating the XB-63 with a B-50 director aircraft for the purpose of evaluating over-all systems operation. The major problem encountered — and this may hamper the prelaunch checkout — was interference between the unattended search radar system and the MCG-1 (Midcourse Guidance) system. From these tests a satisfactory prelaunch checkout procedure was established.

Initial operating tests of the Automatic Tracking Director Relay Antenna (ATDRA) System were made in the laboratory by tracking a video signal relayed from the B-17. The results were satisfactory, and work is now under way to install the ATDRA system in an aircraft so that more extensive testing may be conducted. Figure 29 shows the ATDRA system on a test stand which not only serves as a means of simulating director aircraft movement and position while the antenna is being tested, but also facilitates movement of the entire antenna-receiver assembly to various points for either laboratory or air-to-laboratory testing.

3. EQUIPMENT DEVELOPMENT

a. K_u-band USR System

Convair has delivered the first two production K_u-band unattended search radar (USR) systems.

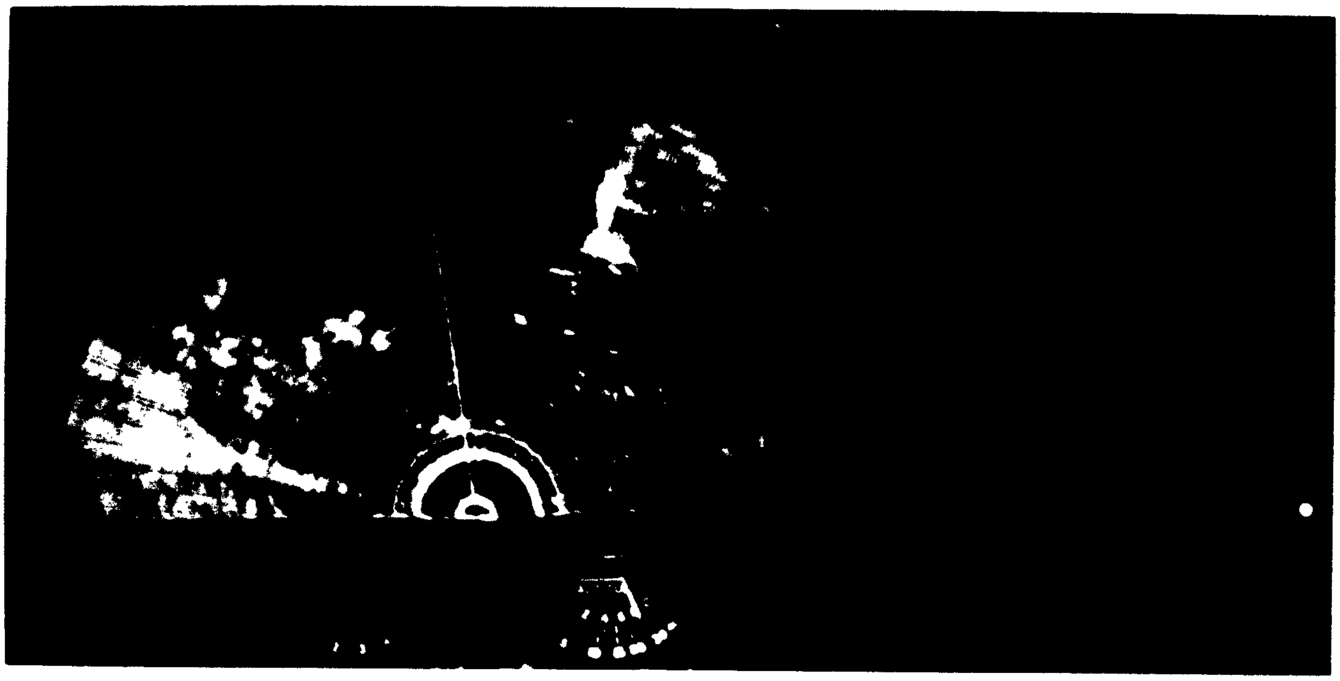


Figure 27A. Typical Radar Return, X-Band Radar

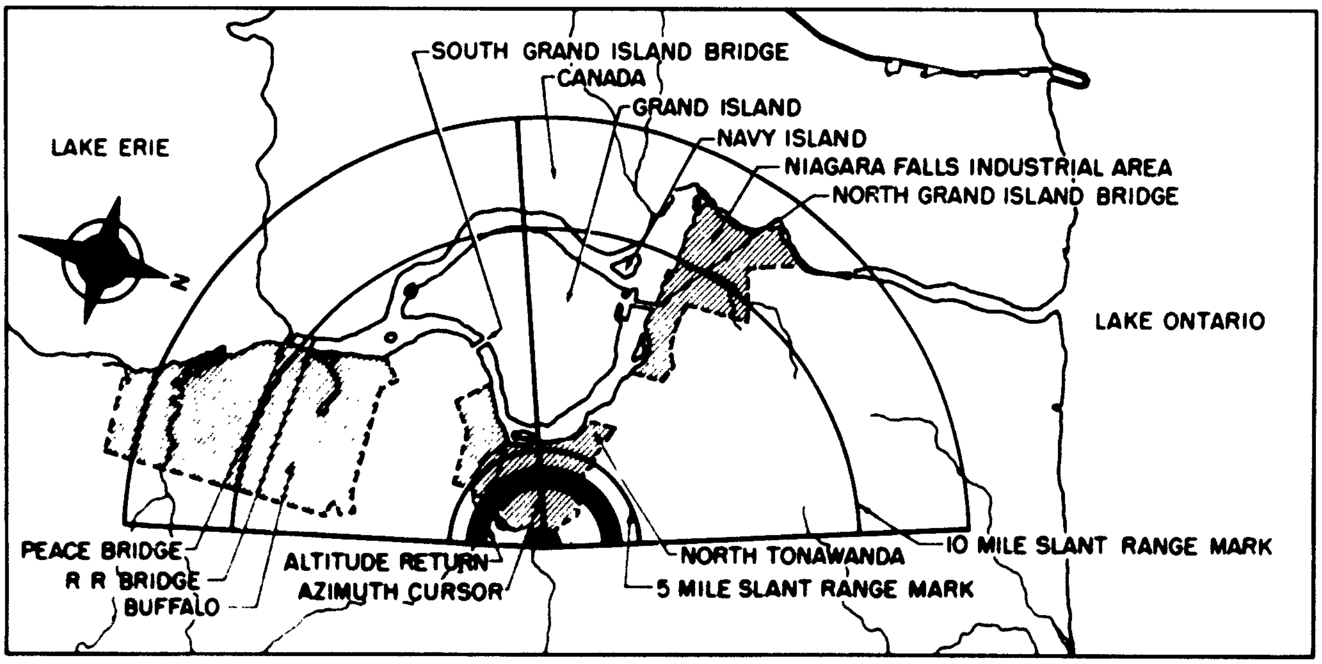


Figure 27B. Area Scanned by X-Band Radar

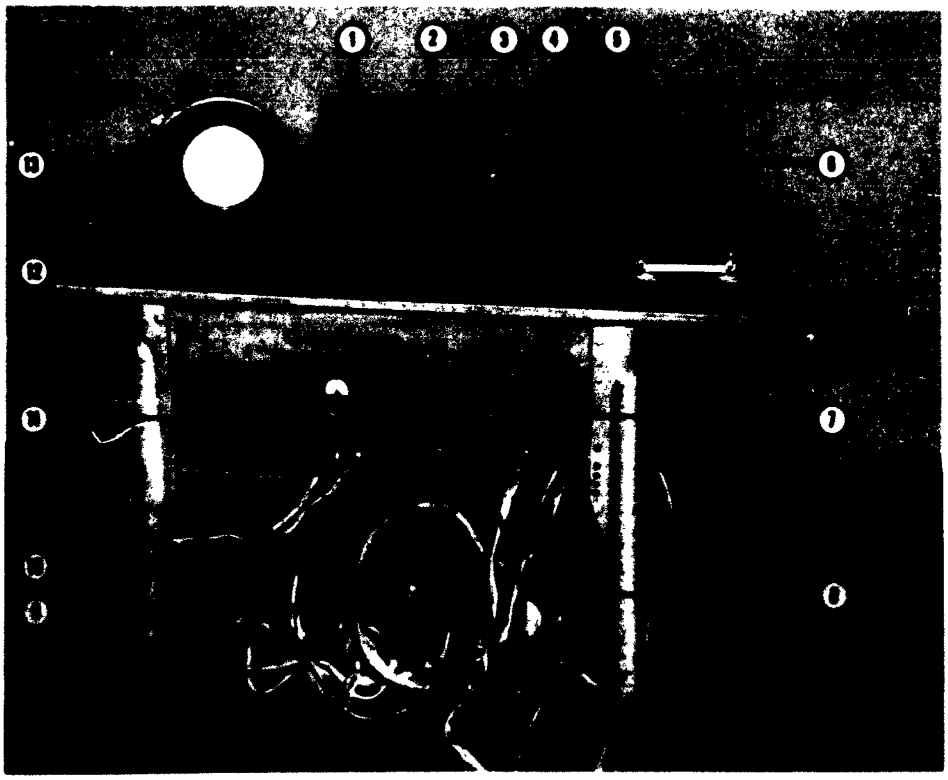
The third system has passed all the bench tests and is now being subjected to environmental tests at Convair.

Some difficulty has been experienced with the VC 1258 thyratron tube in the modulator. The original specifications for this tube specified a trigger pulse amplitude of 60- to 90-volts peak and the modulator was designed accordingly. The vendor, Chatham Electronics Corporation, has now determined that for reliable operation the tube requires a trigger pulse of 175 volts amplitude and 2 microseconds duration. On radar units 11 and subsequent, the VC 1258 tube will be replaced by a clocking oscillator to provide greater modulator reliability.

Dalmo Victor has not as yet delivered the antenna for the No. 11 system. Fabrication of this antenna has been completed, but difficulty is being experienced in meeting stability specifications as well as certain specifications on the antenna pattern. Dalmo Victor hopes to solve these difficulties soon and delivery of the antenna is expected by 30 April 1953.

b. X-Band System

A number of design changes have been made in the X-band receiver to improve its performance and reliability. The receiver bandswitching, which was formerly accomplished by a relay, is now done electronically by means of a subminiaturized diode. The efficiency of the second detector has been improved by replacing the 1N52 crystal with a subminiaturized diode. The bias on a number of the receiver stages has been refined to improve the over-all gain of the receiver.



1. Dive Panel
2. Calibration Panel
3. Altitude Panel
4. Synchronizer Panel
5. Lighting Control Panel
6. Monitor
7. Range Computer
8. Synchronizer
9. Voltage Regulator
10. Power Supply
11. Elevation Computer
12. Computer Control
13. Azimuth and Elevation Indicator

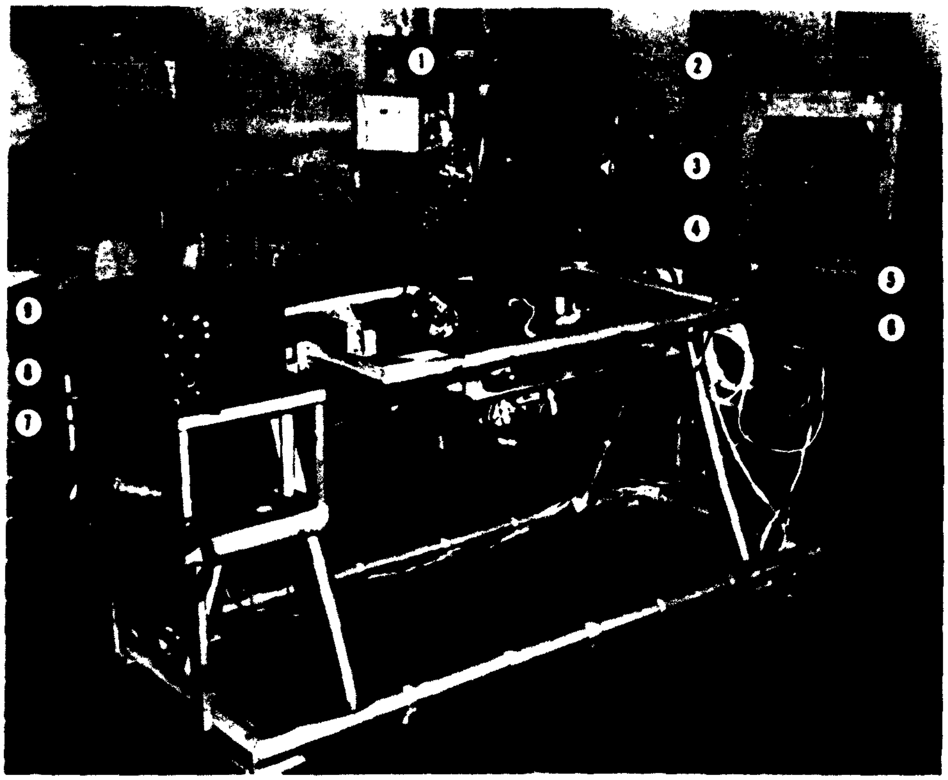
Figure 28. Terminal Guidance Control System

Varian Associates has tested the V-50 reflex klystron to determine the cause for the excessive shift in frequency during low temperatures. The V-50 klystron will give a frequency shift of approximately 300 mc for each 0.001-inch displacement of the grid structure. It is thought that warping of the grid structure at low temperatures causes the tube to shift frequency. However, it was found that if a tube is temperature-cycled at least once, the shift in frequency during successive tests becomes fairly small. Varian Associates has gone into production on the V-50 type reflex klystron; the production tube is designated the V-260.

The new balanced mixer and preamplifier assembly are shown in Figure 30. Based on the dynamic range data from the flight testing program, work has been initiated on the design of a compression receiver to handle the required dynamic range of signals.

c. RCA Magnetron (A1016)

The development by RCA on the A1016 tube for the video transmitter has continued with the main effort directed toward completing the 20-tube order specified in the development contract. Some undesirable temperature effects were noted during use of the tube. To eliminate these, the tubes were exhausted, in the manufacturing process, at a high temperature. Sufficient tubes were furnished to complete the 20-tube order and evaluations were made at Bell Aircraft to determine their performance in the video transmitting system.



1. Antenna Mounting Assembly
2. Antenna Dish
3. Nutating Feed
4. Test Stand
5. Test Box Containing RF Head for Receiver
6. Director Relay Receiver
7. Power Supply and Servo Controller
8. Antenna Control Panel
9. Antenna Servo

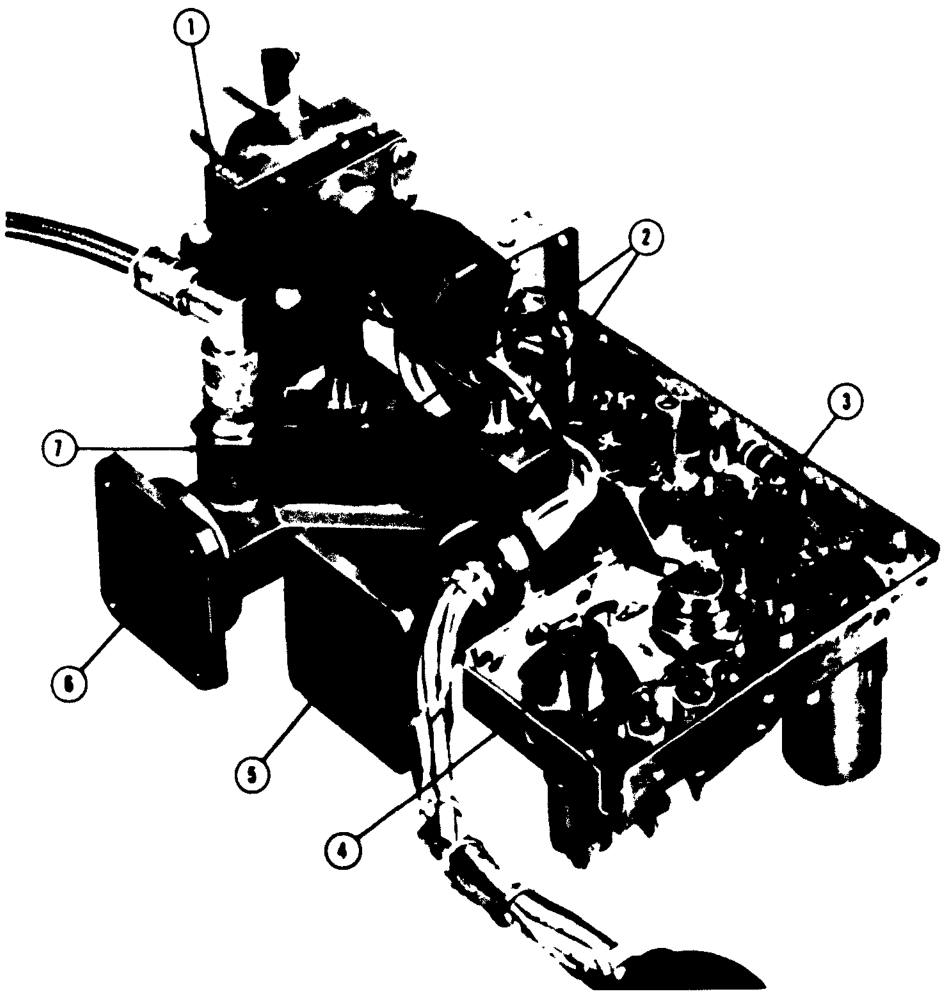
Figure 29. Automatic Tracking Director Relay Antenna System

The development work on the A1016 tube has been extended for another year to obtain tube characteristics suitable for the operational B-63. Programs were started to study instability and the tendency to shift from one mode to another, to extend the life of the main filament, and to change the gun design in order to improve linearity.

Delivery of tubes under the production contract has started with two tubes received in February and a full delivery rate of six tubes per month expected to start in April.

d. XB-63 Relay Antenna

The first of three preproduction models of the XB-63 relay antenna was delivered by the subcontractor in January, and an evaluation was conducted at Bell Aircraft to determine conformance with design specification. The two additional antennas to be de-



1. Klystron
2. Attenuators
3-4. Receiver Crystals (Balanced Input)
5. RF Input through TR Tube for Receiver
6. RF Input for AFC
7. AFC Crystal

Figure 30. New Balanced Mixer and Preamplifier Assembly

livered under the development contract will be sand-cast units and will be delivered during the next quarter.

e. K-System Modification

The modification of the first set of units of the K-system is about 80 per cent complete. The remaining work consists of adding several components which as yet have not been received. The design of five new units is approximately 50 per cent complete with most of the work remaining on the XB-63 release computer and its amplifier unit. The design of this computer was delayed slightly as a result of eliminating the requirement for using velocity signals from the Doppler radar. The time lost here is expected to be recovered, since several servo loops will be eliminated as a result of deleting the Doppler tie-in requirement. Thus less time is required for fabricating and testing.

Also, a decision has been made to disconnect the present time-to-go and steering circuits and to display on the existing indicator range-to-go and steering information from the release computer.

f. Modification of MCG-1

Mechanical drawings for modifying the MCG-1 system for use with the single operator system in a B-50 type aircraft have been completed and fabrication has started on some units. One true-airspeed indicator has been completed and is now being tested. Electrical drawings are expected to be completed by the time mechanical parts are available for assembly.

Provisions are being made to retain azimuth control of the director relay antenna so that present antennas may be used as well as an automatic tracking antenna system.

g. Command Transmitter

The first laboratory model of the command transmitter was tested without the automatic frequency control and will be retested as soon as the AFC is installed. It is anticipated that testing will be completed by the scheduled date, 1 June 1953.

The development of the automatic frequency control was completed and is now being incorporated into drawings.

h. Terminal Guidance Control Station (B-47 Design)

First models of all components of the terminal guidance control station have been completed. These components will be installed in B-17 aircraft (AF-3439) for flight tests. Second models, constructed from drawings on a production lot basis, are being subjected to acceptance and development tests. Accuracy tests on the elevation computer show equipment error, depending upon the specific offsets employed, of ±75 to ±400 feet in the horizontal plane at the expected detonation altitude.

i. Director Autotrack Relay Antenna

Tests of the autotrack antenna have so far been very successful. In addition to laboratory testing, the first model has been operated three times to track an airborne relay transmitter. This antenna is now being installed in B-17 (AF-3437) for air-to-air tests.

Development and design of the gyro stabilization are in progress and should be complete by 1 November, 1953. Performance of the unstabilized equipment has been optimized. This equipment is usable, provided that director maneuverability is restricted somewhat until stabilized equipment is substituted.

Delivery of antenna mounts to and receipt of completed antenna assemblies from the subcontractor have proceeded on schedule.

j. Search Antenna

The addition of the altitude return assembly to the X-band USR (Unattended Search Radar) antenna caused "holes" in the radar presentation. This condition was noted during flight testing. For reliable automatic altitude tracking, it has been established that the gain of the altitude lobe must be approximately 10 db less than the maximum gain of the antenna.

An effort is being made to eliminate the ripples in the vertical radiation pattern, while at the same time retaining the desired altitude lobe.

4. INERTIAL GUIDANCE

a. General

An inertial guidance system, referred to as a single-axis inertial system, has been designed for the XB-63 which will provide midcourse guidance and a preset dive attitude to the target. Radar monitoring and a command link provide accurate vernier terminal control of the XB-63 to the required CEP (Circular Error Probable) of target acquisition.

A new inertial guidance system, referred to as the multi-axis system, is being developed with the objective of complete control (midcourse and terminal phases) to the target with the required CEP without terminal radar assistance.

b. Single-Axis System

The single-axis system consists of an accelerometer, two integrators, directional gyro, vertical reference system, and associated computer units.

Drawings for all components in the single-axis system have been released for production and procurement.

Three sets of prototype units have been fabricated for development test and evaluation. One system will be flight-tested in a B-50 at the Wheatfield Plant during the next quarter. A second system has been in operation in the laboratory for some time undergoing performance and life tests. The components for a third system are being thoroughly evaluated under simulated XB-63 flight and environmental conditions. Figure 31 shows the block diagram of the single-axis system; actual units are indicated in Figure 32.

Provisions are being made to use the B-50 aircraft as a test vehicle to determine the performance of the stable platform erection system in flight. A development model of the system is available and installation of test equipment in the B-50 is under way. The true vertical will be determined optically and compared with the platform position as recorded. Satisfactory completion of these tests should clear the way for installation on the XB-63 and subsequent flight testing.

Construction of the special test equipment for calibrating single-axis system is essentially complete.

c. Multi-Axis System

Preliminary design work on the multi-axis inertial guidance system is continuing. The problems of tie-in with director aircraft instrumentation are being investigated thoroughly. Design reports on the Doppler radar system are available and are being utilized to investigate in detail the Doppler-inertial tie-in necessary to obtain the required accuracy of platform leveling. The design of the platform erection loops are determined by (1) the power spectrum of the Doppler signals, and (2) the power spectrum of the horizontal accelerations acting as disturbances during the leveling process. All of this information must be determined by flight testing and then statistically analyzing the test results. Horizontal acceleration data must be obtained from aircraft

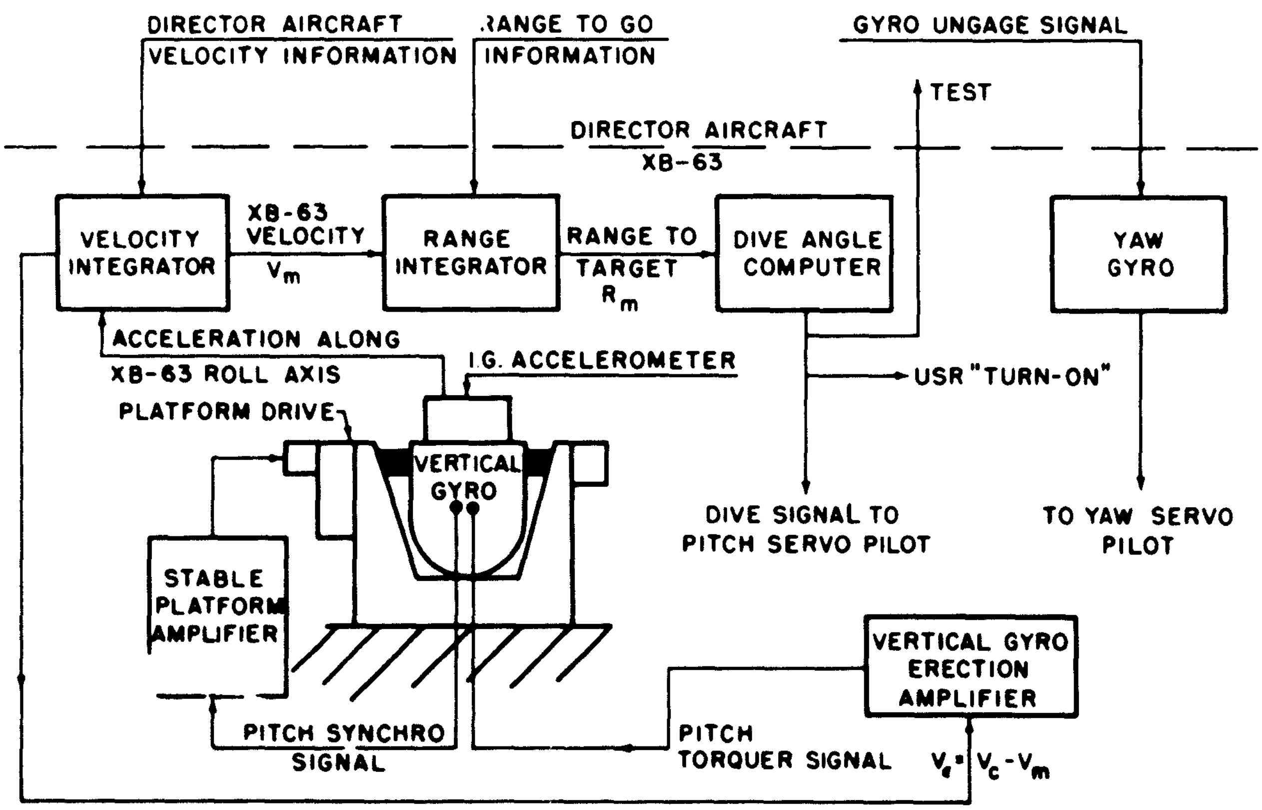
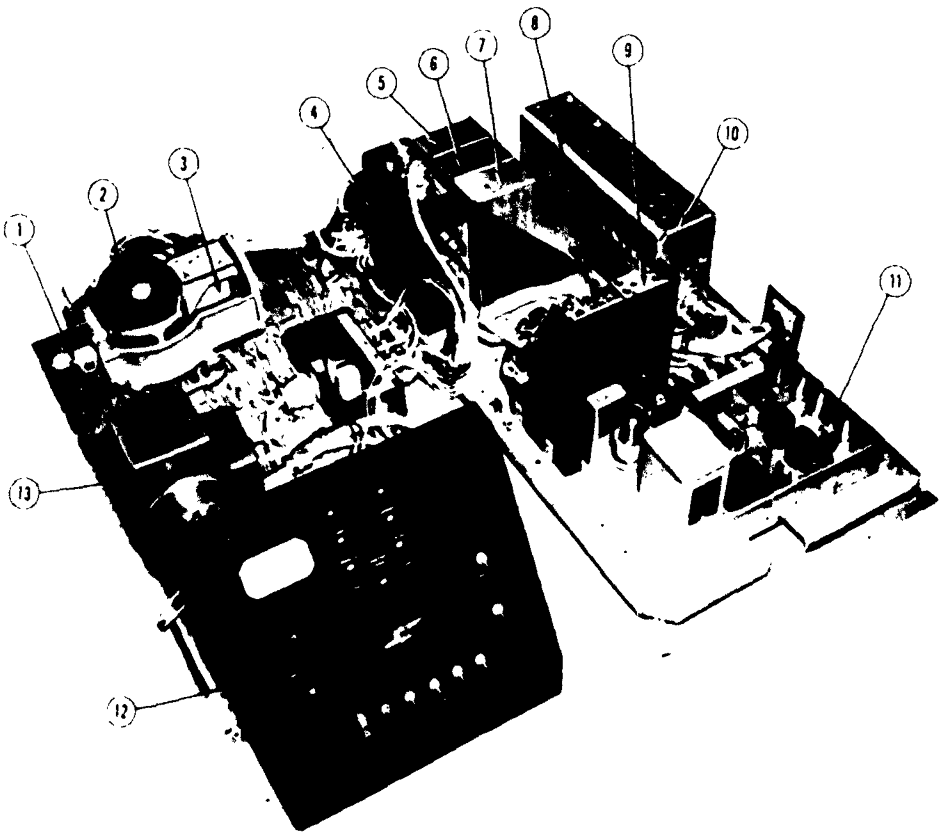


Figure 31. Schematic of Single-Axis Inertial Guidance System

intended as directors such as the B-47 and the B-36. At the present time, Boeing Airplane Company is being contacted for information on means of installing test equipment in the B-47 director. This test equipment is intended to provide the necessary data on accelerations which may affect the leveling process.

The choice of the inertial guidance coordinate system into which the navigational information is inserted was determined by the input data sources available on board the director aircraft. Since the information from the Doppler and search radar (the two main data sources) are resolved into North and East coordinates, it seemed advisable to use the same system to avoid additional resolution of the primary data. Figure 33 is a schematic which shows the geometry of the stable platform (A) and the coordinate systems (B) to be used in the B-63 inertial guidance system.

The vendor is proceeding with the design of the fluid-suspended gyro for the XB-63 inertial guidance system. However, specification changes have been made to make the gyro more compatible with the XB-63 inertial guidance system. Negotiations on the contractual effects of the changes are being completed.



1. Platform Drive
2. Vertical Gyro
3. I.G. Accelerometer
4. I.G. Junction Box
5. Velocity Integrator
6. Range Integrator
7. Dive Angle Computer
8. Stable Platform Amplifier
9. Vertical Gyro Erection Amplifier
10. I.G. Power Supply
11. Test Equipment Power Supply
12. Test Console
13. I.G. Inverter

Figure 32. Actual Units of Single-Axis System

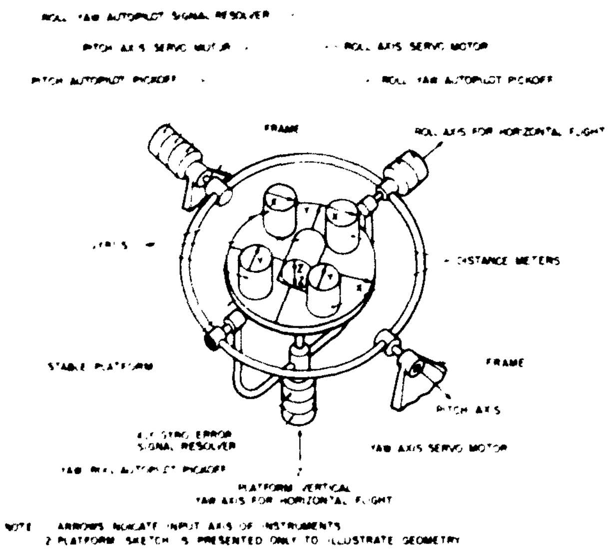


Figure 33A. Geometry of Stable Platform

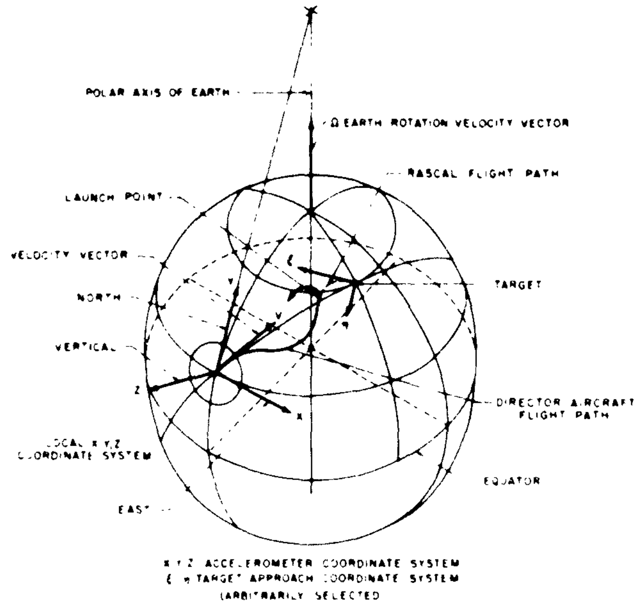


Figure 33B. Coordinate Systems

D. Telemetering and Instrumentation

1 TELEMETERING

a. General

In order to evaluate and record the performance of the guidance, servo, and propulsion systems of XB-63s during flight, an extensive telemetering system has been developed. Telemetered data from the first XB-63s will be obtained through a limited number of high-response channels, augmented by a large number of low-response commutated channels. Of the twelve channels to be used during the first part of the flight testing program, three will be commutated: one for temperature data, and two for relaying general information where the information telemetered does not vary more than one cycle per second. Pilotless parasite bombers 12 through 45 will be equipped with two radio-frequency channels using up to eight subcarriers each. For XB-63s of lot 5, a telemetering system has been developed which will provide 27 commutated and 2 continuous channels of information and packaged compactly to fit within the warhead section.

Most of the telemetering work consisted of following up XB-63 systems tests, ground firings, launchings, and evaluating and improving telemetering designs.

b. XB-63s 0409B and 0510B

The telemetered data from pilotless parasite bombers 0409B and 0510B launched during this quarter were, in general, of good quality. A detailed analysis of each flight is available in Bell Aircraft data reduction reports Nos. 56-980-203 and 56-980-204. Pilotless parasite bombers 0409B and 0510B were both equipped with telemetering systems employing 11 subcarrier oscillators. On 0409B, 7 of these subcarriers were continuous, 2 were fed with standard 5-rps (27-channel) commutators, 1 was fed with a 2.5-rps (20-channel) temperature commutator, and 1 was commutated at a slow rate with 5 vibration pickups. Thus a total of 86 channels of information was available.

There were only 82 channels of information on XB-63 0510B. As vibration data were not telemetered, there were eight continuous channels available.

During the final flight of 0409B, one channel of information, the temperature pickup on the aft wing carry-through, was completely lost. Although discovered in the open position during captive flight, this pickup, because of its location in the XB-63, could not be readily replaced before flight. The telemetering channels on angles of pitch and attack were affected by noise and spiking, probably caused by vibrations affecting the ogive transmitter, but the data from both channels were at least qualitatively reducible.

On XB-63 0510B one channel of the 22-kc commutator was completely lost during flight. This channel telemeters control pressure for the boost propellant valve and it is believed that the gating pulse of the commutator failed to open, because of either a dirty contact or a broken lead, and that this prevented information from getting through to the subcarrier. Difficulties were also encountered from both an intermittent temperature pickup and the static pressure gage in the probe. However, the loss of this relatively small amount of telemetered data did not appreciably affect the over-all information value on this flight.

Telemetered data from two systems tests on XB-63 13B and vibration data from a captive flight of XB-63 8B were obtained. Pilotless parasite bombers 11, 15, and 12 are being calibrated and checked out prior to conducting systems tests.

The a-c strain gage system for measuring control surface hinge moments was reviewed and found inadequate. As the amplifiers used with this system necessarily have a high gain, it was found that variations in the two active arms of the bridges, due to reduced temperatures, caused up to 50 per cent drift in the output of the channel. A program was immediately initiated to correct this situation and the following action taken:

(1) Strain gage hinge moment measurements were removed from XB-63s 12 through 20 and added to XB-63s 21 through 29.

(2) The strain gage system was changed from a two-active-arm to a four-active-arm system so that the gain of the amplifiers could be cut in half thereby correspondingly reducing noise and drift.

(3) The bonding process used on the strain gage elements was investigated and improved and temperature testing of all installations was then started.

c. Altimeters

The Vibrotron and Kollsman altimeters were evaluated for accuracy in connection with the installation of the operational fuze for the warhead and were found susceptible to vibrations. It was therefore decided that the available Giannini unit should remain in use. However, to eliminate errors due to vibration and temperature, the Giannini unit will be shock-mounted and heated to maintain a uniform ambient temperature. Drawings of a shock-mounted and heated unit have been completed and released to the shop for fabrication with installation expected to begin on XB-63 No. 16. Information obtained from this unit will provide a means of evaluating both the static-pressure-probe and the body-manifold methods of measuring altitude. Nevertheless, it is expected that a more accurate measurement of altitude can be obtained with the Vibrotron unit when its vibration troubles have been overcome.

d. Model 56F Telemetering System

Drawings for the Model 56F three-channel telemetering system were completed, prototype units were fabricated, and evaluation tests have been started. In conjunction with this system, a supplier of a suitable pressure switch for monitoring power plant pressures has not been located.

e. Telemetering Ground Station

The main Telemetering Ground Station, Figure 34, at the Wheatfield Plant has been completely re-installed on the north mezzanine with recording facilities improved and expanded. The station comprises the following units:

(1) Two complete 14-channel RREP (Raymond Rosen Engineering Products) ground stations.

(2) A RREP decommutation assembly for use with 5 rps commutator gating units.

(3) Three magnetic tape recorders:

(a) A model 302 Ampex, 15 to 30 inch/sec.

(b) A model 3057 Ampex, 30 to 60 inch/sec.

(c) A model 500 Ampex, four-channel 30 to 60 inch/sec.

(4) Nine CEC (Consolidated Engineering Corporation) photographic recorder positions. This will accommodate a dual RF-type XB-63 plus decommutation of one discriminator output.

Features which give versatility to the station are:

(1) Switch panels at each station so that:

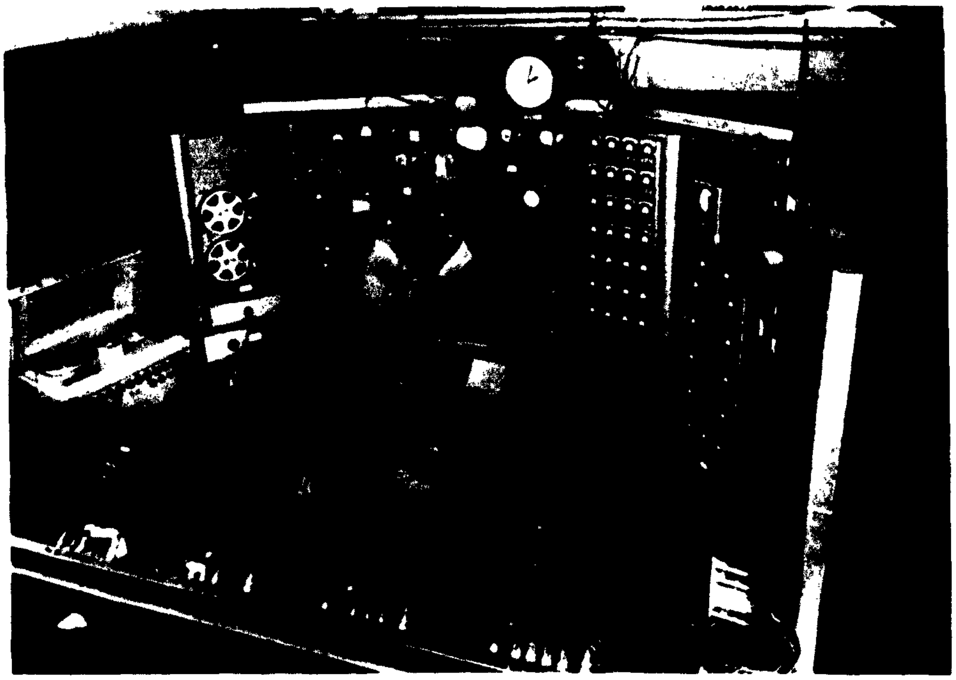


Figure 34. Master Telemetering Ground Station

(a) The output of each subcarrier bandpass filter can be fed to a vacuum tube voltmeter and an E-put meter.

(b) Playback and recordings on the magnetic tape recorders can be fed to, and played back from any recorder channel.

(c) Output from an audio oscillator or other source can be fed to the audio section of either station.

(2) A jack panel at the end of the photographic recorder table provides for connecting any subcarrier discriminator or decommutator analyzer output to any of the nine CEC recorders.

(3) Each CEC position is provided with gain controls for adjusting trace deflection of the recording galvanometers.

(4) A centrally located console provides remote operation (individual or simultaneous) of the CEC recorders. The Ampex models 302 and 500 can also be remotely controlled from this console. Two telephones are available at the console.

(5) A SCR 522 VHF radio can be remotely operated from the ground station and provides radio contact during R & D captive flights.

(6) A rack-mounted low-pass filtering assembly which can be inserted across the outputs of the subcarrier discriminators by means of the jack panel.

The master ground station is used for recording all final XB-63 systems tests at the Wheatfield Plant. These recordings are then compared with those from magnetic tapes of captive and final flights at HADC. This station is also used as a standard for calibrating all other ground stations at both Wheatfield and AF Plant No. 38.

2. INSTALLATIONS

a. Auto-Check System

The Auto-Check System (ACS) is an electromechanical device which automatically initiates function signals and checks their respective return signals from the pilotless parasite bomber and the director aircraft. Return signals, which are checked, must be within prescribed limits for the parasite pilotless bomber before it is launched automatically.

The Model 56 (R&D) Auto-Check System is being prepared for installation in a director aircraft. Tentative plans are to use this equipment in conjunction with, or in place of, the manual checkout equipment. The ACS will be installed with a countdown which will approximate operational requirements.

The Model 110 (tactical) Auto-Check System is a simplified version of the R & D model. As an operational model, it does not contain provisions for changing the measurement sequence, time variation, and other functions. This intentional restriction on the flexibility of the system, in addition to the technical restrictions imposed by including inertial guidance equipment in the final countdown, has delayed completion of a prototype unit.

Several evaluation studies have been completed on subassembly components with the aim of improving over-all ACS accuracy and reliability. Improvements have been incorporated in the limit detector assembly which will insure the accurate checking of return-signal voltages for the full range of expected environmental conditions as specified in Bell Aircraft Specification 110-947-014. Studies are being made to improve the accuracy of the time-base which determines the length of time allocated to check each return signal.

b. Electrical

The long, one-piece, flexible wave guide used on XB-63s Models 56F and 62 was replaced by a solidly formed piece of wave guide having a short piece of flexible wave guide at each end.

New arrangements and space allotment were made in the upper tunnel of the XB-63 to provide for the warhead fuzing requirements. The design of the arming switch has been revised to provide for greater safety and reliability.

Changes required to accommodate the 13° roll angle required by the B-47 director aircraft have been incorporated except for expected changes to vibration isolators.

E. Aerodynamics and Structures

1. AERODYNAMICS

a. Analyses

Analysis of the dynamic stability and control characteristics of the XB-63 airframe-servo combination has continued this quarter. Much of this study has been devoted to conditions involving five degrees of freedom. These conditions require the use of four analogue computers plus simultaneous operation of the pitch, yaw, and roll servo systems. Although this analysis is not yet complete, the preliminary results indicate that the XB-63 is stable about all three axes for all expected flight conditions.

From the results of the afore-mentioned study involving roll stabilization, it has been determined that the present aileron travel of ±15° is adequate. Therefore, plans for increasing the travel to ±27° have been abandoned. With the aileron requirement established, the advantages of the balanced ailerons are not great enough to warrant incorporation. Accordingly, work on balanced ailerons has also been terminated.

A study has been made of the aerodynamic problems involved in operating the XB-63 as a gravity-type bomb in case system failures prevent its normal operation. From the standpoint of accuracy and flight path repeatability, the most feasible scheme seems to be one in which the nose and forward fin sections will be separated from the XB-63 by an explosive charge after the launching phase. The resulting configuration will be statically stable at all angles and speeds, and will tend to follow a zero-lift trajectory.

b. Aerodynamic Tests

The data from the flight testing of RASCAL 0409B are being analyzed from an aerodynamic standpoint. The primary aerodynamic goal of this flight was to program the XB-63 in pitch maneuvers through the transonic region. This programming was successful and the response to the commands was stable. An attempt is being made to compare the flight responses with those obtained in the laboratory dynamic stability analysis.

The wind tunnel program at the Naval Ordnance Laboratory has been completed and the data are being reduced. A total of 243 runs were made; 118 were devoted to measurements of pressure distribution for the fuze pressure-sensing system, and 125 to lift, drag, and moments in connection with the blunt radome nose program.

2. STRUCTURES

a. General

Structural analysis reports for Models 56D and 56E (XB-63 lots 3 and 4), including calculations for the new two-point director-bomber suspension system, have been completed and forwarded to WADC. Revisions and corrections to the "RASCAL Captive Flight Loads" report were also completed. The captive flight loads are complete and up to date for design of attachment points for Model 56F (XB-63 lot 5) while mounted on the B-47. Provision for the balanced-hook loading configuration, reflected in the assumptions contained in the latter report, has been incorporated in the design of the Boeing suspension system. With the exception of final checking and editing, the following stress-analysis reports on Model 56F were completed:

(1) Aft Horizontal Wing Analysis, Appendix B
(2) Forward Horizontal Wing Analysis, Appendix B
(3) Control System and Actuators, Appendix B
(4) Fuselage Analysis, Loads, Vol. I, Part I, Appendix B

A static test program has been outlined for Model 56F including the critical loading conditions required to prove the structural adequacy of redesigned members. Moreover, a comprehensive summary of structural differences between Model 56F and the earlier Models 56D and E has been compiled. Also, a summary of critical buckling loads has been completed for proof-testing hydraulic actuators used in the XB-63.

The motor compartment cowl was redesigned to accommodate the cast aluminum thrust chambers. This change increased the over-all length of the XB-63 by 2.3 inches. A tension bolt splice arrangement was incorporated into this revised design to facilitate interchangeability of the cowling for Model 56F.

Brief studies have been completed on the practicability of using reinforced plastics on the RASCAL. Results of this preliminary examination indicate that the boat tail and perhaps other areas might logically be constructed of reinforced plastics.

b. Criteria and Loads

A revision of the "Air Loads Distribution" report has been completed and submitted to WADC. This revision includes a more refined pressure distribution for the radome at supersonic speeds, and also local pressure distributions on doors and fairings for Model 56F. A new "Design Criteria and Loads" analysis, based on the recently completed wind tunnel reports, has been initiated. This more precise load determination is expected to confirm the conservatism of previous loads (based on theoretically predicted aerodynamic characteristics), and to replace the earlier design loads for use in subsequent redesign studies of the operational pilotless parasite bomber.

A strain gage system has been satisfactorily calibrated for measuring the airload on the aft horizontal surface of airframe 14B. This calibration includes all strain-gaged components to be used in the actual flight testing. Some components of the strain gage systems on airframe 21B and 25B have also been calibrated individually in the laboratory. Figure 35 illustrates the laboratory calibration setup for XB-63 No. 14B. Calibration test data are being gathered, and will be published in a report entitled, "Strain Gage Calibration of RASCAL Flight-Test Airframes".

Structural design criteria were established for several support equipment items and the Chemical Warhead Test Vehicle, and were included as design requirements in the respective model specifications. Among these units are the RASCAL Shipping Containers and the Warhead Loader.

c. Weight and Balance

The "Weight, Center of Gravity, and Moment of Inertia" report for XB-63 No. 0510B has been completed. The gross weight at launch was 17,553.9 pounds with the cg at fuselage station 214.0. Revised estimate, and revised structural design gross weights and center of gravity locations were prepared for the Chemical Warhead Test Vehicle. These weight and balance data are shown in Table I.

A preliminary weight estimate was completed for structural design studies of the operational RASCAL (Model 62). Since the XB-63 (Model 56F) designs are generally carried over to the operational RASCAL, much of the weight data used in making the Model 62 report is patterned from the Model 56F report. Major differences are: (1) Model 62 has aluminum alloy propellant tanks while Model 56F has stainless steel tanks; and (2) Model 62 is designed for a 2800-pound warhead while Model 56F is designed for a 3000-pound warhead. Table II shows estimated values for normal conditions, and Table III contains the structural design conditions being used in operational RASCAL loads analysis.

d. Structural Tests

A test program has been formulated for substantiating the structure of XB-63 Model 56D when

TABLE I Chemical Warhead Test Vehicle (Weight and Balance Data)				
Condition	Revised Estimate		Structural Design	
	Weight (Lbs)	CG (Fuse. Sta.)	Weight (Lbs)	CG (Fuse. Sta.)
Launching Weight	9438.0	218.5	9600.0	220.0
End of Boost	7338.0	200.8	7500.0	202.0

TABLE II RASCAL Model 62 - Normal Load Conditions		
Condition	Weight (Lbs)	Horizontal CG (Fuselage Sta.)
Weight Empty	5484.7	239.9
Launch Weight	17820.5	225.7
Gross Weight (100% Useable Propellants)	18237.5	227.1
Bomber Weight (20% Useable Propellants)	10525.5	210.6

TABLE III RASCAL Model 62 - Structural Design Conditions		
Condition	Weight (Lbs)	Horizontal CG (Fuselage Sta.)
Maximum Design Gross Weight		
Nominal Condition	18200.0	227.5
Most Forward Condition	18200.0	224.5
Most Aft Condition	18200.0	230.5
Maximum Weight for Design (Midcourse Design Phase)		
Nominal Condition	16600.0	223.1
Most Forward Condition	16600.0	219.8
Most Aft Condition	16600.0	226.3
Weight for Design (Maneuvering Flight)		
Nominal Condition	10500.0	211.2
Most Forward Condition	10500.0	206.0
Most Aft Condition	10500.0	216.4

Figure 35. Laboratory Strain Gage Calibration for XB-63 No. 14B

mounted under the director aircraft with the two-point suspension. The test loadings simulate: (1) 4.0g limit vertical acceleration downward based on a gross weight of 18,800 pounds with the cg at stations 223 and 235; and (2) a 1.33g limit upload combined with a 1.0g limit in lateral and longitudinal accelerations. Loads will be applied with the airframe suspended from the two-point gear. The tests will thus serve to structurally prove the two-point gear. RASCAL airframe No. 30 and gear installation on the B-50D aircraft (AF-4811) are to be used for these tests. Airframe No. 30 is scheduled for delivery to the laboratory in May.

Static tests on the recovery strap assembly in the aft section of the XB-63 have been completed. The strap assembly consists of a woven steel-wire rope with cast end-fittings. These tests structurally substantiate the cast end-fittings for the maximum load that can be developed in the woven wire rope and indicate that the strap assembly can develop a maximum static load of 43,000 pounds.

Structural qualification tests on improved 61ST aluminum alloy tanks (production-design) are expected to be performed in April. The difficulties experienced with poor weld penetrations are being rectified prior to these tests.

e. Structural Research and Development

Infrared heat lamps were used to investigate the heating rate of various materials for the XB-63 radome. The results indicate that commercially available heat lamps and suitable reflector materials will permit heating of the sandwich-type radome at a rate which simulates, under laboratory conditions, the aerodynamic heating encountered in flight.

A report, "Materials Development for RASCAL (XB-63) Radome, Progress Report No. 1", was submitted to WADC. This report presents the results of specimen tests which were conducted to judge the structural integrity of various vendor-supplied radome materials. The tests were limited to bending, shear, and edgewise compression of small specimens. Preliminary bending tests on a new sandwich of Goodyear HR-100 high-temperature foam with stypol 16B skins, indicate that this material has twice the bending strength previously available with the best foam sandwich panels tested at an elevated temperature.

F. Dynamics

1. GENERAL

A report has been issued summarizing the reliability of components of the XB-63 guidance system. This report presents several interesting conclusions on reliability data obtained from guidance tests conducted with a B-17 as director aircraft and a specially equipped F-80 simulating the XB-63. (The B-17/F-80 guidance flight testing at Holloman Air Development Center was described in the last Quarterly Report, BMPR-31, page 45.)

At the present time, various methods of adequately appraising the reliability of systems in the XB-63 are being investigated.

The determination of the vibrational characteristics of the environment in which the XB-63 operates has been carried forward. New data obtained during this quarter, are, in many respects, encouraging in that the actual environmental conditions are less severe than those anticipated.

Several studies pertaining to the operational employment of the B-63 have been completed and reports of the results either have been issued or are being prepared. Groupings of director aircraft and the assignment of B-63s to directors are being studied with a view toward minimizing losses of directors and wastage of B-63s. An investigation of the effect of geography on bombing systems has been made and project personnel have attended a number of briefing sessions on this subject. Current studies include analyses of the sources of error in the guidance system, the effects of parallel and series configuration of identical elements on electrical network reliability, logistical problems such as shipping and storing B-63s up to the time of final use, and investigation of factors influencing target-recognition time with respect to the terminal guidance system used.

The flight test data from the final flights of XB-63s 0409B and 0510B were reduced within 10 and 13 days, respectively. Further development of procedures associated with automatic data reduction equipment will permit more rapid data reduction in the future. A program is under way to determine the magnitudes of errors attributable to end-instruments, telemetering, and data reduction, and to develop means of minimizing these errors.

2. RELIABILITY STUDIES

a. General

Weekly, biweekly, and monthly reliability reports on various components and systems were sent to design and development groups most concerned with these items. Weekly reports were also prepared summarizing items which were critically short in the XB-63 which had reached the laboratory testing stage. From a reliability standpoint, it is believed at times, the apparent unreliability and resultant shortages of various items may have been due indirectly to either incorrect test procedures or unnecessarily rigid specifications. These conditions are being investigated.

b. B-17/F-80 Flights

All of the B-17/F-80 flights which were conducted in 1952 were analyzed for the purpose of obtaining information on the feasibility, reliability, and dependability of the RASCAL guidance system. The following conclusions were reached:

(1) B-17/F-80 flight reliability is improving.

(2) Guidance system reliability is improving.

(3) The present over-all reliability of the guidance system is approximately 61 per cent.

(4) Reliabilities of individual subsystems range from 80.5 to 97.5 per cent.

(5) Electron tubes continue to be a major source of trouble. Failures of electron tubes were responsible for 58 and 55 per cent of the difficulties encountered in 1951 and 1952, respectively.

(6) Of the tube failures, 5.16 per cent occurred during the first 50 hours of operation, and 4.81 per cent during the next 50 hours. From this time on the rate of tube failure decreased sharply.

(7) The 6J6-type tube failed more often than expected.

The foregoing helps to bring out the fact that tubes which have not failed should not be replaced unless means can be devised for detecting incipient failures.

Miss distances of the F-80 (simulated XB-63) were also considered, and it was found that the terminal guidance operator has a tendency to overshoot the target. Also, it was shown statistically that the misses could not be attributed to chance.

c. Methods

Efforts to apply available techniques of reliability calculation have led to the conclusion that reliability predictions are better calculated by one method, while historical reliability is better described by a second method of calculation.

To support this conclusion, consider table IV where $r_{1,1}$ is the reliability of system 1 in pilotless parasite bomber 1, and $r_{1,N}$ is the reliability of system 1 in pilotless parasite bomber N, as demonstrated by past experience. It seems reasonable to consider $r_{1,1}$, $r_{2,1}$, and $r_{3,1}$ . . . $r_{M,1}$ as a sample combination of systems 1, 2, 3, . . ., M where the universe of systems would consist of all possible combinations of N system 1's, N system 2's, ... N system M's; i.e., $r_{1,1}$, $r_{2,2}$, $r_{3,2}$ . . . r_{MN}; $r_{1,1}$, $r_{2,2}$, $r_{3,3}$ . . . r_{MN}; etc. It is clear that such a universe could exist in fact, only where a supply of systems 1, 2, 3, . . . M, are available to be interchanged at will so as to make possible the various combinations.

Although it may be practically impossible to create such a universe, theoretically it is useful to imagine its existence in that some samples from it do exist.

Table IV

		Pilotless Parasite Bomber				
		1	2	3	. . .	N
System	1	$r_{1,1}$	$r_{1,2}$	$r_{1,3}$	. . .	$r_{1,N}$
	2	$r_{2,1}$	$r_{2,2}$	$r_{2,3}$	. . .	$r_{2,N}$
	3	$r_{3,1}$	$r_{3,2}$	$r_{3,2}$	. . .	$r_{3,N}$
	.	.	.	.	. . .	.
	.	.	.	.	. . .	.
	.	.	.	.	. . .	.
	M	$r_{M,1}$	$r_{M,2}$	$r_{M,3}$	. . .	$r_{M,N}$

By utilizing the information in Table IV, it can be seen that the reliability of each pilotless parasite bomber is given by

$$R_i = (r_1,i)(r_2,i)(r_3,i) \ldots (r_{Mi}), \quad (1)$$

$$i = 1, 2, \ldots, N.$$

Utilizing equation 1, the average reliability of the sample of N pilotless parasite bombers (and therefore N systems combinations) represented in Table I is given by equation

$$R_{AR} = \frac{1}{N}\sum_{i=1}^{N} R_i \quad (2)$$

which represents the historical aspect of reliability, mentioned previously.

Again looking at Table IV, the average reliability of each system is given by the equation,

$$R_j = \frac{1}{N}\sum_{i=1}^{N} r_{ji} \quad (3)$$

where $j = 1, 2, 3, \ldots, M$.

Then the second type of over-all reliability, utilizing N pilotless parasite bombers becomes

$$\prod_{j=1}^{M} R_j \quad (4)$$

which is of a form differing from 2, and represents the prediction aspect of reliability.

Examination of equation 4 will show that equation 2 is included within 4 along with all the other combinations of systems that could theoretically exist if a population were constructed from the data in Table IV. Consequently it can be considered that 4 represents a population parameter which equation 2 would approach if it were possible to observe enough sample system combinations.

3. ENVIRONMENTAL VIBRATION STUDY

a. General

Vibration data from XB-63 ground firings, captive flights, final flights, and from ground tests of the low-pressure power pack have been analyzed in an attempt to establish the levels of vibration to which RASCAL and its components will be subjected. Data have been obtained from ground and flight tests of XB-63s 07B and 09B equipped with high-pressure power plants. In addition, some vibration information has been obtained from ground firings of the low-pressure power plant which will be used in later pilotless parasite bombers. Data from the final flight of 0307B and from the ground firing of 0409B were presented in BMPR 31.

b. Final-Flight Vibration of XB-63 0409B

Vibration levels encountered during the final flight of XB-63 0409B were somewhat higher than those previously recorded, but in general they confirmed results obtained from the final flight of XB-63 0307B and from captive flights.

It has been verified that a large portion of the vibration emanates from the hydraulic pump unit. Flight at supersonic speed has been found to be particularly smooth, resulting in little vibration in the XB-63. The critical flight condition, so far as vibration in the RASCAL is concerned, occurs when the flight plan requires large acceleration and control deflection at Mach numbers just below one.

Even then vibrations were generally less than 2g although accelerations up to 4g were recorded. These accelerations were measured with pickups attached to a rugged airframe structure and may be considerably less than local accelerations at other points in the RASCAL.

The absence of any appreciable vibration that can be traced to the rocket engines contradicts previous estimates which were based on data from early experimental engines. This is probably due to a great improvement in engine operating characteristics and to the degree of success achieved in the design of isolating mounts for the engine. Recent tests on low-pressure power packs indicate some additional frequencies may be introduced with this system, but the general level of vibration will probably not be significantly increased.

c. Low-Pressure Power Plant Vibration

Vibration pickups were mounted on the gear box attached to the Aerojet gas turbine of the RASCAL low-pressure power plant, and data were obtained during seven turbine and rocket engine runs with three different turbine units. These tests were performed primarily to determine vibration levels and frequencies associated with turbine operation. Some information was also obtained about forcing functions owing to rocket engines, but future tests with pickups located differently are expected to give better data on vibration caused by the engines.

When the turbine speeds and gear ratios are considered, the possible forcing frequencies caused by moving parts are those shown in Table V.

The test results summarized in Table VI indicate that the frequencies of Table IV are predominant. Data from unit No. 13 have been listed separately because different instrumentation was installed on this unit and the accelerations are much larger than those recorded on the other runs. Although the data on units 8 and 9 are believed to be more reliable, it has not been definitely established whether the results of the tests on unit 13 are invalid.

Table V

Forcing Frequencies

Part \ Condition	Boost	By-Pass and Cruise
Turbine	292 cps	246 cps
Alternator	250 cps	210 cps
Hydraulic Pump	69 cps	58.2 cps

Table VI

Summary of Vibration Levels on Gear Box During Turbine Operation

Condition	Frequency (cps)	Acceleration in G: Generally less than: Turbine Units 8 & 9	Acceleration in G: Generally less than: Turbine Unit 13	Acceleration in G: Maximum: Turbine Units 8 & 9	Acceleration in G: Maximum: Turbine Unit 13	Remarks
By-pass & Cruise	58-62	1.0	Insufficient Data to Predict	1.0	1.6	Exists throughout by-pass and cruise. Probably due to hydraulic pump unbalance. (See Table IV.)
	205-235	3.0	Not present	3.2	Not present	Occurs only during by-pass on run No. 4 in longitudinal direction.
	240-250	4.0	Insufficient Data to Predict	5.0	28	Exists throughout by-pass and cruise. Probably due to turbine or gear unbalance. (See Table IV.)
Boost	69-79	1.0	Insufficient Data to Predict	1.5	3.0	Exists throughout boost. Probably due to hydraulic pump unbalance. (See Table IV.)
	80-90	1.6	Not present	3.5	Not present	Longitudinal direction only during motor operation. Noted on runs 6 and 7. Chamber pressure fluctuation at this frequency existed on chamber pressure records.
Boost	285-300	7.0	11.0	12	16.5	Probably due to turbine and gear unbalance. (See Table IV.)
	400-550	14.0	Paper speed too slow to distinguish	17.0	Paper speed too slow to distinguish	Appears intermittently in longitudinal directions
	600	Amplitude too small to compute acceleration	Paper speed too slow to distinguish	Amplitude too small to compute acceleration		Lateral direction in run No. 7 only

4. RASCAL FULL-SCALE VIBRATION SIMULATOR

The full-scale vibration simulator, consisting of two 2500-lb electronic vibrators and a shock-mounted support for the RASCAL, has been completed. This simulator will be used during the final systems testing to simulate vibrations caused by power plant and flight forces. Initial vibration testing will probably be carried out on XB-63 08B since it is equipped with internal vibration pickups at the locations where vibrations were measured in XB-63s 07B and 09B.

5. RASCAL AEROELASTIC STUDIES

A flutter analysis of the model 56F XB-63s (lot 5) has been started. The thickness of the skins of the horizontal surfaces are approximately 10 per cent (at tip) to 20 per cent (at root) thinner than on the earlier models. Although an analysis of the model 56B XB-63 indicated a rather small margin of safety at high subsonic speeds, it is expected that a refined analysis will indicate the absence of bending-torsion flutter despite the reduced skin thickness. However, a preliminary analysis has indicated that a bending-control rotation flutter may occur at low altitudes if the control frequencies are low. This study is being extended to determine what control frequency is required to avert this possibility, and to show whether or not controls can be allowed to float freely while the XB-63 is being carried beneath the director aircraft.

6. OPERATIONAL ANALYSIS

A report entitled, "A Simplified Mathematical Analysis of Air-borne Offense and a Comparison of Conventional and RASCAL Bombing Systems" is being completed. This report develops and illustrates a method of using knowledge of the bombing system, the target, and the enemy defense system to obtain data from which strategic decisions can be made. These decisions result from solutions of such problems as:

(1) Which bombing system should be used to destroy a particular target?

(2) How many planes (cell size) and how many bombs should be used on a strike against a particular target?

The criteria for answering these questions are the expected number of strikes, the expected cost in dollars, the expected number of warheads or bombs used, and the expected number of crews and planes lost in destroying a target.

The complete operational analysis compares the two systems against a wide range of defense parameters. The effect of variations in strategy upon two aspects of the cost of target destruction, when operating against a particular fixed level of defense on a given mission, is shown in Figure 36, which presents the envelope of the expected number of warheads versus the monetary cost of target destruction for both the RASCAL and the conventional bombing system. The strategy is given in terms of n_o (the number of planes or cell size which originally start on the mission) and m_o (the number of aircraft either directing B-63s as in the RASCAL system, or carrying bombs as in the conventional bombing system).

Information on the geographical distribution of probable target systems and their position relative to possible strategic overseas air bases was gathered in order to investigate the effects of enemy defense against the RASCAL system. A list of 180 Iron-Curtain cities was chosen on the basis of their strategic industries. The strategic air bases considered are located at London, Morocco, Southern Arabia, and Thule. Maps similar to the one shown in Figure 37 were drawn indicating great circle distances from each base. Figure 38 indicates the fraction of the target cities within a given distance from each air base.

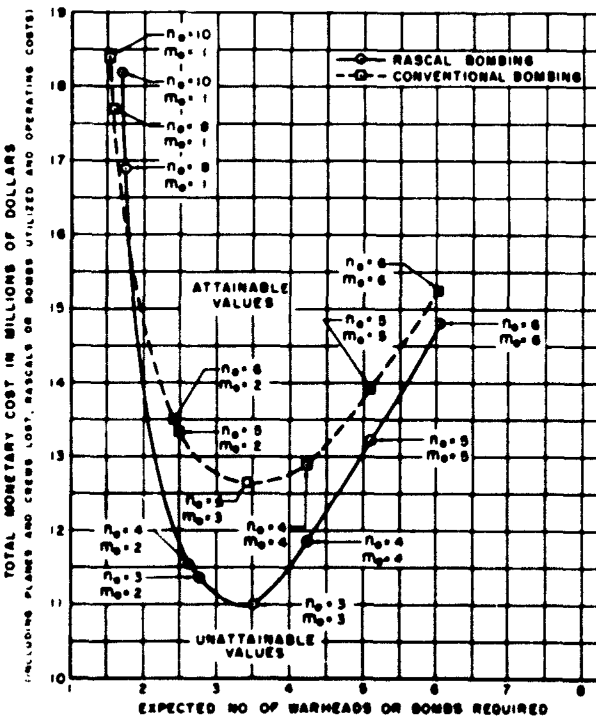


Figure 36. Number of Warheads vs. Cost of Target Destruction

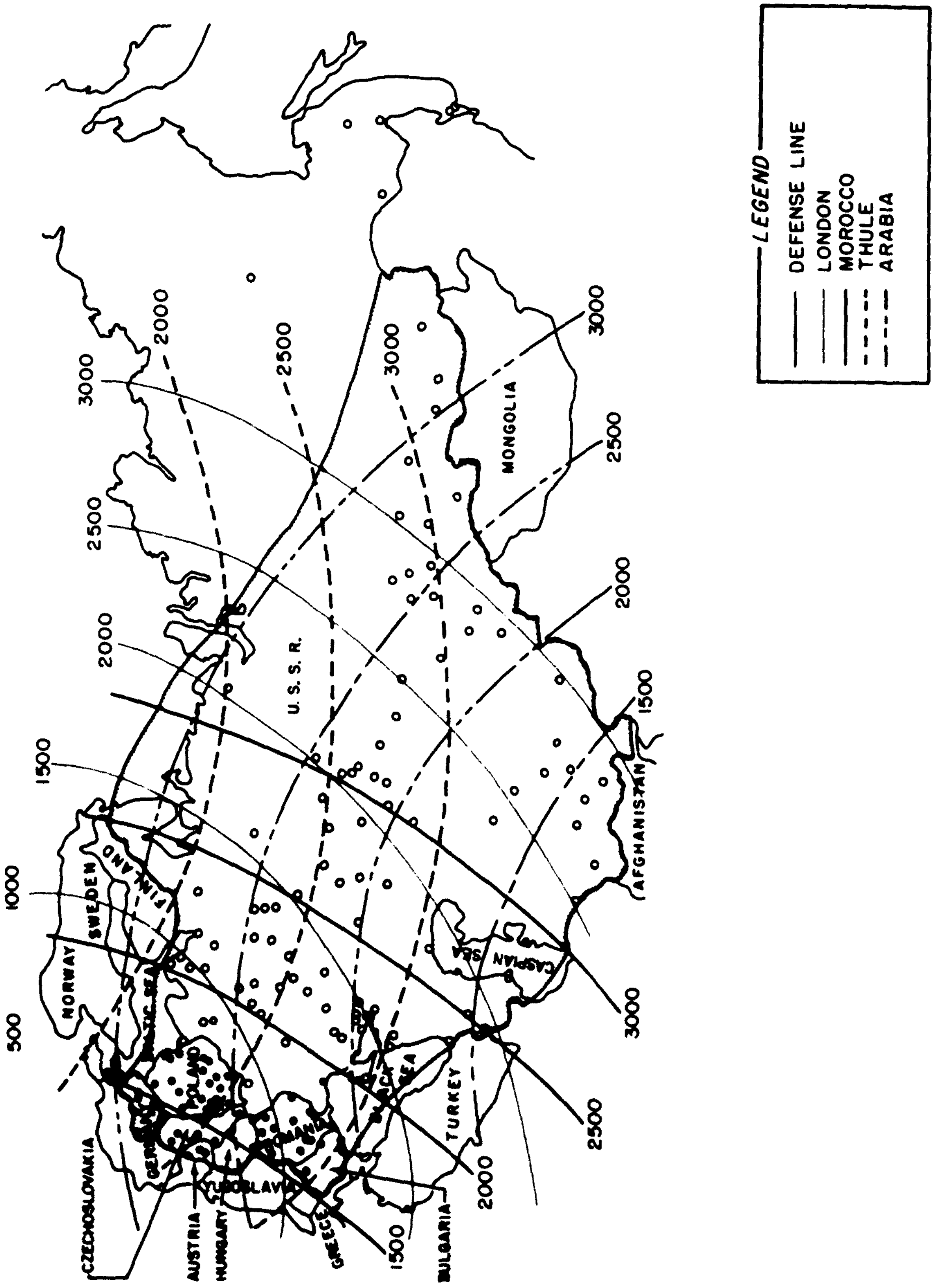


Figure 37. Great Circle Distances from London, Morocco, Thule, and Arabia.

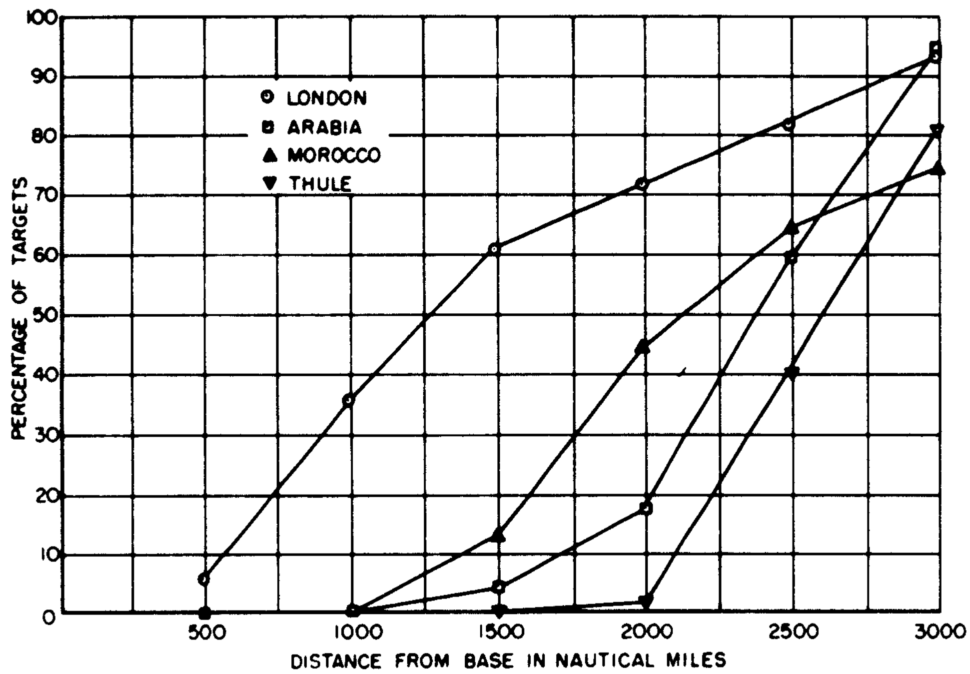


Figure 38. Distance from Base vs. Percentage of Targets

Figure 37 also includes an assumed defense boundary which in Europe outlines the area of Communist control and in Asia surrounds, at a distance permitting defense in depth, most of the target cities. Asiatic target cities not included within this border are assumed to be within a secondary defense network. Examination of the density of targets within the defense border indicates that it is unlikely that each target city will be the center of its own defense system. Rather, it would appear that each city would be the center of only its own local defense (ground-launched weapons) and the entire network of targets will be further protected by an area defense (interceptors) of approximate uniform strength. This type of defense credits the enemy with taking full advantage of the fact that many target cities are quite far from the defense boundary. Hence, they are defended in depth. A study revealed that complete radar coverage of the defended territory can be obtained with 175 to 200 radar stations; 100 miles is the assumed effective range of each radar station. By assuming that each interceptor has a defense radius of 300 miles, it has been calculated that 30 interceptor bases can provide full coverage of the defense area.

The following is a summary of current activities:

(1) Various fuzing circuits are being analyzed for the purpose of determining an optimum circuit from a reliability standpoint. The effect of component duplication on system reliability is being investigated.

(2) The combined effect of errors from the magnetic compass, the air speed indicator, the map, the integrators, the resolvers, and radar tracking and resolution on the accuracy of the radar midcourse guidance system is being derived. At the present time, it appears that the total system error is influenced more and more by compass errors as the flight of the XB-63 progresses.

(3) The operational mertis of various methods of shipping and storing B-63s are being evaluated. The current concept of shipping and storing B-63s in huge metal containers is being compared with alternate schemes, in an attempt to reduce the over-all cost and to increase the ease with which B-63s in storage can be readied for operational use.

(4) Several forms were prepared for recording data from the XB-63 flight test program. These forms were designed to summarize and analyze the performance of both the midcourse and terminal guidance systems.

(5) A preliminary experimental finding indicates a relationship between target recognition time and the length of time the terminal guidance operator attends the scope prior to the appearance of the target. Further study is contingent on obtaining radar films which are of greater length than have heretofore been available. It is hoped that future use of the RCSS (RASCAL Comprehensive Simulation System) will expedite this research program; an experimental method of utilizing the RCSS apparatus has already been worked out. (The RCSS is mentioned in the section on Training.)

(6) As the RCSS will probably be available within the next few months, plans are being made to employ the RCSS to obtain further data on problems related to the radar operator's activities during the terminal guidance phase. These include:

(a) Target Recognition

This has already been discussed in the foregoing text.

(b) Target Tracking

The "human engineering" investigation of the ability of the operator to manually control the present RASCAL system with optimal efficiency should be studied. An experimental procedure is being prepared for this study.

(c) Target Breakup

A study of the factors of tracking behavior during target breakup to determine the relationship between breakup and error has been outlined.

(d) Miss Distance

Experimental procedures have been established for a psychophysical study which will show the relation of the variables of terminal guidance to the miss distance of the missile.

(e) Premission briefing requirements

A method for selecting and employing briefing material to insure the most efficient operation of the RASCAL system is being prepared.

Relative to the afore-mentioned activities, radar films have been reviewed and studied to acquaint personnel with the problems of radar recognition.

7. DATA REDUCTION

After test records of final flight of XB-63s 0409B and 0510B were received, data reduction was completed and a report issued within 10 and 13 days, respectively. This was made possible by two factors: (1) a thoroughly planned procedure to achieve the full benefit of Telecomputing and IBM automatic data reduction equipment, and (2) writing the report during the data reduction process, rather than waiting until the process was completed. With respect to (2), it was proved that it is not necessary to have the flight test data completely plotted before data evaluation can be started. Most items of importance can be discovered during the reading and conversion processes by experienced personnel. If these items so discovered are then fully diagnosed and used to anticipate related developments, which may not be obvious without plotting, all factors of consequence can be detected, interpreted, and described during the reduction process. The importance of planning and data coordination cannot be overemphasized in obtaining speed as well as accuracy in data reduction work. In the future, it appears altogether feasible that the present reduction interim can be further decreased and the value of the report improved.

Data reduction was also completed on the systems checking of RASCAL 13B, the static test firing of RASCAL 10B, and on the acceptance firing tests of the high-pressure rocket engine assemblies on 13B and 15B. Additional data reduction was associated with cold testing the mock-ups of the RASCAL low-pressure rocket engine and malfunction testing of the low-pressure power plant.

Data reduction was continued on the acceptance testing of RASCAL thrust chamber assemblies, and was extended to propellant heat transfer problems associated with the RASCAL R and D program. Preliminary consultations were held for the purpose of establishing data reduction procedures for the proposed development testing of the Bell turbine pump and gas generator. For the over-all data reduction, efforts were continued to improve coordination with the main data reduction system to standardize procedure, and to extend the services of data reduction.

One new item of Telecomputing equipment, a Universal Telereader, was acquired. With this device it is possible to read oscillographic records up to 12 inches wide and film records of any size; magnifications of 2X, 4X, and 11X can be obtained.

Progress is being made in evaluating the accuracy of telemetered test data obtained from the flights of XB-63s. Accuracy figures were initially presented in conjunction with the final flight data of RASCAL 0307B. The objective of this study is to define the present magnitude of all errors attributed to end instruments, telemetering, and data reduction; and then to initiate methods of reducing these errors as much as possible. It is believed that assignable errors can be minimized to the extent that relatively small discrepancies in component performance can finally be disassociated. It has been recommended that present environmental knowledge of temperature and vibration be taken into account during the calibration of end instruments. If the foregoing proves feasible, it should be possible to reduce considerably the present magnitude of assignable errors.

G. Warhead

1. GENERAL

To achieve weapon status, the development of the XB-63 requires extensive testing of the warhead system. Consequently, development must include sufficient testing of each type of warhead and its integration into the weapon system to prove proper functioning and to obtain ultimately a high degree of reliability.

The testing of the simulated warheads will be preceded by developing and testing of the fuzing system. To accomplish this, components will be flight-tested in some of the pilotless parasite bombers prior to those with warhead provisions. These components should have all preflight and supplemental testing completed at the time the flight testing can be initiated. The flight testing and subsequent evaluation of components can further this program and lead eventually to flight testing the entire warhead. These latter tests will develop the target acquisition capabilities of the pilotless parasite bomber guidance and warhead fuzing systems as well as arming and firing reliability. The warhead will be sufficiently instrumented to collect all necessary data independent of the XB-63 instrumentation.

2. ARMING AND FUZING

System specifications, essentially as outlined in Section J (Warhead) of BMPR-31, have been completed and released during this quarter. The only major change is that the setting of the fuzing baro-switch has been made linear with altitude instead of pressure. Detail specifications for the separation timer and the arming and fuzing baro-switches have been written and are scheduled for release during the first two weeks of April. It is planned that the fuzing baro-switch will be designed to operate in conjunction with the setting indicator and switch used in the T-19 control box.

A control panel is being designed to replace the T-18, T-19, and T-35 units, because many of the functions in these units are not used in the RASCAL warhead system. All controls and indicator lights for the warhead will be grouped together on one panel, alongside the remaining guidance equipment.

Two arming baro-switches have been received from Manning, Maxwell & Moore for evaluation. Preliminary results indicate that these units are not affected by extreme temperature changes. Vibration and acceleration tests are currently being performed.

The design of the body-static manifold at Station 270 has been modified to provide a separate line to the fuzing baro-switches. These units formerly shared a line which provided static pressure to several other instruments. The new design should result in improved dynamic response.

The wind-tunnel tests described in Section E, Part b of BMPR-31 have been completed, but the data have not yet been reduced. Results of this study should be available during the next quarter so that design of the fuzing system can proceed.

H. Training

1. GENERAL

Design and fabrication of RASCAL prototype training equipment has continued during this quarter with no major difficulties being encountered.

The scheduling discussed during the recent Training and Provisioning Conference at Bell Aircraft emphasizes the desirability of using prototype training equipment to support the Factory Training Program. It appears that arrangements will be made for diverting the prototype equipment now being fabricated to satisfy this training program.

Every effort is being made to accelerate the design and the manufacture of training equipment to assure its availability at the outset of formalized training courses.

2. CLASSROOM DEMONSTRATORS

The design of the RASCAL Classroom Demonstrators in accordance with WADC Exhibit MCREXE95-339 is complete except for liaison changes which are currently being incorporated. The fabrication of hardware is proceeding according to schedule. A concentrated effort is being made to fabricate harnesses and cables so that the demonstrators can be completed and placed in readiness for testing during the latter part of July 1953.

Test Equipment, to be furnished as part of the Classroom Demonstrators, is being assembled and prepared for final wiring. Delivery of purchased parts is expected to conform with present schedules, permitting completion of this equipment early in June. A lead-time of at least one month is required for completing and checking-out the test racks before using the racks to trouble-shoot the Classroom Demonstrators during systems tests.

Fabrication of the power unit, designed to provide hydraulic and electrical power for the Classroom Demonstrators, is approximately 50 per cent complete, and the unit is awaiting certain purchased parts to complete the installation. The delivery dates promised by the vendors are congruent with current schedules.

Design of Director Aircraft Guidance Demonstrators according to Amendment 3 to Exhibit MCREXE95-339 is continuing. These demonstrators will consist of the following assemblies:

(a) Relay Antenna Mount Demonstrator

An operative unit consisting of a tubular structure on which is mounted the auto-track relay antenna, command transmitter, and relay receiver.

(b) Relay and Command System Demonstrator

An operative unit located in close proximity to the Relay Antenna Demonstrator and consisting of the components of the relay and command systems.

(c) Terminal Guidance Control System Demonstrator

An operative unit consisting of the electronic components normally required for the terminal guidance operator's station in the director aircraft.

(d) Adapter Equipment Demonstrator

An operative unit consisting of those components required to adapt the K-4 system to the TGCS-IV system.

(e) Auto-Check System Demonstrator

An operative unit consisting of components of the Director Aircraft Automatic Checkout System.

(f) Power Cart

A unit which will provide the power needed to operate the Director Aircraft Guidance Demonstrators and the test equipment.

Work has started on the preparation of the Instructor's Manual and the Operation and Maintenance Manual which will be furnished with the Director Aircraft Guidance Demonstrators.

3. RCSS AND ROPS SIMULATORS

a. General

Systems tie-in and control drawings for the RASCAL Comprehensive Simulator System (RCSS) are in work. Details, such as altitude control of RASCAL during midcourse, operator or inertial guidance on-off control of USR and dive initiation, etc., are being worked out. Hardware is being fabricated and installations are under way.

A tentative computation configuration for the RASCAL Operational Procedure Simulator (ROPS) has been made and is being investigated. An estimate of the equipment required to satisfy this configuration will be made in an effort to initiate procurement as soon as possible. After an investigation revealed the need for obtaining additional information on the AN/APQ-T2 trainer before consideration could be given to its combination with the ROPS, a trip to an AF Base where an AN/APQ-T2 trainer is installed was planned.

b. Terminal Guidance System

A Model 3 Terminal Guidance Control Station (TGCS-III) has been manufactured and is being modified to function as a TGCS-IV. An enclosure is being designed to house this equipment and its operator.

c. USR Simulator

Final system tie-in and control details for the USR Simulator are being worked out between Bell Aircraft and the subcontractor. The simulator will consist of three electronic rack units and one map unit. The subcontractor has received the basic map and is developing surfacing techniques for it. Radar indicator photographs to supply surfacing information for the map are being obtained by Bell Aircraft. Investigation has revealed that no urban area analysis exists for the specific area chosen for the map. Light source and altitude measurement problems are being investigated by the subcontractor.

d. Analogue Computers

A static check problem for the analogue computer installation has been established. Completion of this installation is expected within a month or two, and this will be followed by performance of both the static check problem and a three-degree-of-freedom check problem.

e. Servo Load Simulators

A dynamic load stand (test fixture) has been fabricated and is being installed for study. This study will be concurrent with setup, checkout, and operation of the RCSS. The spring load stands, which will be used with the RCSS in the meantime, have been received and are being calibrated.

f. Servopilot Model

The servopilot Model is being readied for initial breadboard operation. Approximately one month will be required to accomplish this.

g. Instructor's Console

The Instructor's Console is approximately 95 per cent complete, and is awaiting the delivery of miscellaneous purchased parts.

4. MOBILE TRAINING UNITS

Proposals covering the design and the manufacture of Mobile Training Units (MTU) were submitted to AMC on 16 March and 25 March 1953, respectively. During the Training and Provisioning Conference, it was established that a complete MTU should be available for squadron use by January 1955. If this date is to be met, it is imperative that contractual authority to proceed with MTU design be obtained within the next six or eight weeks.

I. Ground Support Equipment

1. GENERAL

The supporting equipment for RASCAL includes all equipment, such as checkout, test, repair, ground handling, and ground servicing, necessary to maintain and prepare the pilotless parasite bomber for the accomplishment of its mission during a field-type operation. These include such items as handling and transport carriage, component handling dollies, assembly stands, hoisting slings, special loading and fueling units, mobile system checkout units, special tools, and test equipment.

Operational ground support specifications have been written and submitted to WADC for review and approval.

2. GROUND HANDLING

The design of operational ground handling equipment has progressed steadily during this quarter. An improved design of the transport carriage is now available and negotiations for procurement to suit the immediate needs of the MX-776B Program have been in work for some time.

Adequate supplies of cradles, skids, and hoisting slings have been procured. These are being utilized at Bell Aircraft, at Air Force Plant No. 38, and at Holloman Air Development Center. The XB-63 transport carriage is being used extensively at all facilities to handle the RASCAL in the various testing stations.

The evolution of the warhead handling equipment has progressed to where it now includes an adaptor pan for use in both an assembly cart and a loader. The warhead loader is a manually operated device capable of precision positioning of the warhead in roll, yaw, pitch, tilt, elevation, lateral translation, and longitudinal translation. The assembly cart is a simple caster-mounted framework arranged to hold the warhead at a convenient working height.

3. XB-63 TEST EQUIPMENT

The equipment required to properly test, to troubleshoot, and, in general, to check out the electrical, guidance, servo, and telemetering systems of the XB-63 is being manufactured for an eighteen-test-position (station) plan. Three mobile stations (including the R & D trailer) and four fixed stations have been completed and are now in use. The remaining stations will be fabricated and delivered continuously until completion of the schedule in November. Four test stations are presently in use at the Wheatfield Plant; the two stations at AF Plant No. 38 and the one station at HADC are ready for use in testing pilotless parasite bombers. The test facilities at the Wheatfield Plant are being expanded. The area needed for the eight test stations required for the XB-63 laboratory is nearly complete. This area will have four test stations in use by 15 May 1953, excluding the additional two mobile stations.

In addition to the afore-mentioned test equipment, an extensive research and development program is being conducted on laboratory and field-type test equipment. The design of inertial guidance test equipment is nearly complete and will soon be manufactured for inclusion in the eighteen-test-position (station) plan. Further work is being conducted to streamline the test equipment for permitting greater flexibility with a resultant decrease in testing time.

a. Status of XB-63 Test Equipment

(1) Systems Test Equipment

The engineering design of the eighteen test stations plus the R & D mobile checkout unit has been completed, including terminal guidance and inertial guidance test equipment.

The R & D mobile checkout unit at HADC has been used to check out XB-63s 0409 and 0510. Two fixed checkout units have been installed at AF Plant No. 38, and these are ready for use on XB-63s 0613 and 0715. Two mobile units are in use at the Wheatfield Plant in testing XB-63s 0811 and 0912. In addition, two fixed checkout units are in use at the Wheatfield Plant in testing XB-63s 0613 and 0715.

(2) Operational Redesign

Detail design is progressing rapidly and will be completed at an early date. Work on a mock-up of the operational ground support equipment has started and should be completed by 1 August 1953.

4. DIRECTOR AIRCRAFT AND TEST EQUIPMENT

Test equipment is being designed to check out and test that portion of the director aircraft guidance system which is peculiar to the RASCAL weapon system. Included in this is a B-63 simulator which will be designed to check out and test the Auto-Check System (ACS) in the director aircraft.

SECTION III
WEAPON SYSTEM EVALUATION

A. Introduction

In forthcoming issues of the MX-776 Quarterly Report, this section will include the progress that is being attained in the RASCAL flight test program toward the development of the weapon system in accordance with established specification. Particular attention will be directed not only to the "end result" miss distance accomplished at impact, but also to the accuracy and reliability of each of those systems and subsystems, both director aircraft and XB-63, which contribute to this "end result" at any time during the prelaunch, launch, midcourse, and terminal flight phases. As a result of this evaluation, it is expected that system deficiencies can be pinpointed so that corrective development work may be undertaken.

A determination has been made of that flight information, and methods of gathering it, which is necessary to make a proper and accurate evaluation. In accordance with these plans, the flight test date from the final flights of XB-63s 0307, 0409, and 0510 are now being evaluated and will be presented in the next issue.

B. Systems Testing

1. GENERAL

Acceptance testing of the servo, guidance, and instrumentation systems for RASCAL is conducted in the Missile Laboratory. This consists of making the necessary adjustments and alignments to bring pilotless parasite bomber systems into conformity with the applicable specifications by using the methods as outlined in appropriate test procedures. Whenever a system difficulty is encountered, trouble shooting is undertaken to determine the cause. The necessary corrections are then made and these may include design changes to the extent necessary to insure (1) conformance with specifications, (2) compensation for change in environment accompanying the installation of equipment and wiring, and (3) elimination of, or compensation for, interference and interaction between various systems. Figure 39 shows the RASCAL test area in the Missile Laboratory.

A line setup of fixed test stations is being constructed where eight XB-63s can be simultaneously tested. The stations will be so arranged that XB-63s can be tested at various stations in the following order: servo station for servo systems tests, telemetering station for telemetering systems tests, guidance station for S- and L-band beacon systems tests and guidance systems tests, and, finally, composite systems station for a composite systems test. The final test will be performed with all systems, except power plant, operating simultaneously to simulate in part the flight plan of the particular XB-63 being tested. After all systems tests have been completed, the XB-63 will be transferred to AF Plant No. 38 for testing with the power plant.

Until this arrangement of test stations is complete, systems tests of XB-63s will be conducted with two mobile and two fixed stations which are capable of testing the servo, telemetering, and guidance systems.

2. SYSTEMS TESTING

a. RASCAL No. 0613B

Individual systems tests on RASCAL No. 0613B have been completed. Two composite systems tests were run, and, although these were not satisfactory for acceptance of the XB-63, invaluable information was obtained regarding reliability. A third run is scheduled for the next quarter.

In addition to the normal production difficulties which necessitate minor reworks and repairs, several developmental difficulties were encountered and corrected through close coordination with the respective development groups. These include:

(1) Drifting of the vertical gyro under slow erection — corrected by changing the value of the voltage divider in the power supply.

(2) The phase shift in the 55° emergency dive signal — corrected by adding a condenser in the programmer junction box.

(3) Noise in the yaw command channel — corrected by redesigning the yaw and pitch command modulators.

(4) The false commands encountered during interference checks, caused by a drop in the 400-cycle line voltage when the USR system was placed "ON" — corrected by a design change.

b. RASCAL No. 0715B

Individual systems tests on RASCAL No. 0715B are 76 per cent complete. These tests are progressing more favorably than those conducted on 0613B. Completion of the remaining tests, including the composite systems tests, is expected in the next quarter.

The following developmental difficulties were experienced and corrected:

Figure 39. RASCAL Test Area in Missile Laboratory

(1) Noise on the pitch surface and in the "G" limiting loop — corrected by lowering the amplifier gain and rerouting the "G" loop wiring.

(2) The high command sensitivity in the command package — corrected by a design change.

(3) Insufficient deflection of the relay antenna — corrected by a design change.

(4) Unstability of the dive relay — also corrected by a design change.

c. RASCAL Nos. 0811 and 0912

The individual systems tests are 78 per cent complete on RASCAL 0811 and 60 per cent complete on RASCAL 0912. Progress on these RASCALS has been appreciably better than was experienced with previous XB-63s containing guidance equipment. This can be attributed to the following:

(1) Fewer developmental difficulties have been experienced with 0811 and 0912.

(2) The design changes necessary on previous RASCALS with guidance equipment were incorporated in 0811 and 0912.

(3) Recurring difficulties were corrected within a shorter time.

(4) Test work on the first XB-63s has increased the experience level of personnel.

Composite systems tests on both 0811 and 0912 are scheduled for the next quarter.

C. Flight Testing

1. RASCAL

a. General

The flight testing program provides an integrated method for testing all XB-63s and is laid out in steps which start with the simplest possible arrangement, and advances to the point where an operational warhead-carrying weapon is under test. These test steps are built upon one another in the following manner:

(1) Glide XB-63s are used to obtain data on airplane stability, and to test the recovery system. Plans included use of 3 pilotless parasite bombers. (This phase of the program has been completed.)

(2) Powered XB-63s are used to test the power plant, servo, and the Model III X-band guidance system. This step takes in 19 pilotless parasite bombers, and actually consists of two parts: (a) High-pressure power plant system which comprises the first five powered XB-63s; and (b) turbine-pump power plant system, which will start with airframe No. 11. Emphasis will be placed upon aerodynamics, servo, and power plant. Preliminary guidance evaluation will begin with pilotless parasite bomber No. 13.

(3) Starting with No. 26, more extensive guidance testing will take place until at No. 35 the inertial system is tested in combination with the X-band system. This step runs through No. 45 and also includes testing of the fuzing system.

(4) Starting with No. 46, the warhead part of the weapons system is emphasized. Simulated atomic and chemical warheads are tested through No. 74. The B-47 director aircraft with single operator guidance is used through No. 64. The B-36 and B-47 are both used for firing pilotless parasite bombers No. 64 through 74.

(5) Warhead testing at this stage is still of primary importance with emphasis shifted to chemical warheads. This test step starts with pilotless parasite bomber No. 75 and continues through the end of the present R & D program, ending with pilotless parasite bomber No. 82.

Two RASCAL Pilotless Parasite Bombers, XB-63s 0409B and 0510B, were flight-tested during this quarter. Both were powered by the high-pressure power plant system. Of the five "high-pressure" type XB-63s originally scheduled, three have been flight-tested. The performance results are shown in Figure 40.

Except for the programming used, the flight plans for XB-63s 0409B and 0510B were similar. Programming for 0409B was restricted to the pitch plane. The purpose of this program was to obtain information concerning the response of the servopilot/airplane combination in the supersonic, transonic, and high-subsonic Mach number ranges. Programming for 0510B consisted of (1) elevator position programming during the unpowered portion of flight for obtaining aerodynamic longitudinal stability parameters in the supersonic, transonic, and high-subsonic Mach number regions, and (2) small pitch and yaw attitude changes during powered flight for determining the effectiveness of the roll stabilization system.

Operation of the power plant, servo, and telemetering systems was satisfactory on both flights. Operation of the recovery system was satisfactory on only 0510B.

Table VII shows the purpose of flight for XB-63s through No. 20.

b. XB-63 0409B

RASCAL 0409B, the second powered XB-63 to be flight-tested, was delivered to HADC on 19 December 1952, and was launched 15 January 1953. Flight test objectives were: (1) to obtain satisfactory separation of the XB-63 from the director aircraft, and satisfactory operation of the power plant and servo stabilization systems; (2) to obtain data concerning airframe/servopilot response to pitch angle changes introduced by the flight programmer; (3) to obtain vibration data; and (4) to obtain satisfactory operation of the recovery system.

RASCAL 0409B was launched at an altitude of approximately 30,000 feet MSL, satisfactorily separating from the director aircraft. Power plant operation was normal; at the end of the 81-second timer-controlled boost period, a Mach number of 1.36 was attained at an altitude of 29,700 feet. Servopilot operation was satisfactory; the small roll disturbance incurred at launch was quickly damped out. Airframe/

Predicted Performance				Actual Performance				Purpose of Flight	Rating
Rascal No.	Max. Altitude (MSL)	Max. Mach No.	Max. Range (Naut.Mi.)	Max. Altitude (MSL)	Max. Mach No.	Max. Range (Naut.Mi.)	Max. Time (Sec.)		
0104	30,000	0.91	2.2	30,400	0.88	2.25		U,L	Good
0205	30,000	0.91	2.2	31,000	0.88	2.00		U,L,R	Good
0307	25,000	1.42	20.0	25,400	1.22	18.0	111	HI-P,R,3AS	Excellent
0409	34,000	1.60	31.0	31,500	1.36	31.0	198	HI-P,R,SPP	Excellent
0510	38,000	1.60	33.5	32,700	1.43	28.0	172	HI-P,R,SPP,SYP	Excellent
0613	34,000	1.60	25.5					HI-P, MGM, TGC	
0715	38,000	1.60	24.5					HI-P,R,3AS,ARP,MGM	
0811	51,000	2.40	52.0					LO-P,3AS,MGM,TGC	
0912	40,000	2.40	67.0					LO-P,3AS,APP,AYP,MGM	
1014									

Legend

Symbol	Meaning	Symbol	Meaning
HI-P	High-Pressure Power Plant	AYP	Aero Yaw Program
LO-P	Low-Pressure Power Plant	RS	Roll Stabilized
R	Recovery	ARP	Aero Roll Program
3AS	3-Axis Stabilization	MGC	Midcourse Guidance Control
SPP	Stabilized Pitch Program	MGM	Midcourse Guidance Monitoring
APP	Aero Pitch Program (Stabilization Disconnected)	TGC	Terminal Guidance Control
		U	Unpowered Glide Bomber
SYP	Stabilized Yaw Program	L	Locked Surfaces

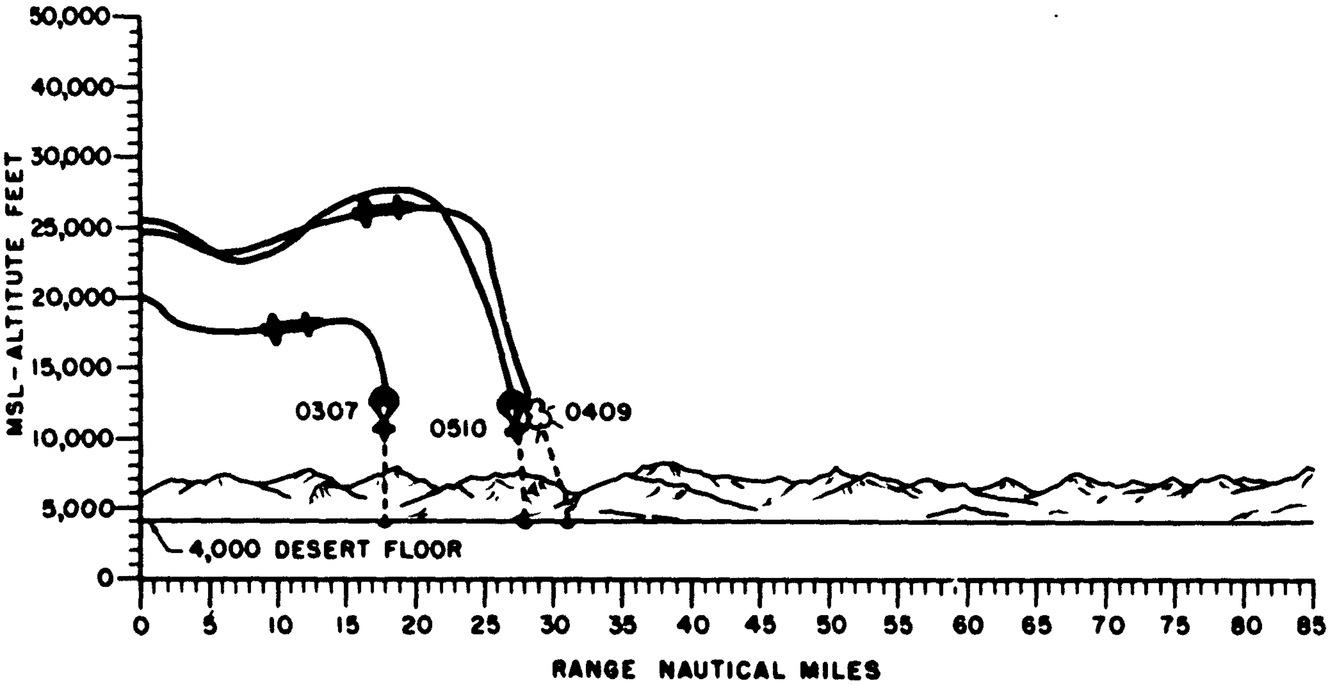


Figure 40. Predicted and Actual Performances of XB-63s

TABLE VII

XB-63 – PURPOSE OF FLIGHT

XB-63 NUMBER (3)	MACH NO. (MAX.)	MAX. ALTITUDE (FEET)	PURPOSE OF TEST	INSTALLATIONS REQUIRED SEE NOTE (2)
0001	---	---	Power Plant Mock-Up	c
0002	---	---	Servo and Guidance Mock-Up	b, d, e, f, g
0003	---	---	Master Mock-Up	a, b, c, d, f, g
0104		30,000	Launching Technique - Recovery System Check	a, b
0205		30,000	Launching Technique - Recovery System Check	a, b
0307 *	1.22	25,400	Stabilized Flight, Pressurized Power Plant System, Recovery System Check, Vibration and Aerodynamic Drag Data	a, b, d, j
0409 *	1.36	31,500	Servo-Airframe Pitch Response, Pressurized Power Plant and Recovery System Check, Vibration, Temperature, and Aerodynamic Drag Data	a, b, d, g, j
0510 *	1.43	32,700	Servo-Airframe Response to Combined Pitch and Yaw Maneuvers, High-Pressure Power Plant and Recovery System Check, Temperature Data, and Aerodynamic Stability Characteristics	a, b, d, g, j
0613	1.60	34,000	3-Axis Stabilized Flight, Complete Model III Guidance Control and High-Pressure Power Plant System Check	a, b, d, e, g, j
0715	1.60	38,000	Servo-Airframe Response Characteristics, Aerodynamic Characteristics, High-Pressure Power Plant, and Recovery Systems Checks	a, b, d, g, j
08 (1)	---	---	Ground Test Vehicle	---
0811	2.40	51,000	Testing of Mid-course and Terminal Guidance System, Turbine-Pump Power Plant System Check, Aerodynamic Heating Data	a, b, c, d, e, g
0912	2.40	40,000	Stabilized Flight with Altitude Control, Aerodynamic Characteristics, Mid-Course Guidance Control	a, b, c, d, e, g
14	2.20	40,000	Servo-Airframe Response Characteristics, Aerodynamic Characteristics, Mid-Course and Terminal Guidance System Checks, Structural Load Data	a, b, c, d, e, g
16	2.00	33,000	Servo-Airframe Response Characteristics, Aerodynamic Characteristics, Mid-Course and Terminal Guidance Check, Testing for Developing of Fuze System	a, b, c, d, e, g
17	2.40	35,000	Stabilized Flight with Altitude Control; Aerodynamic Characteristics, Mid-Course and Terminal Guidance Check, Testing for Developing of Fuze System	a, b, c, d, e, g
18	2.05	35,000	Servo/airframe Response Characteristics, Aerodynamic Characteristics, Mid-Course and Terminal Guidance Check, and Testing for Developing of Fuze System	a, b, c, d, e, g
19	2.50	60,000	Stabilized Flight with Altitude Control, Complete Mid-Course and Terminal Guidance Control, and Testing for Development of Fuze System	a, b, c, d, e, g
20	2.20	35,000	Stabilized Flight with Altitude Control, Aerodynamic Characteristics, Model III Guidance Check, Testing for Development of Fuze System	a, b, c, d, e, g

NOTE (1) Restricted evaluation testing on this unit will proceed toward the following: Elimination of electrical noise due to mutual interference among Guidance & Servo Power supplies, electrical wiring interconnections, etc, Checking out of Guidance equipment, Ground testing of Power Plant; Elimination of electrical noise in Servo and Guidance systems due to Power Plant vibrations. After completion of this work, the unit will be launched, minus guidance.

NOTE (2) Installations Code

- a. Recovery
- b. Instrumentation (R & D)
- c. Power Plant (Turbine Pump)
- d. Servo System
- e. Model III Guidance
- f. Inertial Guidance
- g. Flight Programmer
- h. Simulated Atomic Warhead
- j. High-Pressure Power Plant
- k. Instrumentation (Trouble-Shooting)
- l. Chemical Warhead

*Actual Flight Test Data.

NOTE (3) The first two digits of the number shown indicate XB-63 firing order, the second two digits indicate airframe number. Thus, XB-63 0613 is the sixth PPB to be fired and is the thirteenth airframe constructed. Where firing order has not been established only airframe number is shown.

servopilot response to programmed pitch angle changes was obtained as planned. In addition, vibration data was obtained. Although the destruction sequence was as planned, operation of the recovery system was not satisfactory because the shroud lines of the main parachute failed and the forward instrumentation section was demolished. The maximum Mach number was somewhat lower than predicted, but the range to destruction was 31 nautical miles as planned.

Except for recovery of the forward equipment section, all flight test objectives were attained.

c. XB-63 0510B

RASCAL 0510B, the third powered XB-63 to be flight-tested, was delivered to HADC on 1 February 1953, and was launched 13 March 1953. Flight test objectives were: (1) to obtain satisfactory separation of the XB-63 from the director aircraft, and satisfactory operation of the power plant and servo stabilization systems; (2) to obtain aerodynamic longitudinal stability parameters; (3) to obtain airframe/servopilot response to programmed pitch angle and yaw angle changes; and (4) to obtain satisfactory operation of the recovery system.

RASCAL 0510B was launched at an altitude of approximately 30,000 feet MSL, satisfactorily separating from the director aircraft. Power plant operation was normal; at the end of the 85-second timer-controlled boost period, a Mach number of 1.43 was attained at an altitude of 31,600 feet. Servopilot operation was satisfactory; the small roll disturbances incurred during the programmed yaw angle changes were quickly damped out. Airframe response to elevator angle programming, introduced for obtaining aerodynamic longitudinal stability data, was obtained. Operation of the recovery system was satisfactory.

The maximum Mach number obtained with 0510B was lower than predicted but was higher than obtained on the two previous powered flights. The range to destruction was 28 nautical miles, somewhat less than planned.

d. B-17/F-80 at HADC

Personnel formerly assigned to the B-17/F-80 and SHRIKE guidance groups were integrated into a newly formed Guidance Group will be responsible for all guidance testing at HADC, including work on guided XB-63s, director aircraft, and unfinished portions of the B-17/F-80 Flight Testing Program.

During this quarter, the Guidance Group was primarily concerned with:

(a) Assisting in the firing of two XB-63s, as well as two SHRIKE missiles.

(b) Training on the complete RASCAL guidance system.

(c) Modifying the F-80 (AF No. 8484) radar system so that its presentation to the director aircraft will be identical to that of RASCAL.

(d) Modifying the F-80 so that it will be compatible with director aircraft No. 4.

(e) Installing, arranging, and checking laboratory guidance equipment to provide a compact and efficient laboratory for future testing.

(f) Installing search and relay antennas on the laboratory roof to facilitate F-80-to-laboratory tests.

2. SHRIKE

a. General

In accordance with the provisions of Contract W33-038ac-14169, the SHRIKE flight testing program was conducted at Holloman Air Development Center, New Mexico. With the launching of two chemical warhead test vehicles during this quarter, the flight testing of SHRIKE missiles was brought to a close.

The last two Model 59A missiles to undergo flight testing, SHRIKE 2713 and SHRIKE 2812, were fired for the Army Chemical Center.

b. SHRIKE 2713

Missile 2713 was the second of three test vehicles acquired by the Army Chemical Center to test warhead separation and to determine the dispersion pattern of chemical warheads under certain conditions of release.

The warhead in Missile 2713, Figure 41, was an inert BW-type identical with that tested in SHRIKE 2111. The flight test objectives were: (1) to demonstrate guidance control during the launching and midcourse phases of flight; (2) to determine the dispersion pattern of a chemical warhead when separation occurs at a particular velocity, altitude, and flight path angle; and (3) to obtain successful destructor action and separation of the warhead section. (The warhead was to be released at a Mach number of 1.31 during a 30° dive and at a pressure altitude of 15,000 feet, approximately 10,000 feet above the terrain.)

SHRIKE 2713 was launched 20 January 1953, at a pressure altitude of 30,000 feet and a launch-point-to-target distance of 22.7 nautical miles. Immediately after leaving the launching gear, the missile veered 35° left of the desired course. (Since there was no internal instrumentation in the missile, the exact cause of this sudden change in course cannot be determined.) The missile stabilized on this course and at X + 84 seconds, a right yaw command caused the missile to turn 13.5° right, indicating correct response (guidance-servo link) to a given command. At X + 100 seconds, the timer in the missile initiated terminal dive. The dive angle assumed by the missile was 20° rather than the planned 30°. At X + 114 seconds, a yaw command of 7.5° right was transmitted, but instead of 7.5° the flight path of the missile changed 30° to the right. It is believed that the malfunction at launch cleared itself at this time. The resultant flight path was parallel with but approximately 9.8 nautical miles west of the intended heading. The radar plot for Missile 2713 is shown in Figure 42.

As SHRIKE 2713 approached an altitude of 15,000 feet during terminal dive, the warhead ejection sequence was initiated. At this point, it is assumed that the aneroid switch in the missile initiated destruction, although the pulse repetition rate of the ground radar was changed to the destruct frequency at nearly the same instant.

Flight conditions at the time of warhead deployment were not entirely as planned. Although the altitude of the missile was 15,000 feet, as indicated

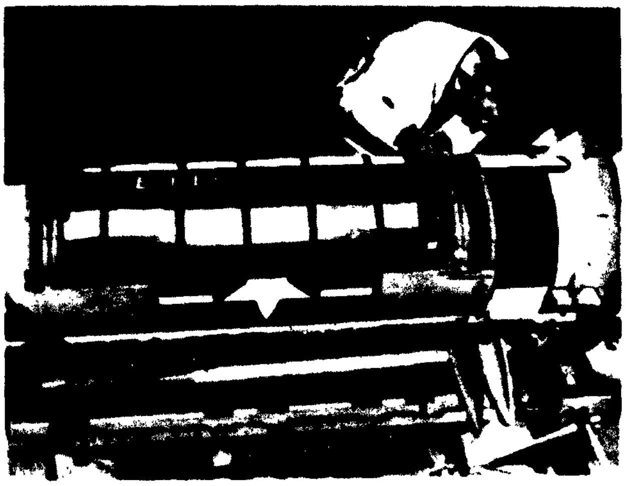


Figure 41. Warhead Installation, SHRIKE 2713

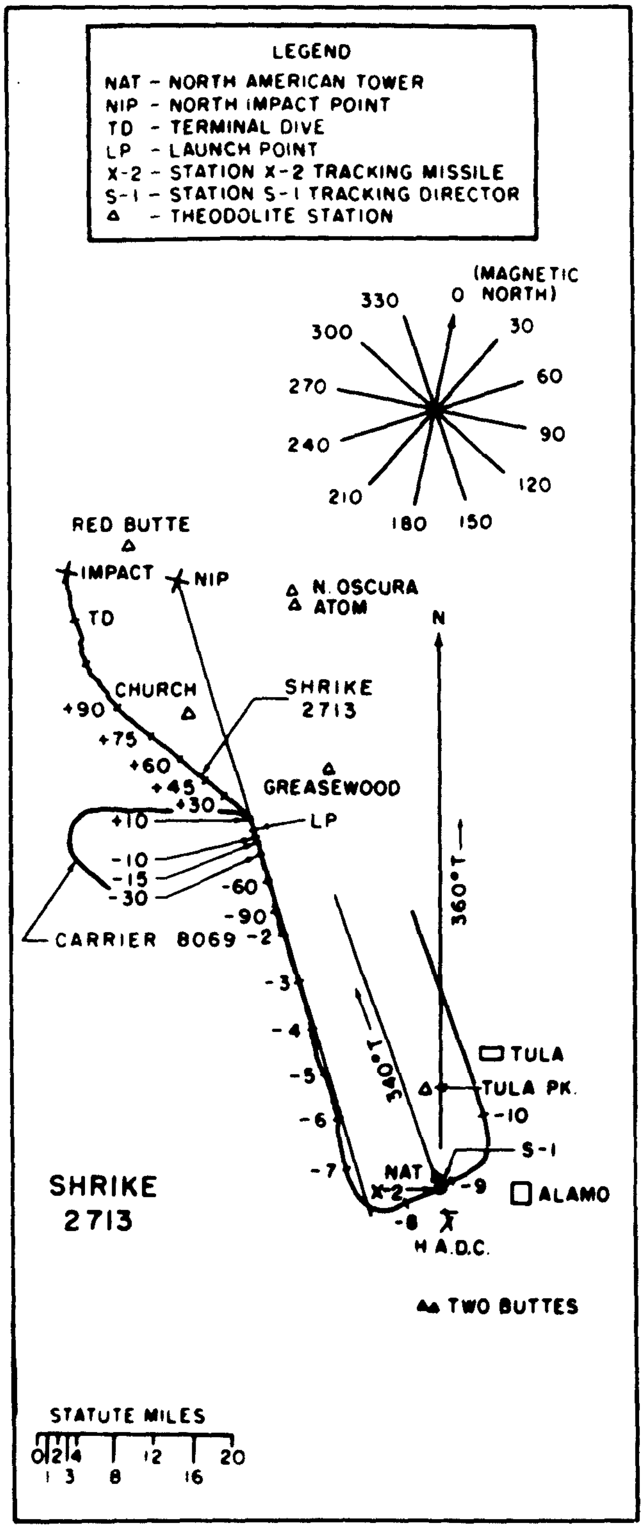


Figure 42. Radar Plot of SHRIKE 2713

in Figure 43, the Mach number was approximately 0.99 and the flight path angle was 20°. (The flight path angle is the angle formed by the tangent to the flight path and its projection on a plane perpendicular to the radius of the earth.) Owing to the shallow dive angle and the change in heading, the flight time and range of the missile at destruction exceeded the planned values. Flight time was 140 seconds and range was 27.8 nautical miles. Predicted values were 188 seconds and 24.0 nautical miles. Because of the large displacement of the flight path, Askania coverage of the deployment sequence was not reducible. However, Askania stations obtained a bearing on the impact so that the recovery crew had no difficulty in locating the area. With approximately 75 per cent of the warhead units recovered, the surveyed dispersal area was found to be slightly smaller than expected.

c. SHRIKE 2812

Missile 2812 was the last of three test vehicles acquired by the Army Chemical Center. The firing of 2812 concluded the SHRIKE flight testing program.

The flight test planning for SHRIKE 2812 was the same as that for 2713. However, the warhead contained inert GB-type bombs with active fuses. One unit of the warhead contained an S-band beacon to provide for radar coverage of the ballistic path after deployment. The flight test objectives were: (1) to demonstrate guidance control during the launching and midcourse phases; (2) to determine the dispersion pattern of a chemical warhead when separation occurs at particular conditions of velocity, altitude, and flight path angle; (3) to obtain successful destructor action and separation of the warhead section (the warhead was to be released at a Mach number of 1.31 during a 30° dive and at a pressure altitude of 15,000 feet, approximately 10,000 feet above the terrain); and (4) to determine the ballistic path of a warhead unit after deployment.

SHRIKE 2812 was launched 23 January 1953, at a pressure altitude of 30,000 feet and a launch-point-to-target distance of 21.8 nautical miles.

Prior to launching, difficulties were experienced with the midcourse guidance computer and radar, the relay antenna system, and the command system. These troubles were corrected before the director aircraft entered the final leg of the launch pattern, except for heading control which was transferred from the computer to the ground control station during the final leg.

At X - 10 seconds, the "fire" switch was engaged as scheduled in the launching procedure and the guidance operator started the 10-second countdown which precedes automatic release of the missile. In the last few seconds, the operator at the launch panel noticed that the indicator light for hydraulic pressure in the missile went out, indicating that the pressure had dropped below the minimum operating pressure. Before the launching sequence could be interrupted, the computer countdown was completed and the rocket motors fired.

The missile, on leaving the zero-length launching rail without sufficient hydraulic pressure, immediately entered an erratic dive. When a pressure altitude of 15,000 feet was reached, the aneroid switch

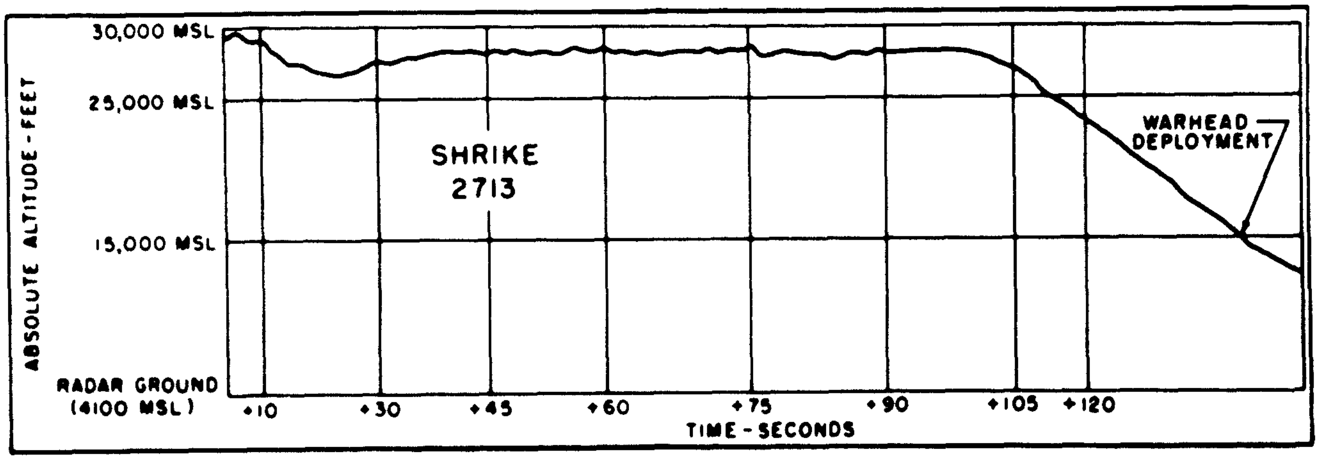


Figure 43. Elevation Plot of SHRIKE 2713

initiated destruction of the missile and deployment of the bomb load. Again, the deployment sequence functioned as planned, and the bombs were deployed without interference from missile debris. Ninety-four per cent of the bombs were recovered, Figure 44, in an area approximately 800 x 2500 feet.

Askania coverage was complete, indicating that at the time of breakup, the Mach number was 0.86, the absolute altitude was 14,038 feet, and the flight path angle was 65°.

Both X-band and S-band radars lost track of the missile immediately after launch. Guidance control was not established. Range from launch point to destruction was 3.9 nautical miles.

Figure 44. Recovered Unit of GB Cluster Bomb, SHRIKE 2812

APPENDIX
Trip Reports

The large number of visits made to subcontractors and vendors, and for liaison purposes, has made it impractical to list all trips. The following are representative of the more important visits:

WADC and AMC, Wright Field, Ohio; HADC, Alamogordo, New Mexico; Special Weapons Center, Kirtland Air Force Base, Albuquerque, New Mexico; Offutt Air Force Base, Omaha, Nebraska; Patrick Air Force Base, Cocoa, Florida; Eglin Air Force Base, Valpariso, Florida; Photo Record and Service Division, Pentagon, Washington, D. C.; Consolidated Vultee Aircraft Corporation, San Diego, California; Boeing Airplane Company, Seattle, Washington; North American Aviation, Inglewood, California; Convair, Fort Worth, Texas; Liquid Propellants, China Lake, California; Benson Manufacturing Company, Kansas City, Missouri; Aerojet Engineering Corporation, Azusa, California; Hillyer Instrument Company, New York, New York; Dalmo Victor Company, San Carlos, California; Kollsman Instrument Corporation, Elmhurst, New York; Rahm Instruments, Inc., New York, New York; Reeves Instrument Corporation, New York, New York; Vickers Inc., Detroit, Michigan; Frank G. Hough Company, Libertyville, Illinois; and Baker-Lull Corporation, Minneapolis, Minnesota.

Distribution of this report has been made to parts A and B, and Abstracts to part C, of the US R & DB Guided Missile Technical Information Distribution List No. 2, MML 200/2, dated 16 February 1953.

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WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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88 CS/SCOKIF (FOIA)
3810 Communications Blvd
Wright-Patterson AFB OH 45433-7802

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8725 John J. Kingman Rd, Suite 0944
Ft Belvoir VA 22060-6218

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Technical Report Title: Project Rascal
Technical Report Date: 31 Mar 1953
Previous classification/distribution code: Confidential

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