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No. NMC-TM-59-31

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EVALUATION OF AN/TPQ-10(XN-2)
RADAR COURSE DIRECTING CENTRAL
(Interim Report)

(Title Unclassified)

U.S. NAVAL MISSILE CENTER
POINT MUGU, CALIF.

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11 September 1959

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This report has been prepared primarily for timely presentation of information. Although care has been taken in the preparation of the technical material presented, conclusions drawn are not necessarily final and may be subject to revision.

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SUMMARY

The preproduction model (XN-2) of the AN/TPQ-10 radar course directing central, serial No. 1, was evaluated by the Marine Aviation Detachment at the Naval Missile Center, Point Mugu, California, in accordance with tests prescribed by the Marine Corps Equipment Board to fulfill the purpose of project TED MTC AV-31009. The tested equipment was returned to the contractor for indicated modifications, after which this evaluation will be completed.

Interim findings are that the AN/TPQ-10(XN-2) radar course directing central (RCDC) satisfies the physical specifications and intended employment of the system except that (1) the specified maximum weight of the equipment is exceeded by about 2,500 pounds and (2) although the equipment fits on the bed of a 2-1/2-ton 6 x 6 truck, it cannot be operated from this position.

This RCDC is considered to be capable of operating under tactical conditions and satisfactorily performing its operational function. The capabilities of the RCDC for use in all-weather aerial-resupply operations and as an aid to a pilot for approaching a landing under conditions of low visibility have been adequately demonstrated and are expected to be important functions of the RCDC.

At this stage of development, the RCDC does not meet the accuracy requirements of the contract specification. However, the modifications being made by the contractor are expected to correct the factors and deficiencies believed to have contributed to the errors found during the evaluation of the preproduction model.

INTRODUCTION

A method of utilizing close air support during all conditions of visibility and weather has been desired since the merit of close air support was demonstrated during World War II. In 1950, a Marine Corps Liaison Unit at the then U. S. Naval Air Missile Test Center (NAMTC) - now Naval Missile Center (NMC) - at Point Mugu fabricated a terminal control system for the LOON missile. This terminal control system was later modified so that target information could be inserted into a computer to guide an aircraft to a target and to release the aircraft's ordnance at the proper moment for accurate delivery on the target. Since the results obtained with this system were favorable, a priority program was initiated that resulted in the development of the AN/MPQ-14 radar course directing central (RCDC). The first RCDC unit was constructed at Point Mugu and was combat tested in Korea by Marine Corps units. Because of the success of the AN/MPQ-14 RCDC in Korea, a production model (the AN/MPQ-14A), a complete system including tracking radar, computer, power supplies, and test equipment, was introduced into Marine Corps aviation units (reference 1).

In the light of new theories and advancement in the development of equipment, it appeared feasible to improve the accuracy and to increase the mobility of the RCDC. Consequently, a contract was granted to General Electric Company to develop a system similar in function to the AN/MPQ-14A RCDC but having longer range, multiple target capabilities, greater versatility, better transportability, and less bulk. The system developed under this contract was the AN/TPQ-10 RCDC. The developmental model of the RCDC, the AN/TPQ-10(XN-1), was evaluated by the Marine Aviation Detachment at Point Mugu under Bureau of Aeronautics project TED MTC AV-31007. 3 (reference 2).

The preproduction model of the RCDC, the AN/TPQ-10(XN-2), was built in accordance with the results and recommendations of the evaluation of the AN/TPQ-10(XN-1) model. The AN/TPQ-10(XN-2) model, serial No. 1, was shipped from the General Electric Company at Syracuse, New York, and was delivered to Point Mugu on 10 May 1958 for evaluation to determine its operational suitability for Marine Corps use.

This evaluation, under project TED MTC AV-31009 (reference 3), was initiated "To determine if the operation of AN/TPQ-10(XN-2) equipment meets the performance requirements of the contract specification and if it performs its operational function." The operational specifications are outlined by Bureau of Ships Contract Specification Radar Course Directing Central AN/TPQ-10(XN-2), Ships-R-2310, dated 9 March 1956, and Addendum 1 thereto, dated 20 June 1957.

This evaluation project was assigned to the Marine Aviation Detachment at Point Mugu, and the Radar Unit of the Marine Aviation Detachment conducted the necessary tests.

These tests were prescribed by the Marine Corps Equipment Board, Quantico, Virginia, project ET-1341 (reference 4). The tests and evaluations prescribed in reference 4 were as follows:

Test No. 1. Physical characteristics.
Test No. 2. Transportability.
Test No. 3. Ease of erection and orientation.
Test No. 4. Ease of operation.
Test No. 5. Acquisition capability.
Test No. 6. Capability of automatically tracking aircraft.
Test No. 7. Capability of aircraft control and direction.
Test No. 8. Capability of all-weather aerial cargo delivery.
Test No. 9. Maximum control range.
Test No. 10. Accuracy of system.
Test No. 11. Repeatable accuracy.
Test No. 12. Adequacy of associated equipment.
Test No. 13. Operator training requirements.
Test No. 14. Adequacy of instructional material.
Test No. 15. Ease of maintenance.
Test No. 16. Special maintenance and test equipment requirements.
Test No. 17. Ruggedness and reliability.
Test No. 18. Weatherproofness.
Test No. 19. Modifications.
Test No. 20. Suitability for Marine Corps use.

In addition to the tests prescribed by the Marine Corps Equipment Board, the Radar Unit also tested the utilization of the AN/TPQ-10(XN-2) RCDC system as a pilot aid for low-visibility approach to a landing.

This report summarizes the progress of work performed during the initial testing period. On 26 February 1959, the AN/TPQ-10(XN-2) RCDC, serial No. 1, was returned to the General Electric Company at Syracuse, New York, for modifications to correct a computer drift problem and to improve the accuracy of the system. A final report of the evaluation will be submitted upon completion of the testing of the refurbished system.

EQUIPMENT

The AN/TPQ-10(XN-2) radar course directing central (RCDC) is a lightweight, two-unit, helicopter-transportable, and self-contained system. The AN/TPQ-10(XN-2) RCDC is designed to guide an aircraft, equipped with the proper control equipment, to a release point for accurate all-weather delivery of ordnance and supplies to a preselected target.

In the AN/TPQ-10(XN-2) RCDC system, aircraft-position information supplied by the tracking radar is automatically inserted into a computer. This computer has had target information, ballistic data, and information on certain aircraft parameters introduced manually just prior to the actual commencement of closed-loop control of an aircraft. The computer continuously solves the guidance problem and generates the necessary commands to maintain the aircraft on a proper course. The closing course of the aircraft to the target may be preselected in which case a fixed-course mode of operation would be used, or the aircraft may be flown to the target on a direct heading in which case a normal-course mode of operation would be used.

If the aircraft has the automatic control equipment necessary to utilize the commands sent by the AN/TPQ-10(XN-2) RCDC, the aircraft will respond to these commands, closing the control loop formed by the RCDC and the aircraft system. In the event the aircraft is not configured for automatic control, the strike controller must verbally supply the necessary course changes to the pilot, who, by manuevering the aircraft, closes the control loop. The computer generates a command to release the aircraft stores for accurate delivery to the preselected target.

Ground Directing System

For the two-helicopter lift of the AN/TPQ-10(XN-2) RCDC, the ground equipment is arranged in two packages, the control shelter (figure 1) and the antenna pallet (figure 2). In the transport condition, all accessory test equipment, spares, and cables are stored in the control shelter.

The control shelter contains the radar control console and an AC analog computer (figure 3). The radar control console (on the left in figure 4) houses the radar presentation scope and the necessary controls to operate the radar to automatically track the desired aircraft. The AC analog computer (on the right

Figure 1. Control Shelter of AN/TPQ-10(XN-2) Radar Course Directing Central.

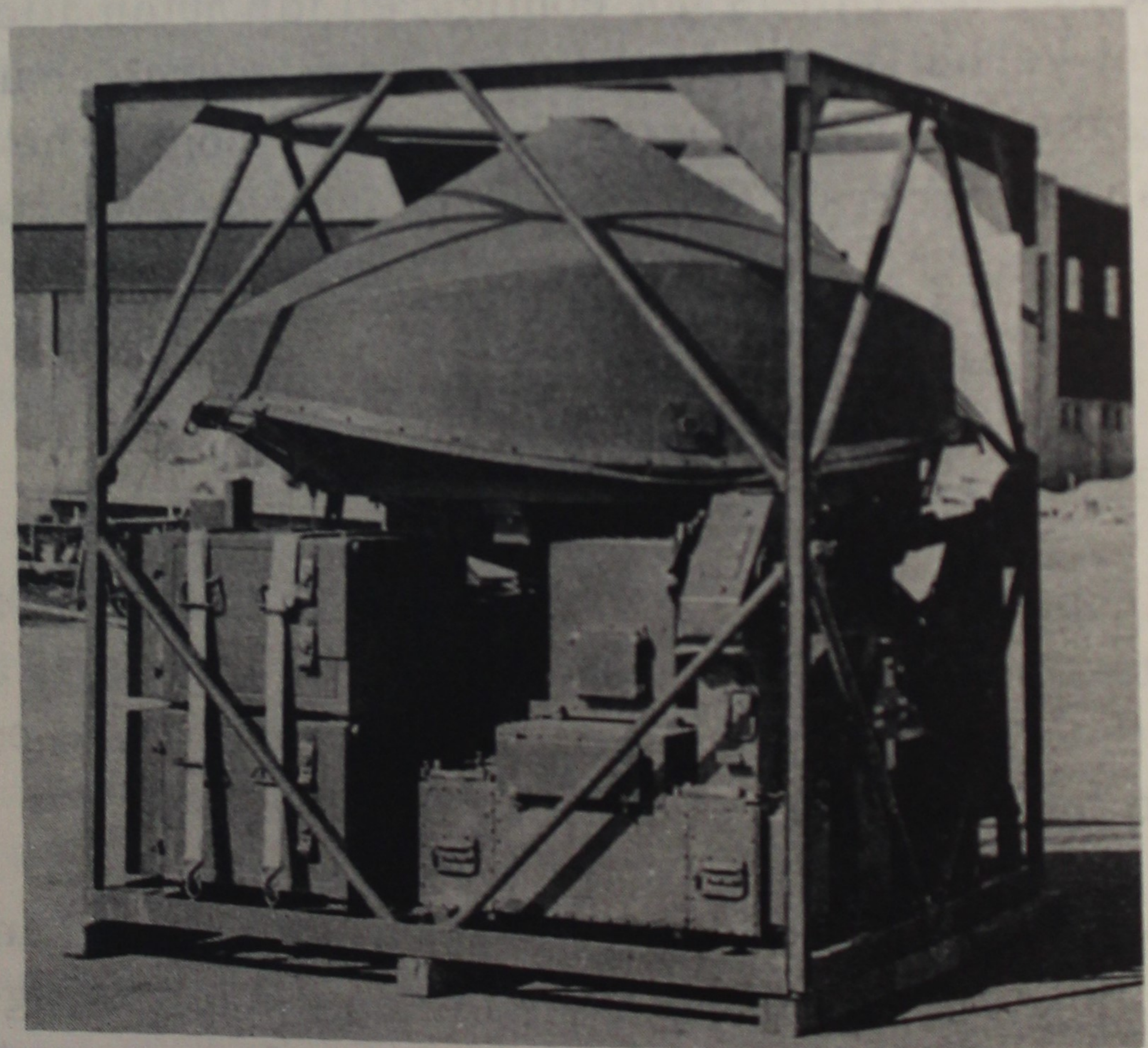

Figure 2. Antenna Pallet of AN/TPQ-10(XN-2) Radar Course Directing Central.

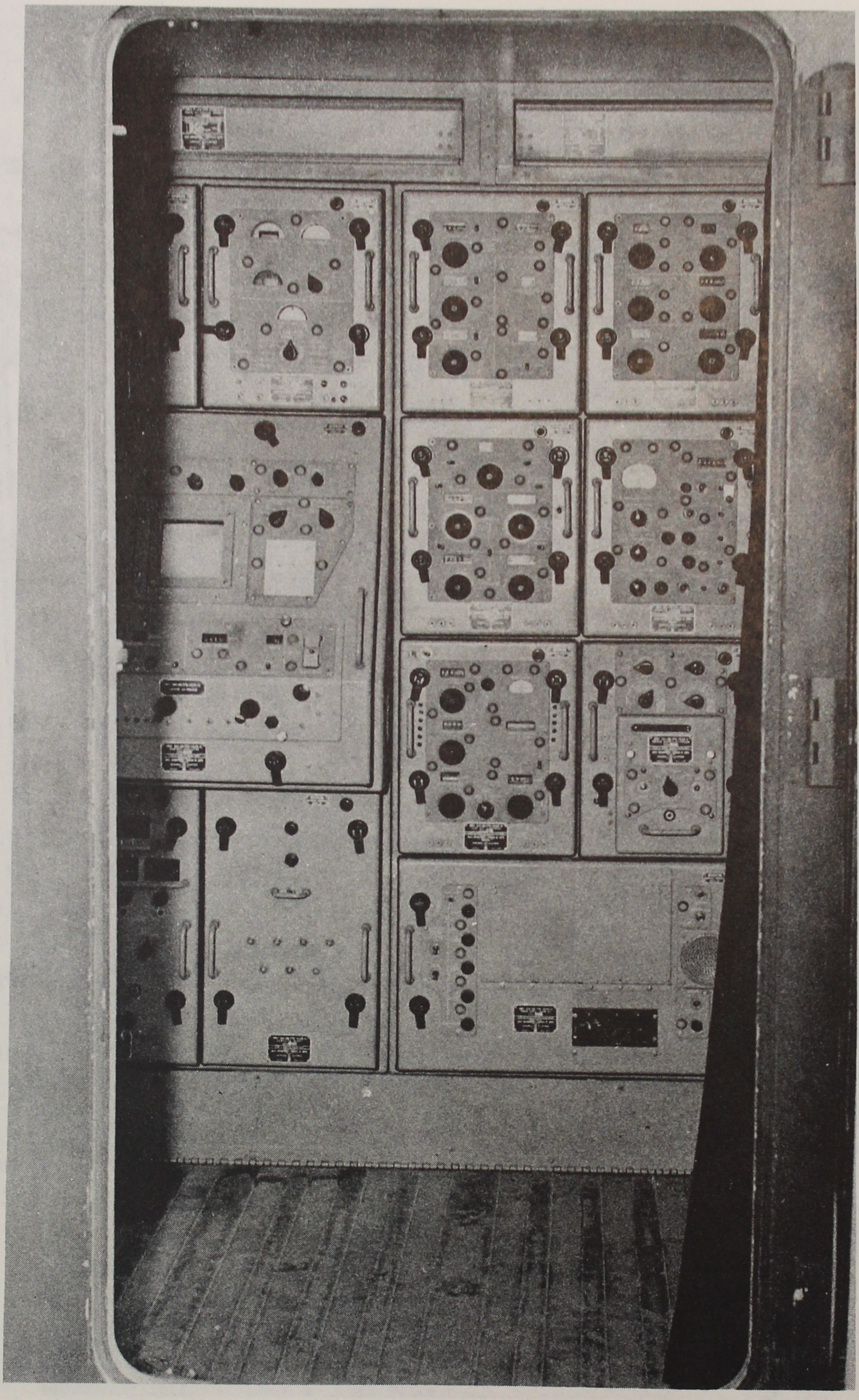

Figure 3. Interior View of Control Shelter.

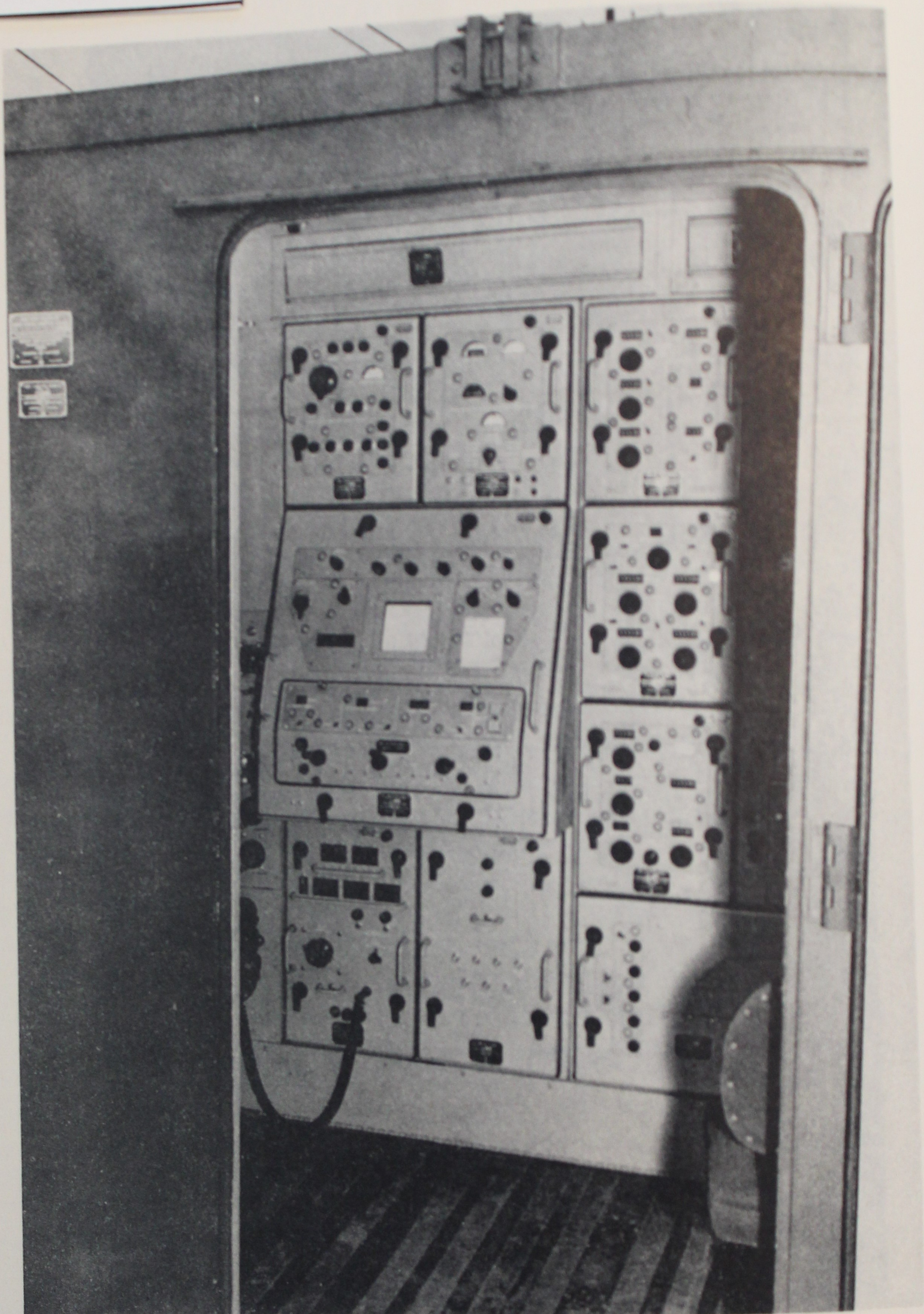

Figure 4. Radar Control Console in Control Shelter.

in figure 5) solves the guidance problem and generates the commands necessary to maintain the aircraft on a proper course. The computer is composed of the following six units:

1. Aircraft position computer.
2. Course computer.
3. Ballistic computer.
4. Command computer.
5. Compensation computer.
6. Flight simulator.

An AN/ARW-66/KY-51 coder is utilized in the command computer. A Brush recorder is used to present to the strike controller a continuous record of course error and transmitted commands. An automatic plotting board is located in the control shelter to indicate continuous aircraft position in relation to the radar and target. The plotting board is positioned to the right of the computer for easy access by the strike controller. UHF radio communication will be provided by an AN/ARC-52 radio set, but because of the non-availability of this equipment, an AN/ARC-27 radio set was used in the evaluation. The precision power supply of the computer and the UHF radio set are located immediately below the computer. An AN/ARA-25 direction finder, used as an aid for acquisition of an aircraft, is located immediately to the left of the radar control console.

The antenna pallet contains the radar, the radar antenna, and the power generator for the system. The radar is an X-band, phase-amplitude comparison, monopulse, automatic tracking radar. It is contained in three cases attached to the base of the antenna. The radar antenna with the cases containing the radar, erected for operation, is shown in figure 6. An AN/ARW-66 command link transmitter is located immediately behind the antenna reflector. The antenna for the command link transmitter is a dipole mounted inside the radome to utilize the radar antenna as a reflecting element.

A standard Marine Corps PU-346 diesel engine generator is the power unit used with the system. This generator (figure 7) is a 3-phase, 400-cycle, 8-kilowatt unit that supplies 120 volts phase-to-neutral.

Aircraft Control Systems

An AD-5 aircraft and an A4D-1 aircraft were used in the evaluation of this RCDC. Both aircraft were configured with automatic control equipment. The

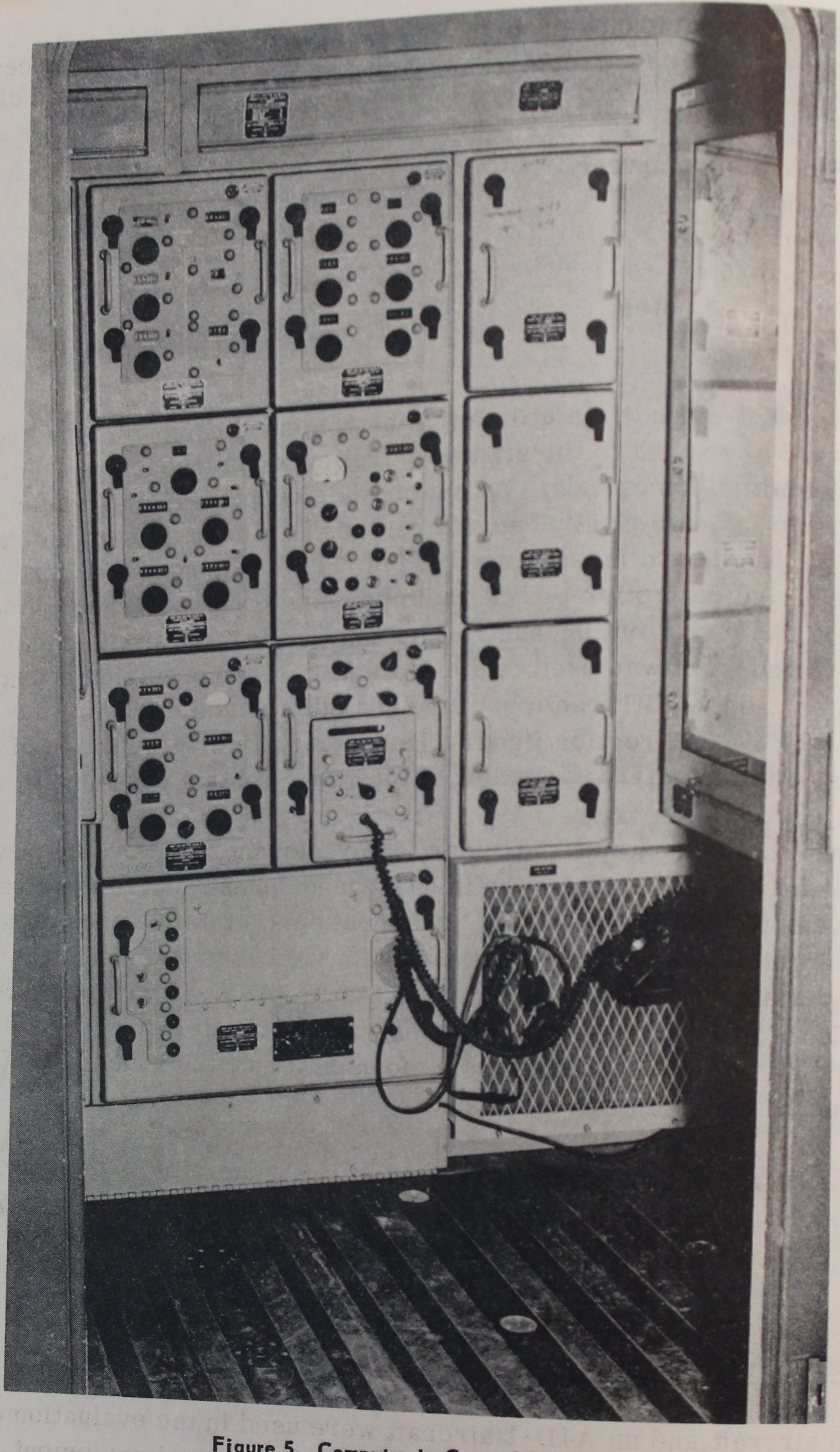

Figure 5. Computer in Control Shelter.

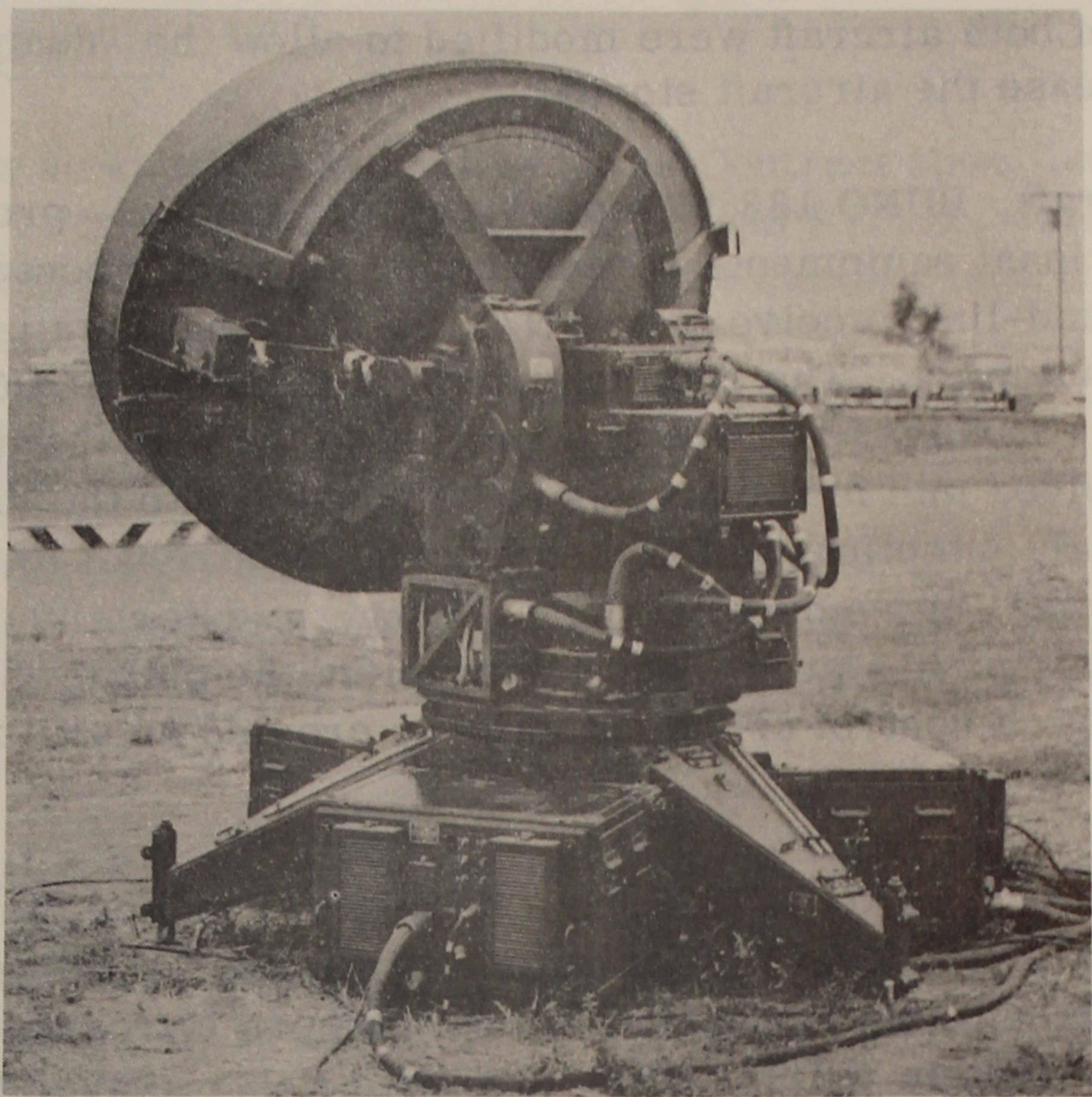

Figure 6. Radar Antenna, With Radar in Three Cases at Base, Erected for Operation.

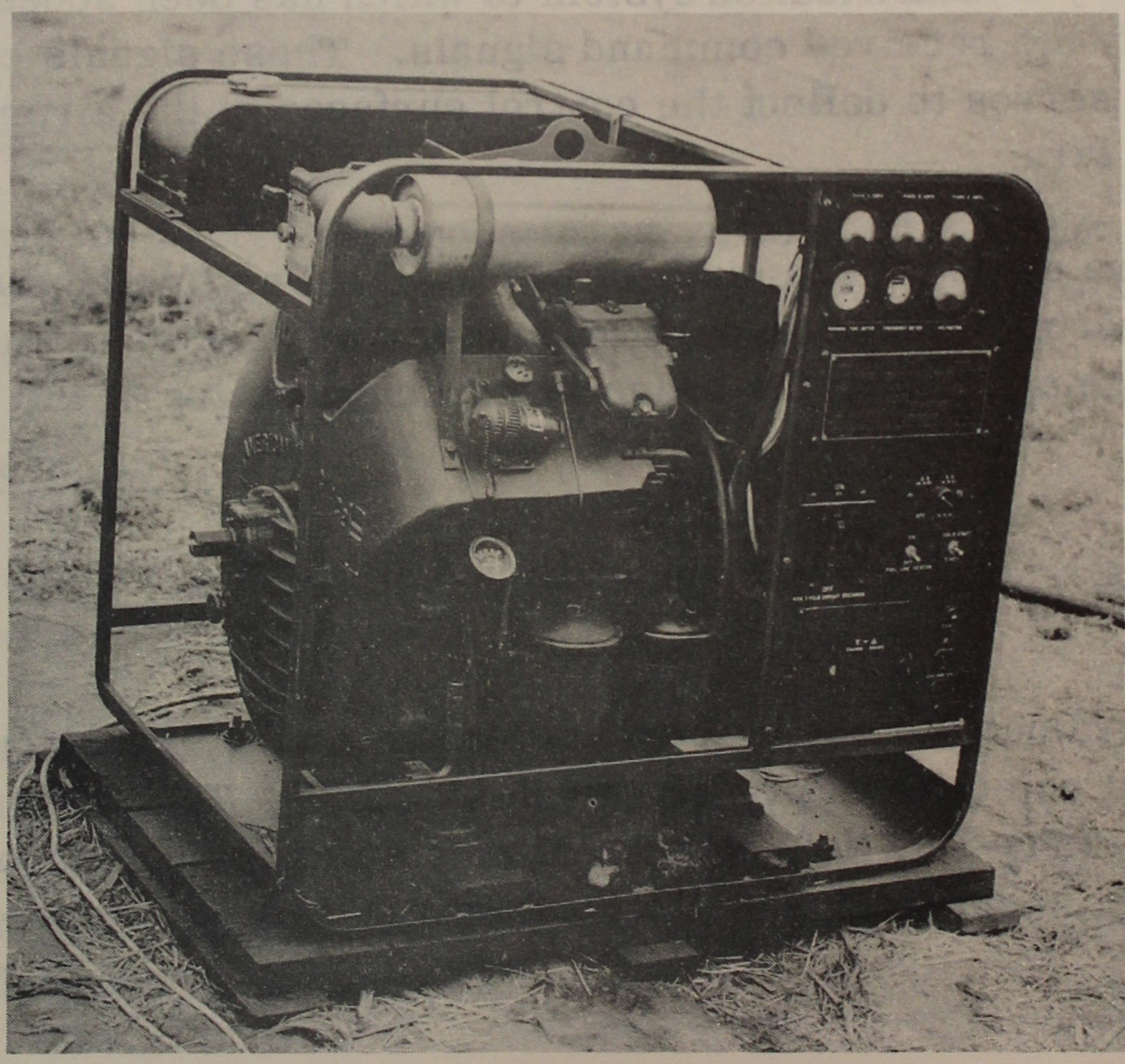

Figure 7. PU-346 Diesel Engine Generator for RCDC Power Supply.

ordnance circuits of both aircraft were modified to allow the "dump" signal sent by the RCDC to release the aircraft stores.

The AD-5 aircraft, BUNO 133899, is a high-performance, propeller-driven aircraft. The additional equipments necessary for automatic control are an AN/ARW-67 command-link receiver, an AN/ARA-39 signal data converter, and the aircraft's P-1 autopilot. The command signals from the RCDC are received by the command-link receiver and are transmitted to the signal data converter, where they are resolved into error signals to be coupled into the directional channel of the aircraft autopilot, which then causes the aircraft to change course by a coordinated turn. The amount of course change is determined by the RCDC. The signal data converter has provisions for coupling the output of an aneroid barometer into the pitch control of the autopilot to provide an altitude-retain capability.

The A4D-1 aircraft, BUNO 137828, is a high-performance, jet aircraft. The additional equipments necessary for automatic control of this aircraft are an AN/ARW-67 command link receiver and the Summers Gyroscope Company 1028A bomb director system (BDS). This command link receiver functions in the A4D-1 aircraft in an identical manner as in the AD-5 aircraft. The received command signals are transmitted to the 1028A bomb director system, which is a two-axis (roll and yaw) stabilization system to which has been added a computer amplifier to amplify the received command signals. These signals cause the rudder and aileron servos to deflect the control surfaces of the aircraft to produce a coordinated turn.

Provisions were made in both aircraft to install a Pacific-Bendix RBX-2 superheterodyne beacon. This beacon transponder was used to extend the tracking and control range and to test the beacon-track capabilities of the RCDC.

METHODS

The tests and evaluations outlined by the Marine Corps Equipment Board meet the operational objective of project MTC-AV-31009, "To determine if the operation of the AN/TPQ-10(XN-2) equipment meets the performance requirements of the contract specification and it performs its operational function."

Procedures and Criteria

Specifications as stated in Bureau of Ships Contract Specification Radar Course Directing Central AN/TPQ-10(XN-2), Ships R-2310, dated 9 March 1956, and Addendum 1 thereto, dated 20 June 1957, are summarized in the following procedures and criteria.

Physical Characteristics

The system was inspected, weighed, and measured to determine whether the system satisfied the contract specification of 5,000 pounds maximum weight and whether the system fit internally into an R4Q aircraft and onto the bed of a 2-1/2-ton 6 x 6 truck.

Transportability

When the system was moved to various locations, the different modes of transportation were noted, in particular the modes referred to in the contract specification. The specification states that the system must be capable of being transported by one R4Q aircraft or one 2-1/2-ton 6 x 6 truck. In addition, it must be helicopter transportable and composed of no more than two helicopter lifts.

Ease of Erection and Orientation

The system was erected for operation at various sites to determine if eight trained men were capable of assembling the equipment in less than 40 minutes, as prescribed in the contract specification.

Ease of Operation

During the operations with the system, the radar operator and strike controller evaluated the following:

1. Convenience and adequacy of controls.
2. Frequency of necessary adjustments to controls.
3. Presentation of information.
4. Number and complexity of operations during a controlled run.
5. Fatigue and stress to the operator.

Acquisition Capability

A record was maintained of the time required for acquisition of aircraft.

Capability of Automatically Tracking Aircraft

Data were recorded on all runs to determine the percentage of successful tracking operations with the RCDC utilizing both the "skin track" and the beacon transponder return.

Capability of Aircraft Control and Direction

The capability of the equipment to control and direct aircraft to the bomb-release point was determined and evaluated from the results of the bomb-drop operations that pertained to the dynamic solution of the guidance problem.

Capability of All-Weather Aerial Cargo Delivery

Aerial cargo delivery capabilities were evaluated with an AD-type aircraft carrying Mark 2 aerial resupply containers. In these tests, the aircraft was flown at an indicated airspeed of 150 knots, and both fixed-course and normal-course modes of operation were used.

In the fixed-course mode of operation, an aircraft was flown to the target on a preselected course in the following manner: When the aircraft was initially engaged under closed-loop control, the computer generated commands such that the aircraft was flown in a circle with the target at its center. The radius of this circle was the distance from the target to the aircraft when the aircraft was first taken under control. At the proper time, the aircraft was turned onto the preselected course heading.

In the normal-course mode of operation, the aircraft was guided directly to the target from the point where the aircraft was initially taken under closed-loop control. In the aerial resupply tests, the pilot would descend to an altitude near the minimum for radar tracking and control (500 feet), then would level off and complete the run at a constant altitude.

The evaluation was conducted to determine the capability of controlling an aircraft to release supplies to friendly troops.

Maximum Control Range

Aircraft were controlled at increasing ranges until the maximum range was reached at which the system could maintain an automatic track and could supply usable information to the computer. The AN/TPQ-10(XN-2) RCDC, must be capable of automatically tracking and controlling aircraft at a range of 200,000 yards, with maximum target range being 100,000 yards from the radar.

Accuracy of System

In evaluating the accuracy of the AN/TPQ-10(XN-2) RCDC, both normal-course and fixed-course modes of operation were used. The pilot would fly at an airspeed and an altitude directed by the strike controller. The computer would solve the guidance problem and would generate and transmit the necessary commands to control the course of the aircraft. It was necessary for the pilot to control the airspeed and altitude of the aircraft. At the proper time, determined by the computer, a "dump" signal was transmitted to release the aircraft stores.

The location of the bomb impact was determined by the use of theodolites and aiming circles. All the impact points of an operation were plotted on one chart. The mean point of impact (MPI) and circular error probable (CEP) of the operation were determined from this chart. The CEP is defined as the radius of a circle containing 50 per cent of the total impact points. The center of the circle is designated as either the MPI or the target.

The over-all accuracy required of the system is that any bomb-dispersal pattern have a CEP about the target of not more than 50 yards. This accuracy must be achieved under any combination of the following conditions at bomb release:

1. Aircraft altitude, 20,000 feet or less.
2. Aircraft range (from radar), 40,000 yards or less.
3. Aircraft velocity (true airspeed), 300 knots or less.

Accuracy of the system at other aircraft altitudes or velocities shall be proportional thereto down to the point at which fixed errors become paramount.

Repeatable Accuracy

Repeated operations were conducted at the various testing sites under the same conditions. The system must have repeatable accuracy to satisfy the contract specification of a 50-yard CEP about the target.

Adequacy of Associated Equipment

Performance of all Government furnished equipment was investigated, and the findings were recorded.

A PU-346 diesel engine generator must be able to satisfy the power requirements of the system.

Provisions must be made in the system for utilization of a beacon transponder to aid in tracking aircraft at longer ranges where radar skin return is unusable. The command signals must correctly control aircraft configured with an AN/ARA-39 signal converter or a Summers 1028A bomb director system.

Operator Training Requirements

All strike controllers and radar operators were questioned to determine the amount and type of training necessary to qualify personnel to operate the system.

Adequacy of Instructional Material

This evaluation could not be performed because no instructional material on the system was released.

Ease of Maintenance

A record was maintained which included the frequency of calibrations and malfunctions of the equipment. The records were evaluated to determine the requirements to maintain an acceptable level of system performance.

Special Maintenance and Test Equipment Requirements

A study was made of special maintenance equipment utilized in the adjustment and repair of the system to determine the items of test equipment required to maintain the system.

Ruggedness and Reliability

During the testing period, an evaluation was made to determine the ability of the system to withstand transportation and field use without loss of effectiveness.

Weatherproofness

Observation and investigation were conducted to determine the ability of the system to operate at an acceptable level of performance under various conditions of weather.

Modifications

A study was made to determine if modifications are desirable to improve the capabilities of the system.

Suitability for Marine Corps Use

A study of the previous evaluations was made to determine the suitability of the system for Marine Corps use as a replacement for the AN/MPQ-14A RCDC.

In addition to the tests outlined in the Marine Corps Equipment Board Test Procedure, tests were made to evaluate the system as an aid to a pilot in approaching an airstrip under conditions of low visibility. In these tests, the position of the landing end of the desired runway was inserted as the target information in the computer. The computer was operated on fixed-course mode, with the runway heading as the selected course. With the computer automatically controlling the heading of the aircraft, and the strike controller verbally directing the altitude changes, the aircraft was guided to the end of the runway.

Scope of Tests

The testing of the AN/TPQ-10(XN-2) RCDC was accomplished in the following four phases:

Phase I. The AN/TPQ-10(XN-2), serial No. 1, was delivered to NMC, Point Mugu, directly from the contractor, General Electric, Syracuse, New York, in an R4Q aircraft. The system was off-loaded at NMC and was immediately erected for checkout of the system, for trouble-shooting of the equipment, and for familiarization of operating personnel with the system. During phase I, aircraft were flown under conditions of closed-loop guidance control, and bombs were dropped on a virtual target to demonstrate that the system was functioning properly.

Phase II. After the initial checkout of the equipment, the system was transported to Oxnard Air Force Base, where a radar-to-target range of 16,000 yards was available. The virtual target was located in the sea test range of NMC. The bomb impact locations were observed and plotted by use of Askania theodolites located approximately 1,500 yards from the virtual target. These theodolites are part of the range instrumentation of NMC. The low-visibility approach tests, the aerial resupply tests, and a limited number of bomb-drop operations were conducted during phase II.

Phase III. Upon completion of the low-visibility approach tests and the aerial resupply tests, the system was transported to the Point Dume area, where medium-range (33,000 yards) tests were conducted. The same virtual target and theodolites were used as in phase II.

Phase IV. Because of adverse weather and range limitations at NMC, operations were very intermittent. To complete the evaluation and testing, the system was transported to NAAS, El Centro, California, where medium-range (33,000 yards) and long-range (67,000 yards) tests were conducted. The medium-range target was the Carrizo Canyon impact area, and the long-range target was Target 57 in the Salton Sea. Artillery aiming circles were used to observe and record the bomb impact location. The observation posts for these aiming circles were located 500 to 700 yards from the target at Carrizo Canyon and 4,000 yards from Target 57 in the Salton Sea. Although a beacon transponder was tested during all phases, it was necessary to employ a beacon during the long-range tests.

The movement of the system to various testing sites offered opportunities for the evaluation of transportability, erection and orientation, ruggedness and reliability, and personnel training requirements.

After completion of the El Centro phase of the evaluation, the equipment was returned to NMC, Point Mugu. The RCDC was then returned to the contractor, General Electric Company, at Syracuse, New York, for modification and refurbishing.

RESULTS

The following results were obtained during the evaluation of the AN/TPQ-10 (XN-2) RCDC.

Physical Characteristics

The control shelter and the antenna pallet were measured and weighed in the transport condition, with the following results:

Control Shelter	
Dimensions	82-5/8 x 85-1/2 x 84-1/2 inches.
Weight	3, 850 pounds.
Antenna Pallet	
Dimensions	86-7/8 x 85-1/2 x 92 inches.
Weight	3, 698 pounds.

The weight of the control shelter includes the weight of the AN/UMP-32 radar test set, approximately 50 pounds. The RCDC system will fit internally into an R4Q aircraft and onto the bed of a 2-1/2-ton 6 x 6 truck. The system will overhang the tail of the truck approximately 2 inches.

Transportability

The system has been successfully transported by R4Q aircraft (figures 8 and 9), by flat-bed truck, and by stake truck. The system has been placed aboard a 2-1/2-ton 6 x 6 truck to determine if it would fit, but has not been transported on this type of truck.

Ease of Erection and Orientation

The system was erected and disassembled four times during the evaluation. The erection time of the system on the fourth attempt was slightly more than 1 hour. The erection technique has not been written. A sequence to optimize erection time was being sought. If the radar site and reference points were surveyed in, orientation would take less than 15 minutes.

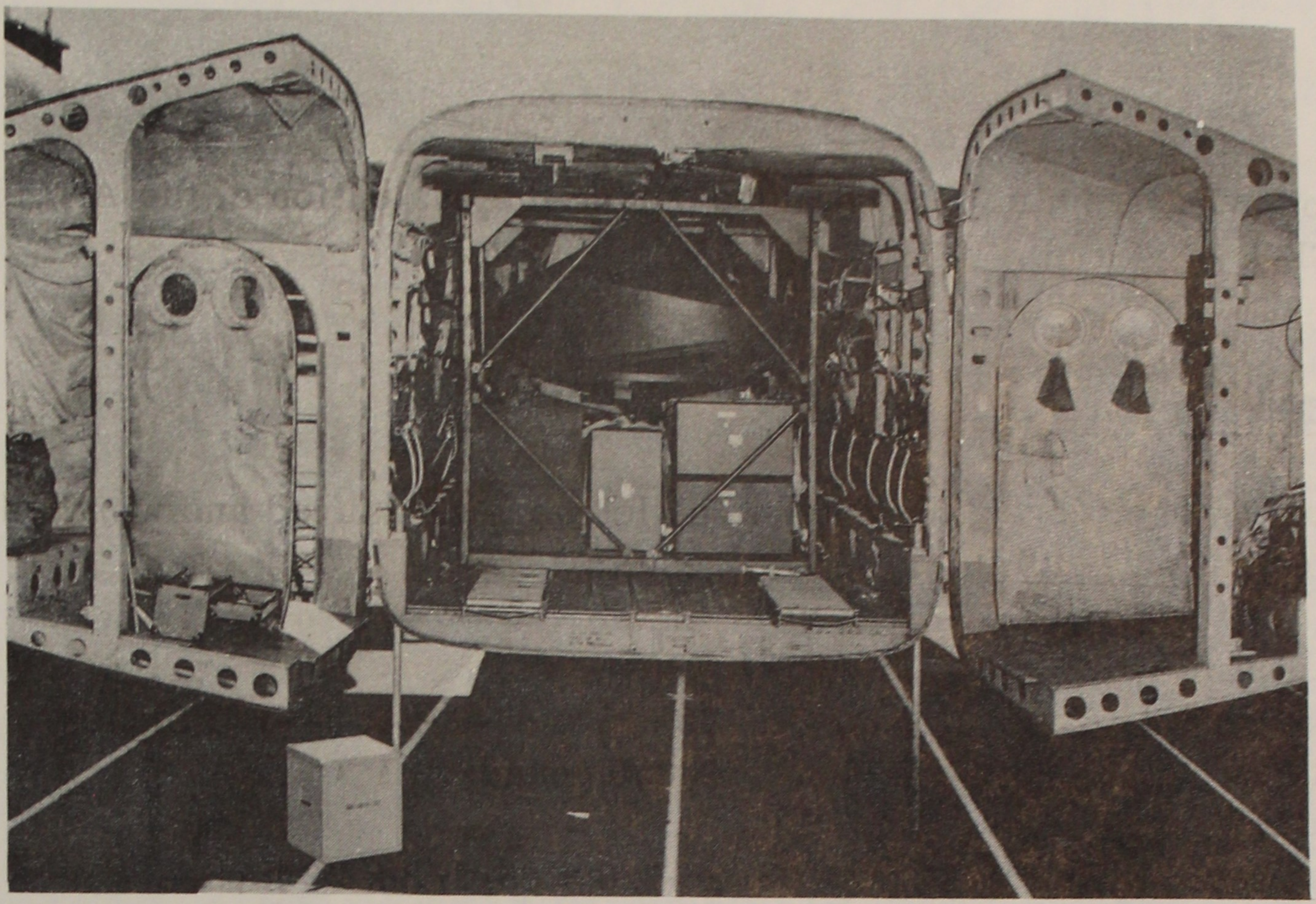

Figure 8. Antenna Pallet Loaded into R4Q Aircraft.

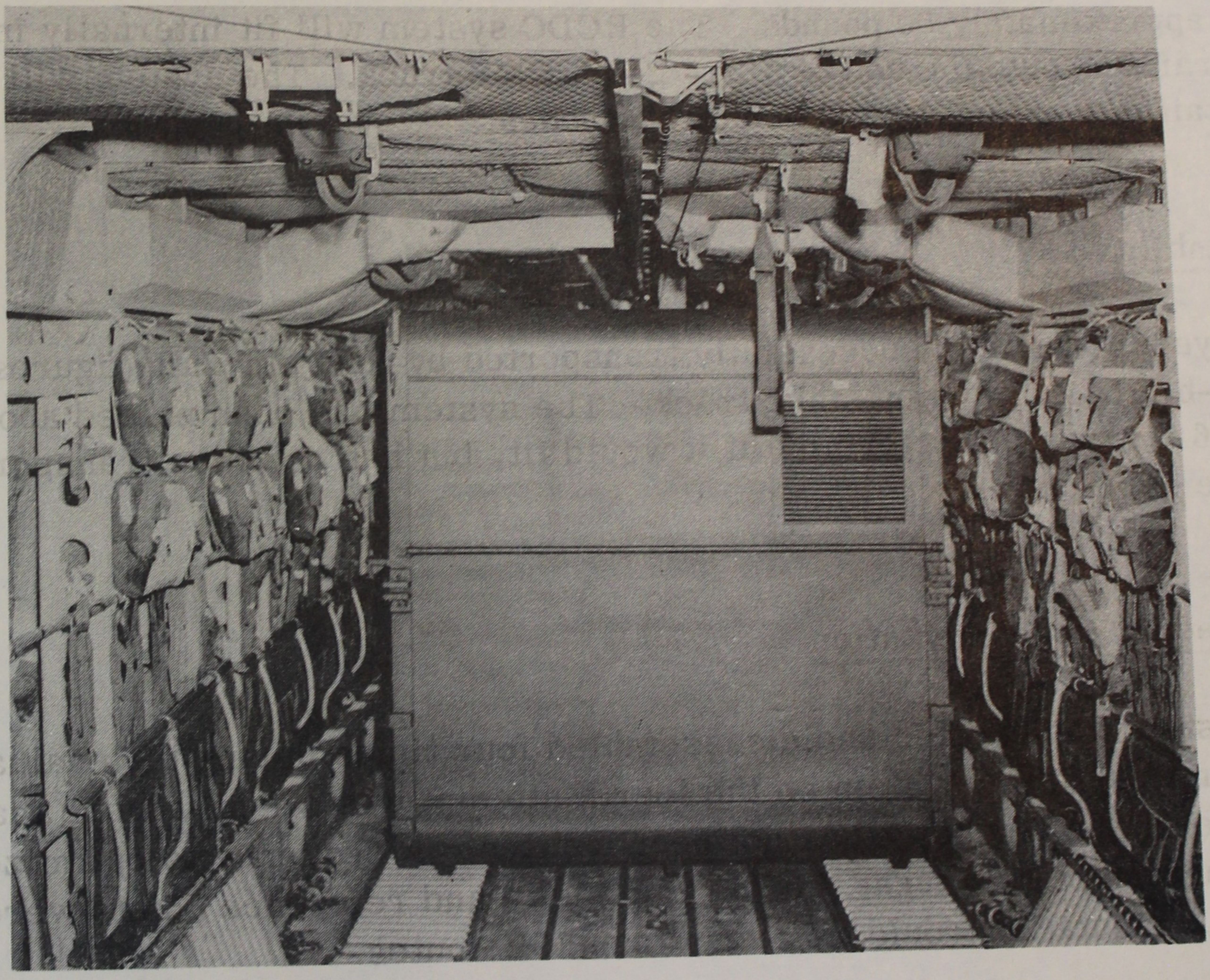

Figure 9. Control Shelter Loaded into R4Q Aircraft.

Ease of Operation

All controls are convenient, and the majority are adequate. The radar operator is handicapped in reacquiring a fast-moving aircraft because the control to place the radar in automatic track is a simple toggle switch. To reacquire the aircraft, the operator must momentarily remove his hand from the elevation and azimuth knobs to throw the tracking switch.

While an aircraft is being tracked and after the necessary inputs have been placed into the computer, no adjustment of controls is needed unless the aircraft is "lost" by the tracking radar. Such loss of tracking is infrequent.

The presentation of the radar information is quite adequate. The error off-course (bomb impact error meter) information was not usable. The meter fluctuated wildly and presented no worthwhile information.

While the aircraft is being automatically tracked, the strike controller must throw four switches during the entire course of a bombing run.

Acquisition Capability

With trained operators, the average acquisition time was less than 60 seconds. An untrained operator would require between 1 and 2 minutes to acquire an aircraft.

Capability of Automatically Tracking Aircraft

During phase I, 43 per cent of the operations were successful as pertaining to the ability of the system to automatically track aircraft. During September and October, the system was not used while the contractor modified the gear trains. Since the middle of October, when the gear train modification was completed, the system has automatically tracked satisfactorily for 95 per cent of the operations.

Capability of Aircraft Control and Direction

The results of the tests of the accuracy of the RCDC system demonstrated that the RCDC can control and direct aircraft to the bomb-release point.

Capability of All-Weather Aerial Cargo Delivery

During tests of the capability of the RCDC to guide an aircraft during all-weather aerial resupply operations, 16 aerial resupply containers were dropped. Since no accurate ballistic information was available for the container used, a crude approximation of the trajectory of these containers was made. Because of this lack of ballistic information, the container was not expected to hit a target. The tests were expected to show the feasibility of using this RCDC in all-weather aerial resupply operations. Between certain test operations, the target information supplied to the computer was changed to test the effect of such changes on the location of impact of the containers. The impact area would shift in accordance with the change of information supplied to the computer. By theoretically transposing all impacts to a common target, it was determined that all containers would have impacted within a circle with a 50-yard radius about this target.

Maximum Control Range

When radar skin return was used, the AD-5 aircraft was controlled to a maximum range of 40,000 yards, and the A4D-1 aircraft was controlled to a maximum range of 35,000 yards.

When the return from the Pacific-Bendix RBX-2 superheterodyne beacon was used, both aircraft were controlled at the maximum range of 200,000 yards.

Accuracy and Repeatable Accuracy of System

A total of 66 bomb-drop operations resulted in 653 impact points. These operations were divided in the following manner:

Testing Site	Range (Yards)	Operations	Impact Points
Oxnard AFB	16,000	20	148
Point Dume	33,000	6	62
El Centro	33,000	36	401
El Centro	67,000	4	42

Only the results of bomb-drop operations obtained at medium range and long range at NAAS, El Centro, are significant, because of the intermittency of operations up to 1 December, the time when the system was moved to NAAS, El Centro. These operations were sporadic because of adverse weather conditions, aircraft problems, and circuit changes and modifications being made by the contractor. Each operation resulted in 7 to 12 points of data. The east-west and north-south variations of mean point of impact (MPI) about the target for the medium-range operations at El Centro are shown in table 1. Figure 10 shows plots of the MPI's for the medium-range operations at El Centro.

Because of the random variations of the MPI's about the target, the circular error probable (CEP) about the target for each individual operation would have little significance. The CEP about the MPI for each operation at medium range while the system was at El Centro is shown in table 1 and indicated graphically in figure 11. The dashed line represents operations with A4D-1 aircraft, and the solid line represents operations with AD aircraft.

A compact grouping of impact points was observed for all runs along each vector heading for any particular operation in which various course headings to the target were used. However, from one operation to another, there was random variation of the orientation of these impact-point groups with the vector heading. At airspeeds of 150 to 180 knots, the distances between the MPI's of the separate groups varied from 10 to 50 yards, but at airspeeds of 250 knots, these distances varied from 50 to 100 yards. The impacts from all medium-range operations at El Centro were plotted on one master chart. The target was approximately the MPI of all impacts.

The percentage of the total number of bombs falling within given distances from the target are shown in table 2. The over-all CEP about the target for the total number of bombs was approximately 95 yards.

The results obtained at long range were comparable to those obtained at medium range.

Adequacy of Associated Equipment

The powers required for operation of the AN/TPQ-10(XN-2) RCDC, with the computer and radar on but not transmitting, were as follows:

Condition	Power Required (Kilowatts)
Hydraulics normal	5.2
Hydraulics slew	5.4
Radar Transmitter on	5.8
Low heaters on	7.5
High heaters on	10.0

A power factor of 0.84 was obtained in all instances.

Table 1. North-South and East-West Variations of Mean Points of Impact for Medium-Range Operations at El Centro.

Operation No.	Aircraft	True Airspeed (Knots)	Altitude (Thousands of Feet)	MPI From Target (Yards)		CEP About MPI (Yards)
				East-West	North-South	
1	AD-5	178	10	W 41	S 132	38
2	AD-5	179	10	W 39	S 58	25
3	AD-5	179	10	W 97	N 74	48
4	A4D-1	298	10	W 44	N 23	134
5	AD-5	179	10	W 49	S 8	48
6	A4D-1	245 350	10 20	W 28	N 30	187*
7	AD-5	179	10	W 41	N 21	76
8	A4D-1	295	10	E 21	N 103	82
9	AD-5	179	10	E 6	S 10	28
10	A4D-1	179	10	W 32	N 38	47
11	AD-5	179	10	W 29	S 7	120
12	A4D-1	295	10	W 1	S 60	44
13	A4D-1	298	10	E 54	S 21	110
14	AD-5	156	10	E 22	N 35	35
15	A4D-1	298	10	W 18	S 41	67
16	AD-5	215	10	W 28	N 74	33
17	AD-5	215	10	E 16	N 17	62
18	AD-5	213	10	E 37	N 56	36
19	AD-5	214	10	E 52	S 11	31
20	AD-5	214	10	E 91	S 50	51
21	AD-5	214	10	E 33	N 65	45
22	AD-5	214	10	E 10	N 65	57
23	AD-5	214	10	E 72	N 25	37
24	AD-5	214	10	E 7	S 17	35
25	AD-5	214	10	W 17	S 109	24
26	AD-5	224	20	E 46	S 6	70
27	AD-5	214	10	W 41	N 8	52
28	AD-5	214	10	E 56	S 13	27
29	AD-5	214	10	W 141	S 43	63
30	AD-5	178	10	W 30	N 25	41
31	A4D-1	350	20	W 48	N 43	77
32	A4D-1	296	10	W 69	S 45	90
33	A4D-1	297	10	W 16	N 53	99
34	AD-5	214	10	E 2	N 54	19
35	A4D-1	178	10	E 8	N 37	81
36	A4D-1	300	10	E 8	N 35	47

*6 Bombs Each Combination at Altitude and Airspeed.

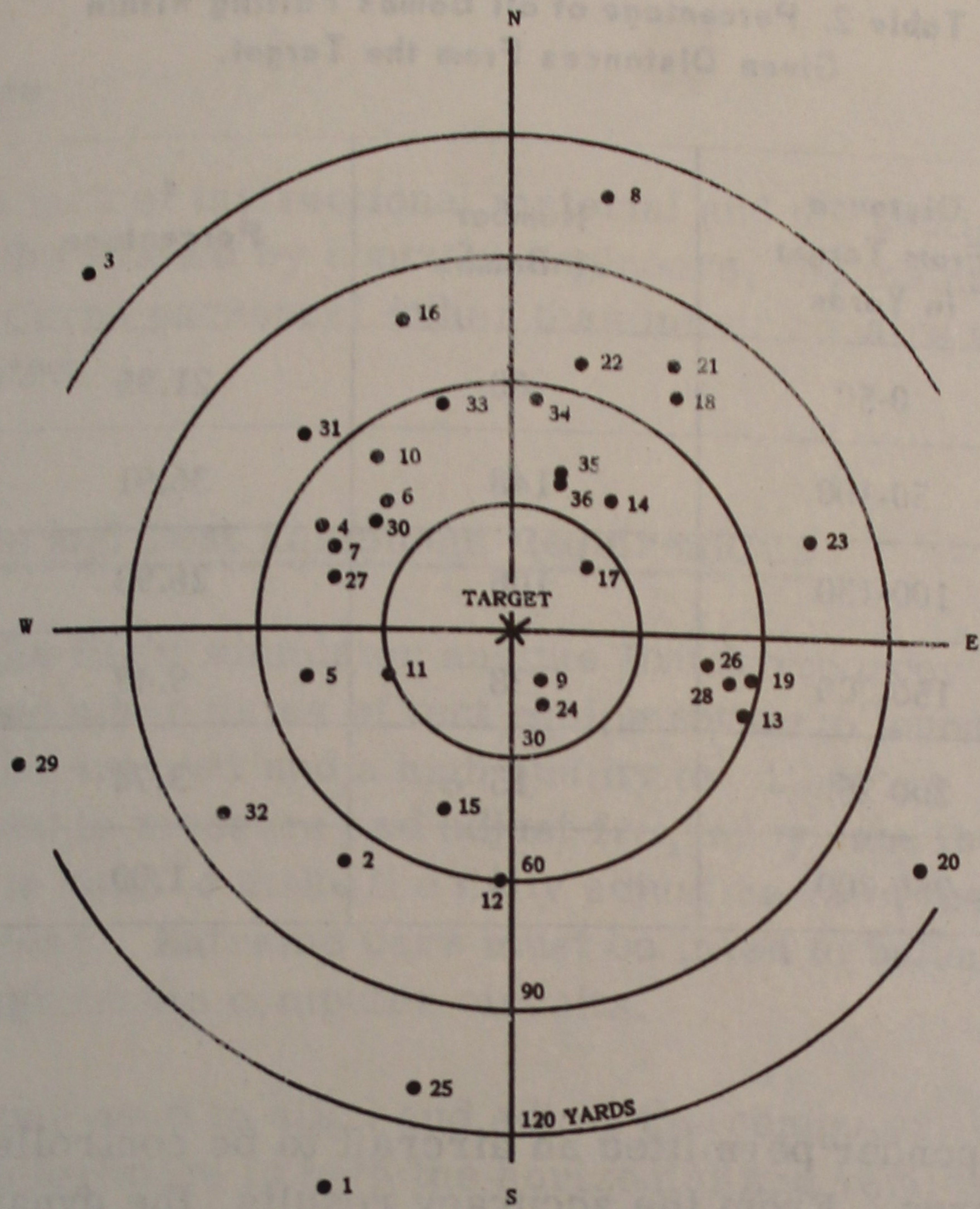

Figure 10. Plots of the MPI's for the Medium-Range Operations at El Centro.

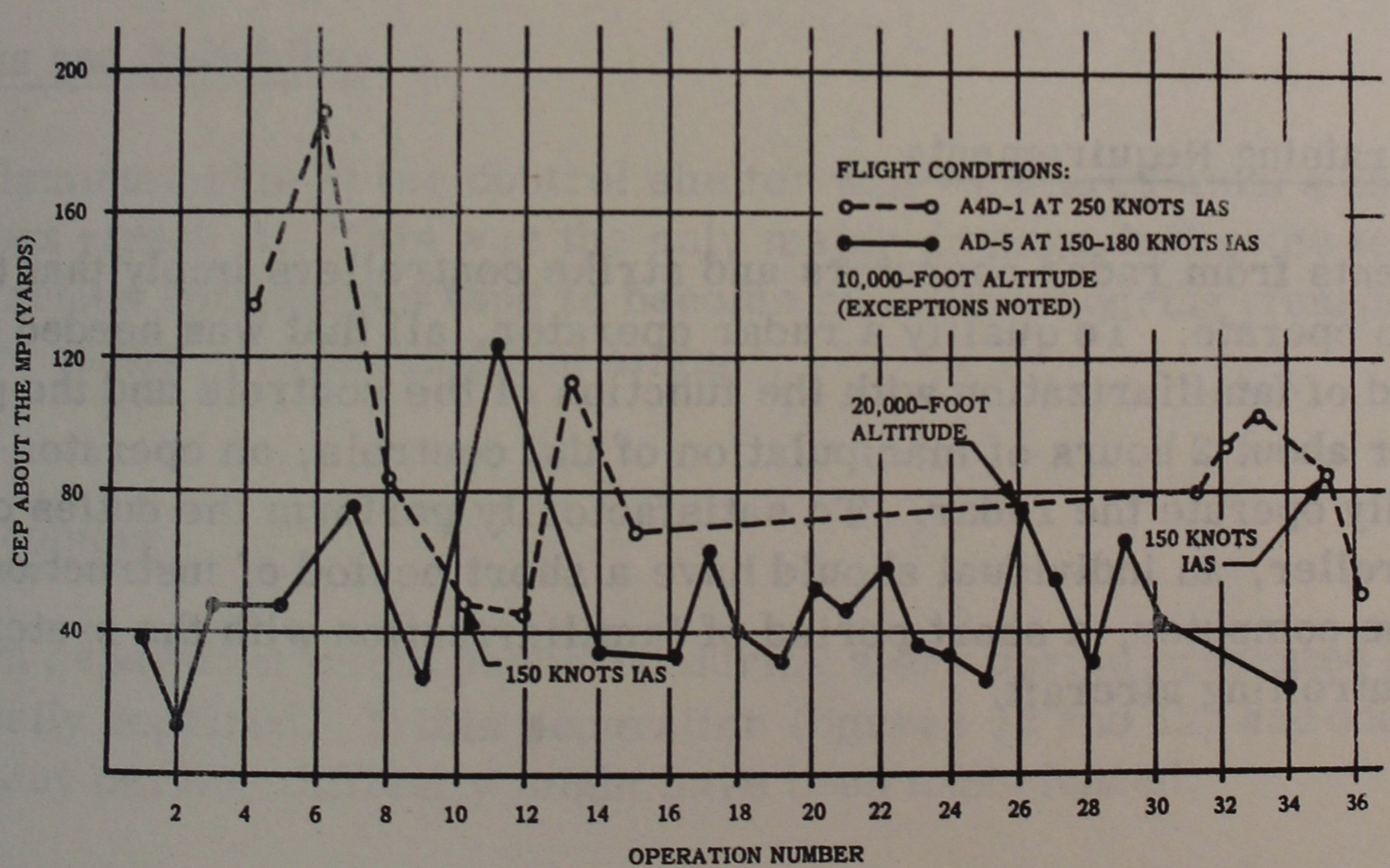

Figure 11. CEP About the MPI for the Medium-Range Operations at El Centro.

Table 2. Percentage of all Bombs Falling Within Given Distances From the Target.

Distance From Target in Yards	Number of Bombs	Percentage
0-50	88	21.95
50-100	148	36.91
100-150	108	26.93
150-200	38	9.47
200-250	15	3.74
250-300	4	1.00

A beacon transponder permitted an aircraft to be controlled at the maximum range of 200,000 yards. From the accuracy results, the dynamic solution appears to be solved satisfactorily. The aircraft which respond primarily to the dynamic solution are considered to have been correctly controlled by the transmitted commands.

Operator Training Requirements

Comments from radar operators and strike controllers imply that the system is simple to operate. To qualify a radar operator, all that was needed was a short period of familiarization with the function of the controls and the procedure used. After about 2 hours of manipulation of the controls, an operator could satisfactorily operate the radar. To satisfactorily perform the duties of the strike controller, an individual should have a short period of instruction on the theory of the computer, a short period of familiarization with the system, and 2 hours of controlling aircraft.

Ease of Maintenance

Because of the lack of instructional material and the continual modification of the circuitry of the system by contract engineers, the maintenance of the system by Marine Corps personnel (other than minor repairs and maintenance) could not be evaluated.

Special Maintenance and Test Equipment Requirements

In addition to the flight simulator and the Brush recorder to provide limited test capabilities, two other items of test equipment were found to be necessary, an AN/UPM-32 radar test set and a high quality oscilloscope. The AN/UPM-32 radar test set is used to measure and adjust frequency, and the pulse feature of this radar test set is used to make the daily adjustments of the automatic tracking circuit of the radar. Extreme care must be taken to balance out all errors in phase shift throughout the computer circuits.

The oscilloscope, used to align and adjust the computer, must have excellent phase characteristics in both the horizontal and vertical input channels. The oscilloscope must also have good high-frequency characteristics to allow its use in maintenance and alignment of the system radar.

Ruggedness and Reliability

The aluminum skin of the control shelter was punctured when a sharp cornered box struck it. This was the only major damage during the testing period. Various components tend to become misaligned during transportation, but they are easily recalibrated and aligned.

Weatherproofness

A seam separation which occurred during a dry period presented no problem and was easily repaired. If this separation (figures 12 and 13) had occurred during a rainy period, difficulty might have been experienced.

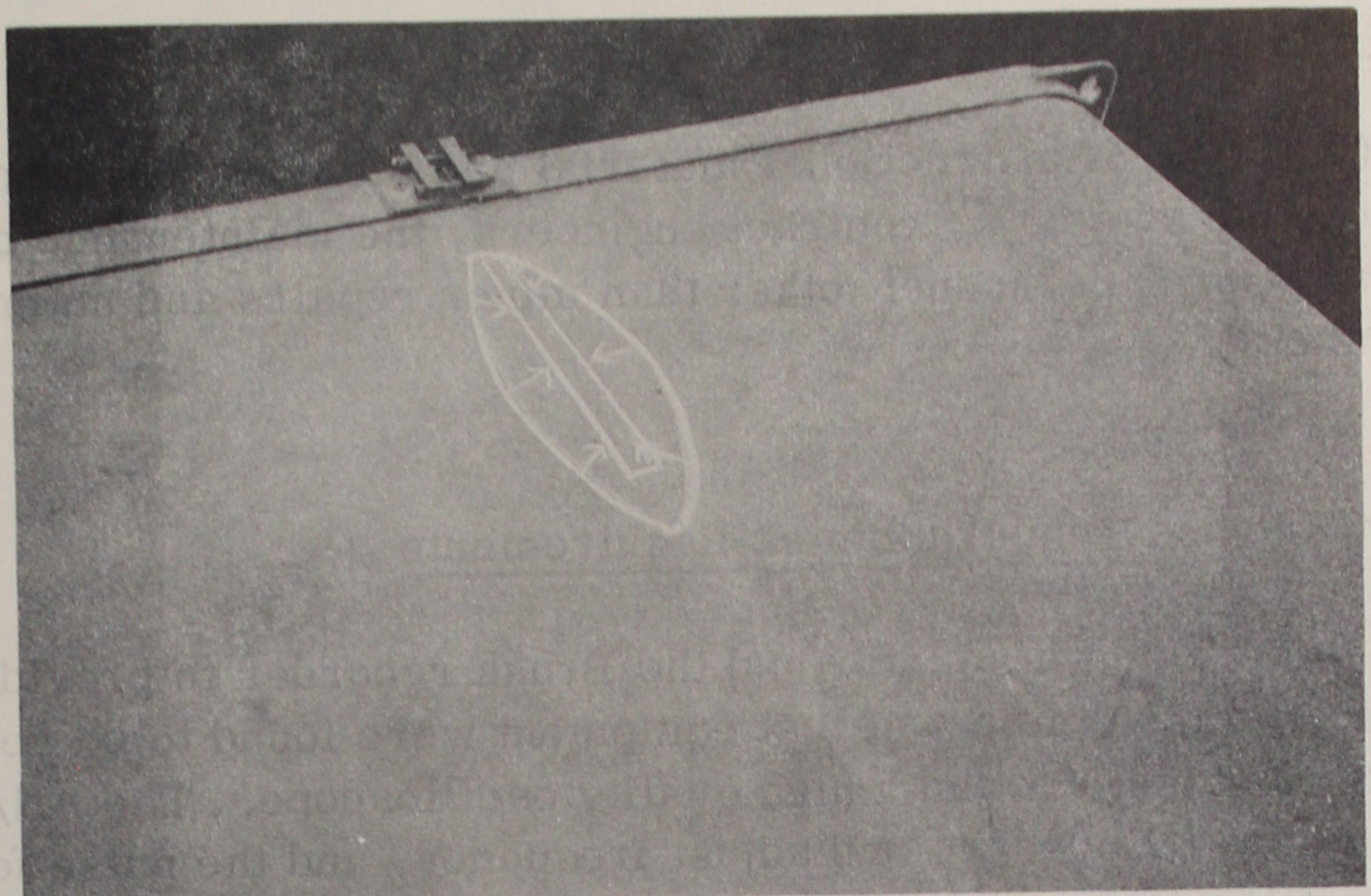

Figure 12. Seam Separation on Control Shelter.

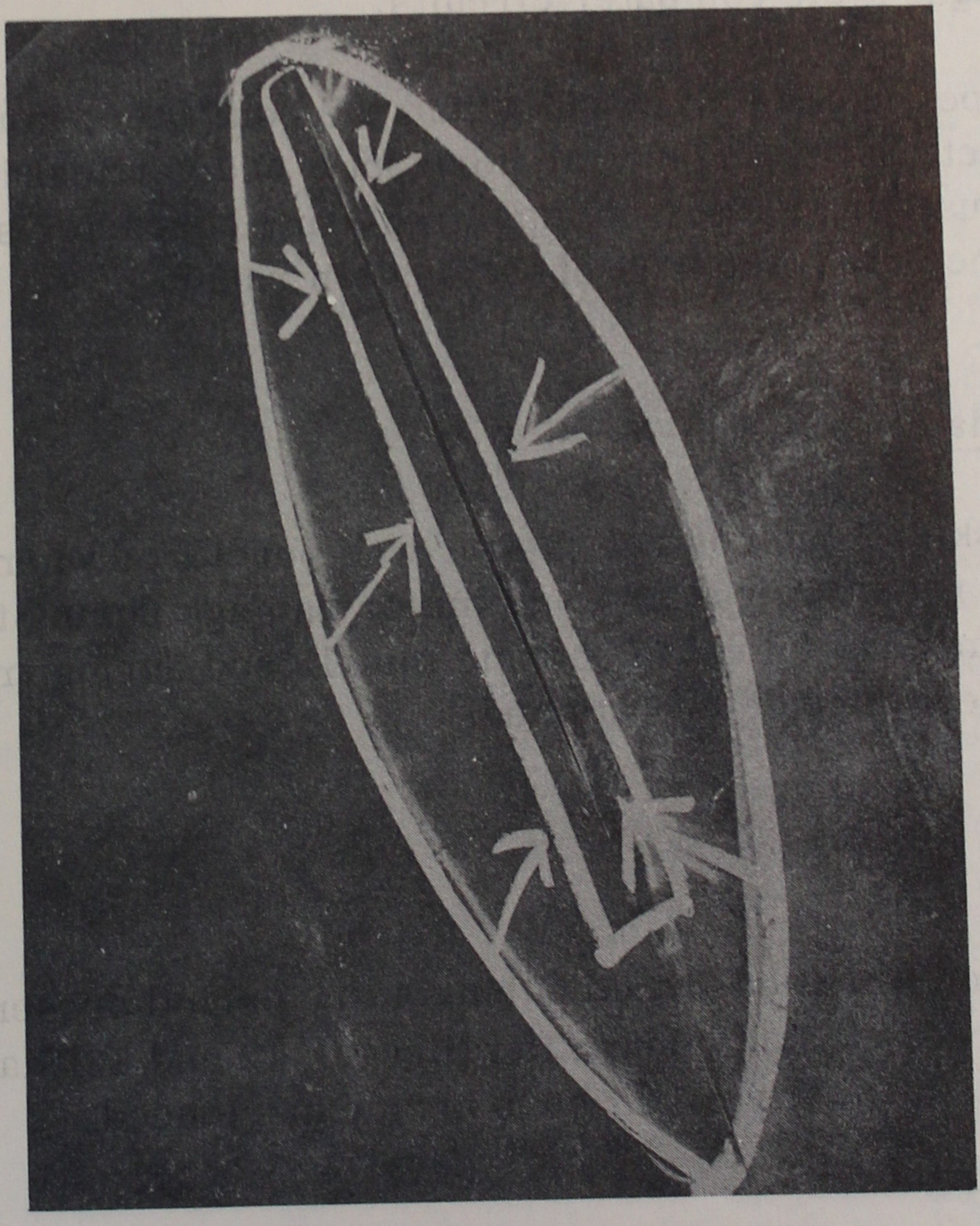

Figure 13. Close-Up View of Seam Separation on Control Shelter.

Modifications and Suitability for Marine Corps Use

Because of the constant modification by the contractor and the return of the system to the contractor for modification, no conclusion can be made at present concerning modifications to improve the system nor concerning its suitability for Marine Corps use.

Low-Visibility Approach

Approximately 50 simulated low-visibility approaches were conducted during the evaluation period. These operations utilized radar skin return or the return from the Pacific-Bendix RBX-2 beacon transponder. When radar skin return was used, the aircraft was able to descend to an altitide of 1,000 feet before the radar return became unusable. When beacon transponder return was used, radar tracking and control were possible down to an altitude of 250 feet. Under normal procedures, when radar track and control were lost, the pilot would resume control of his aircraft and would continue for a normal landing. All simulated low-visibility approach operations were highly successful, with the aircraft being aligned with the runway and in a proper position for landing.

DISCUSSION

The dimensions and configuration of the AN/TPQ-10(XN-2) RCDC satisfy the requirements of the proposed employment of the system. The weight of the system exceeds the contract specification by approximately 2,500 pounds. The suitability of the system to be transported by one R4Q aircraft, by one 2-1/2-ton 6 x 6 truck, and by other vehicular forms of transportation has been adequately demonstrated. Because of the non-availability of helicopter aircraft, transportation by helicopter was not evaluated. However, cognizant personnel of the Third Marine Aircraft Wing indicated that the characteristics of the system make it transportable by helicopter. Although the dimensions of the loading door of the HR2S helicopter prevent the RCDC from being carried internally, the system can be carried in a sling by the helicopter.

The specifications require that the control shelter be operable from the bed of a 2-1/2-ton 6 x 6 truck. The AN/TPQ-10(XN-2) model of the system cannot be so operated for the following reasons:

1. The direction of skids to slide the shelter is such that the door of the control shelter will be against the side boards of the truck.

2. If the shelter is turned so the door faces the rear of the truck, the panel for connecting the cables for power and radar control is inaccessible.

The erection of the system presents no problems, and with 8 trained personnel the erection time of less than 40 minutes should be readily obtainable. Accurate locations of both the radar and orientation points for the radar were required in order to utilize the accuracy of the system. All testing sites, targets, and observation posts were surveyed points. In combat situations, accurate radar and target information must be available or a process similar to "zeroing in" artillery must be used.

System operation is simple and straightforward. Personnel with a minimum of instruction can perform the necessary functions to satisfactorily operate the system.

An average acquisition time of less than 60 seconds demonstrated the ease with which aircraft could be acquired for automatic tracking by the radar. When the radar would lose the aircraft during automatic tracking, which was infrequent, little trouble was experienced in the reacquisition of the aircraft.

The ability of the system to control an aircraft is considered to be adequate. The problem of drift, as experienced in the random shift of the MPI about the target between operations is not considered to be an inability to accurately control the aircraft but is considered to be a function of drift in the amplifiers connected with the computer of the system.

The capability of the RCDC for use in aerial resupply operations is considered to be one of the primary missions of the system. The techniques of aerial resupply delivery have unlimited possibilities. For example, a system for automatic closed-loop control for large transport-type aircraft could be devised, and all forms of stores could be delivered by this technique. If automatic control is not feasible, an ARB-2 bomb directing set radio could be installed, and the pilot could close the control loop by flying course changes indicated by this instrument. Projects are being conducted to gain the necessary ballistic data for the various aerial-resupply containers. This information will permit accurate first-attempt, one-shot, aerial-resupply deliveries.

The system satisfies the contract specification of controlling aircraft at a range of 200,000 yards. The accuracy obtainable with the RCDC is degraded with an increase in airspeed. Tests were conducted in which the testing aircraft, the A4D-1 and AD-5, were flown at the same indicated airspeed to determine if the degradation in accuracy was a function of the radar target each aircraft presented. The results obtained were comparable, indicating that the degradation could be a function of airspeed and not of the radar target (aircraft). The number of tests was insufficient to determine conclusively whether the discrepancies were a function of airspeed. Additional tests will be conducted to resolve this problem, when the system is returned to the testing unit after current modification. The random shift in MPI about the target for the various operations indicates that repeatable accuracy is not obtainable with the present system. However, the results show this shift to be attributed to static errors rather than to dynamic errors. Replacing the amplifiers to which the drift is attributed should enable the system to produce repeatable results.

The KY-51 coder, AN/ARW-66 command link transmitter, and PU-346 diesel power generator, government furnished components of the AN/TPQ-10(XN-2) RCDC, all operated satisfactorily during the evaluation. The system was designed to be coupled to the AN/ARA-25 direction finder, which would be an automatic aid in acquisition of aircraft. Successful acquisition by use of this method was never accomplished, however, and the RCDC appears to be inadequate in this respect.

The aircraft control system, the AN/ARA-39 signal data converter and the Summers 1028A bomb director system, proved adequate and satisfactory when used with the RCDC. Results of the low-visibility approach tests, the aerial-resupply tests, and the long-range tests indicated the need for a beacon transponder in the aircraft. The Pacific-Bendix RBX-2 superheterodyne beacon proved satisfactory during the evaluation period.

The requirements for training of the radar operator, the strike controller, and the maintenance personnel are varied. The radar operator and strike controller need little instruction in the operation of the system. However, new mechanization techniques, new concepts, and the complexity of the system will require that personnel receive extensive schooling in maintenance of the AN/TPQ-10(XN-2) RCDC. A Tektronix model 515 oscilloscope adequately satisfies the requirement for a suitable oscilloscope to be used with the system. Because of the difference in requirements imposed by the computer and the radar, certain advantages could be gained by the use of two oscilloscopes that would have different characteristics. These advantages are:

1. Work could be performed on the computer and the radar simultaneously.
2. Separate oscilloscopes would be less complex in regards to maintenance than one which incorporates all characteristics.
3. There is no oscilloscope that satisfies the requirements of the military specifications.

Disadvantages are:

1. Two items of test equipment instead of one.
2. A probable increase in weight.

During numerous movements of the RCDC to different testing sites, the system was shown to be rugged. After the system was modified early in phase II by the contractor, the operation of the system was reliable, with no extended period of shutdown because of failure of the system. The RCDC withstood all kinds of weather to which it was subjected. The system has been subjected to numerous environments but not to snow and extreme cold. The panels of the control shelter are merely butted together; however, it is thought that if the panels are overlapped or a strip used to cover the seams, separations like that shown in figures 12 and 13 would be prevented.

The capability of the RCDC to aid a pilot in performing an approach to a landing under conditions of low visibility has been adequately demonstrated. The use of the RCDC for a low-visibility approach is not intended as a replacement for the use of ground controlled approach (GCA) equipment, but this technique is intended to augment GCA or to direct an aircraft to a pickup point for GCA. With improved techniques, the aiding of a pilot in conditions of low visibility during a combat situation may be an important function of the RCDC.

Because the AN/TPQ-10(XN-2) RCDC was returned to the contractor, General Electric Company, on 25 February 1959 for extensive modifications and refurbishing, comments on modifications and suitability for Marine Corps use must be reserved until after the system is returned to NMC and the final evaluation is performed.

CONCLUSIONS

1. The physical characteristics of the AN/TPQ-10(XN-2) RCDC satisfy the physical specification and intended employment of the system, with the following exceptions:

   a. The equipment exceeds the specified maximum weight by approximately 2,500 pounds.

   b. Although the system fits on the bed of a 2-1/2-ton 6 x 6 truck, it can not be operated from this position.

2. The AN/TPQ-10(XN-2) RCDC is considered to be capable of operating under tactical conditions and satisfactorily performing its operational function.

3. The capabilities of the RCDC for use in all-weather aerial-resupply operations and as an aid to a pilot for approaching a landing under conditions of low visibility have been adequately demonstrated and are expected to be important functions of the AN/TPQ-10(XN-2) RCDC.

4. At present, the system does not meet the accuracy requirements of the contract specification. However, the factors and deficiencies contributing to the errors in the system are expected to be corrected during the modification and refurbishing of AN/TPQ-10(XN-2) RCDC, serial No. 1.

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