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AERIAL REFUELING EVALUATION OF THE CH - 47D HELICOPTER

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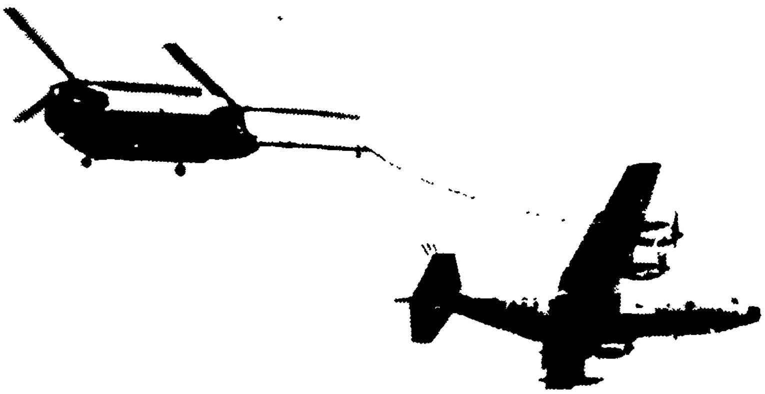
FINAL REPORT



UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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Aerial Refueling Feasibility Evaluation
CH-47D Helicopter

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A feasibility evaluation of aerial refueling the Boeing Vertol CH-47D helicopter (USA S/N 84-24159) equipped with a Boeing Vertol designed prototype aerial refueling system was conducted by the US Army Aviation Engineering Flight Activity (USAAEFA). The test was conducted at the Boeing Vertol flight test facility in Wilmington, Delaware between 6 and 9 August 1985. Five flights were performed totaling 8 flight hours (4.1 productive hours). Aerial refueling system tests were performed by Boeing Vertol and monitored by USAAEFA prior to

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) the initial refueling system flight evaluation. Aerial refueling operations were performed with an HC-130P tanker aircraft and included a tanker turbulence evaluation, handling qualities while performing refueling procedures, and prototype aerial refueling system operations. Twenty-five refueling probe to drogue engagements were performed. During one engagement, 5070 pounds of fuel were transferred from the tanker to the CH-47D. Six shortcomings, all of which were related to the aerial refueling system, were identified for correction in the production design. The most significant of these was the increased maintenance requirements imposed by the use of refueling probe restraint cables. Within the limited scope of this evaluation aerial refueling of the CH-47D helicopter is a feasible concept.

DEPARTMENT OF THE ARMY
HEADQUARTERS, US ARMY AVIATION SYSTEMS COMMAND
4300 GOODFELLOW BOULEVARD, ST. LOUIS, MO. 63120-1798

REPLY TO
ATTENTION OF

AMSAV-E

SUBJECT: Directorate for Engineering Position on the Final Report of USAAEFA Project No. 85-09, Aerial Refueling Evaluation of the CH-47D Helicopter

SEE DISTRIBUTION

1. The purpose of this letter is to establish the Directorate for Engineering position on the subject report. In general the report exceeds the scope and objectives intended in this test. This was a prototype system and the objective of the test was to verify the feasibility and pilot techniques for aerial refueling the CH-47D helicopter. These tasks were performed and reported exceptionally well Additionally, recommendations are made relative to potential system design improvements that could be included in a production design should the Army decide to procure such a system. While these comments are good and appropriate to the test this Directorate does not consider them shortcomings, but rather as suggested improvements for a production design. There were no design specifications to be met and there is no current mission requirement for an aerial refueling capability for the CH-47D helicopter.

2. This Directorate agrees with the report conclusions and recommendations, with the exceptions identified herein that reflect the above stated approach. Conclusions and recommendations are discussed by paragraph as indicated:

a. Paragraph 29a: AVSCOM does not agree that the restraint cables are a shortcoming in this feasibility test, however the recommendation that the cables be deleted in a production design is appropriate. It may be necessary to retain these cables to prevent the probe from becoming too massive. If the cables are retained, they should be attached in such a manner that they do not interfere with maintenance activities or endanger the helicopter if they break in flight.

b. Paragraph 29b: AVSCOM does not agree this is a shortcoming as there currently are no approved, crashworthy internal cabin fuel tanks. The need for both crashworthy internal fuel tanks and an aerial refueling system as range extension programs on the same aircraft is not known. If aerial refueling is available, crashworthy internal tanks may not be necessary. However, we agree that if a mission is defined to require both aerial refueling and crashworthy internal fuel tanks, on the same aircraft, the ability should exist to refuel the internal tanks through the aerial refueling system. If a development specification for the aerial refueling system is written, it should include this capability.

AMSAV-E
SUBJECT: Directorate for Engineering Position on the Final Report of USAAEFA Project No. 85-09, Aerial Refueling Evaluation of the CH-47D Helicopter

c. Paragraph 29c: AVSCOM does not agree that this is a shortcoming for a prototype system. The prototype system was to investigate the aerial refueling capability of the CH-47D. We do agree, though, that should the requirement for aerial refueling capability be established, the ability to selectively refuel individual fuel cells should be incorporated into the production design.

d. Paragraph 29d: While AVSCOM does not agree this is a shortcoming for the prototype system, we do agree that the ability to simultaneously check the primary and secondary fuel shutoff valve operation in each tank should be incorporated in a production design.

e. Paragraph 29e: AVSCOM does not agree this is a shortcoming in a prototype system. However, we do agree that if a development specification for production aerial refueling system is written it should include provisions to provide the flight crew the ability to accurately monitor fuel flow.

f. Paragraph 29f: AVSCOM does not agree that this is a shortcoming in a prototype system. The fuel switches were deliberately wired in this manner for expediency in fabrication of the prototype system to minimize the wiring changes required in the test helicopter. While this might be a shortcoming in a production design, it is considered acceptable for a prototype system to evaluate the feasibility of aerial refueling. However, we do agree that this should be considered for improvement in a production design.

g. Paragraph 31: AVSCOM agrees that the tests recommended in this paragraph be included in qualification tests of a production aerial refueling system. Additionally, the items discussed in subparagraphs a through f above should also be incorporated prior to any further flight or qualification testing.

FOR THE COMMANDER:

Daniel M. McEneany
DANIEL M. McENEANY
Director of Engineering

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INTRODUCTION

BACKGROUND

1. The US Army Aviation Systems Command requested (ref 1, app A) that the US Army Aviation Engineering Flight Activity (USAAEFA) conduct a flight evaluation of the CH-47D helicopter equipped with a prototype aerial refueling system. The tests set forth in the test plan (ref 2) as modified by reference 3 were designed to evaluate the CH-47D equipped with a prototype aerial refueling system. The scope of this evaluation was subsequently modified (ref 4) to conduct testing necessary to evaluate the feasibility of aerial refueling the CH-47D equipped with a Boeing Vertol (BV) designed prototype aerial refueling system.

TEST OBJECTIVE

2. The objective of this test was to verify the feasibility of conducting aerial refueling operations with the CH-47D helicopter and qualitatively document any handling quality changes with the prototype aerial refueling system installed. The appropriate pilot techniques for tanker approach, hook-up, fuel transfer, and disengagement were determined.

DESCRIPTION

3. The test helicopter was a production CH-47D, USA S/N 84-24159, configured with a prototype aerial refueling system. The prototype aerial refueling system consisted of a two-piece telescoping refueling probe mounted on the right side of the helicopter at right buttline (RBL) 57.75, waterline (WL) -36.0 with support fittings at fuselage stations (FS) 95 and 160. Two restraint cables were mounted at the outer end of the stationary probe section and were attached to the aircraft. One was attached to the right side of the forward transmission at FS 98.0, RBL 27.0, WL +65.0, and the other was attached at the forward jack point at FS 95.0, left BL 18.5, and WL -36.0. The probe inner section was extended and retracted by fuel pressure supplied by two additional fuel boost pumps located in the dry bay aft of the right main fuel cell. Fuel lines for extension, retraction and refueling were externally routed from the refueling probe and boost pumps to the refueling panel located in the dry bay between the right forward auxiliary and right main fuel cells. A detailed description of the CH-47D is contained in the operator's manual (ref 5, app A). Appendix B contains a more complete description of the prototype aerial refueling system.

TEST SCOPE

4. The initial flight tests of the CH-47D with the prototype aerial refueling system were conducted by BV at the Philadelphia, Pennsylvania production facility and the Wilmington, Delaware flight test center. The USAAEFA flight tests were conducted from the Wilmington flight test center from 6 through 9 August 1985. Five flights were conducted for a total of 8 hours, of which 4.1 hours were productive. Twenty-five refueling drogue engagements were performed. During one engagement, 5070 pounds of fuel was transferred from the HC-130P tanker to the test aircraft. Prior to performing this evaluation the flight crews attended a four day aerial refueling ground and flight training orientation course conducted by the 1551st Flying Training Squadron at Kirtland Air Force Base, New Mexico. The HC-130P tanker aircraft and flight crew used during the evaluation was provided by the 6594th Test Group from Hickam Air Force Base, Hawaii. The crash rescue helicopter and flight crew were provided by the US Army Test and Evaluation Command from the Aberdeen Proving Ground Flight Detachment, Aberdeen, Maryland. Boeing Vertol provided a fixed wing chase aircraft and crew, test aircraft maintenance, instrumentation and data reduction support. Tests were conducted at gross weights between 28,720 and 33,790 pounds with center of gravity at FS 324.0, 100% rotor speed (225 rpm), and a density altitude of 6000 feet. The limitations contained in the operator's manual (ref 5, app A) the airworthiness release (ref 6) and those prescribed by BV were observed.

TEST METHODOLOGY

5. Flight test techniques are briefly described in the Results and Discussion section of this report. Flight parameters were recorded by an on-board magnetic tape recording system and were also telemetered to a ground recording station. A listing of the recorded parameters is contained in appendix C. Video and photographic documentation were recorded from the test, tanker, and fixed wing chase aircraft. Qualitative ratings of the handling qualities and vibrations were based on the Handling Qualities Rating Scale (HQRS) and the Vibration Rating Scale (VRS) contained in appendix D. Methods of natural frequency determination and structural load analysis is also presented in appendix D.

RESULTS AND DISCUSSION

GENERAL

6. A feasibility evaluation of aerial refueling the CH-47D helicopter modified with a prototype aerial refueling system was conducted. All tests by the US Army Aviation Engineering Flight Activity (USAAEFA) were conducted with the aerial refueling system configuration described in appendix B. Aerial refueling operations were performed with an HC-130P tanker to identify potential handling quality, procedural, and prototype aerial refueling system design problems. Six shortcomings, all of which were related to the prototype aerial refueling system, were identified for correction in the production design. Based on the limited scope of this evaluation, aerial refueling of the CH-47D helicopter is a feasible concept.

AERIAL REFUELING SYSTEM TESTS

Static Load Test

7. Static load tests were conducted (as described in app D) with the probe fully extended to determine tip deflection and verify structural integrity at design limit tip loads of 1000 pounds. Loads were applied to the probe tip in four directions: vertically downward, laterally left and right, and axially in tension. At 1000 pounds, the vertical tip deflection was approximately 10 inches downward, and the left and right lateral tip deflections were approximately 20 inches and 10 inches, respectively. No axial deformation was apparent.

Natural Frequency Response Test

8. Accelerometers were mounted on the end of the fixed section of the probe to measure probe vibrations in the vertical and lateral directions. Natural frequency response tests were conducted on the ground using these accelerometers and the method described in appendix D. The natural frequencies of the probe in the extended position were 3.75 hertz vertically and 2.80 hertz laterally.

Functional Tests

9. The aircraft was refueled on the ground through the aerial refueling system to verify system operation and to check for leaks. A drogue attachment was used on the fuel truck hose to connect to the probe refueling nozzle. The fuel pressure at the truck was 50 pounds per square inch and the resultant flow rate through the system was 900 pounds per minute (ppm). On the ground probe extension and retraction times were 22 and 27 seconds,

respectively. In flight at 110 knots indicated airspeed (KIAS) the extension and retraction times were 30 and 34 seconds, respectively.

Static Blade to Probe Clearance Checks

10. Measurements were taken on the ground with rotor blades stopped to determine minimum vertical clearance between the rotor blades and the extended probe. The clearances were a function of forward longitudinal cyclic trim actuator position, cockpit flight controls position, and whether hydraulics were ON or OFF. Results are presented in table 1.

Weight and Balance

11. The aircraft was weighed both prior to and after the installation of the aerial refueling system. The weight of the aerial refueling system was 502 pounds. Aircraft center of gravity (cg) movement with extension or retraction of the probe is primarily a function of aircraft gross weight. As aircraft gross weight increases, movement of the aircraft longitudinal cg with probe extension/retraction decreases. As weighed at 32,820 pounds, the aircraft cg movement was 1.7 inches forward with extension of the probe.

Electro-magnetic Interference Checks

12. The aerial refueling system was tested for electro-magnetic interference (EMI) with standard aircraft electrical systems to include communications and navigation systems. No EMI was found to be present during ground or in-flight tests.

CONTRACTOR FLIGHT TESTS

13. Contractor flight tests were performed to establish a limited flight clearance envelope. The flight tests included flight control inputs to excite refueling probe oscillations in hover and forward flight, tanker turbulence evaluation, and aerial refueling operations. The contractor flight tests were conducted from the Boeing Vertol (BV) manufacturing facility at Philadelphia, Pennsylvania and the BV flight test facility at Wilmington, Delaware. BV conducted ten flights for 8 4 total flight hours during the period 28 July to 4 August 198[illegible]. The resulting limitations under which the USAAEFA tests were conducted are presented in table 2. Several modifications were made to the CH-47D aerial refueling system while the contractor flight tests were in progress. The most significant modification was

Table 1. Static Blade to Probe Clearance

Forward Longitudinal Cyclic Trim Actuator Position	Cockpit Flight Control Position: Thrust Control	Cockpit Flight Control Position: Longitudinal Cyclic Control	Cockpit Flight Control Position: Lateral Cyclic Control	Cockpit Flight Control Position: Directional Control	Hydraulics	Clearance[1] (inches)
Ground	Ground Detent	Full Forward	Neutral	Neutral	On	6.0
Full Extend	Ground Detent	Full Forward	Neutral	Neutral	On	4.8
Full Extend	Ground Detent	Full Forward	Neutral	Full Left	On	-6.0
Ground	Ground Detent	Neutral	Neutral	Neutral	On	12.0
Full Extend	Ground Detent	Neutral	Neutral	Neutral	On	10.0
Full Extend	Ground Detent	Full Forward	3.9 inches left of neutral	Full Left	On	-11.5
Full Extend	Full Down	Full Forward	3.9 inches left of neutral	Full Left	On	-14.9
Full Extend	Ground Detent	1 inch forward of neutral	Neutral	Neutral	Off	-0.3
Full Extend	Detent	2 inches forward of neutral	Neutral	2 inches left of neutral	Off	-2.8
Ground	Detent.	Neutral	Neutral	Neutral	Off	1.0

NOTE:

[1] All blade tip to probe clearances were measured with probe extended. Negative clearance indicates that the blade would contact the probe.

Table 2. Flight Limitations

Parameter	Limit
Maximum forward airspeed, refueling probe retracted	140 KIAS
Maximum forward airspeed, refueling probe extended	130 KIAS
Maximum sideslip angle	Equivalent to 8° constant bank angle with zero heading change
Maximum climb power (dual engine)	Intermediate rated power (30 minute limit)
Maximum rate of descent	Autorotation
Maximum gross weight	44,500 pounds
Maximum density altitude	6000 feet
Maximum steady state cruise guide indicator reading	100% green arc
Takeoff and landing	Vertical (no rolling takeoffs or landings)
Meteorological conditions	Visual
Refueling hookups	Probe extended only
Refueling disconnects	No intentional assymetric disconnects (probe must be aligned with refueling hose)
Manual longitudinal cyclic trim operation	Aft actuator at 110 KIAS trim position and Forward actuator programmed to GND position
Automatic longitudinal cyclic trim operation	Automatic programming within the airspeed range.

the addition of refueling probe restraining cables designed to reduce excessive probe loads and oscillations. The results of the contractor flight tests will be published as a separate BV report.

AERIAL REFUELING

General

14. The USAAEFA aerial refueling test conditions are listed in table 3. Flight crews consisted of USAAEFA/contractor pilots for the first flight, USAAEFA pilots for flights two through four, and USAAEFA/user pilots for the last flight. An Air Force observer experienced in aerial refueling operations was onboard the test aircraft for the first three flights.

Aerial Refueling Procedures

15. Refueling procedures used during the test were standard Air Force procedures described in reference 7, appendix A. These procedures were used as a basis to develop the test aircraft checklist (app E). Photographs and diagrams of the relative positions of the tanker and receiver aircraft are presented in appendix F. The tanker and receiver aircraft rendezvous at a predetermined location time and track. The tanker assumes formation lead after overtaking the receiver aircraft to it's right, then maintains the desired airspeed, normally 110 KIAS, and prepares to transfer fuel. The receiver aircraft maintains the left observation position until cleared by the tanker for left refueling drogue contact. The left observation position is left of the tanker at approximately 45° from the tanker centerline, slightly above and aft so that the receiver probe tip is abeam a point 10 feet aft of the drogue. When the tanker gives the receiver clearance to contact the drogue and transfer fuel, the receiver moves down and right to the precontact position. The precontact position is aft of the drogue, with the probe tip in line and 5 to 10 feet behind the drogue. The receiver then moves forward so that the probe nozzle contacts the drogue with a positive rate of closure. Too small a closure rate will result in a soft contact, and the drogue will not seat properly on the probe nozzle. Approximately 140 pounds of force is required to properly seat the nozzle in the drogue receptacle. After contact, the receiver moves to the left refueling position to transfer fuel. This position is aft of the left wing tip of the HC-130P. The HC-130P fuel transfer hose is designed to automatically retract and extend as the receiver aircraft moves fore and aft. Fuel can be transferred when the refueling hose is extended

Table 3. Aerial Refueling Test Conditions[1]

Test	Gross Weight (lb)	Center of Gravity (FS)	Trim Indicated Airspeed (kt)	Density Altitude (ft)	Remarks
Tanker Turbulence Evaluation	31,500	324.8	110	6000	Probe retracted Longitudinal Cyclic Trim - AUTO
Refueling Operations[2]	28,720 to 33,790	324.0	110	6000	Probe extended Left, right observation positions Left, right precontact positions Left, right contact positions Left, right refueling positions Left, right disconnect positions Missed engagements Crossover

NOTES:

[1]Both AFCS-ON, 225 rotor RPM, flight in formation with an Air Force, HC-130P tanker aircraft. High frequency radio, heater and vent blower selected-OFF, all windows, doors, hatches and ramp closed.

[2]Conducted from both pilot and copilot seats. Longitudinal cyclic trim "AUTO" or "MANUAL" with forward actuator programmed to GND position and aft actuator programmed at the trim refueling speed.

between 56 feet and 76 feet from the tanker refueling pod. These distances are marked by five feet white bands on the refueling hose. When fuel transfer is complete, the receiver moves right and down, then straight back to disconnect. Approximately 420 pounds of force is required to unseat the nozzle from the drogue receptacle. The disconnect should be made five to ten feet above the contact position so that the drogue drops away from the receiver aircraft refueling probe. The receiver aircraft then moves to the left observation position. Crossover from left to right observation position is made approximately 50 feet above and 100 feet behind the tanker, to avoid tanker turbulence. Refueling operations from the right drogue are conducted in a similar manner as from the left drogue. The aerial refueling procedures used during this test were satisfactory.

Handling Qualities in Aerial Refueling Environment

Turbulence Evaluation Behind Tanker:

16. The effect of the turbulence created by the HC-130P tanker on the CH-47D was evaluated by stabilizing the test aircraft approximately 100 feet aft and high behind the tanker left wing tip, centerline, and right wing tip and flying downward through the turbulence while maintaining the 100 feet aft standoff distance. HC-130P gross weight during this evaluation was approximately 105,000 pounds. The turbulence caused an increase in airframe vibration and was perceived as low frequency buffeting. The highest level of vibration was experienced behind and below the HC-130P right wing tip (VRS 6). This required an approximate 10° left yaw attitude change to maintain trimmed flight. The lowest level of vibration was behind the HC-130P fuselage centerline. Aircraft control was maintained at all times during the tanker turbulence evaluation, and the pilot could easily fly out of the tanker turbulence. The flying qualities of the CH-47D in HC-130P tanker turbulence are satisfactory.

Aerial Refueling Operations:

17. Test aircraft handling qualities during aerial refueling operations were qualitatively evaluated behind both left and right refueling drogues and from both pilot and copilot seats. User pilot comments are presented in appendix G. A total of 27 drogue engagements were attempted, with 25 successful and two missed engagements. The tests were flown in smooth air with occasional light turbulence. Tanker turbulence caused vibration levels to be higher in the right precontact position (VRS 6) than in the left precontact position (VRS 5). Higher pilot workload was experienced when refueling from the right drogue

during the contact phase while moving to the right refueling position. An approximate one inch left pedal input producing a 5° left yaw attitude change was required to trim the aircraft into the HC-130P slipstream and maintain proper probe to drogue alignment (HQRS 5). Refueling operations from the left seat were slightly more difficult than from the right seat during the precontact and contact phases because probe and drogue hose alignment was more difficult to perceive. The right seat pilot could verbally assist the left seat pilot to properly align the probe. No control position trim changes or aircraft trimmed attitude changes were perceived by the pilots during probe extension or retr .on, or du..ng fuel transfer operations. The tip of the ret..ling probe on the test aircraft was 8 feet 7 inches further in front of the nose of the aircraft than the probe on the HH-53 helicopter flown during pilot training. The longer probe, combined with basic aircraft flying qualities and control system characteristics, made drogue contact significantly easier in the CH-47D. Aircraft attitude changes necessary to correct any probe to drogue misalignment during the drogue contact maneuver required only small control inputs. Field-of-view was adequate during all phases of aerial refueling operations except when flying in the right refueling position from the right pilot seat or in the left refueling position from the left pilot seat. In these instances, the opposite windshield post obstructed the pilot's view of the refueling hose in some seating positions when the receiver was slightly out of the proper refueling position. This could be corrected by changing the pilot or copilot seat position. Neutrally damped vertical and lateral probe tip oscillations of approximately ± 2 inches at the 1/rev rotor frequency, occurred in smooth air with the probe extended. These oscillations did not adversely affect aerial refueling operations. Within the scope of this test, the flying qualities of the CH-47D are satisfactory for aerial refueling.

Longitudinal Cyclic Trim Operation:

18. Aerial refueling tests were conducted to qualitatively compare aircraft handling qualities with longitudinal cyclic trim (LCT) in both the automatic (AUTO) and manual modes of operation. Pilot workload was increased and main rotor tip path plane (TPP) to probe clearance was decreased during aerial refueling operations with LCT selected to AUTO. To maintain the precontact position in LCT AUTO mode, longitudinal cyclic control inputs of $\pm 1/2$ inch approximately every 2 seconds were required to compensate for neutrally damped aircraft pitch oscillations (HQRS 6). Nominal probe to TPP clearance was estimated to be 6.2 feet with transient excursions to 6.0 feet in very light turbulence Aerial refueling operations were then performed with LCT in the manual mode at 110 KIAS. The aft LCT actuator remained in the

110 KIAS trim position, and the forward LCT actuator was programmed to the ground operating position (GND). The change in forward LCT actuator position from 110 KIAS trim position to GND, caused a change in trimmed pitch attitude of approximately two degrees nose down which was not objectionable. Aircraft pitch oscillations were not apparent although infrequent small control inputs necessary to maintain relative position with the drogue were required (HQRS 4). Nominal probe to TPP clearance was estimated to be 7.4 feet with transient excursions to 5.6 feet. The user evaluation was conducted in the LCT manual configuration. Further testing of the production aerial refueling system should be accomplished to determine the optimum LCT actuator position for aerial refueling operations throughout the mission center of gravity and gross weight range.

Airspeed System Characteristics:

19. The ship's airspeed system indicated 110 KIAS in the observation and precontact positions. In the refueling position, airspeed was nominally 105 KIAS with frequent excursions of ±5 knots and occassional excursions of ±15 knots. When the aircraft was flown approximately 40 feet behind the precontact position, airspeed indications were as high as 130 KIAS. The changes in indicated airspeed were a function of test aircraft position relative to the tanker turbulence pattern and did not adversely affect refueling operations.

In-flight Loads

20. Probe bending moments were monitored during refueling operations and were used to derive tip loads as described in appendix D. Nominal tip loads when engaged with the drogue during normal refueling operations (including contact and disconnect), were 350 pounds in the downward and lateral directions. A maximum tip load of 750 pounds downward was observed while the test aircraft was out of trim approximately 1/2 ball width on the turn and slip indicator. In smooth air at the observation position, Cruise Guide Indicator (CGI) levels were 40 percent at a nominal gross weight of 31,000 pounds and 110 KIAS. The CGI was at acceptable levels throughout refueling operations; nominally 50 to 60 percent with some spikes above 100 percent in the precontact and refueling positions.

Aerial Refueling Systems Operation

General:

21. The CH-47D aerial refueling systems operation was evaluated throughout this test. The aerial refueling system cockpit controls

were easy to operate in flight. Average probe extension time at 110 KIAS was 30 seconds and average retraction time was 34 seconds. The probe failed to retract on several of the early test flights, and the test aircraft was landed with the probe extended. This malfunction was corrected on later flights. A total of 7645 pounds of fuel was transferred from the tanker to the test aircraft during the contractor and USAAEFA evaluations. One fuel transfer test, performed by USAAEFA, was from minimum fuel (1750 pounds) to the maximum that the CH-47D would accept (5070 pounds tranferred). Rate of fuel transfer varied from 600 ppm to 1000 ppm. The CH-47D automatic fuel shutoff valves operated properly and stopped fuel flow to each fuel cell when the cell was full. Within the scope of this test, the operation of the prototype CH-47D aerial refueling system was satisfactory.

Restraint Cables:

22. Refueling probe restraint cables were installed to reduce excessive probe loads and oscillations. The restraint cables prevented maintenance personnel from lowering the forward pylon right work platform. Excessive maintenance would be required in an operational unit to adjust and check cable tension. If a restraint cable were to fail in flight, aerial refueling would not be possible due to excessive probe tip oscillations and structural failure may result from excessive probe loads. Additionally, there is a high probability that the upper restraint cable would contact the rotor blades and definitely the fuselage if the cable failed near the forward end of the refueling probe stationary tube. The requirement for refueling probe restraint cables is a shortcoming that should be corrected in the production design.

Internal Fuel Tanks:

23. No provisions were made in the refueling system design tested to refuel internal cabin fuel tanks in flight. Internal cabin fuel tanks will be necessary for the CH-47D to achieve greater unrefueled range. The inability to refuel internal cabin fuel tanks in flight is a shortcoming that should be corrected in the production design.

Refueling Selected Cells:

24. Individual fuel cells could not be selectively refueled in flight. This capability may be required for center of gravity control during aerial refueling or for fuel balancing. The inability to selectively refuel individual fuel cells in flight is a shortcoming that should be corrected in the production design.

Shutoff Valve Check:

25. The primary fuel shutoff valves in each fuel cell were checked for proper operation by activating all primary shutoff valves and observing that fuel flow from the tanker to the receiver stopped. The secondary shutoff valves were checked in the same manner. The check could not be performed on the primary and secondary shutoff valves simultaneously. If a primary shutoff valve is inoperative, and a secondary shutoff valve is inoperative in a different fuel cell, aerial refueling could be safely performed. However, the pilot will not know if both valves in a single cell have failed, which would result in potential fuel cell overpressurization. The inability to simultaneously check the primary and secondary fuel shutoff valve operation is a shortcoming that should be corrected in the production design.

Fuel Flow:

26. Fuel flow is monitored during the fuel shutoff valves check by observing the totalizer on the fuel quantity gauge. This was not an accurate check to determine if refueling system fuel flow had stopped. The pilot must monitor the totalizer for 15 to 30 seconds to determine the totalizer trend (whether fuel quantity is increasing or decreasing). Total fuel quantity may decrease or increase slowly if fuel flow rate to the engines is approximately equal to fuel flow through a defective dual fuel cell shutoff valve. The defective dual fuel cell shutoff valve may not be detected, and fuel cell overpressurization may result. The inability to accurately monitor fuel flow during the fuel shutoff valves check is a shortcoming that should be corrected in the production design.

Cockpit Fuel Gage:

27. The pressure refueling power control switch for ground refueling is located on the pressure refueling system control panel in the right forward landing gear bay. When the switch is in the PWR ON position, and the aerial refueling system power switch is positioned to ARM, the cockpit fuel quantity gauge is inoperative, regardless of the position of the REFUEL STATION switch on the overhead cockpit fuel control panel. If the pressure refueling system power control switch is inadvertantly positioned to PWR ON prior to takeoff, the pilot will be unable to monitor fuel quantity during aerial refueling operations. The loss of cockpit fuel quantity indication when the pressure refueling power control switch is positioned to PWR ON and the aerial refueling system power switch is positioned to ARM is a shortcoming that should be corrected in the production design.

CONCLUSIONS

GENERAL

28. The following conclusions were reached upon completion of this evaluation:

a. Aerial refueling of the CH-47D helicopter is feasible.

b. Six shortcomings, all of which related to the prototype aerial refueling system, were identified for correction in the production design.

SHORTCOMINGS

29. The following shortcomings of the CH-47D prototype aerial refueling system were identified and are listed in order of importance:

a. The requirement for refueling probe restraint cables (para 22).

b. The inability to refuel internal cabin fuel tanks in flight (para 23).

c. The inability to selectively refuel individual fuel cells in flight (para 24).

d. The inability to simultaneously check the operation of the primary and secondary fuel shutoff valves (para 25).

e. The inability to accurately monitor fuel flow during the fuel shutoff valves check (para 26).

f. The loss of cockpit fuel quantity indication when the pressure refueling power switch is positioned to PWR ON and the aerial refueling system power switch is positioned to ARM (para 27).

RECOMMENDATIONS

GENERAL

30. The shortcomings listed in paragraph 28 should be corrected in the CH-47D production aerial refueling system.

RECOMMENDED TESTS ON A PRODUCTION AERIAL REFUELING SYSTEM

31. As requested in reference 4, appendix A, the following tests are recommended for qualification of a CH-47D production aerial refueling system:

a. All tests included in the US Army Aviation Engineering Flight Activity Test Plan, Project No. 85-09 (ref 2, app A) including tests to optimize longitudinal cyclic trim actuator position in the manual mode (para 19).

b. Aerial refueling flight tests over the full mission gross weight and center of gravity envelope.

c. Aerial refueling operations at night.

d. Aerial refueling operations with the refueling probe retracted.

e. Limited level flight and hover performance testing.

f. Single-engine and single AFCS aerial refueling operations.

g. Aerial refueling operations with US Air Force, US Marine Corps, and any other tanker aircraft that may be utilized during actual missions.

APPENDIX A. REFERENCES

1. Letter, AMSAV-ED, 24 June 1985, subject: In Flight Refueling Evaluation of the CH-47D Helicopter.

2. Test Plan, USAAEFA Project No. 85-09, *In Flight Refueling Evaluation of the CH-47D Helicopter*, July 1985.

3. Letter, AMSAV-ED, 5 August 1985, Data Fax Aug 05 '85, 15:03 p.m., subject: In Flight Refueling Evaluation of the CH-47D Helicopter, USAAEFA Project No. 85-09.

4. Letter, AMSAV-ED, 5 August 1985, Data Fax Aug 06 '85, 07:01 p.m., subject: In Flight Refueling Evaluation of the CH-47D Helicopter, USAAEFA Project No. 85-09.

5. Technical Manual, TM 55-1520-240-10, *Operator's Manual Army CH-47D Helicopter*, 10 November 1982 with change 5, 8 March 1985.

6. Letter, AMSAV-E, 5 August 1985, subject: Airworthiness Release for Flight Evaluation of CH-47D Helicopter S/N 84-24159 with Aerial Refueling System Installed.

7. Flight Manual, T.O. 1-1C-1-20, United States Air Force, *Flight Crew Air Refueling Procedures, MC/HC-130, HH-3 and HH-53*, 1 May 1978 with change 6, 30 November 1984.

APPENDIX B. DESCRIPTION

TEST HELICOPTER

1. The test aircraft was a production configuration CH-47D, USA S/N 84-24159. It was modified to incorporate a Boeing Vertol designed and manufactured prototype aerial refueling system. These modifications include: structural rework, installation of a refueling control panel and wiring, fuel system modifications, and installation of an aerial refueling probe. The test aircraft also had an airborne data acquistion system and ballast boxes installed in the cabin, and a video camera was mounted on the right side of the companionway. A detailed description of the CH-47D may be found in the operator's manual (ref 5, app A).

AERIAL REFUELING PROBE

2. The aerial refueling probe is a two-piece, single extension telescoping tube arrangement with inner and outer shells constructed of graphite composite. The stationary tube has a 10 inch outside diameter while the sliding inner tube has a 9 inch outside diameter. The sliding inner tube provides a fluid actuator system for both extension and retraction modes. It also provides a fluid flow path for fuel transfer during aerial refueling. The principle dimensions of the aerial refueling probe are presented in figure 1. The refueling probe assembly is shown retracted and extended in photos 1 and 2, respectively. The probe was mounted on the right side of the fuselage with attachments at fuselage stations (FS) 95 and 160, waterline (WL) -36.0, and right buttline (RBL) 57.75. Two probe restraint cables were installed. The cables were attached by fixed links to an aluminum alloy collar mounted on the forward end of the stationary tube. The restraint cables were attached to the aircraft fuselage by a mount added to the forward transmission support structure (FS 98, WL 65.0 and RBL 27.0) and a mount that replaced the forward aircraft jack point (FS 95, WL -36.0 left buttline (LBL) 18 5). The restraint cables were preloaded to a value that provided 70,000 inch-pounds vertical and left lateral refueling probe bending moment. Nylon strap safety restraints were wrapped around the stationary tube and attached to the fuselage at FS 95 and 160. The safety restraints normally carried no loads, but were designed to restrain the probe if the primary mounts failed. The refueling nozzle (photo 3) was attached to the forward end of the sliding inner tube by a frangible fitting. The frangible fitting provided an additional 1.75 inches of probe to nozzle clearance, and prevented the probe from contacting the refueling drogue spokes when the nozzle was seated in the drogue. The frangible fitting was designed to shear if the design limit of probe tip lateral or vertical loads (1000 pounds) were exceeded. Two internal

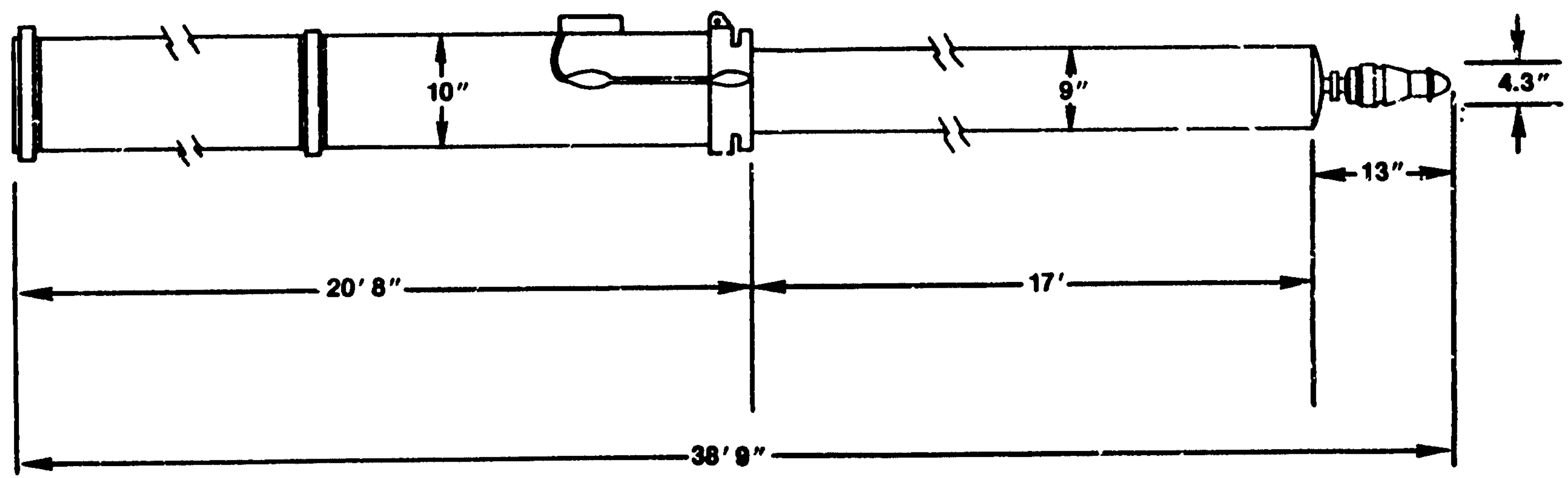


Figure 1. Aerial Refueling Probe Principal Dimensions

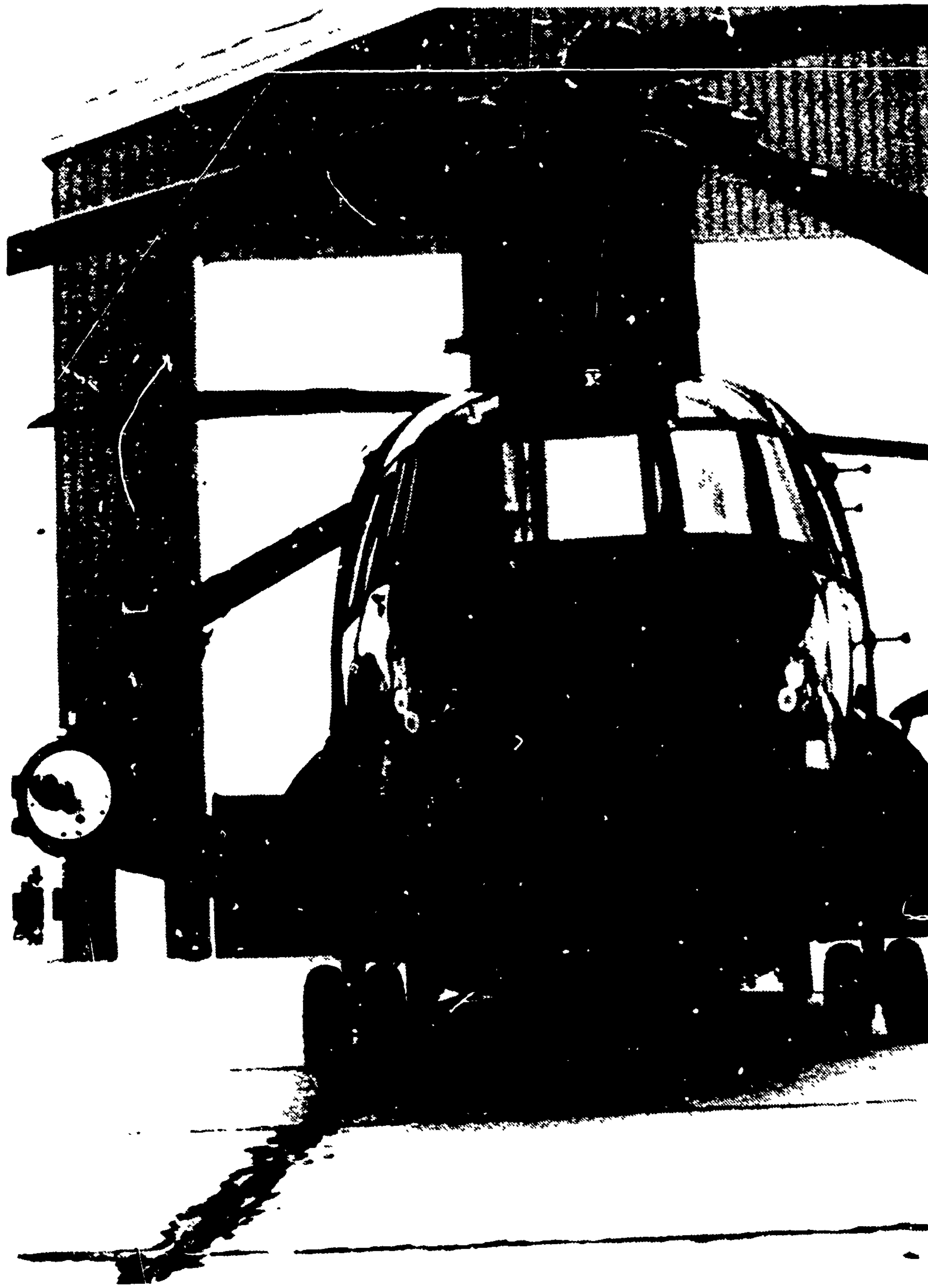


Photo 1. Probe Retracted

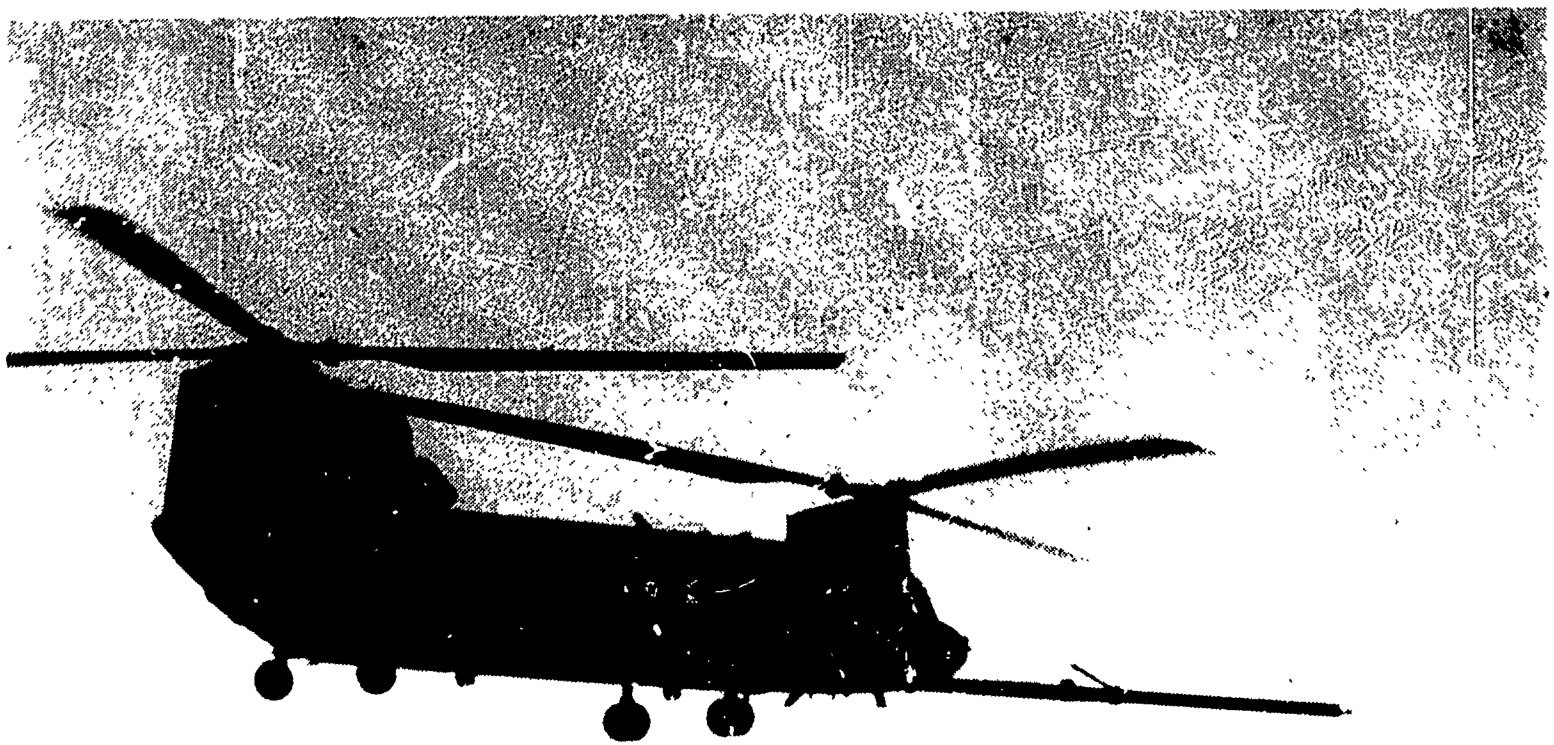


Photo 2. Probe Extended

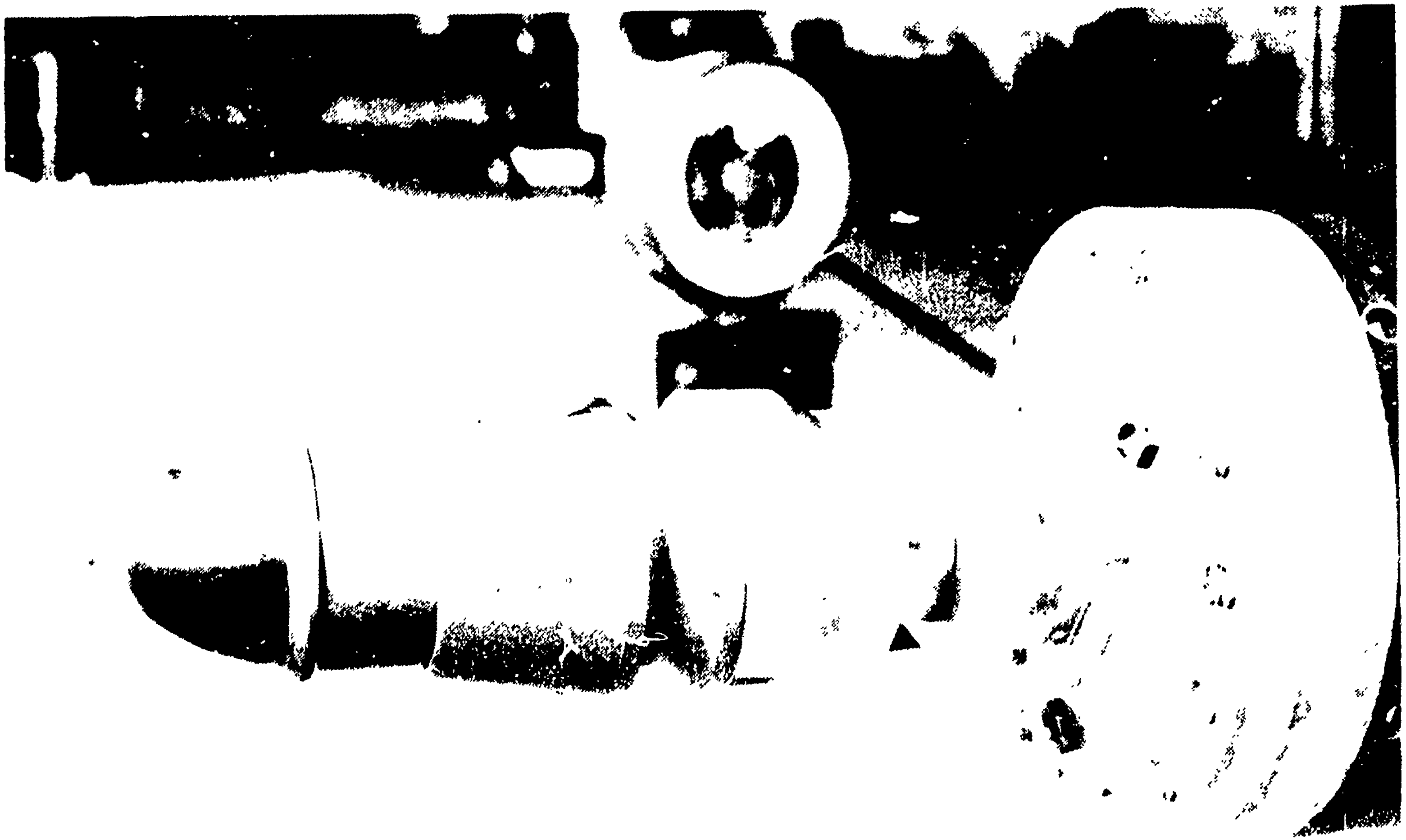


Photo 3. Probe Nozzle with Frangible Fitting

shutoff valves were installed to stop fuel flow from the probe and from the tanker refueling drogue if the nozzle sheared. The nozzle was designed to rotate freely in either direction in the event that contact was made with a rotating drogue. Extend and retract magnetic proximity switches detect when the probe is in the full extend or full retract position. Extend and retract locking pins actuated by electro-mechanical-servos lock the sliding inner probe in either the fully extended or retracted position.

AERIAL REFUELING SYSTEM OPERATION

3. The aerial refueling system taps into the aircraft production pressure refueling system (fig. 2) in the dry bay on the right side of the aircraft between the forward auxiliary and main fuel cells. Two additional fuel boost pumps located between the aft right auxiliary and right main fuel cells supply fuel under pressure from the right main fuel cell providing the motive power for extension and retraction of the refueling probe. Fuel lines from these boost pumps to the forward dry bay and from the dry bay to the aft end of the refueling probe are routed externally along the bottom and right side of the fuselage. The aerial refueling system components located in the right dry bay are shown in photo 4. The aerial refueling system electronic sequencing unit is located under the cabin soundproofing at FS 232. A cockpit mounted control panel provides the pilot with the means of selecting the extend and retract modes and testing the primary and secondary fuel shutoff valves. The aerial refueling system is designed to operate at a maximum of 315 gallons per minute with 55 pounds per square inch (psi) maximum pressure. The complete system including all components weighs 502 pounds. The operation of the various components of the aerial refueling system is shown in table 1 and explained in more detail in the following paragraphs.

EXTEND CYCLE

4. The refueling probe is extended by fuel pressure (fig.3). When the extend cycle is initiated, the retract lock is electromechanically released. Fuel from the right main fuel cell is routed through two fuel boost pumps connected in series and pressurized to approximately 70 psi. The transfer gate valve is closed to prevent the boost pump pressurized fuel from returning to the production pressure refueling system. The pressurized fuel is routed to the probe inner chamber, and hydraulically extends the inner sliding tube. Trapped fuel from the retract

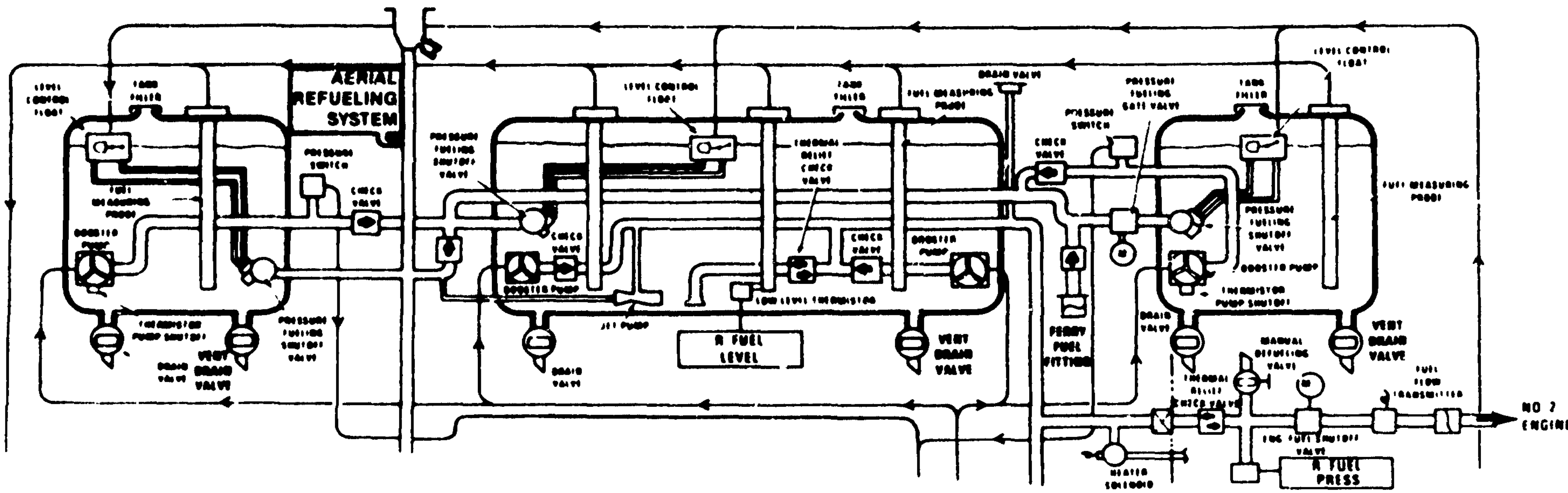


Figure 2. CH-47D Production Refueling System

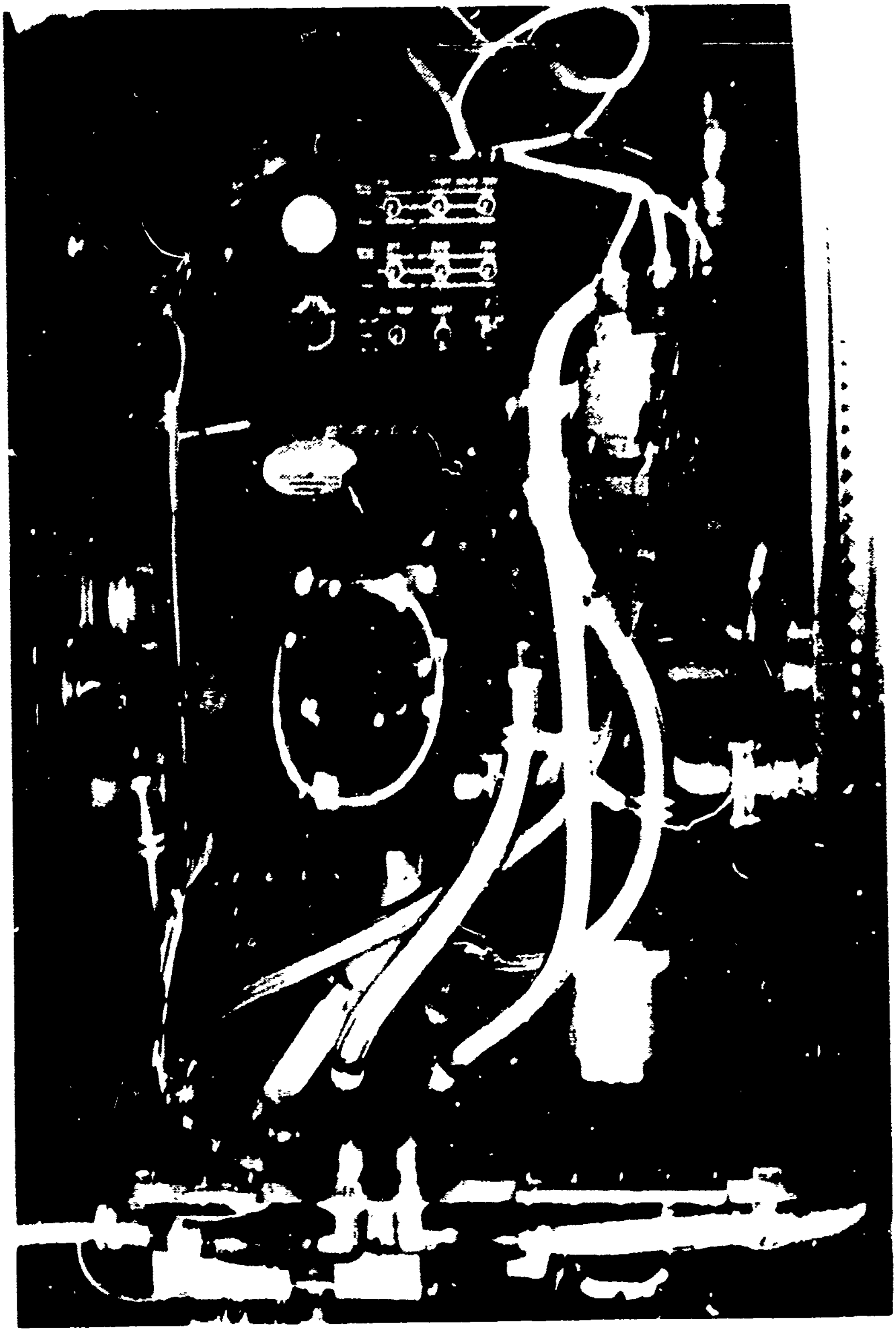


Photo 4. Pressure Refueling Station

Table 1. Aerial Refueling System Operation

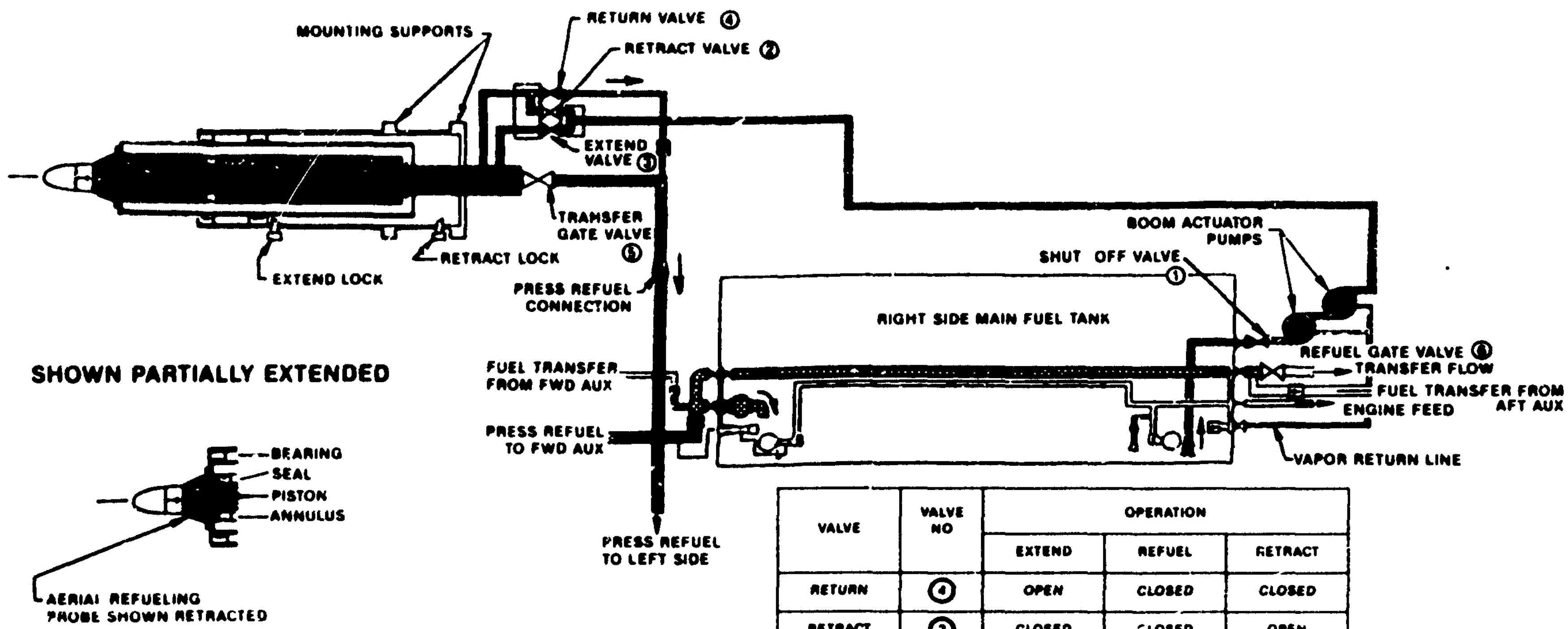
Mode of Operation[1]	Proximity Switches		Mechanical Lock Solenoids[2]		Valves (O open, X closed)						Pumps		Cockpit Lights		Remarks
	Retract	Extend	Retract	Extend	1 Shut off	2 Re-tract	3 Ex-tend	4 Re-turn	5 Trans-fer Gate Valve	6 Re-fuel	1	2	Retract	Ready	
PWR SWI OFF PROBE SWI RETRACT	OFF	OFF	NO PWR	NO PWR	X	X	X	O	X	X	OFF	OFF	OFF	OFF	Probe full retracted
PWR SWI TO ARM PROBE SWI RETRACT	ON	OFF	NO PWR	NO PWR	O	O	X	X	X	X	OFF	OFF	ON	OFF	Probe full retracted
PWR SWI ARM PROBE SWI TO EXTEND	OFF	OFF	PWR ON	NO PWR	O	X	O	O	X	X	ON	ON	OFF	OFF	Probe extending
PWR SWI ARM PROBE SWI EXTEND	OFF	ON	NO PWR	NO PWR	O	X	X	X	O	O	OFF	OFF	OFF	ON	Probe full extended
PWR SWI ARM[3] PROBE SWI TO RETRACT	OFF	OFF	NO PWR	PWR ON	O	O	X	X	O	X	ON	ON	OFF	OFF	Probe retracting
PWR SWI ARM PROBE SWI RETRACT	ON	OFF	NO PWR	NO PWR	O	O	X	X	O	X	OFF	OFF	ON	OFF	Probe full retracted
5 minute 20 second delay	ON	OFF	NO PWR	NO PWR	O	O	X	X	X	X	OFF	OFF	ON	OFF	Probe full retracted. Valve change occurs 5 min. 20 sec. after full retract
PWR SWI TO OFF AFTER 5 minute 20 second delay	ON	OFF	NO PWR	NO PWR	X	X	X	O	X	X	OFF	OFF	OFF	OFF	Valve change occurs when PWR SWI is turned to OFF position
PWR SWI TO OFF IMMEDIATELY AFTER FULL RETRACT	ON	OFF	NO PWR	NO PWR	X	X	X	X	O	X	OFF	OFF	OFF	OFF	Probe full retracted
AFTER PWR SWI TO OFF	ON	OFF	NO PWR	NO PWR	X	X	X	O	X	X	OFF	OFF	OFF	OFF	Probe full retracted Valve change delayed 5 mins. 20 secs. after full retract
PWR SWI ARM PROBE SWI RE-TRACTED GATE VALVE OVER-RIDE SWI CLOSE	ON	OFF	NO PWR	NO PWR	O	X	X	O	X	X	OFF	OFF	OFF	OFF	Probe full retracted Conditions shown are before 5 min. 20 sec delay
TRANSFER GATE VALVE OVERRIDE SWI OPEN	ON	OFF	NO PWR	NO PWR	X	X	X	O	O	X	OFF	OFF	OFF	OFF	
PWR SWI ARM PROBE SWI EXTEND TRANSFER GATE VALVE OVERRIDE SWI CLOSE	OFF	ON	NO PWR	NO PWR	X	X	X	X	O	X	OFF	OFF	OFF	OFF	Probe full extended

NOTES:

[1] Transfer gate valve override switch and proximity override switch are both in normal position except where noted

[2] Both mechanical locks are spring loaded to the lock position and solenoid actuated to the unlock position

[3] The aerial refueling system boost pumps are not energized for 2 seconds after probe switch is moved to RETRACT to allow the extend locking pin to move to the unlock position.



VALVE	VALVE NO	OPERATION		
		EXTEND	REFUEL	RETRACT
RETURN	4	OPEN	CLOSED	CLOSED
RETRACT	2	CLOSED	CLOSED	OPEN
EXTEND	3	OPEN	CLOSED	CLOSED
TRANSFER GATE	5	CLOSED	OPEN	OPEN
SHUT OFF	1	OPEN	CLOSED	OPEN
PUMPS		RUNNING	STOPPED	RUNNING
REFUEL GATE VALVE	6	CLOSED	OPEN	CLOSED

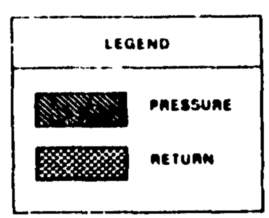


Figure 3. Extend Cycle

annulus is routed into the pressure refuel system. The probe is then locked in the full extend position and the boost pumps are automatically shut off.

REFUELING

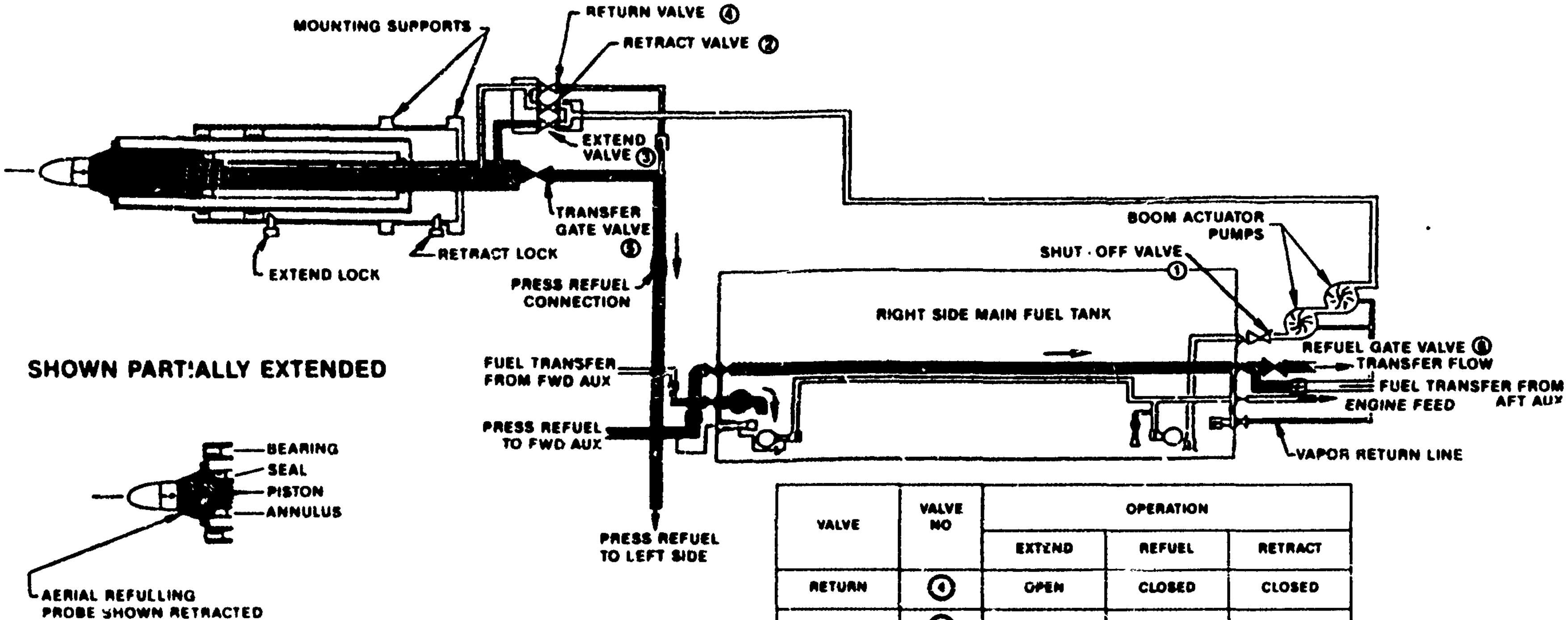
5. Fuel from the tanker is routed from the tanker drogue receptacle through the probe nozzle, inner probe chamber and transfer gate valve into the production pressure refueling system (fig. 4). The two production refueling valves between the main and aft auxiliary fuel cells are opened to allow fuel to flow into the aft auxiliary fuel cells. Fuel flow is automatically stopped by dual fuel cell shutoff valves when the respective fuel cell is full.

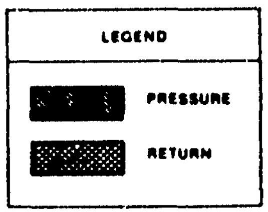
RETRACT CYCLE

6. The refueling probe is retracted by fuel pressure (fig. 5). The extend lock is electro-mechanically released by placing the probe extend/retract switch to retract. After a two second time delay, the two boost pumps are energized, and pressurized fuel is routed to the probe retract annulus, hydraulically retracting the inner sliding tube. Fuel from the probe inner chamber is routed into the production pressure refueling system. During aerial refueling operations, the retract cycle is normally not initiated until two minutes have elapsed after filling all fuel cells, so that sufficient fuel has been consumed by the aircraft engines to provide the fuel cell capacity to accept the fuel remaining in the probe inner chamber. The probe fully retracts and is locked in place by the retract lock. The transfer gate valve remains open 5 minutes 20 seconds. This sequence is designed so that fuel can be evacuated from the probe inner chamber by the production fuel system jet pumps. After a 5 minute 20 second time delay, the transfer gate valve closes and the return valve opens so that the retract annulus can be evacuated. The time delay mechanism is operational even if the refueling system power switch is OFF.

COCKPIT CONTROLS

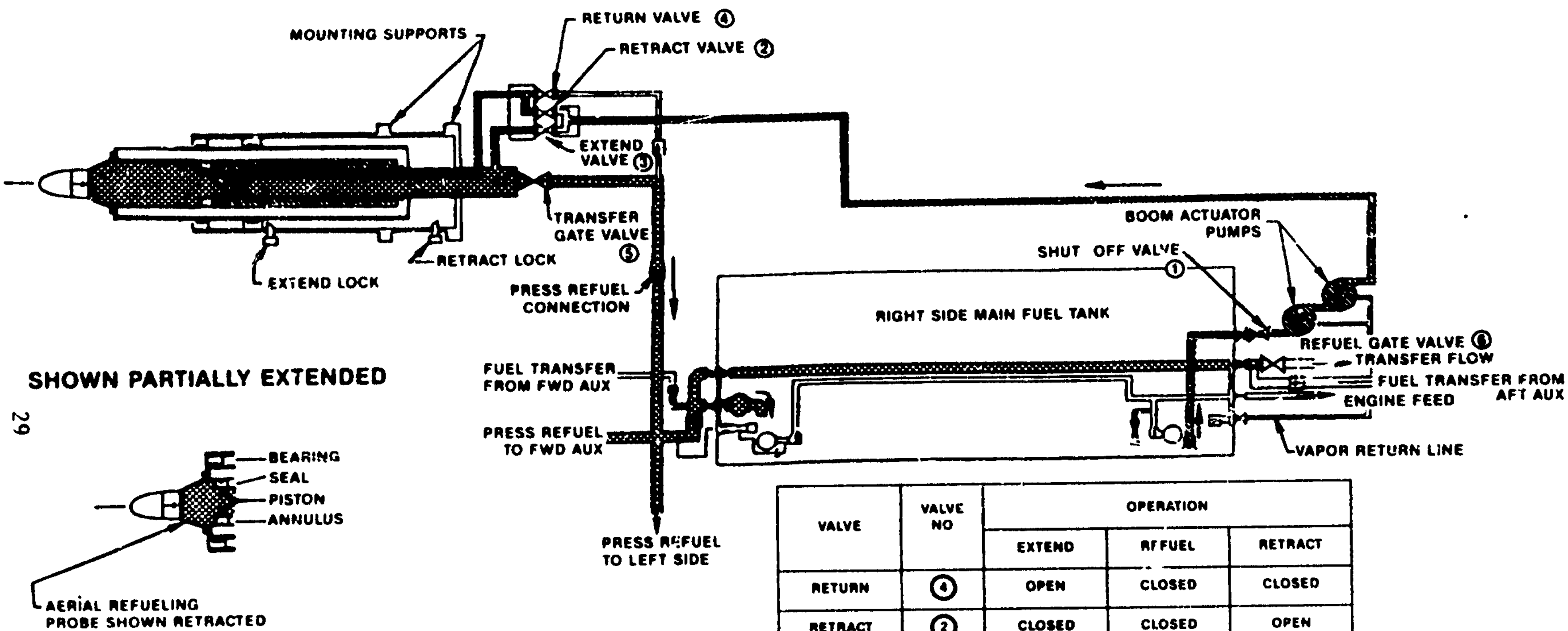
7. The aerial refueling system cockpit control panel, mounted on the center pedestal, is shown in photo 5. The function of each control or indicator is as follows:

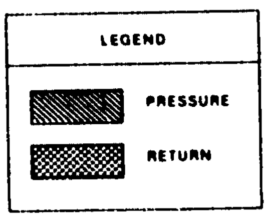




VALVE	VALVE NO	OPERATION		
		EXTEND	REFUEL	RETRACT
RETURN	4	OPEN	CLOSED	CLOSED
RETRACT	2	CLOSED	CLOSED	OPEN
EXTEND	3	OPEN	CLOSED	CLOSED
TRANSFER GATE	5	CLOSED	OPEN	OPEN
SHUT - OFF	1	OPEN	CLOSED	OPEN
PUMPS		RUNNING	STOPPED	RUNNING
REFUEL GATE VALVE	6	CLOSED	OPEN	CLOSED

Figure 4. Refueling





VALVE	VALVE NO	OPERATION		
		EXTEND	REFUEL	RETRACT
RETURN	4	OPEN	CLOSED	CLOSED
RETRACT	2	CLOSED	CLOSED	OPEN
EXTEND	3	OPEN	CLOSED	CLOSED
TRANSFER GATE	5	CLOSED	OPEN	OPEN
SHUT OFF	1	OPEN	CLOSED	OPEN
PUMPS		RUNNING	STOPPED	RUNNING
REFUEL GATE VALVE	6	CLOSED	OPEN	CLOSED

Figure 5. Retract Cycle

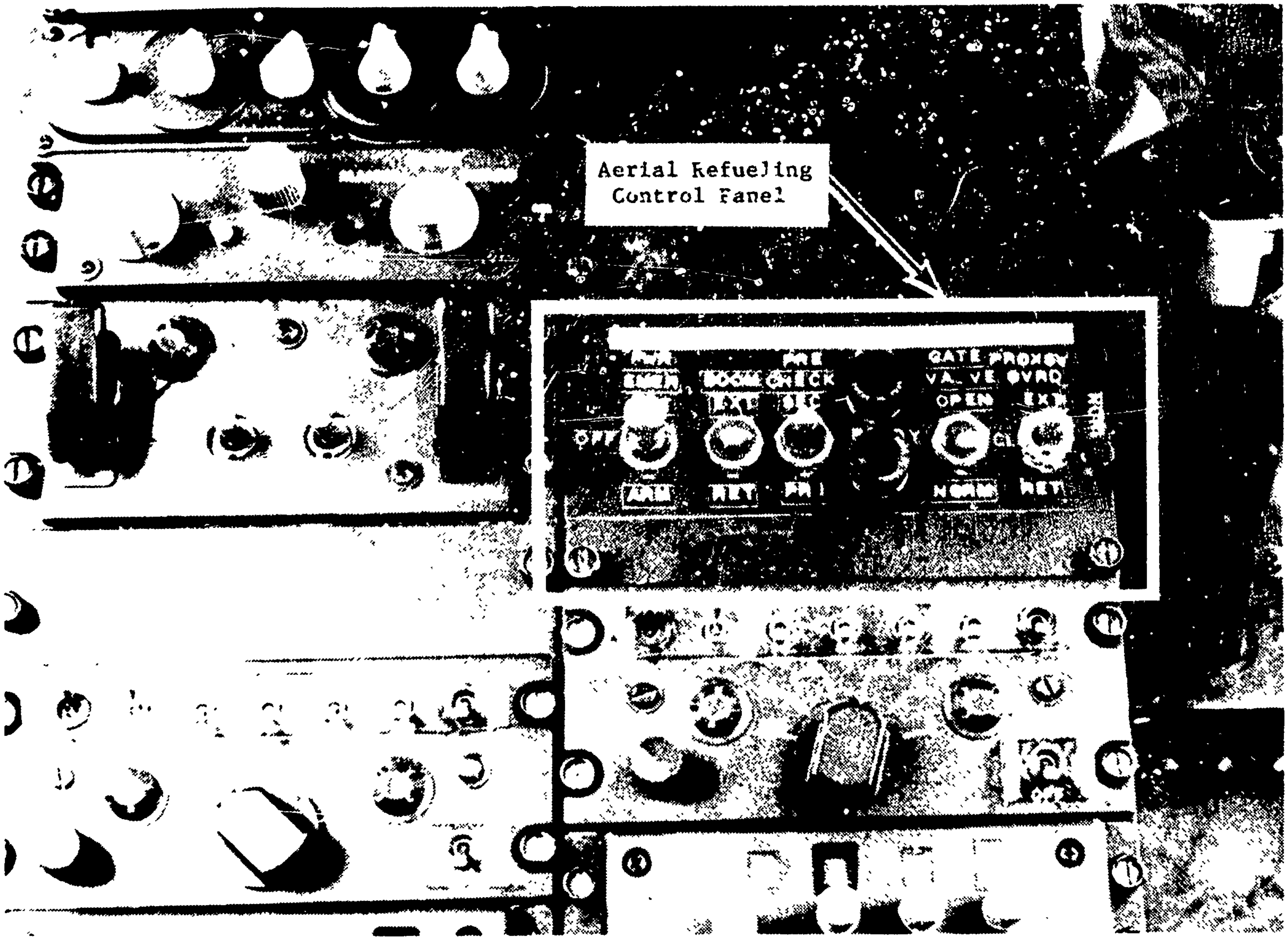


Photo 5. Cockpit Control Panel

a. PWR switch - 3 position

(1) EMER EXT -not used; however, in the prototpye design this posiiton interrupts the 5 minute 20 second delay cycle and resets refueling valve logic circuit

(2) OFF - removes electrical power from the control panel

(3) ARM - applies electrical power to the control panel

b. BOOM switch - 2 position

(1) EXT - boom will extend if PWR switch is in the ARM position

(2) RET - boom will retract if PWR switch is in the ARM position

c. PRE CHECK - 3 position

(1) SEC - closes all fuel cell secondary shutoff valves

(2) center position (unlabeled) - fuel cell shutoff valves function automatically

(3) PRI - closes all fuel cell primary shutoff valves

d. The yellow RET and green READY lights indicate that the probe is retracted or extended, respectively.

e. GATE VALVE switch - 3 position

(1) OPEN - designed to open fuel transfer gate valve

(2) CL - designed to close fuel transfer gate valve

(3) NORM - fuel transfer gate valve is sequenced automatically

f. PROX SW OVRD switch - 3 position

(1) EXT - designed to override the refueling probe extend proximity switch and apply a probe full extended signal to the sequencing unit

(2) NORM - refueling system is sequenced automatically

(3) RET - designed to override the refueling probe retract proximity switch and send a probe full retracted signal to the sequencing unit

g. Three circuit breakers labeled PUMP 1, PUMP 2, AND REFUEL CONT are mounted on the number two power distribution panel.

APPENDIX C. INSTRUMENTATION

1. Test instrumentation was installed, calibrated and maintained by the Boeing Vertol Company. Data was recorded by onboard magnetic tape and via telemetry to a ground monitoring station.

2. Parameters measured during this evaluation were:

Airspeed (knots)
Rotor 1/rev counter
Sensitive rotor speed (rpm)
Time (hours:minutes:seconds)
Event counter
Cruise guide indicator level (%)
Ambient air temperature (deg C)
Altitude (feet)
Acceleration, Vertical, Fuselage Station (FS) 50, right buttline (BL) 30 (g)
Acceleration, Lateral, FS 50, Right BL 30 (g)
Acceleration, Vertical, tip of probe fixed section (g)
Acceleration, Lateral, tip of probe fixed section (g)
Probe fuel pressure - extend (psig)
Probe fuel pressure - retract (psig)
Probe bending moment, vertical, FS 90 (in-lb)
Probe bending moment, lateral, FS 90 (in-lb)
Probe tension, axial, FS 90 (lb)
Top strut inner bending moment, lateral, FS 95 (in-lb)
Top strut outer bending moment, lateral, FS 95 (in-lb)
Diagonal strut tension, axial, FS 95 (lb)
Bottom strut tension, axial, FS 95 (lb)
Lower link tension, axial, FS 160 (lb)
Probe restraint cable tension, vertical cable (lb)
Probe restraint cable tension, lateral cable (lb)

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

STATIC LOAD TESTS

1. Static load tests were conducted on the ground with the probe extended to measure tip deflection and verify structural integrity at design limit tip loads of 1000 pounds. Loads were applied to the tip in increments of approximately 65 pounds in four directions; vertically, downward, laterally left and right, and axially in tension. The aircraft was not on jacks so measurements were taken (with respect to a fixed reference) at two locations on the airframe to account for aircraft movement due to tip loads. The actual tip deflection due to tip load was determined by taking the difference between the total tip deflection and the tip deflection due to aircraft movement.

NATURAL FREQUENCY RESPONSE TEST

2. Accelerometers were mounted on the end of the fixed section of the probe and were used to determine the natural frequency of the probe in the vertical and lateral directions. With the probe in the extended position, loads were applied manually at the tip to induce oscillation and the number of cycles per second were counted using the accelerometer data. The natural frequency data were used to predict aircraft and pilot induced probe oscillations.

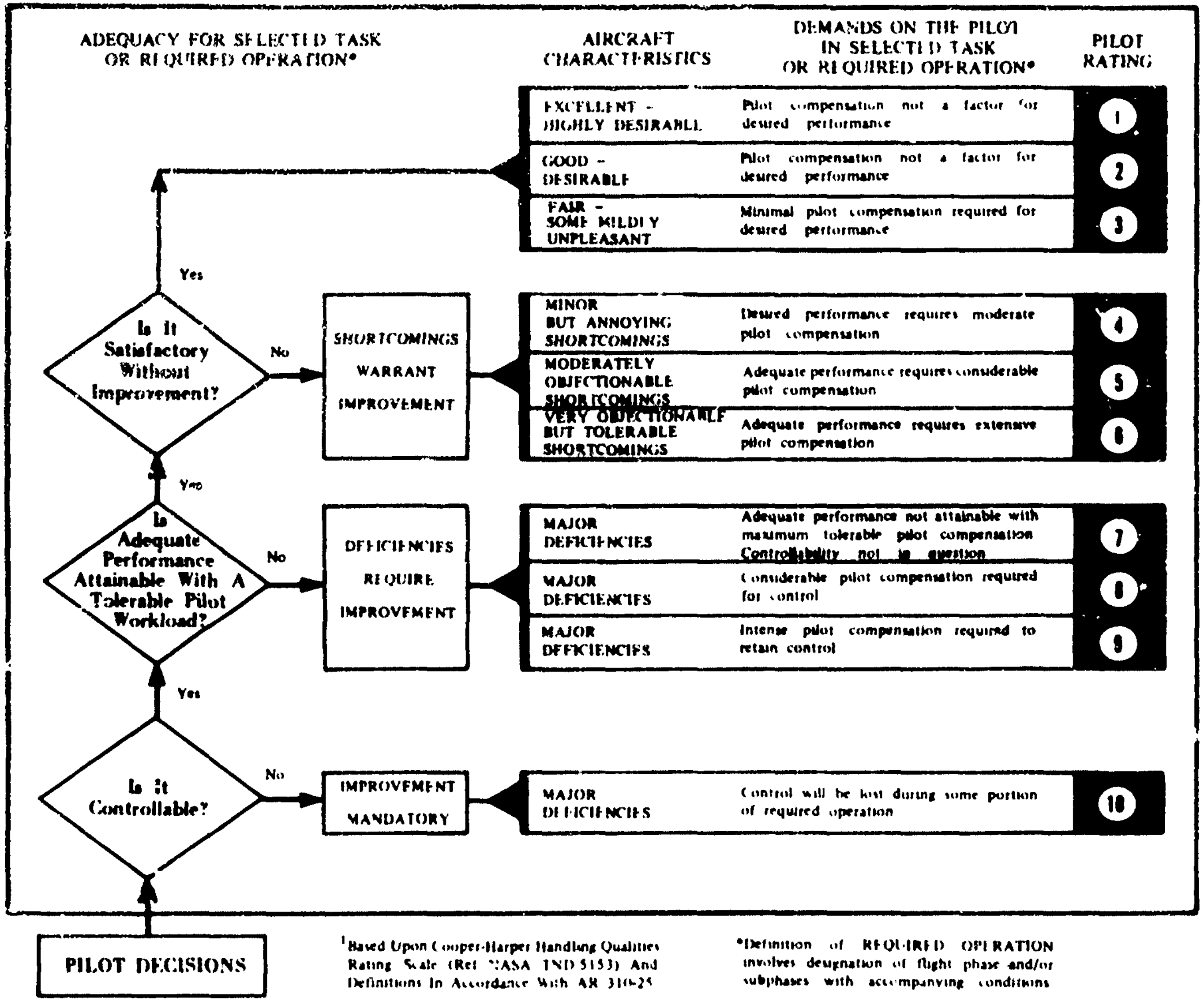
IN-FLIGHT TIP LOADS

3. Strain gages were mounted on the fixed section of the probe at fuselage station 90 to measure vertical and lateral probe bending moments. These strain gages were calibrated in conjunction with the static load tests and the resultant relationship between probe bending moment and tip loading was used to attain in-flight tip loads.

DEFINITIONS

Qualitative Rating Scales

4. A Handling Qualities Rating Scale was used to augment pilot comments and is presented as figure 1. The Vibration Rating Scale was used to augment pilot comments on vibrations and is presented as figure 2.



[1]Based Upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TND 5153) And Definitions In Accordance With AR 310-25

*Definition of REQUIRED OPERATION involves designation of flight phase and/or subphases with accompanying conditions

Figure 1. Handling Qualities Rating Scale

DEGREE OF VIBRATION	DESCRIPTION[1]	PILOT RATING
No vibration		0
Slight	Not apparent to experienced aircrew fully occupied by their tasks, but noticeable if their attention is directed to it or if not otherwise occupied	1 2 3
Moderate	Experienced aircrew are aware of the vibration but it does not affect their work, at least over a short period.	4 5 6
Severe	Vibration is immediately apparent to experienced aircrew even when fully occupied. Performance of primary task is affected or tasks can only be done with difficulty	7 8 9
Intolerable	Sole preoccupation of aircrew is to reduce vibration level.	10

[1] Based upon the Subjective Vibration Assessment Scale developed by the Aeroplane and Armament Experimental Establishment, Boscombe Down, England.

Figure 2. Vibration Rating Scale

Shortcoming

5. A shortcoming is defined as an imperfection or malfunction occurring during the life cycle of equipment which must be reported and which should be corrected to increase efficiency and to render the equipment completely serviceable. It will not cause an immediate breakdown, jeopardize safe operation, or materially reduce the usability of the material or end product.

APPENDIX E. CH-47D AERIAL REFUELING CHECKLIST

BEFORE REFUELING

1. Cyclic trim - Manual, set as required
2. Cockpit windows, air control handles, and cockpit air knobs - closed
3. Search lights (night) - as required
4. HF radio - off
5. Heater and vent blower - off
6. Cabin - all doors, windows, and hatches closed
7. Refueling system power switch - ARM
8. Probe - extend, check ready light illuminated

DURING REFUELING

Check fuel quantity and monitor fuel tanks for venting

AFTER REFUELING

1. Cyclic trim switch - AUTO
2. Mission equipment - as required
3. Probe - retract after two minutes, check retract light illuminated
4. Refueling system power switch - OFF

APPENDIX F. AERIAL REFUELING OPERATIONS - POSITIONS

1. The receiver aircraft standard positions with respect to the tanker aircraft are listed below:

Observation - left and right
Precontact - left and right
Refueling - left and right
Disconnect - left and right
Crossover

2. Photographs from selected positions are presented in photographs 1 through 6 with appropriate pilot visual cues.

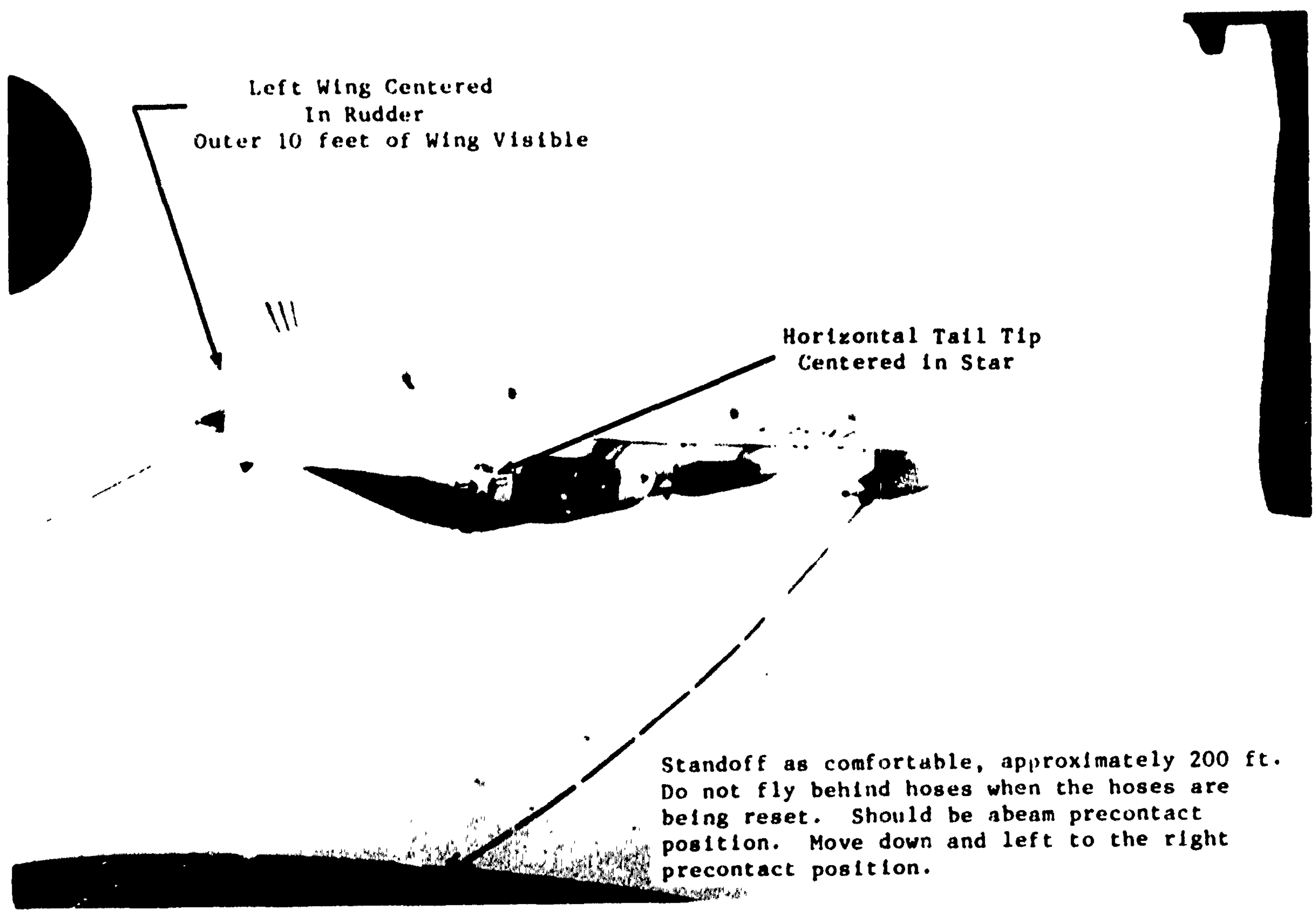


Photo 1. Right Observation Position

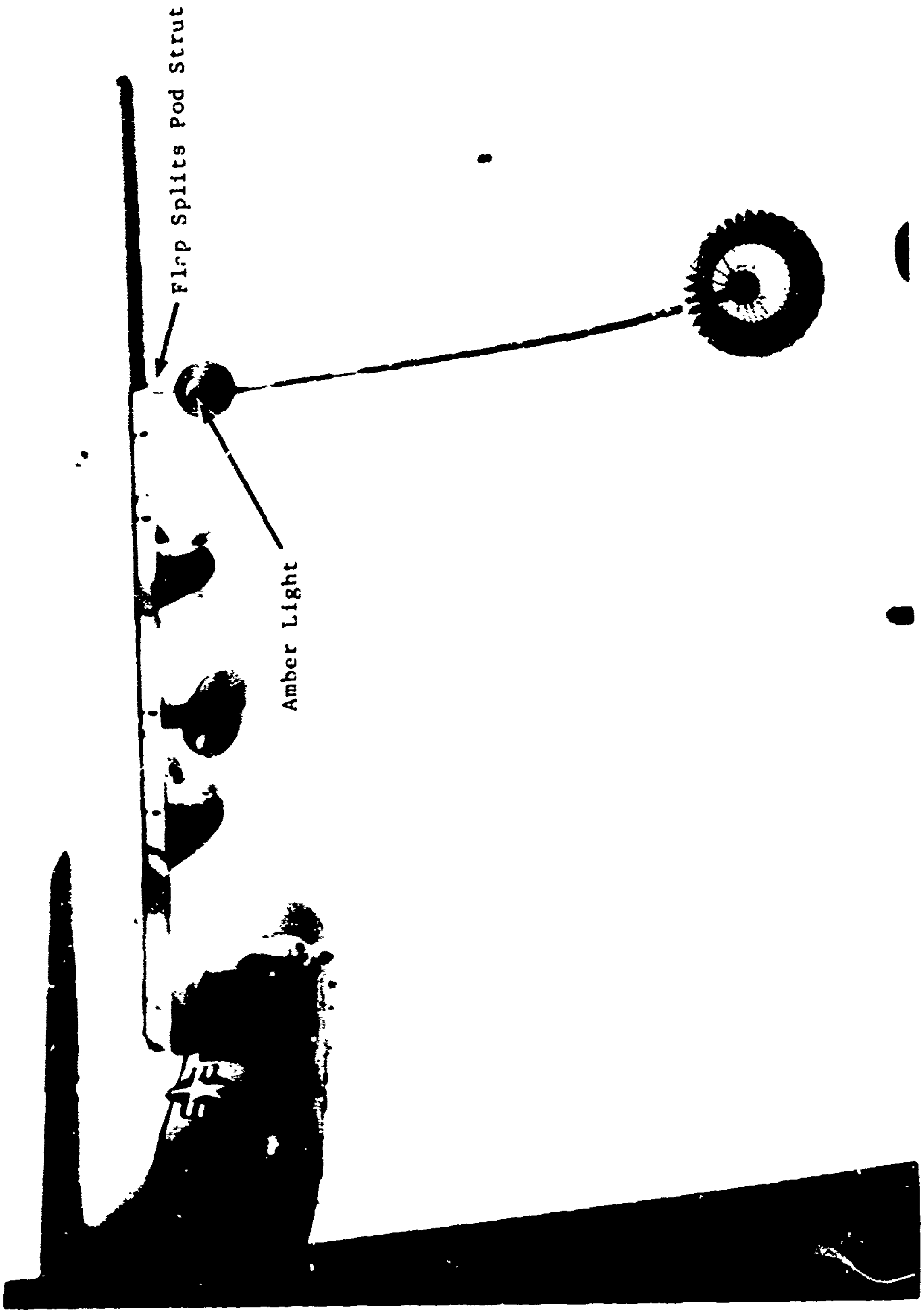


Photo 2. Right Precontact Position

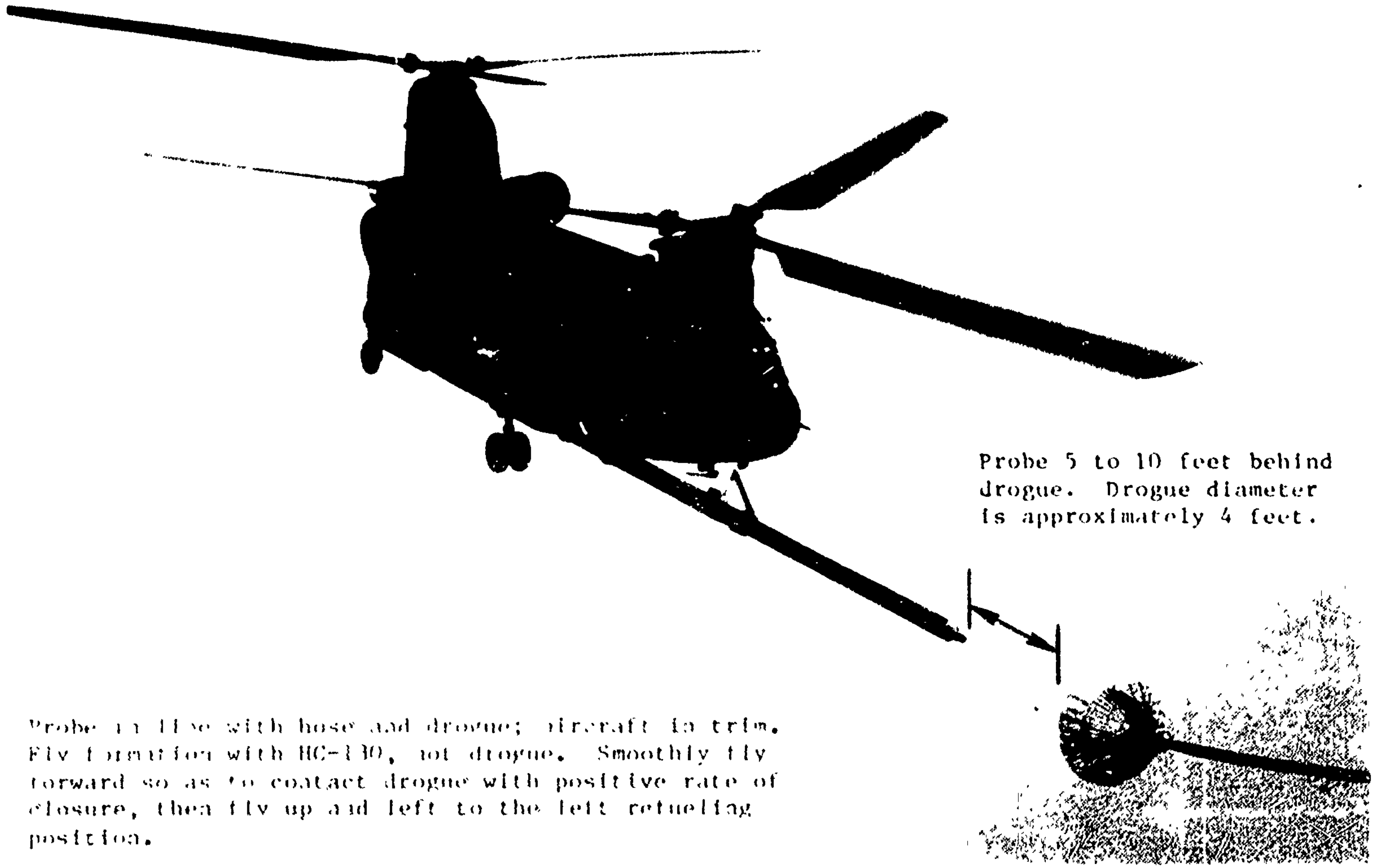


Photo 3. Left Precontact Position as Viewed from HC-130

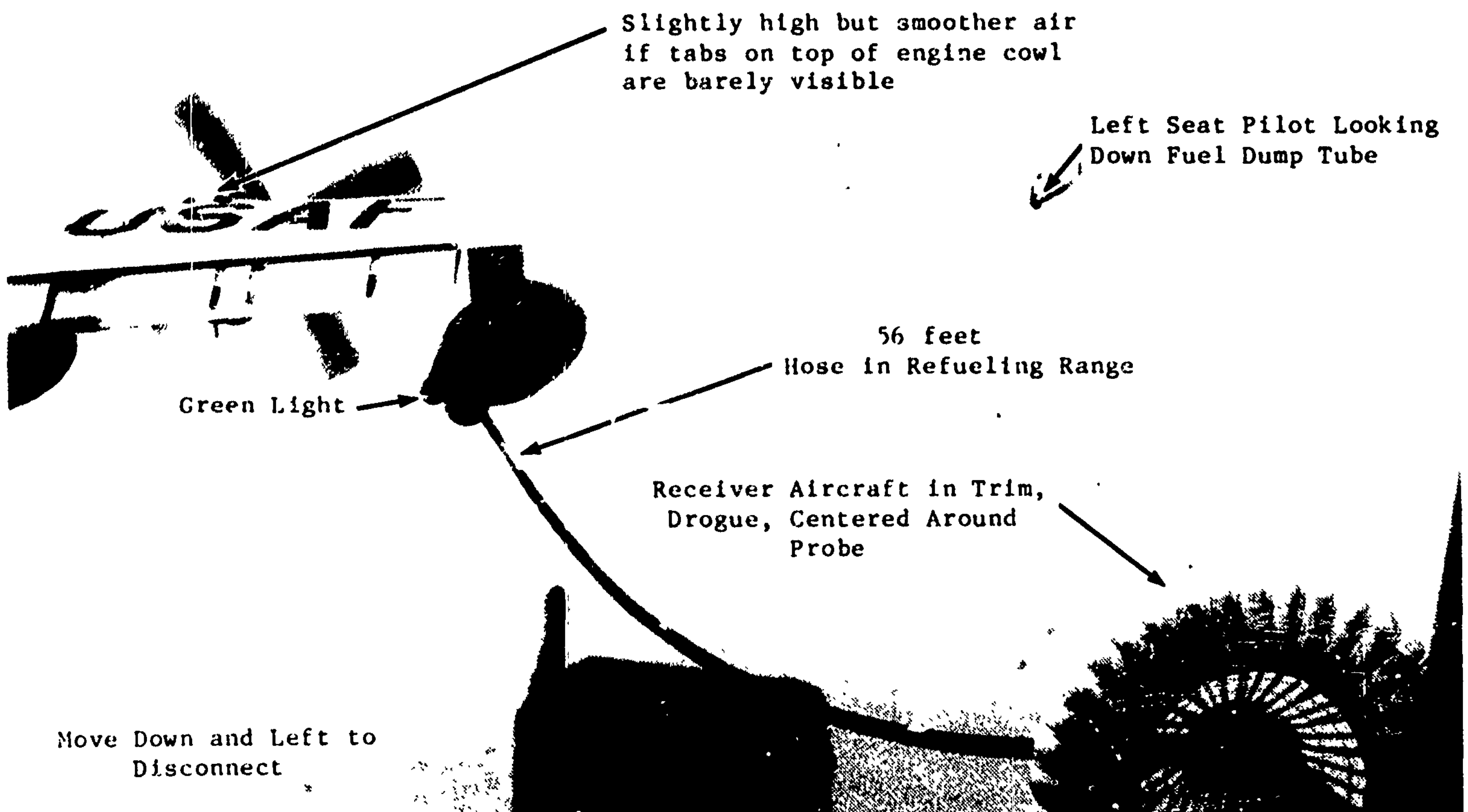


Photo 4. Right Refueling Position

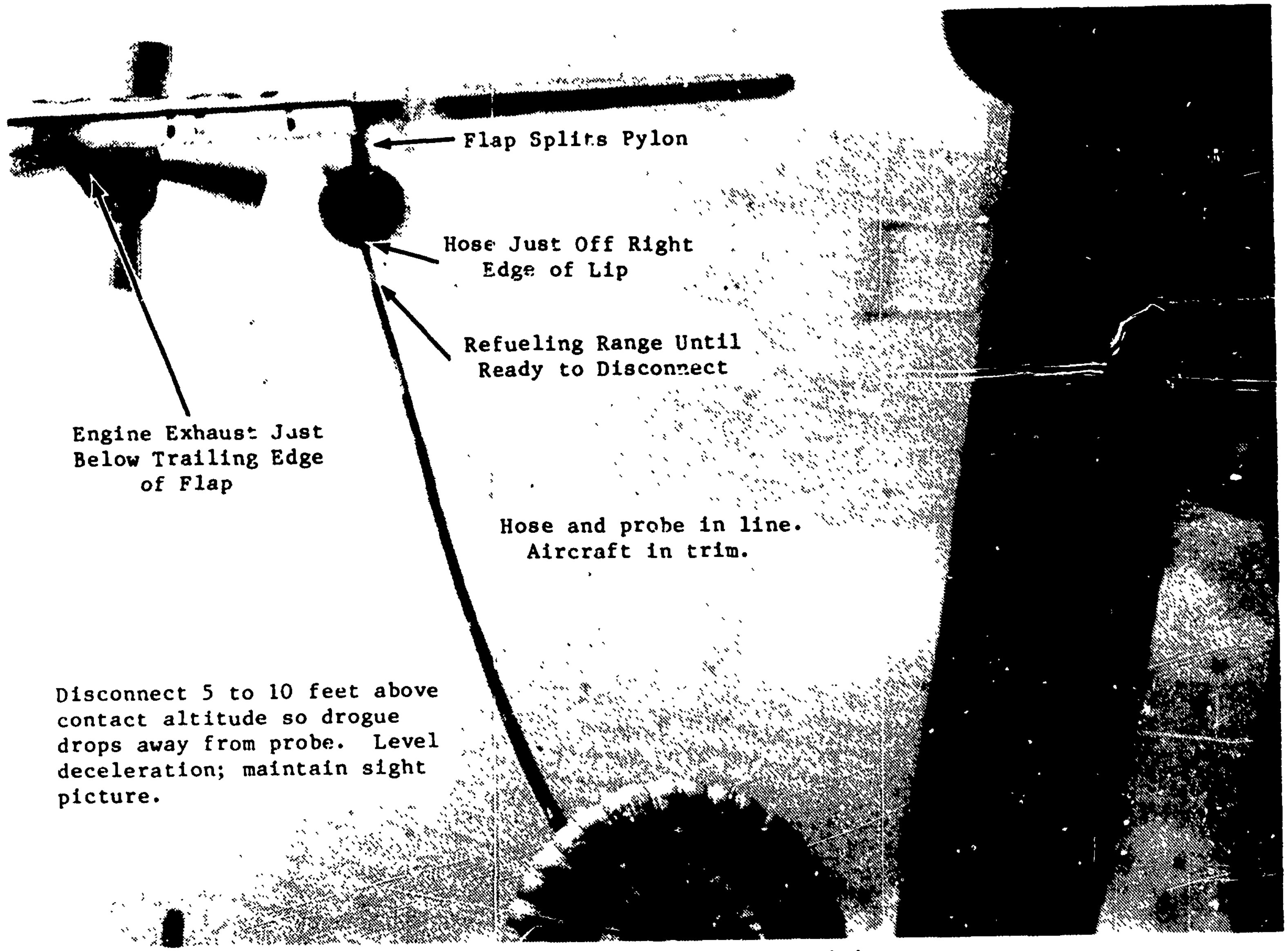


Photo 5. Right Disconnect Position

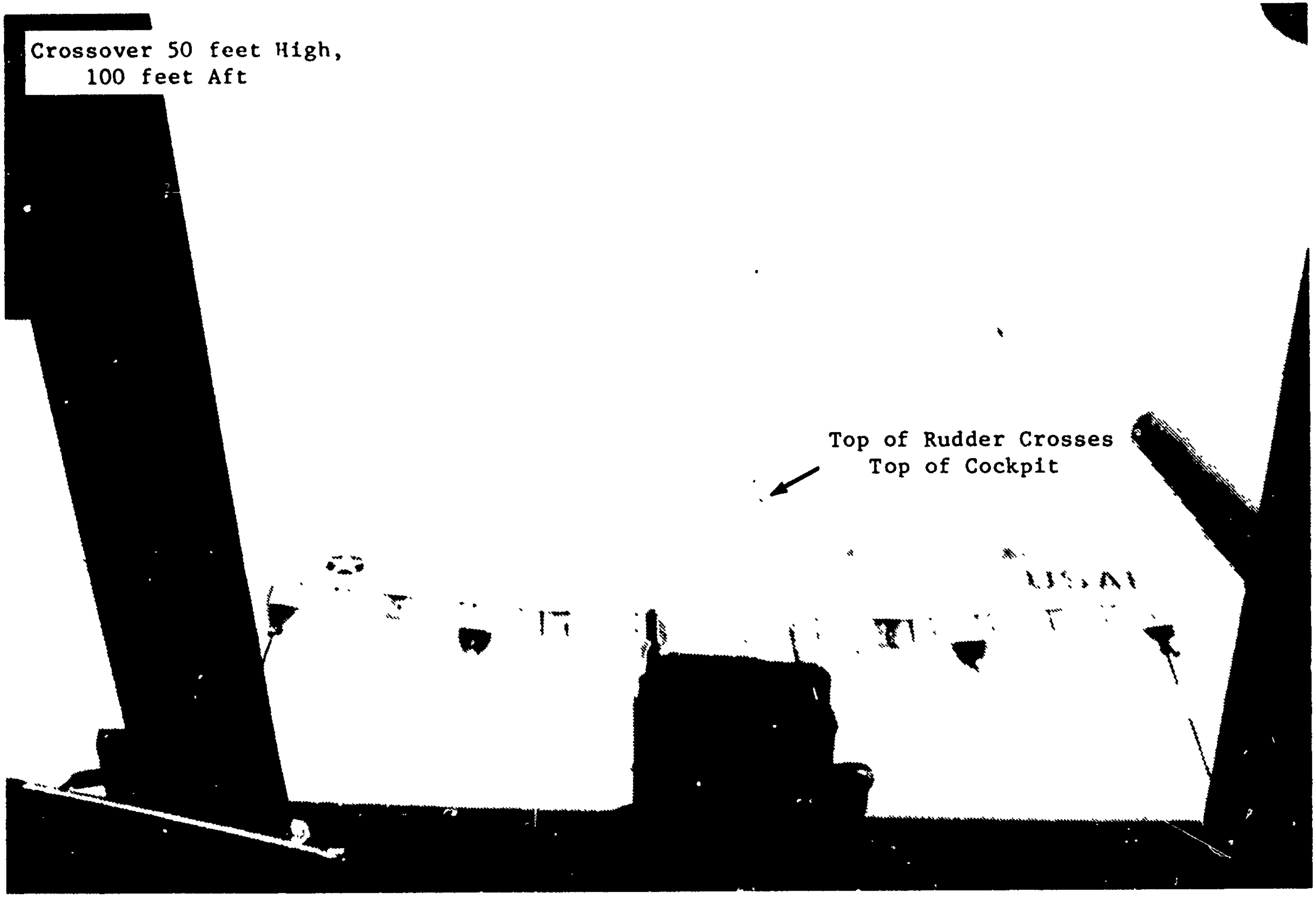


Photo 6. Crossover

APPENDIX G. USER COMMENTS ON AERIAL REFUELING OPERATIONS WITH THE CH - 47D HELICOPTER

9 August 1985

1. Clearance (from the tanker) from the right seat view appeared to be as good or better than from H-53.

2. Probe oscillations were not a problem.

3. Length of probe was not a problem, possibly helpful since small pedal inputs produced significant lateral movement of the probe tip.

4. Aircraft more stable in precontact position than H-53. More stable in all positions particularly in the pitch axis.

5. Level acceleration from precontact to contact made the hookup easier.

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