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AEFA

ARTIFICIAL AND NATURAL ICING TESTS OF THE EH-60A QUICK FIX HELICOPTER

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Artificial and natural icing flight tests were conducted on the EH-60A, Quick Fix helicopter (USA SN 84-24019) to establish a moderate icing flight envelope for the helicopter with the AN/ALQ-151(V)2 countermeasures system installed. The tests were conducted at Duluth, Minnesota from 24 February to 20 March 1988. A total of 11.8 flight hours were flown in the icing environment. After damage to an unprotected direction finding (DF) dipole antenna during an icing encounter, the project was terminated. During these tests, two deficiencies and eight shortcomings were noted. The two icing related deficiencies are: excessive DF dipole antenna element oscillations induced by ice accumulation resulting in damage to the DF antenna element mounts and phenolic blocks, and the ice accretion and shedding characteristics of the EH-60A helicopter forward of the engine inlets resulting in a high probability of engine foreign object damage. The major shortcomings are: the excessive increase in power required with rotor system ice accumulation, the excessive Electronic Countermeasures (ECM) antenna oscillations induced by ice accumulation, the ice accretion and shedding characteristics of the outside air temperature probes, and the inability of the ECM antenna to fully retract following an icing flight. Four additional shortcomings were identified. The EH-60A Quick Fix helicopter, as configured for this test, was not suitable for flight into an icing environment. The EH-60A Quick Fix helicopter, as configured for this test, should not be cleared for flight in icing conditions. (SDW)

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INTRODUCTION

BACKGROUND

1. The YEH-60A has undergone artificial and natural icing airworthiness flight tests (ref 1 through 3, app A) and was determined to be unsuitable for flight into moderate icing environments. The EH-60A helicopter Quick Fix system consists of a UH-60A helicopter modified to accept an AN/ALQ-151(V)2 countermeasures system. Artificial and natural icing tests were required to qualify the helicopter, in this configuration, for flight in moderate icing conditions. The U.S. Army Aviation Systems Command (AVSCOM) directed the U.S. Army Aviation Engineering Flight Activity (AEFA) to conduct artificial and natural icing tests of the EH-60A helicopter Quick Fix system (ref 4) during February 1988 in accordance with the approved test plan (ref 5).

TEST OBJECTIVES

2. The objective of this test was to conduct limited artificial and natural icing flight tests to provide AVSCOM the basis for establishing a moderate icing flight envelope for the EH-60A helicopter Quick Fix system.

DESCRIPTION

3. The EH-60A helicopter Quick Fix system is a twin turbine, single main rotor helicopter with all weather, day or night capability to identify, locate and jam ground based electronic communication transmissions. The airframe is a UH-60A helicopter manufactured by Sikorsky Aircraft Division of United Technologies Corporation and incorporates significant modifications to accommodate the Special Electronic Mission Aircraft (SEMA) mission equipment and the Aircraft Survivability Equipment (ASE). Nonretractable wheel type landing gear are provided. Both the main and tail rotors are four-bladed with the capability for main rotor blade and tail pylon folding. The UH-60A with the deicing kit installed incorporates a main and tail rotor deicing system and an ice detection system. In addition, anti-icing systems are incorporated in the windshield, pitot static tubes and support struts, and engines and engine inlets. The SEMA equipment consisted of an AN/ALQ 151(V)2 countermeasures system. The AN/ALQ 151(V)2 electronics are contained in the two rack assemblies and two operator console assemblies located in the helicopter cabin. The Quick Fix system antennas include two UHF antennas mounted on the underside of the aircraft, one Electronic Countermeasures (ECM) antenna mounted on the underside of the aircraft forward of the transition section, a Direction Finding (DF) antenna set mounted on the left and right tail cone, and a built-in test equipment antenna located on the rear vertical section of the tail rotor pylon. The ASE equipment consists of an AN/ALQ 144 (V) IR Countermeasures Set, the AN/ALQ 39 Radar Signal Detection Set, two M-130 Chaff/Flare Dispensers, the AN/ALQ-156 Missile Detection System and the AN/ALQ-162 Radar Countermeasures System. The test helicopter (S/N 84-24019) was operated with the AN/ALQ-144 removed and a single AN/ALQ-162 antenna mounted on the front of the helicopter. Additionally, the helicopter was equipped with the Hover Infrared Suppressor Subsystem (HIRSS). A detailed description of the EH-60A is contained in the UH-60A Operator's Manual (ref 6, app A) and appendix B. A description of the Helicopter Icing Spray

System (HISS) installed on the JCH-47C helicopter, S/N 68-15814, is presented in appendix C. A detailed description of the HISS and the JU-21A configured with the cloud particle measuring system used to document the icing test environment is presented in reference 7, appendix A.

TEST SCOPE

4. In-flight artificial and natural icing tests were conducted in the vicinity of Duluth, Minnesota from 24 February to 20 March 1988. A total of 8 icing flights were conducted totaling 11.8 hours. Of these flights, five were in the artificial icing environment totaling 7.3 hours. Maintenance support was provided by the U.S. Army Aviation Development Test Activity, Fort Rucker, Alabama. Tests were conducted at an average gross weight of approximately 16,110 pounds and an average longitudinal center of gravity located at fuselage station 361.0. Average pressure altitude varied from 3,010 to 9,850 feet. Icing was accomplished at ambient temperatures from -19.6°C to -5.1°C at average liquid water content (LWC) of 0.2 to 0.99 grams per cubic meter (gm/m^3). Test airspeeds ranged from 78 to 123 knots true airspeed and the main rotor speed was 258 rpm (100 percent). Anti-ice and deice systems were operated continuously while in the icing environment. A summary of icing test conditions is presented in table F-1. Flight limitations contained in the operator's manual and the airworthiness release (ref 8, app A) were observed during testing.

TEST METHODOLOGY

5. Artificial icing was conducted by flying in a spray cloud generated by the HISS. The JU-21A configured with the cloud particle measuring system was used to document conditions of the HISS cloud and provide visual chase and photographic documentation while the test aircraft was in the artificial cloud. Ice accretion was also documented on the ground following icing encounters. The EH-60A was immersed in the cloud for one hour durations (limited by HISS fuel and water capacities). A detailed discussion of the test sequence and procedures is contained in reference 7.

6. Natural icing tests were conducted by flying in instrument meteorological conditions (IMC) icing conditions under instrument flight rules (IFR). The JU-21A chase aircraft configured with the cloud particle measuring system was used to locate and document the icing conditions. Photos were taken in flight from the JU-21A after the test aircraft exited the icing environment. Close coordination between air traffic control and the chase and test aircraft crews was required to locate and remain in the icing environment and to implement inflight aircraft join-up for photographic documentation. In addition to the coordination, a combination of radar vectoring, navigational aid holding, and block airspace assignment were used. Time in the clouds was limited by the availability of the natural icing conditions and aircraft IFR fuel requirements.

7. An AEFA designed and fabricated visual ice accretion measuring device was mounted on the copilot's door and was used to observe the rate of ice accretion on the airframe

and correlate LWC readings. One video camera was mounted on the right side of the aircraft to record dipole antenna motion and a second video camera was mounted on the bottom of the fuselage to record ECM motion. A detailed description of special equipment and instrumentation is provided in appendix D.

8. Test techniques, data analysis methods, methods used to determine cloud parameters, and definitions of icing and severities are presented in appendix E.

RESULTS AND DISCUSSION

GENERAL

9. Artificial and natural icing tests were conducted to provide data for establishing a moderate icing envelope (up through 1.0 gm/m^3 LWC) for the EH-60A Quick Fix helicopter. Antenna and airframe ice accumulation and shedding characteristics were documented. A summary of the specific test conditions for each flight is presented in table F-1. Two deficiencies and eight shortcomings were noted. The two deficiencies were (1) the excessive DF dipole antenna element oscillations induced by ice accumulation resulting in damage to the DF antenna element mounts and phenolic blocks (2) the ice accretion and shedding characteristics of the EH-60A helicopter forward of the engine inlets resulting in a high probability of engine foreign object damage (FOD). In addition, twenty four shortcomings were identified, eighteen of which had been previously reported. The major shortcomings were (1) the excessive increase in power required with rotor system ice accumulation (2) the excessive ECM antenna oscillations induced by ice accumulation (3) the ice accretion and shedding characteristics of the outside air temperature (OAT) probes and (4) the inability of the ECM antenna to fully retract following an icing flight. The icing related deficiencies noted during this test should be corrected prior to further flight in icing conditions. The shortcomings should be corrected. The EH-60A Quick Fix helicopter, as configured for this test, is not suitable for flight in an icing environment.

ROTOR SYSTEM ICE ACCRETION AND SHEDDING CHARACTERISTICS

General

10. Rotor system ice accretion and shedding characteristics were evaluated throughout these tests. Specific test conditions are presented in table F-1. A large increase in percent indicated torque, with ice accretion, which did not return to the initial power setting following ice shed from main rotor, was observed. Following flight in both natural and artificial conditions, the droop stops returned to the retracted (shutdown) position. Tail rotor blades and stabilator were damaged during flights under both artificial and natural icing conditions. Uncontrolled ice sheds from the main rotor were observed striking the windshield and nose section of the aircraft. During aircraft shutdown, large pieces of ice were shed from the rotor head (yoke and bifilar) and fell to the main rotor pylon creating a potential (FOD) problem.

Main Rotor Accretion

11. The ice accretion and operational characteristics of the main rotor were evaluated throughout these tests. During a natural icing flight at -13.0°C and LWC of 0.55 gm/m^3, an increase of 27% indicated torque was observed. The cloud was entered with a 55% indicated torque and was flown collective fixed. After approximately fifteen minutes an indicated torque of 72% was attained. Following a blade deice cycle, the indicated torque dropped to 67% and began cycling between 68% to 72% correlating with the blade deice cycles. At twenty minutes the cloud was exited to visual meteorological conditions. One minute after exiting the cloud, the indicated torque returned to 58%. Post flight inspection revealed one inch fingers of ice protruding forward from the trailing edge of

the deice heater mats from the blade root to approximately 60% span (fig. H-1). The excessive increase in power required with rotor system ice accumulation is a shortcoming.

AIRFRAME ICE ACCRETION AND SHEDDING CHARACTERISTICS

General

12. The airframe ice accretion and shedding characteristics of the EH-60A Quick Fix helicopter were evaluated throughout these tests. Specific test conditions are presented in table F-1. In-flight photographic documentation was utilized from chase aircraft, the HISS and onboard photography. A photograph of the helicopter with typical ice accretions is shown in figure H-2. Specific conditions of this photo were 57 minutes of exposure at -5.1°C and LWC of 0.95 gm/m^3. Ice formed on all stagnation areas and sharp protrusions from the airframe. One deficiency associated with the airframe ice accretion and shedding characteristics was the excessive DF dipole antenna element oscillation induced by ice accumulation resulting in damage to the DF dipole antenna element mounts and phenolic blocks.

Direction Finding Dipole Antennas

13. The ice accretion characteristics of the DF dipole antennas were evaluated throughout these tests. Ice accumulation varied with antenna location (fig. H-3). The number three antenna accreted less ice than the other three throughout the tests. The upper elements of the DF antennas accreted ice from the phenolic blocks upward to approximately 20% of the element length and did not shed during flight. The lower elements accreted ice the full length of the element with a bulbous accretion just below the phenolic block (fig. H-3). Ice accumulation caused the DF antennas to oscillate. During oscillation, the upper 50 to 60% of the lower elements would self shed leaving the remaining accumulated ice near the tip (fig. H-4). Following the self shed, the amplitude of the oscillation would increase. Post flight inspection revealed loose DF element retaining screws. Flight in artificial icing conditions resulted in a high frequency vibration of the lower element of the number two DF antenna with tip amplitudes of $\pm$4 inches. At forty four minutes into an artificial icing immersion at -15.0°C and LWC of 0.52 gm/m^3, the upper left screw on the number two lower DF antenna mount sheared just below the screw head (fig. H-5). At 21 minutes into a natural icing immersion at -9.3°C and LWC of 0.20 gm/m^3, the upper right screw on the number two lower DF antenna mount sheared approximately 0.2 inch below the screw head (fig. H-6). Post flight measurement recorded 1.25 inches of ice accumulation on portions of the DF antenna elements (fig. H-7). No damage to the DF antennas or their mounts was noted. At 30 minutes into a natural icing immersion at -13.0°C and LWC of 0.55 gm/m^3, a $\pm$4 inch tip amplitude vibration of the lower element of the number two DF antenna element was observed and abruptly stopped with a simultaneous shed of ice from the element. Post flight inspection of the DF antennas revealed a cracked phenolic support block of the front right DF antenna (#2) (figs. H-8 and H-9). The Test Incident Reports (TIR) submitted by AEFA on these incidents are included in appendix G. The effect of ice accumulation on the proper function of the DF system was not tested. The excessive DF dipole antenna element oscillation induced by ice accumulation resulting in damage to

the DF dipole antenna element mounts and phenolic blocks is a deficiency. Further testing to determine the effect of ice accumulation on the proper function of the DF system should be accomplished.

Electronic Countermeasures Antenna

14. The ice accretion and shedding characteristics of the ECM antenna were evaluated throughout these tests. Icing tests were conducted with the ECM antenna in the extended position. The test aircraft was positioned in the cloud to effectively ice the DF antennas. This position did not permit a total immersion of the ECM antenna and resulted in an immersion of approximately the top 50% of the ECM antenna (fig. H-10). Ice accumulation induced oscillations on the ECM antenna causing tip deflections of up to ± 1 foot. The oscillations occurred approximately every 10 minutes in moderate icing conditions and usually lasted between 10 and 30 seconds ending when the accumulated ice was shed. Retraction of the ECM antenna with accreted ice resulted in the ice being shed upon the antenna contact with the antenna cradle. The operational characteristics of the ECM antenna after ice accumulation or while oscillating were not evaluated. The ECM antenna oscillations caused by ice accumulation were identified as a shortcoming during previous icing tests (ref 3). The excessive ECM antenna oscillations caused by ice accumulation are a shortcoming. Further testing to determine the effect of ice accumulation on the proper function of the ECM system should be accomplished.

AN/ALQ-156 Countermeasures System Antennas

15. The ice accretion and shedding characteristics of the AN/ALQ-156 antennas were evaluated throughout these tests. Ice accreted on the screw heads and flat surfaces of the face of the forward antennas and propagated along the aerodynamic streamlines across the face of the antennas (fig. H-11). Ice accumulation varied from a light frosting to a thickness of approximately 1.5 inches. No accumulations were present on the rear antennas. The ice accumulations and subsequent shedding did not adversely affect the operation of the helicopter. The operational characteristics of the AN/ALQ-156 countermeasures system after ice accumulation were not tested. Within the scope of this test, the ice accretion and shedding characteristics of the AN/ALQ-156 antennas are satisfactory. Further testing to determine the effect of ice accumulation on the proper function of the AN/ALQ-155 system should be accomplished.

AN/ALQ-162 Countermeasures System Antenna

16. The ice accretion and shedding characteristics of the AN/ALQ-162 antenna were evaluated throughout these tests. Ice accreted on the stagnation points of the antenna antenna mounting base and the fuselage of the helicopter and propagated along the aerodynamic streamlines across the top and face of the antenna (figs. H-12 and H-13). Ice accumulations varied from a thickness of approximately 0.75 to 2.0 inches. Minimal accumulations were present on the wave guide located on the left underside of the fuselage. The aft antenna was not available for installation. The ice accumulations and subsequent shedding did not adversely affect the operation of the helicopter. The operational characteristics of the AN/ALQ-162 countermeasures system after ice accumulation were not tested. Within the scope of this test, the ice accretion and

shedding characteristics of the AN/ALQ-162 antennas are satisfactory. Further testing to determine the effect of ice accumulation on the proper function of the AN/ALQ-162 system should be accomplished.

Hover Infrared Suppresser Subsystem

17. The ice accretion and shedding characteristics of the HIRSS were evaluated throughout these tests. Ice accretion on the engine cooling air inlet fairing varied from 0.75 inch to in excess of 4 inches (fig. H -14). The ice did not accrete beyond the engine inlet and all sheds were outboard, thereby creating no adverse effects to helicopter operation. Ice accretion on the exhaust ram inlet scoop was minimal with accumulations of less than 0.75 inch (fig. H-15). The accretions on the upper portions of the exhaust ram inlet scoop were consistently thicker than those on the lower section. The ice accumulations and subsequent shedding did not adversely affect the operation of the helicopter. Within the scope if this test, the ice accretion and shedding characteristics of the HIRSS are satisfactory.

Stabilator

18. The ice accretion and shedding characteristics of the stabilator were evaluated throughout these tests. Asymmetric ice accretions between the left and right portion of the stabilator were present throughout the tests. Ice accreted the full length of the leading edge of the right side of the stabilator while the left side accreted ice only on the tip and root (fig. H-16). The asymmetric accretion resulted in no unusual vibration of the stabilator. The ice accumulations and subsequent shedding did not adversely affect the operation of the helicopter. Within the scope of this test, the ice accretion and shedding characteristics of the stabilator are satisfactory.

Outside Air Temperature Probes

19. The ice accretion and shedding characteristics of the OAT probes were evaluated throughout these tests. Both OAT probes accreted ice at approximately the same rate. Following a 56 minute immersion icing test flight at -9.9°C with a LWC of 0.99 gm/m^3, the aircraft was returning to base utilizing a 500 ft/min rate of descent. An uncontrolled shed from the right OAT probe ricocheted off the control access fairing and into the main rotor tip path, thereby destroying the ice formation. Following a 57 minute immersion icing test flight at -5.1°C with a LWC of 0.95 gm/m^{3}m, the OAT probe passed between the main rotor pylon and the #2 engine inlet, barely missing being ingested by the #2 engine. Ice shedding from the OAT probes presents a significant potential for engine FOD. The ice accretion and shedding characteristics of the OAT probes are a shortcoming.

AIRCRAFT DAMAGE

#2 Engine Foreign Object Damage

20. Throughout these tests, the ice accretion and shedding characteristics of the front of the aircraft, forward of the engine inlets, were evaluated. This portion of the aircraft

accreted large amounts of ice on the stagnation surfaces and local stagnation points (fig. H-18). Previously published UH-60 icing reports have identified ice shedding from the windshield and windshield wipers (refs 10 and 11), the wirestrike protection system (WSPS) and pitot static tube support strut fairings (ref 12), and the main rotor system (ref 13) as engine FOD sources or potential FOD sources. The OAT probes were identified as possessing significant potential for engine FOD (para 19). Following a natural icing flight of 61 minutes duration at 9800 ft pressure altitude (PA), -7.2°C, and LWC of approximately 0.70 gm/m^3, while transitioning from a forward flight to a hover, uncontrolled ice sheds from the forward fuselage and rotor system resulted in a #2 engine FOD. Post flight inspection revealed six first stage compressor blades damaged beyond limits, requiring engine replacement. The TIR submitted by AEFA is presented in appendix G. Historical data of E/UH-60 icing tests indicate that in 146.6 flight hours, a total of three engines have sustained sufficient damage from ice ingestion to require replacement. The summation of probabilities for engine FOD from the many discrete sources creates a high probability of ice ingestion and engine FOD. The ice accretion and shedding characteristics of the U/EH-60 helicopter forward of the engine inlets resulting in engine FOD are a deficiency.

Stabilator Damage

21. The stabilator was damaged during flights in both artificial and natural icing conditions. Throughout these tests, the stabilator was monitored for damage from ice sheds. Several small dings were noted along and in the vicinity of the stabilator leading edge. Video coverage from the aft facing cameras documented ice shedding from the DF antennas impinging the stabilator. The damage did not affect the operation of the stabilator or change any of the aircraft handling qualities. Ice impact damage to the stabilator is a shortcoming.

Tail Rotor Paddle Damage

22. The tail rotor was damaged during an artificial icing flight of one hour duration at -19.6°C and a LWC of 0.45 gm/m^3. Post flight inspection revealed a cut and dented area on the tail rotor blade which required replacement (fig. H-19). The damage caused no unusual vibration or change in aircraft handling characteristics. The TIR submitted by AEFA is presented in appendix G. Ice impact damage to the tail rotor paddle from uncontrolled shedding is a shortcoming.

Electronic Countermeasures Antenna Damage

23. Following a natural icing flight of 1.5 hours duration at -9.3°C with a LWC of 0.2 gm/m^3, the ECM antenna failed to fully retract to the stowed position (fig. H-20). The aircraft was brought to a hover and the ECM antenna removed from the antenna mount. Post flight inspection revealed the right pivot stud on the antenna mount had sheared (fig. H-21). The sheared pivot stud permitted the antenna mount to skew in the housing during retraction resulting in the antenna mount being jammed against the housing. The left pivot stud was bent and the actuator connecting point to the stud arm subassembly would not rotate due to torsion damage (fig. H-22). The ECM antenna was removed for the remainder of the tests. The TIR submitted by AEFA is presented in

appendix G. The damage to the pivot stud of the ECM antenna mount following an icing encounter, preventing full retraction of the ECM antenna, is a shortcoming.

RELIABILITY AND MAINTAINABILITY

Blade Deice System Reliability

24. The blade deice system was evaluated throughout these tests. Upon receipt of the test aircraft, the blade deice system was inoperative in both the automatic and manual modes. During the blade deice test with the blade deice test panel switch in the NORM position, both the main rotor deice fail and the tail rotor deice fail segment caution lights would illuminate at 105 seconds into the test. After replacement of the deice system controller, main rotor slip ring assembly and power distributor, the system was operational. Approximately three flight hours later, an additional main rotor fault was isolated to a defective deice test panel. Replacement of the deice test panel alleviated the problem. No additional faults occurred throughout the remainder of the flight tests. The poor reliability of the blade deice system is a shortcoming.

Integrated Inertial Navigation System Reliability

25. The AN/ASN-132 Integrated Inertial Navigation System (IINS) was evaluated throughout these flight tests. The aircraft was received with an inoperative signal data converter (SDC), thereby rendering the TACAN inoperative. Following replacement of the SDC, the IINS was fully operative for approximately two days during which time position and TACAN data were loaded into the system. The IINS provided ground speed and bearing data to the pilot and upon termination of flights, position data was in error by only 0.3 kilometer. Upon initialization of the IINS on the third day, none of the stored data remained in memory. Troubleshooting of the IINS revealed a faulty navigation processing unit (NPU). Upon arrival and installation of the new NPU, the IINS displayed the same characteristics as with the faulty NPU. Further investigation revealed that the factory had failed to program the replacement NPU. Only two locations were available to program the NPU and were not accessible for the purposes of this test. The IINS was operable only 2 of 24 days it was tested. The poor reliability of the IINS was identified as a shortcoming during previous icing tests (ref 3). The poor reliability of the AN/ASN-132 IINS is a shortcoming.

MISCELLANEOUS

26. No corrective action was accomplished for several of the previously identified (refs 3 and 4, app A) shortcomings on the YEH-60A in icing conditions and no specific evaluation was accomplished to investigate them. However, the following discrepancies remain:

a. The failure of the anti-flapping restrainers to return to the shutdown position with ice accumulation.

b. The large decrease in power available with engine and engine inlet anti-ice systems ON.

c. The poor location of the deice system circuit breakers.

d. The inadequate water tightness of the cockpit.

e. The ice accumulation on the cockpit steps.

f. The ice accumulation on the FM homing antennas which interferes with cockpit door opening.

g. The poor reliability and high maintenance requirement of the main rotor blades as indicated by red "failed" bands on the BIM indicator.

h. The accumulation of M-130 chaff in the tail rotor slipring assembly which shorted out the tail rotor blade deice system.

i. Ice impact damage to the tail rotor tip caps.

j. The excessively long and complicated normal alignment procedures required for the AN/ASN-132 IINS system.

k. The poor location of the emergency ECM antenna retract switch.

l. The false illumination of the ICE DETECTED caution light caused by EMI from the ECM system.

27. No corrective action was accomplished for several of the previously identified (refs 9 and 10, app A) shortcomings on the UH-60A in icing conditions and no specific evaluation was accomplished to investigate them. However, the following discrepancies remain:

a. The large ice accretions on the WSPS components which subsequently shed and cause FOD to the aircraft.

b. The large ice accretions on the forward portion of the improved airspeed system pitot-static tube support strut fairings or wedges.

c. The inadequate anti-ice provisions on the pitot-static tube support struts as installed with the improved airspeed system fairings or wedges.

d. The insufficient main transmission drip pan capacity.

28. The following recommendations still apply from previous YEH-60 icing tests since either no corrective action has been accomplished or the corrective action taken was inadequate to warrant deletion of the previous (refs 3 and 4) recommendation:

a. The Windshield Anti-Ice Copilot and Pilot switches should be labeled to indicate the reset feature of the OFF position.

b. The following CAUTION should be placed in the operator's manual prior to release of the aircraft for operation in an icing environment.

CAUTION

If ice accumulates on one or more sections of the anti-iced windshields, with the windshield anti-ice system ON, the respective windshield should be turned OFF and the icing conditions exited due to the possibility of engine FOD if the ice should shed from the windshield.

CONCLUSIONS

GENERAL

29. The EH-60A, as configured for this test, is not suitable for flight into an icing environment (para 9). A total of two deficiencies and twenty four shortcomings exist with respect to the EH-60A operation in an icing environment.

DEFICIENCIES

30. The following deficiencies were noted and are listed in decreasing order of importance:

a. The ice accretion and shedding characteristics of the U/EH-60A helicopter forward of the engine inlets resulting in a high probability of an engine FOD (para 20).

b. The excessive DF dipole antenna element oscillation induced by ice accumulation resulting in damage to the DF antenna element mounts and phenolic blocks (para 13).

SHORTCOMINGS

31. The following shortcomings were identified and are listed in decreasing order of importance:

a. The excessive increase in power required with rotor system ice accumulation (para 11).

b. The excessive ECM antenna oscillations induced by ice accumulation (para 14).

c. The ice accretion and shedding characteristics of the OAT probes (para 19).

d. The damage to the pivot stud of the ECM antenna mount, following an icing encounter, preventing full retraction of the ECM antenna (para 23).

e. The poor reliability of the AN/ASN-132 IINS (para 25).

f. The poor reliability of the blade deice system (para 21).

g. Ice impact damage to the tail rotor paddle from uncontrolled shedding (para 24).

h. Ice impact damage to the stabilator (para 23).

32. The following previously identified icing related shortcomings remain:

a. The failure of the anti-flapping restrainers to return to the shutdown position with ice accumulation (para 26a).

b. The large decrease in power available with engine and engine inlet anti-ice systems ON (para 26b).

c. The poor location of the deice system circuit breakers (para 26c).

d. The inadequate water tightness of the cockpit (para 26d).

e. The ice accumulation on the cockpit steps (para 26e).

f. The ice accumulation on the FM homing antennas which interferes with cockpit door opening (para 26f).

g. The poor reliability and high maintenance requirement of the main rotor blades as indicated by red "failed" bands on the Blade Integrity Monitor (BIM) indicator (para 26g).

h. The accumulation of M-130 chaff in the tail rotor slip ring assembly which shorted out the tail rotor blade deice system (para 26h).

i. Ice impact damage to the tail rotor tip caps (para 26i).

j. The excessively long and complicated normal alignment procedures required for the AN/ASN-132 IINS system (para 26j).

k. The poor location of the emergency ECM antenna retract switch (para 26k).

l. The false illumination of the ICE DETECTED caution light caused by electro-magnetic interference from the ECM system (para 26l).

m. The large ice accretions on the WSPS components which subsequently shed and cause FOD to the aircraft (para 27a).

n. The large ice accretions on the forward portion of the improved airspeed system pitot-static tube support strut fairings or wedges (para 27b).

o. The inadequate anti-ice provisions on the pitot-static tube support struts as installed with the improved airspeed system fairings or wedges (para 27c).

p. The insufficient main transmission drip pan capacity (para 27d).

RECOMMENDATIONS

33. The deficiencies listed in paragraphs 30a and b should be corrected prior to flight in icing conditions.

34. The shortcomings listed in paragraphs 31a through h and paragraphs 32a through p should be corrected.

35. Further tests should be conducted to fully evaluate the effect of ice accumulation on the proper function of the DF system (para 13).

36. Further tests should be conducted to fully evaluate the effect of ice accumulation on the proper function of the ECM system (para 14).

37. Further tests should be conducted to fully evaluate the effect of ice accumulation on the proper function of the AN/ALQ-156 Countermeasures System (para 15).

38. Further tests should be conducted to fully evaluated the effect of ice accumulation on the proper function of the AN/ALQ-162 Countermeasures System (para 16).

39. The Windshield Anti-Ice Copilot and Pilot switches should be labeled to indicate the reset feature of the OFF position (para 28a).

40. The following CAUTION should be placed in the operator's manual prior to release of the aircraft for operation in an icing environment (para 28b).

CAUTION

> If ice accumulates on one or more sections of the anti-iced windshields, with the windshield anti-ice system ON, the respective windshield should be turned OFF and the icing conditions exited due to the possibility of engine FOD if the ice should shed from the windshield.

APPENDIX A. REFERENCES

1. Letter, AVSCOM, DRDAV-DI, 7 September 1983, subject: Limited Artificial and Natural Icing Tests of the YEH-60A Quick Fix Helicopter.

2. Test Plan, AEFA, Project 83-21, *Artificial and Natural Icing Tests, YEH-60A, Quick Fix Helicopter*, December 1983.

3. Final Report, AEFA Report No. 83-21, *Artificial and Natural Icing Tests YEH-60A Quick Fix Helicopter*, June 1984.

4. Letter, AVSCOM, AMSAV-8, 25 February 1988, subject: Artificial and Natural Icing Tests of the EH-60A Helicopter, Phase II (Test Request).

5. Test Plan, AEFA, Project 88-06, *Artificial and Natural Icing Tests, Production EH-60A Helicopter*, 26 February 1988.

6. Technical Manual, TM 55-1520-237-10, *Operator's Manual, UH-60A and EH-60A Helicopter*, 8 January 1988, 21 May 1979 change 1 dated 29 March 1988.

7. Letter, AEFA, DAVTE-TI, 22 June 1982, subject: AEFA Project No. 80-04-2, Helicopter Icing Spray System (HISS) Evaluation and Improvements.

8. Letter, AVSCOM, AMSAV-E, 26 February 1988 and 29 February 1988, subject: Airworthiness Release for the Operation of EH-60A S/N 84-24019 For Artificial and Natural Icing Testing.

9. Final Report, AEFA Report No. 83-22, *Limited Artificial and Natural Icing Tests of the External Stores Support System (ESSS) Installed on a UH-60A Aircraft*, June 1984.

10. Final Report, AEFA Report No. 79-19, *Artificial and Natural Icing Tests Production UH-60A Helicopter*, June 1980.

11. Final Report, AEFA Report No. 80-14, *Limited Artificial And Natural Icing Tests Production UH-60A Helicopter (Re-evaluation)*, August 1981.

12. Final Report, AEFA Report No. 83-22, *Limited Artificial and Natural Icing Tests of the External Stores Support System (ESSS) on a UH-60A Aircraft*, June 1984.

13. Final Report, AEFA Report NO. 81-18, *UH-60A Light Icing Envelope Evaluation with the Blade Deicing Kit Installed but Inoperative*, June 1982.

APPENDIX B. DESCRIPTION

GENERAL

1. The test helicopter, S/N 84-24019 is a production EH-60A helicopter. A complete deicing kit incorporating main and tail rotor deicing and an ice detection system as well as anti-icing for the pilot and copilot windshields, pitot-static tubes and their support struts, and engine and engine inlets, was installed. The external modifications required for the AN/ALQ-151(V)2 countermeasures system included the addition of two UHF antennas mounted on the underside of the fuselage; one retractable countermeasures antenna installed on the underside of the helicopter just forward of the transition section; a dipole antenna set mounted on the tailcone exterior; and two M-130 chaff/flare dispensers mounted on the left side of the tailcone (figs. B-1 through B-4). The EH-60A was also equipped with the AN/APR-39 Radar Signal Detecting Set; the AN/ASN-132 Integrated Inertial Navigation System (IINS); built-in test equipment located in the rear vertical section of the tail; Hover Infrared Suppressor Subsystem; the AN/ALQ 156(V)2 Countermeasures Set; and the AN/ALQ-162(V)2 Countermeasures Set. Mission electronic equipment was mounted in the cabin area and controlled by two operators. Cockpit instruments and controls allowed the pilot/copilot to control Electronic Countermeasures (ECM) antenna position; conduct secure voice transmission; and interface with the mission equipment operators. Principle dimensions and features of the EH-60A are presented in the UH-60A operator's manual (ref 6, app A).

Direction Finding Antennas

2. The EH-60A was equipped with a Direction Finding dipole antenna set consisting of four antennas mounted on the tailcone exterior. Two antennas were mounted on each side of the tailcone at fuselage stations 536 left and right and 596.6 left and right. Each antenna consisted of two monopole antenna elements, each 32.25 inches long and constructed from 1 inch diameter, 0.080 inch thick hollow aluminum tubing. These monopole elements were attached to phenolic blocks and mounted to the tailcone with a horizontal brace (fig. B-5). The antenna positions were numbered clockwise with the left rear antenna labeled antenna #4. All electrical wiring was routed internally through the horizontal braces and the tailcone.

ELECTRONIC COUNTERMEASURES ANTENNA

3. The ECM antenna is an eight pound 109 inch long monopole antenna mounted on the fuselage just forward of the tailcone assembly fuselage station (FS) 483 as shown in figures B-6 and B-7. Constructed of 1/8 inch thick hollow aluminum tubing, its diameter varies incrementally from 3.0 inches at its base to 0.50 inches at the tip. The ECM antenna rotates downward and forward pivoting about the base mounting structure to extend. Power for ECM antenna extension is provided by an electronic actuator controlled by a three-position guarded switch on the center instrument panel (fig. B-8). The ECM antenna will automatically retract whenever the copilot's radar altimeter is turned on and the aircraft's absolute altitude becomes less than the value selected on his L (LO SET) indicator or 100 feet above ground level (AGL) whichever comes first. Whenever the ECM antenna is fully retracted, the ANTENNA RETRACTED status advisory light on the caution/advisory panel will go on and remain on. When the antenna

Figure B-1. Front View

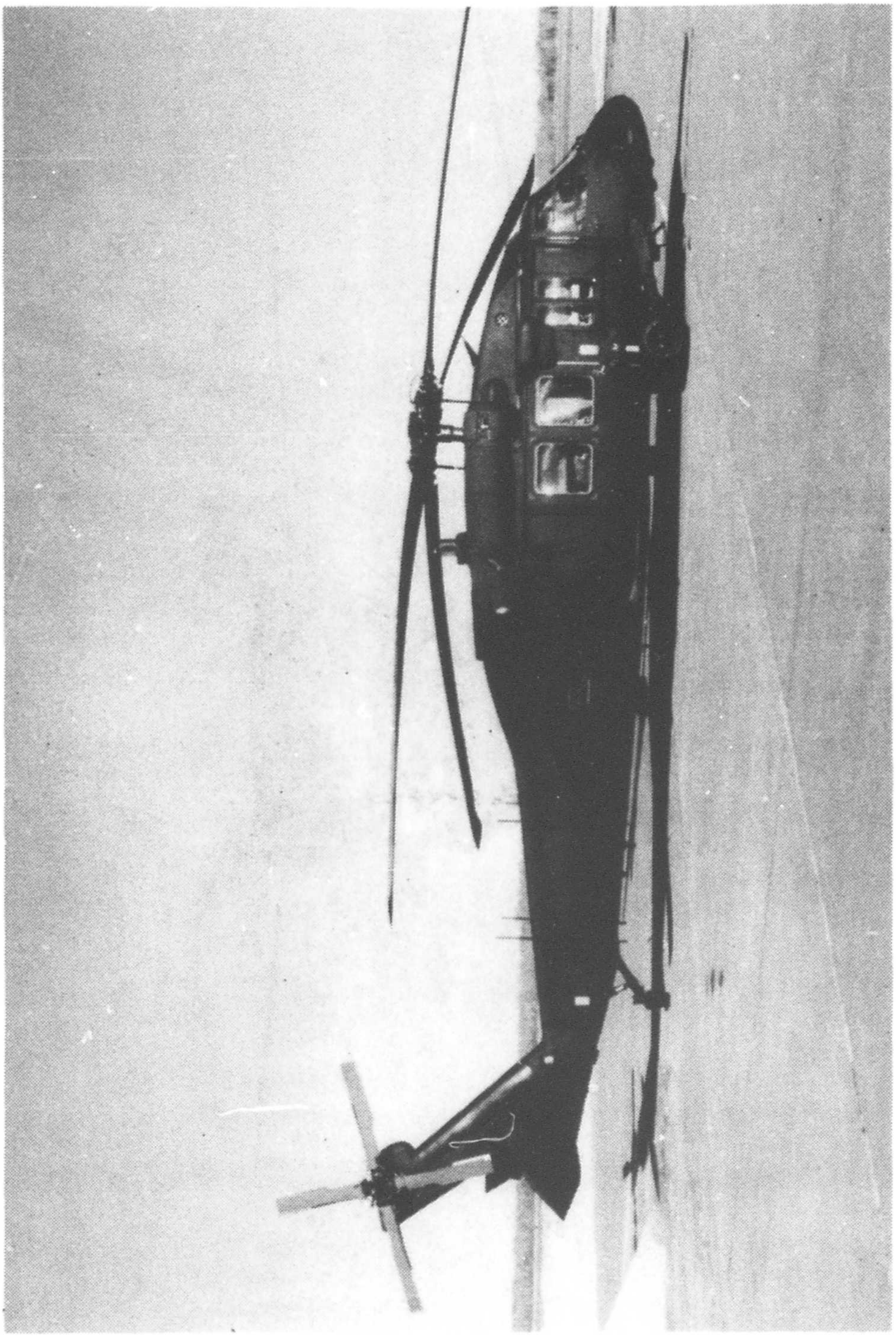

Figure B-2. Right Side View

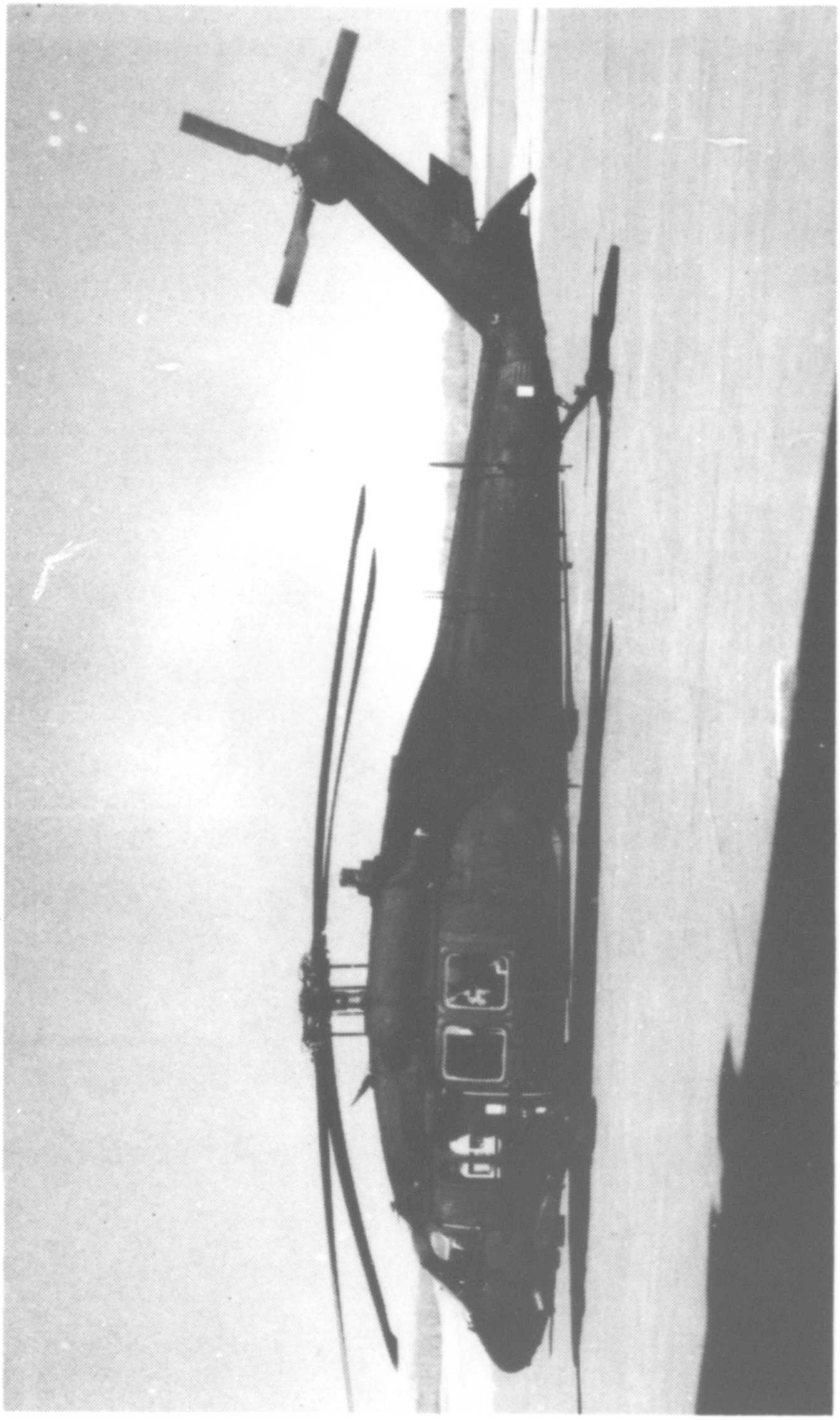

Figure B-3. Left Side View

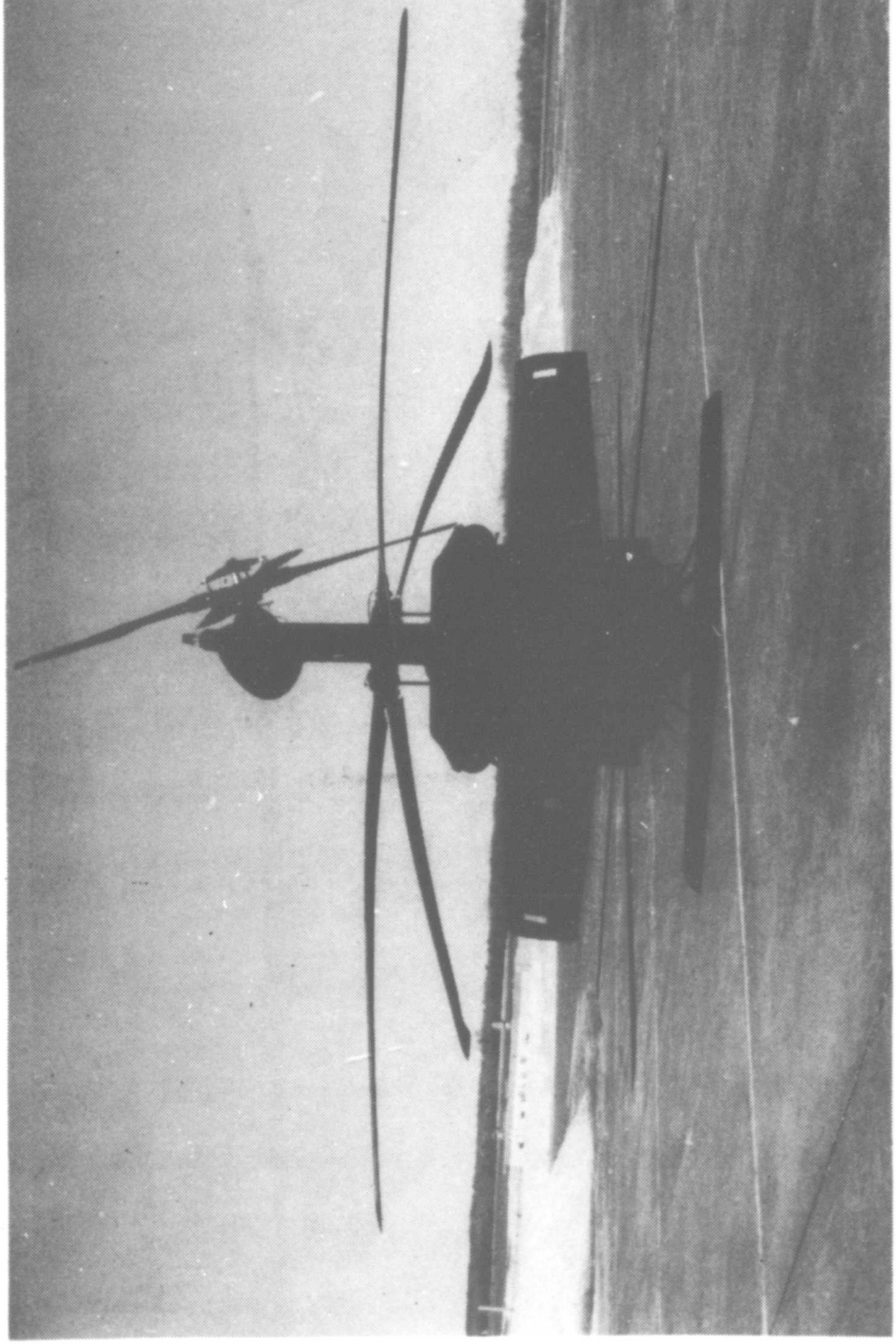

Figure B-4. Rear View

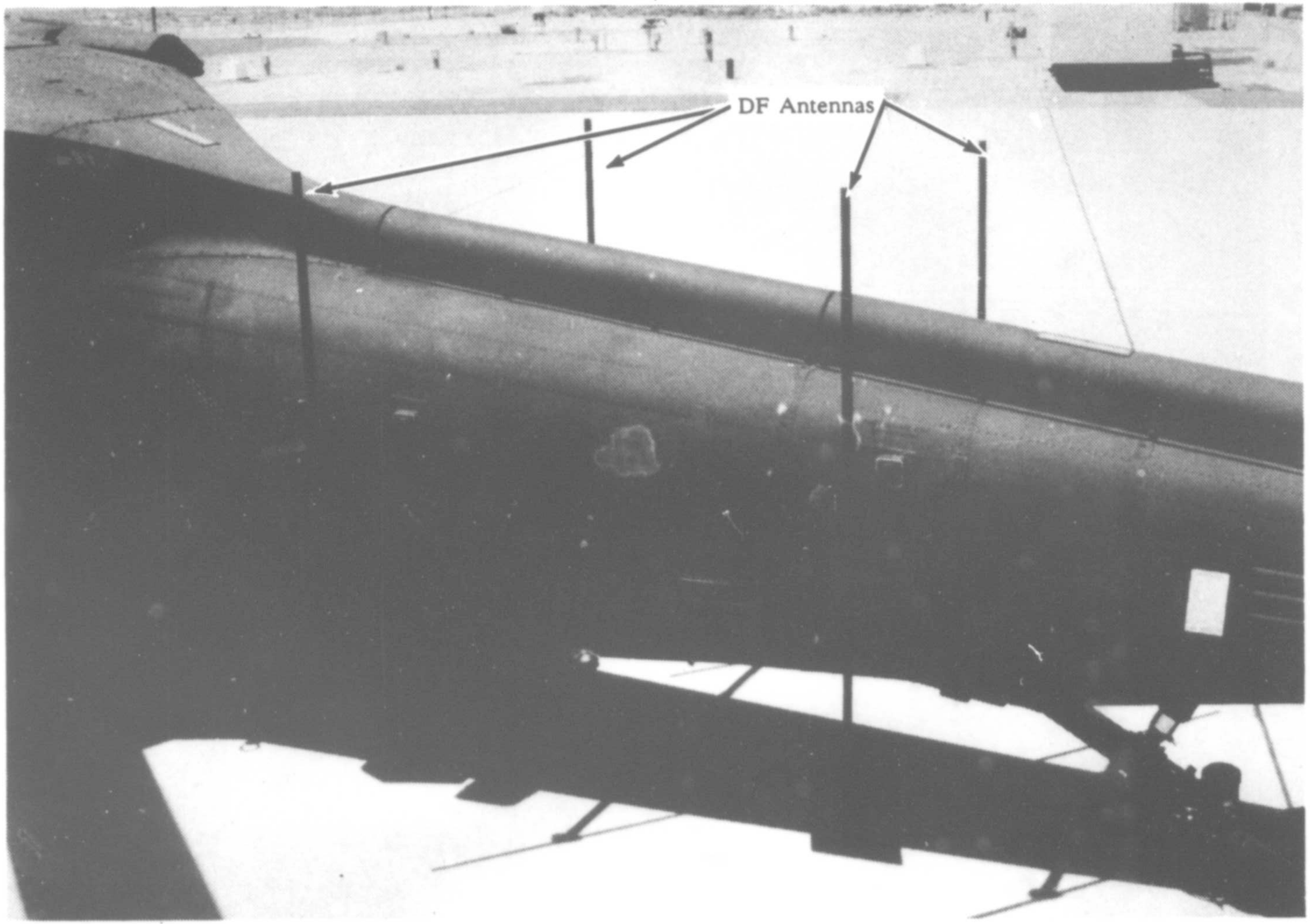

Figure B-5. DF Dipole Antennas

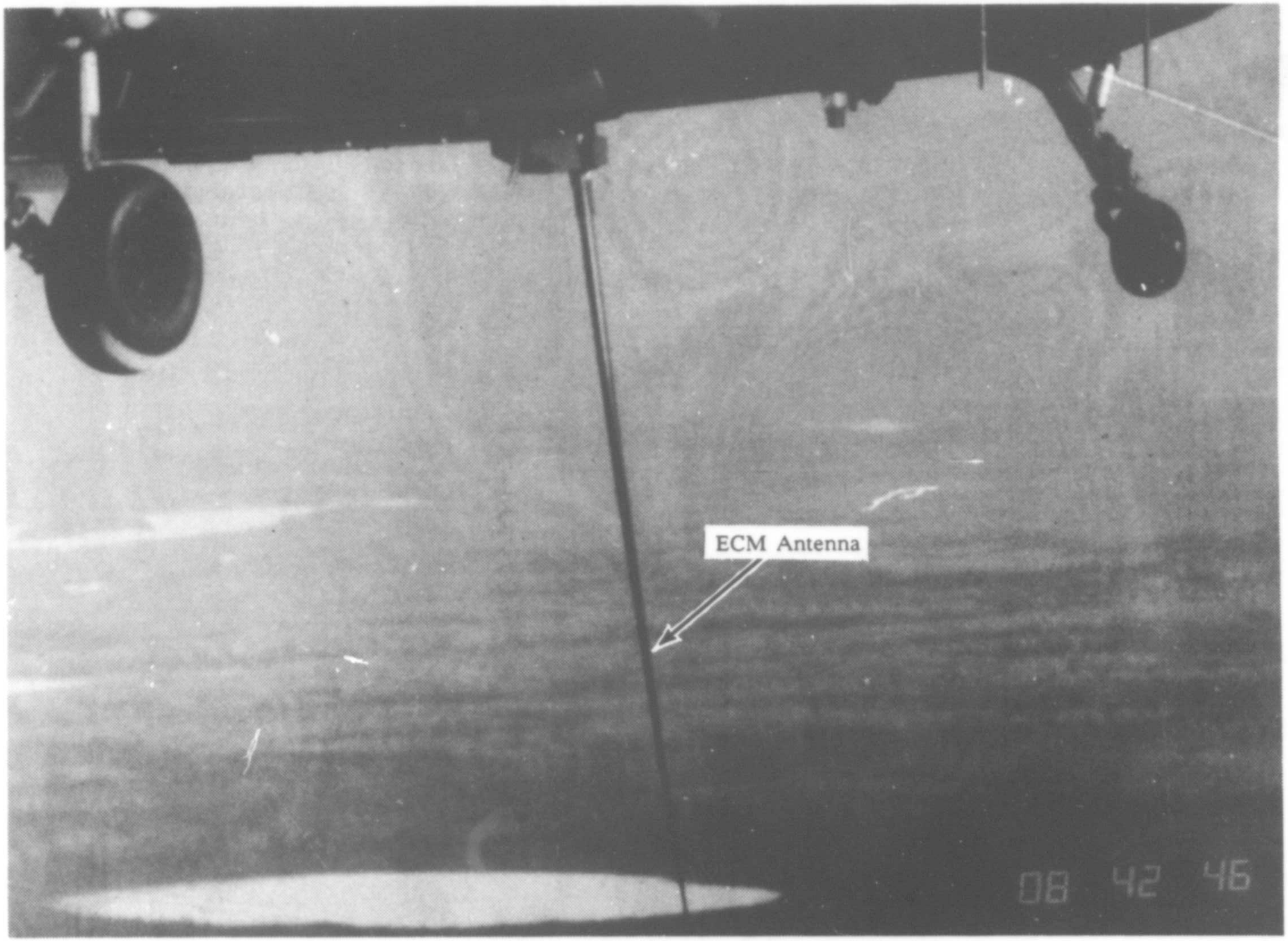

Figure B-6. ECM Antenna (Extended)

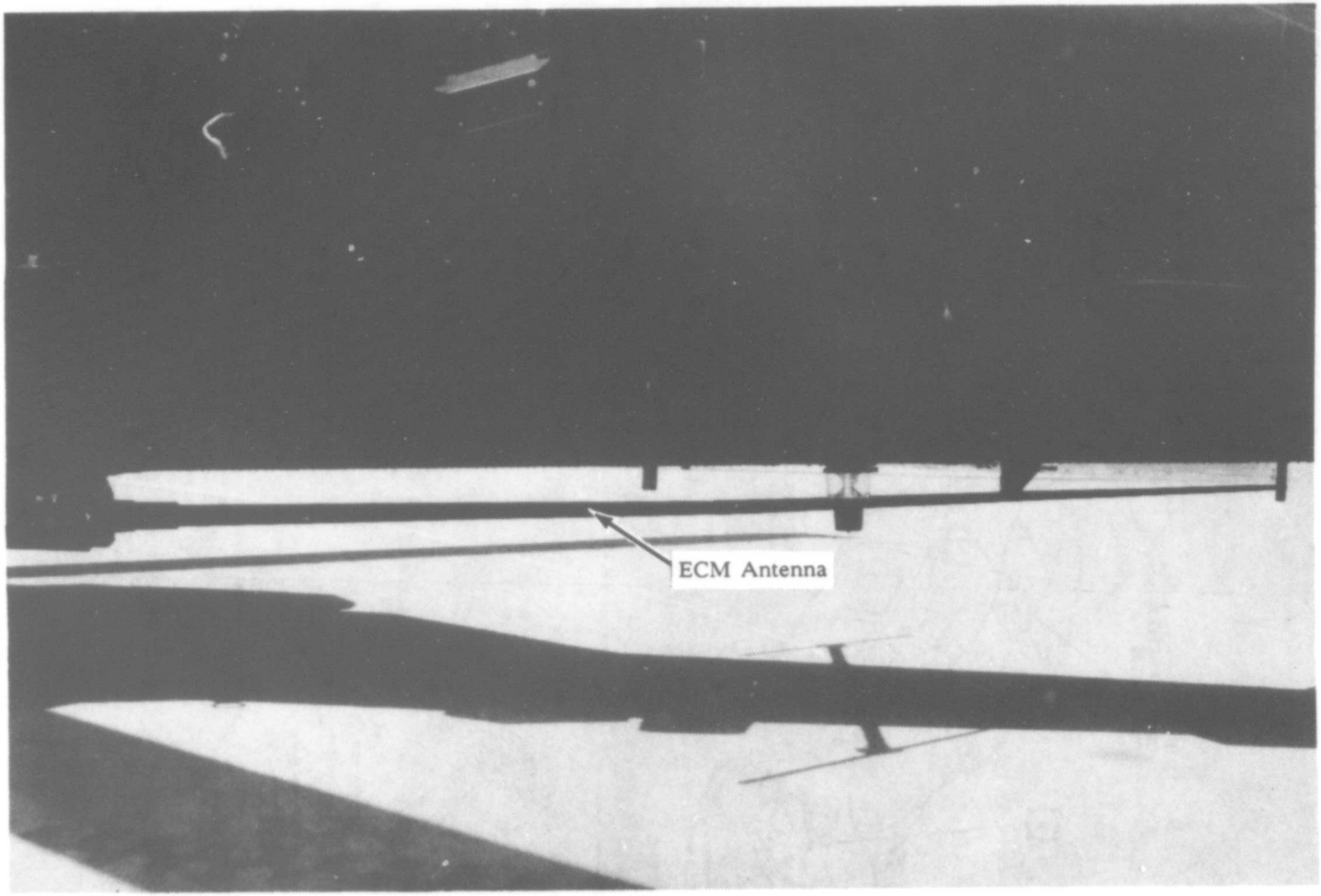

Figure B-7. ECM Antenna (Retracted)

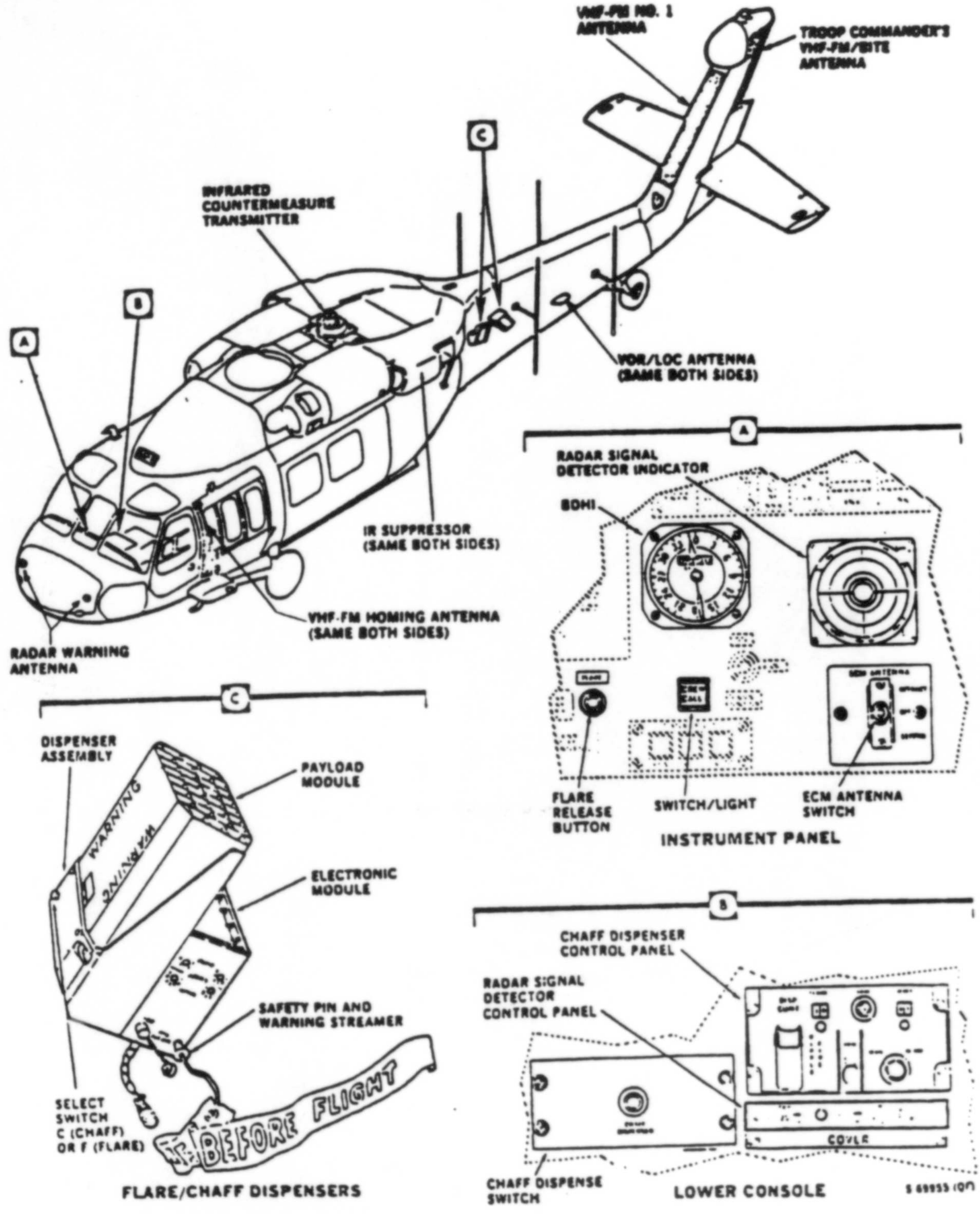

Figure B-8. Mission Kits

is fully extended, a light on the ECM operator's console marked ANTENNA DEPLOYED will go on and remain illuminated until the antenna is fully retracted. The ANTENNA EXTENDED caution light on the caution/advisory panel will also remain illuminated as long as the antenna is not fully retracted and at least one of these conditions exist: the helicopter is below the radar altimeter LO bug setting; power is lost; or the AN/APN-209 is turned off or removed.

AN/ALQ-156 COUNTERMEASURES SYSTEM ANTENNAS

4. The EH-60A was equipped with an AN/ALQ-156 antenna set consisting of four antennas mounted on the forward and rear exterior of the aircraft. The two forward antennas were mounted at FS 205, baseline right and left of 45 and waterline 206. The two aft antennas were mounted asymmetrically with the left antenna at FS 476, baseline 24 and waterline 208. The right antenna was located at FS 461, baseline 31 and waterline 217. Each antenna consisted of a hollow composite mount with a base of 15.5 inches which tapered to a 10 inch diameter face plate. The mount was constructed with an elbow bend of approximately 60° which oriented the face of the antenna approximately 45° from the longitudinal axis of the aircraft (fig. B-9). The forward and rear antennas were oriented in their respective directions (fig. B-10).

AN/ALQ-162 COUNTERMEASURES SYSTEM ANTENNA

5. The AN/ALQ-162 antenna was located on the nose of the aircraft at FS 162, baseline of left 4 and waterline of 211 as presented in figures B-11 and B-12. The antenna was constructed of composite material with a base plate of 4.5 inches diameter.

MISSION EQUIPMENT

AN/ALQ-151(V)2

6. The AN/ALQ-151(V)2 radio countermeasures system is capable of detecting radiated RF signals, automatically referencing the location of the transmitter, and initiating active countermeasures against the emitter. The systems consist of six subsystems: direction finder group; intercept group; communications group; computer/navigation group; active countermeasures group (AN/TLQ-17A); and system power group. The electronic surveillance measures (ESM) equipment and the ECM equipment operate independently of each other. A DF (ESM) operator controls the electronic surveillance functions and the ECM operator controls the active countermeasures functions. These operations interface via the system intercommunications network. The majority of the equipment is housed in the cargo compartment (fig. B-13). Additional equipment is located in the tail, tailcone, nose, and cockpit.

AN/ASN-132, INTEGRATED INERTIAL NAVIGATION SYSTEM (IINS)

General

7. The AN/ASN-132 IINS provides self-contained, world-wide position and navigation information which can be automatically updated wherever TACAN facilities

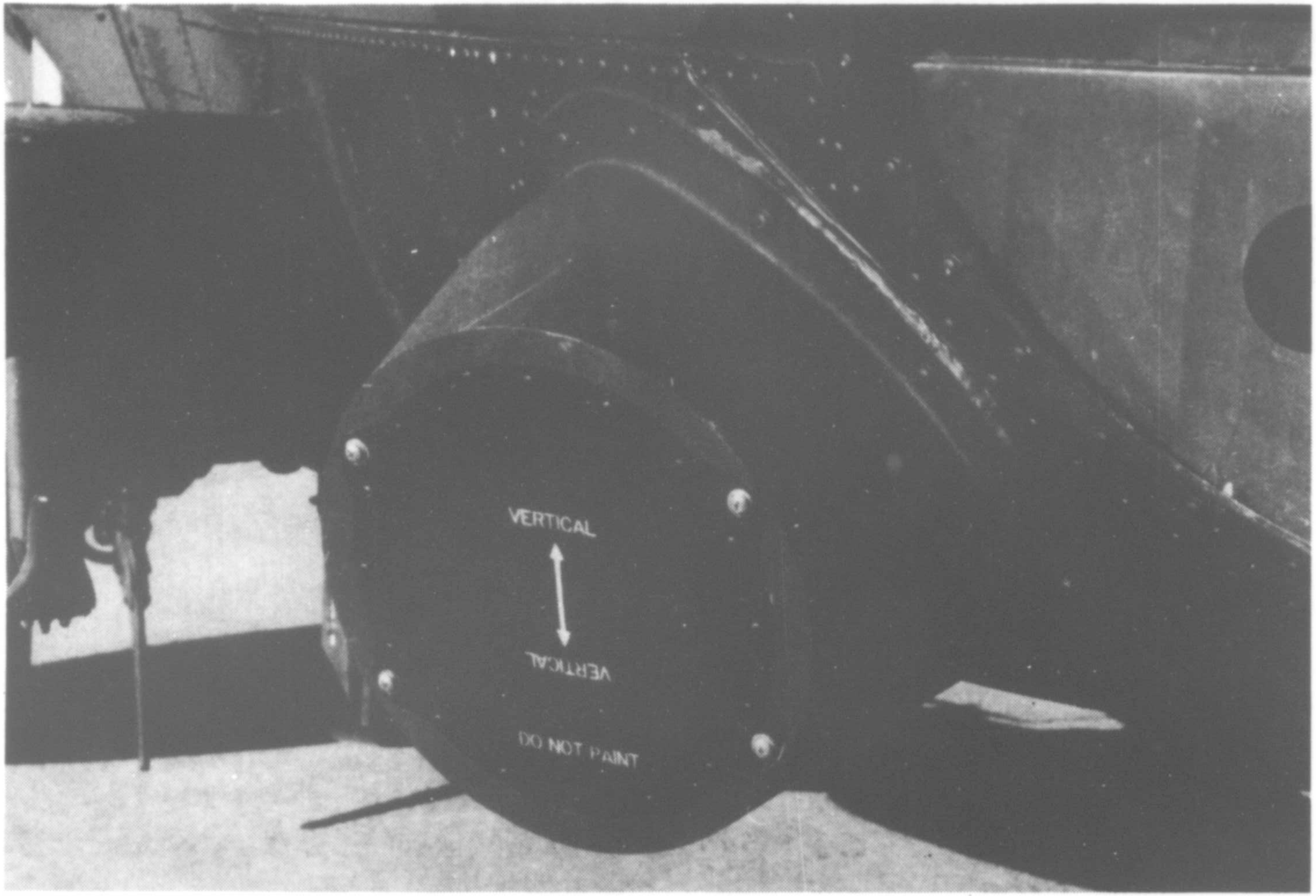

Figure B-9. AN/ALQ 156 Countermeasures System Antenna (Right Front)

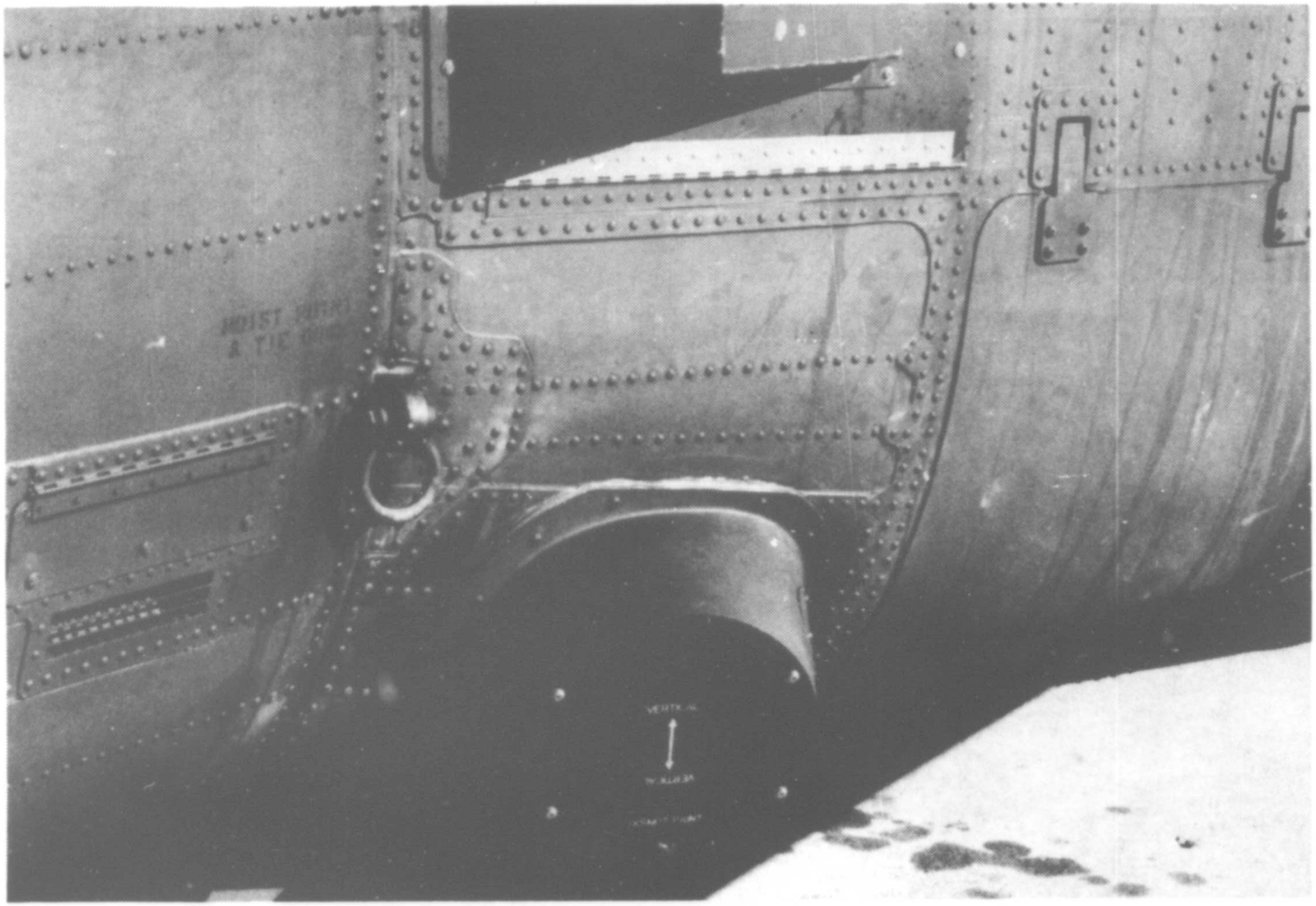

Figure B-10. AN/ALQ 156 Countermeasures System Antenna (Right Rear)

Figure B-11. AN/ALQ-162 Countermeasures Systems Antenna

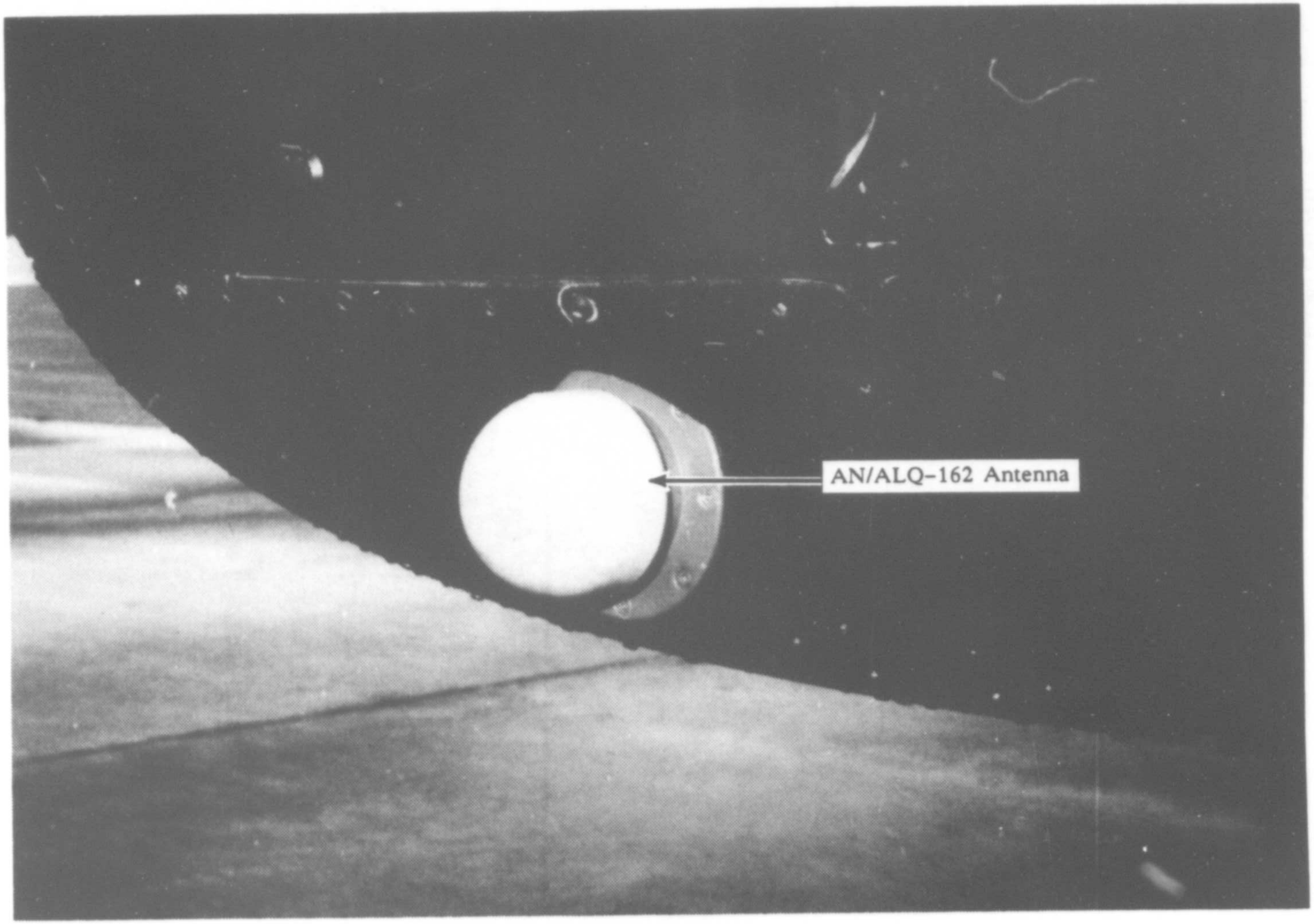

Figure B-12. AN/ALQ-162 Countermeasures System Antenna

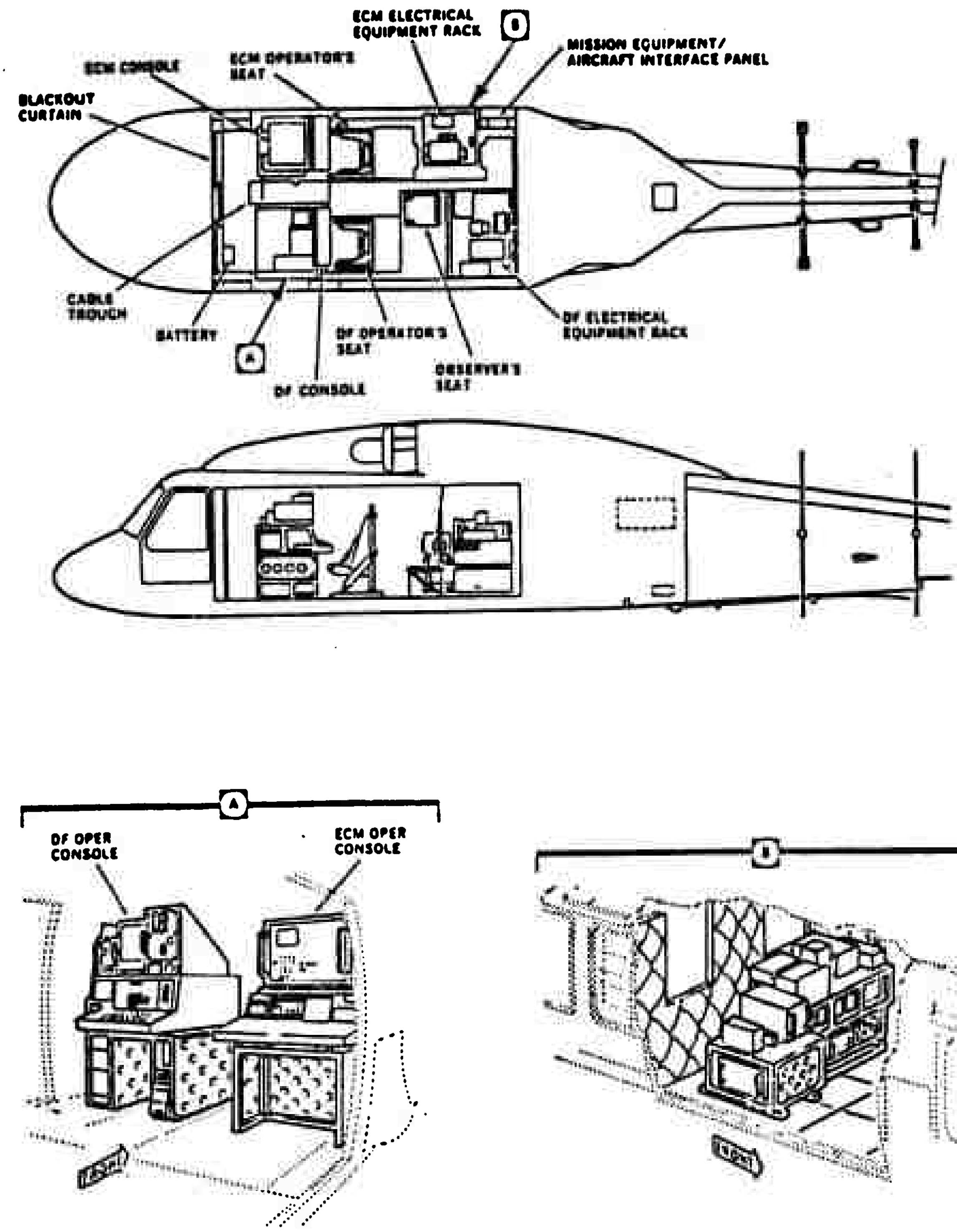

Figure B-13. Cabin Equipment Arrangement exist or manually updated without TACAN data. The IINS uses a gyrostabilized, four gimbal, all attitude platform to measure aircraft acceleration and provide present position and velocity data, course-line information, steering commands, and angular pitch, roll, and heading information.

Installation

8. The AN/ASN-132 Control and Display Unit (CDU) contains the IINS operating controls and indicators and is mounted on the lower center console (fig. B-14). The CDU enables the operator to enter data and control the information displayed on the cathode ray tube. In addition to providing navigation information, the IINS is interfaced with the aircraft flight instruments and altimeter/encoder AAU-32A. The attitude gyroscope (CN-1314) outputs, which supply pitch and roll inputs to Automatic Flight Control System (AFCS) for standard UH-60A helicopters, are replaced by appropriate outputs from the IINS. Heading information from the IINS also replaced the aircraft's AN/ASN-43 compass inputs to the AFCS. A bank of three switches provides the capability to select either IINS or standard helicopter information inputs to the AFCS.

Chaff/Flare Dispenser (M-130) System

9. The EH-60A is equipped with two M-130 General Purpose Dispensers to provide survival countermeasures against radar guided weapons and infrared seeking missiles. The systems are mounted on the left side of the tailcone (fig. B-15) and consist of two dispenser assemblies, payload modules, and electronic modules. The dispenser control panel and chaff dispense push-button are mounted on the lower console. The flare dispense push-button is mounted on the instrument panel.

Hover Infrared Suppression Subsystem

10. The hover infrared (IR) suppression system (figs. B-16 and B-17) has no moving parts. It reduces the helicopter's IR signature by mixing ram air with the engine exhaust gases, and by blocking line-of-sight view of hot metal parts. The IR suppresser channels exhaust gases through a sheet metal core mounted within a Fiberglass honeycomb sandwich-constructed nacelle. The suppresser core is constructed of short segments; each successive segment, in the direction of gas flow, has a larger cross-sectional area than the previous one. The inside surface of each segment is coated with low-reflectance material. Cooling air, entering the ram inlet scoop, is ducted around the suppresser core and passes through the gaps between overlapping core segments, providing film-cooling of the core surface. The engine exhaust plume is cooled internally by mixing the core film-cooling air, and externally by crossflow mixing with ambient freestream at the suppresser exit. The core turns outboard and downward to prevent line-of-sight seeking of the hot engine turbine and rear frame and to direct the engine exhaust into the cooling air of the free-stream and rotor downwash.

Countermeasures Set AN/ALQ-144(V)

11. The countermeasures system provides infrared countermeasure capability. The system transmits radiation modulated mechanically at high and low frequencies using an electrically-heated source. A built-in test feature monitors system operation and alerts

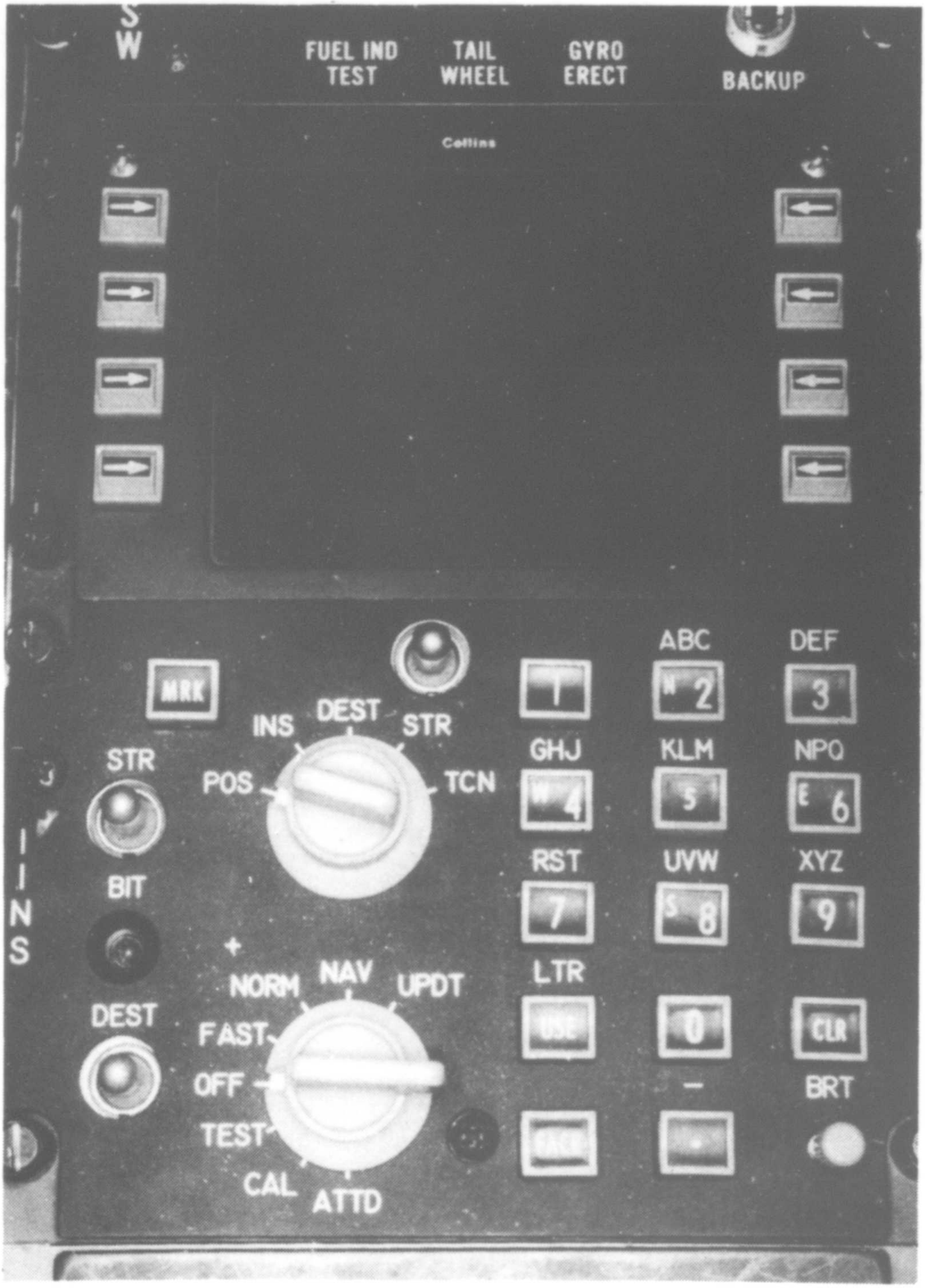

Figure B-14. AN/ASN-132 Control and Display Unit

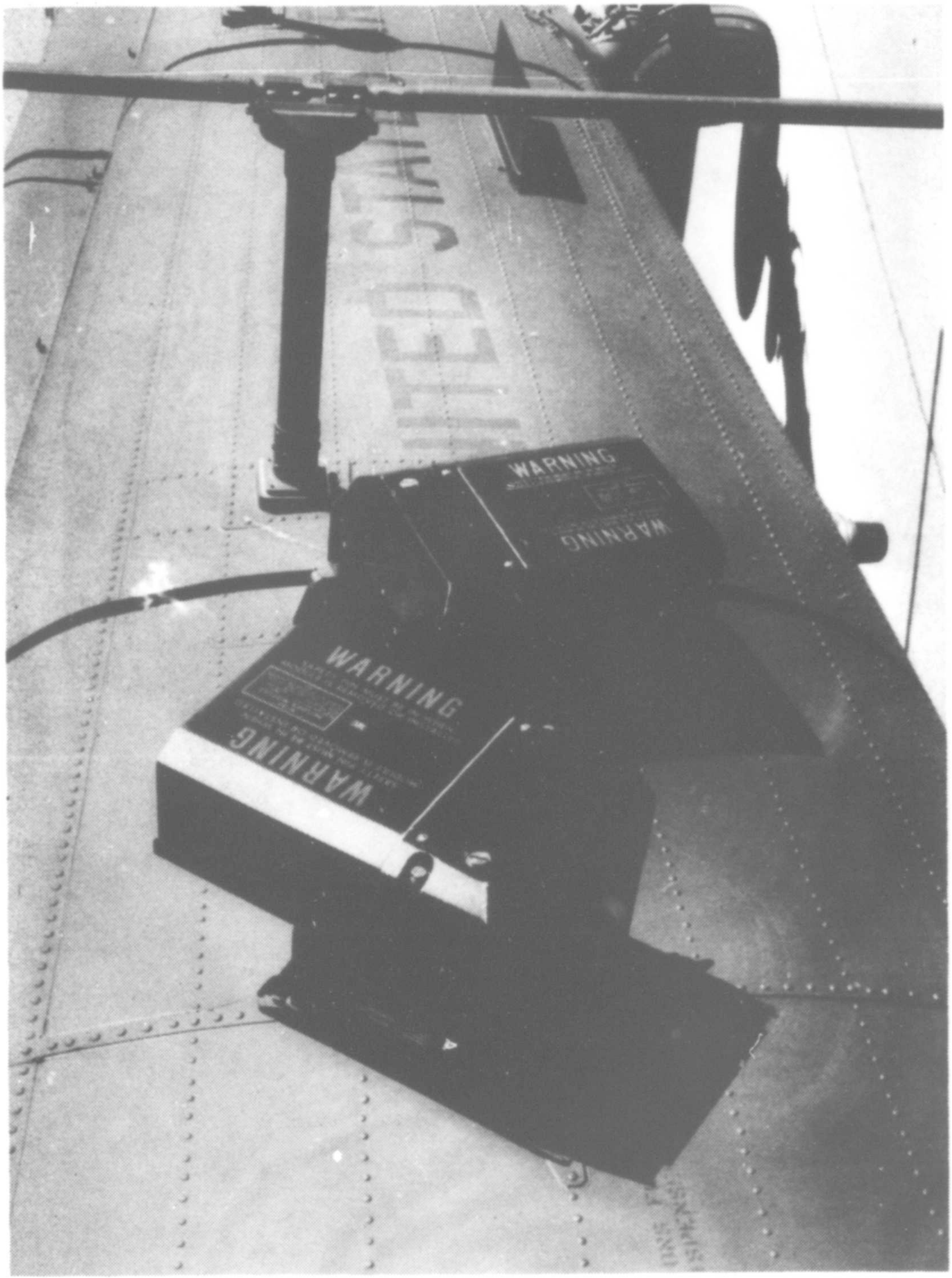

Figure B-15. M-130 Chaff/Flare Dispensers

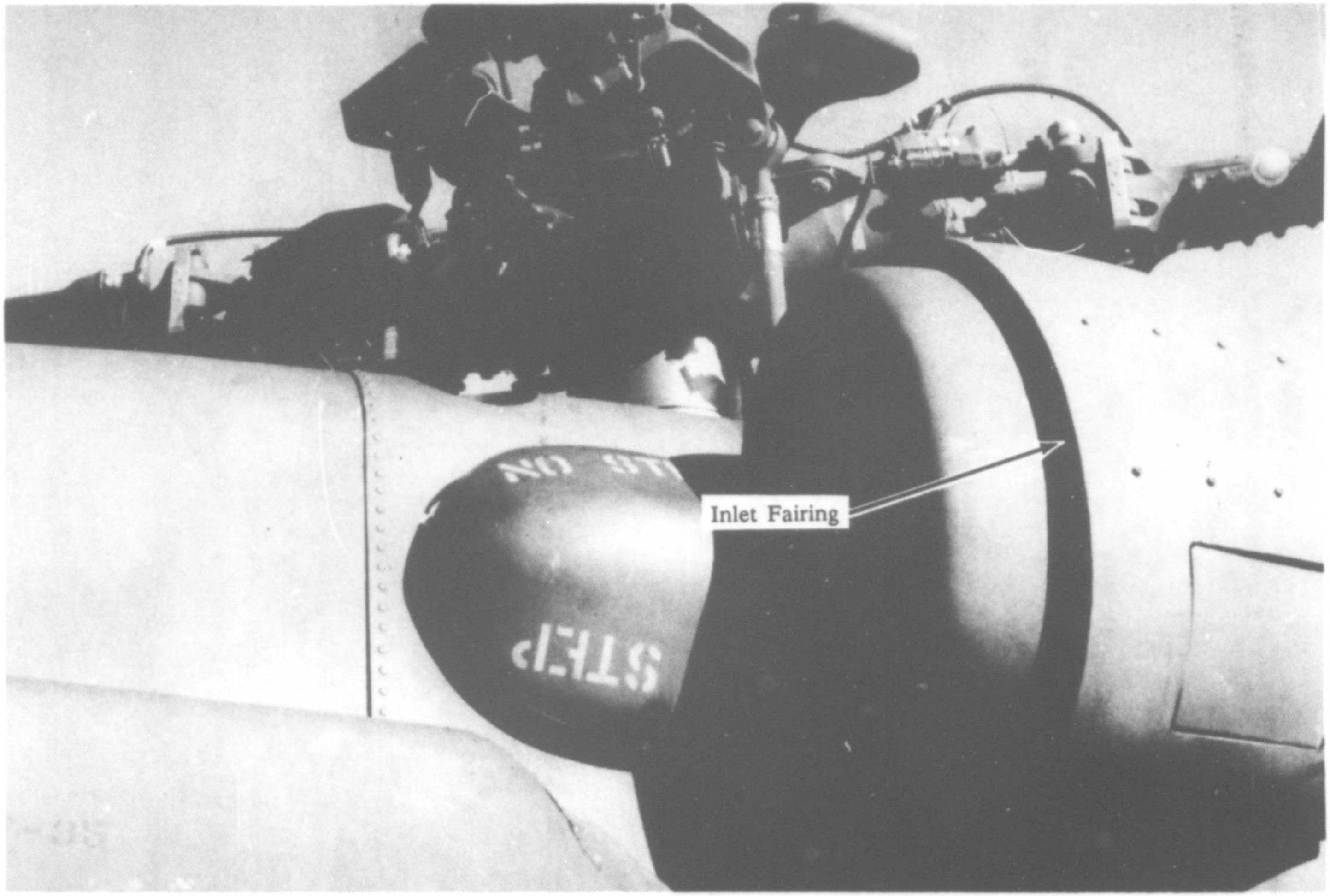

Figure B-16. HIRSS Engine Cooling Air Inlet Fairing

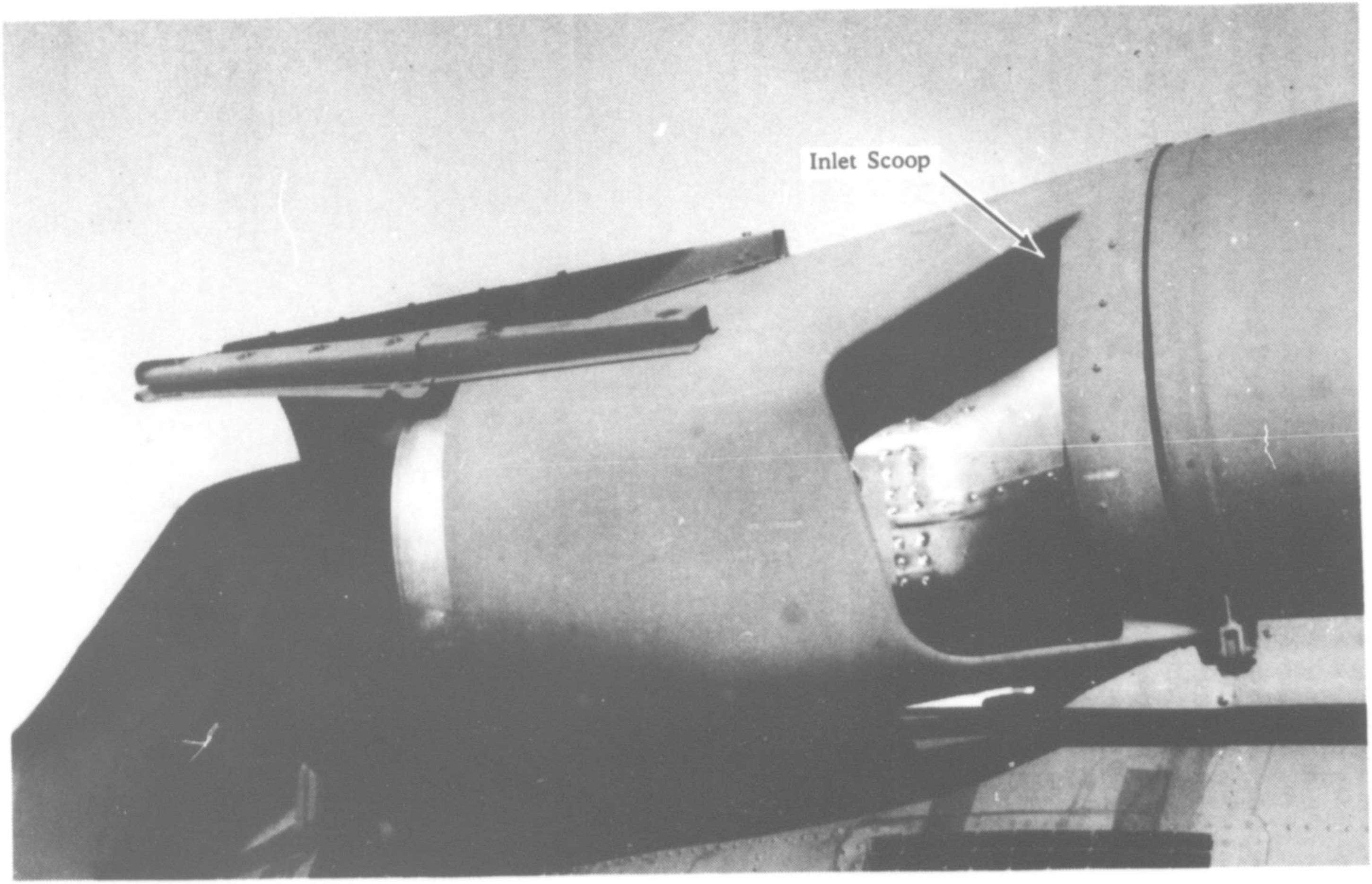

Figure E-17. HIRSS Exhaust Ram Inlet Scoop the pilot should a malfunction occur. The system is made up of a control panel on the instrument panel and a transmitter on top of the main rotor pylon aft of the main rotor (fig. B-18). When the control unit ON-OFF switch on the control panel is momentarily place ON, the power distribution and control circuits are activated, the source begins to heat, the servo motor and drive circuits are energized, turning on the high and low speed modulators, and a signal is applied to stabilize system operations before energizing the built-in test function. After a warmup period, the stabilizing signal is removed, and the system operates normally. Placing the ON-OFF control switch momentarily to OFF causes the power distribution and control circuits to de-energize the source and initiates a cool-down period. During the cool-down period, the servo motor drive circuits remain in operation, applying power to the motors that cause the modulators to continue turning.

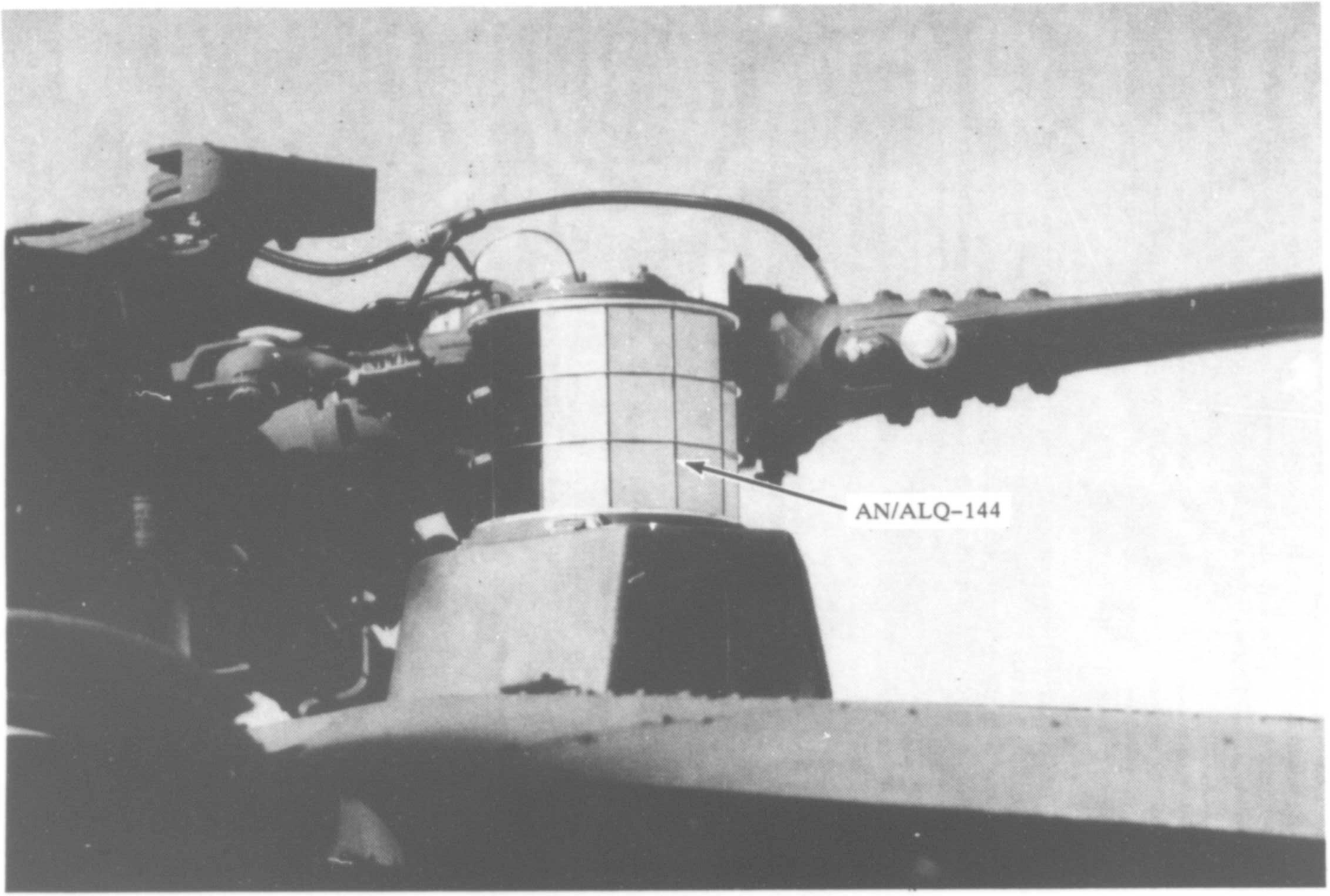

Figure B-18. AN/ALQ-144 Countermeasures Set

APPENDIX C. HELICOPTER ICING SPRAY SYSTEM DESCRIPTION

1. The Helicopter Icing Spray System (HISS) is installed in a modified Boeing Vertol JCH-47C helicopter, US Army S/N 68-15814, with fiberglass rotor blades. It is a twin-engine, turbine-powered tandem-rotor helicopter with a maximum gross weight of 48,000 lb. Power is provided by two Lycoming T55-L-712 turboshaft engines. Each engine has an installed power rating of 3,750 shaft horsepower at standard day sea level conditions. Each rotor system is 60 ft in diameter and is equipped with three fiberglass blades with 32 in. chords. Normal operating rotor speed is 225 rpm. Fuselage length is 50 ft 9 in., and distance between the fore and aft rotor hubs is 39 ft 2 in. A hydraulically powered loading ramp is located at the rear of the cargo compartment.

2. The HISS installation was initially developed under contract by the All American Engineering Co. and has been used for artificial icing evaluations since 1973. Various modifications from the original configuration have included a dual-trapeze spray boom incorporated in 1975, replacement of the original atomizers with Sonicore nozzles in 1979, addition of a gas-turbine bleed air source in 1981, and air and water plumbing improvements to the cabin and external boom assemblies since 1982. The present system is described in reference 8, appendix A, and side and rear views of the overall arrangement are shown in figure C-1. The internally mounted aluminum water tank has an 1800 gallon capacity, and when deployed the spray boom assembly is suspended 19 ft beneath the aircraft from a torque tube through the cargo compartment. Hydraulic actuators rotate the torque tube to raise and lower the boom assembly, and mechanical latches hold the boom assembly locked in either the fully deployed or retracted positions. Both the external boom assembly and the internal water supply can be jettisoned in an emergency.

3. The boom assembly consists of two parallel 27-ft trapeze sections with 5 ft vertical separators, and two 17.6-ft outriggers attached by 4-way junctions to the upper trapeze. When lowered, the outriggers are swept aft 20° and angled down 10° giving a tip-to-tip boom width of 60 ft. The boom is constructed of concentric metal pipe. The outer pipe (4 in. diameter) is the structural trapeze and outrigger assembly and provides a passage for bleed air. Water is pumped through the inner pipe at selected flow rates from the tank to the nozzles on the boom assembly. Aircraft engine compressor bleed air mixed with bleed air from a Solar T-62T-40C2 auxiliary power unit (APU) are supplied through the outer pipe to the nozzles for atomization. Sonic Development Corporation Model 125-H Sonicore nozzles are installed at 97 locations on the center trapeze sections only. The outriggers are retained for structural reasons but are isolated from the water and bleed air supply. At the nominal 150 feet distance from the booms used for icing tests, the size of the visible spray cloud cross-section is approximately 8 feet high and 36 feet wide.

4. To produce a selected liquid water content (LWC), the initial water flow rate is set to a value calculated from the relationship between water volume, airspeed, and cloud cross-sectional area that assumes an homogeneous spray dispersion and no water loss from evaporation:

$$LWC = \frac{1320.06 \times flow\ rate}{airspeed \times area}$$

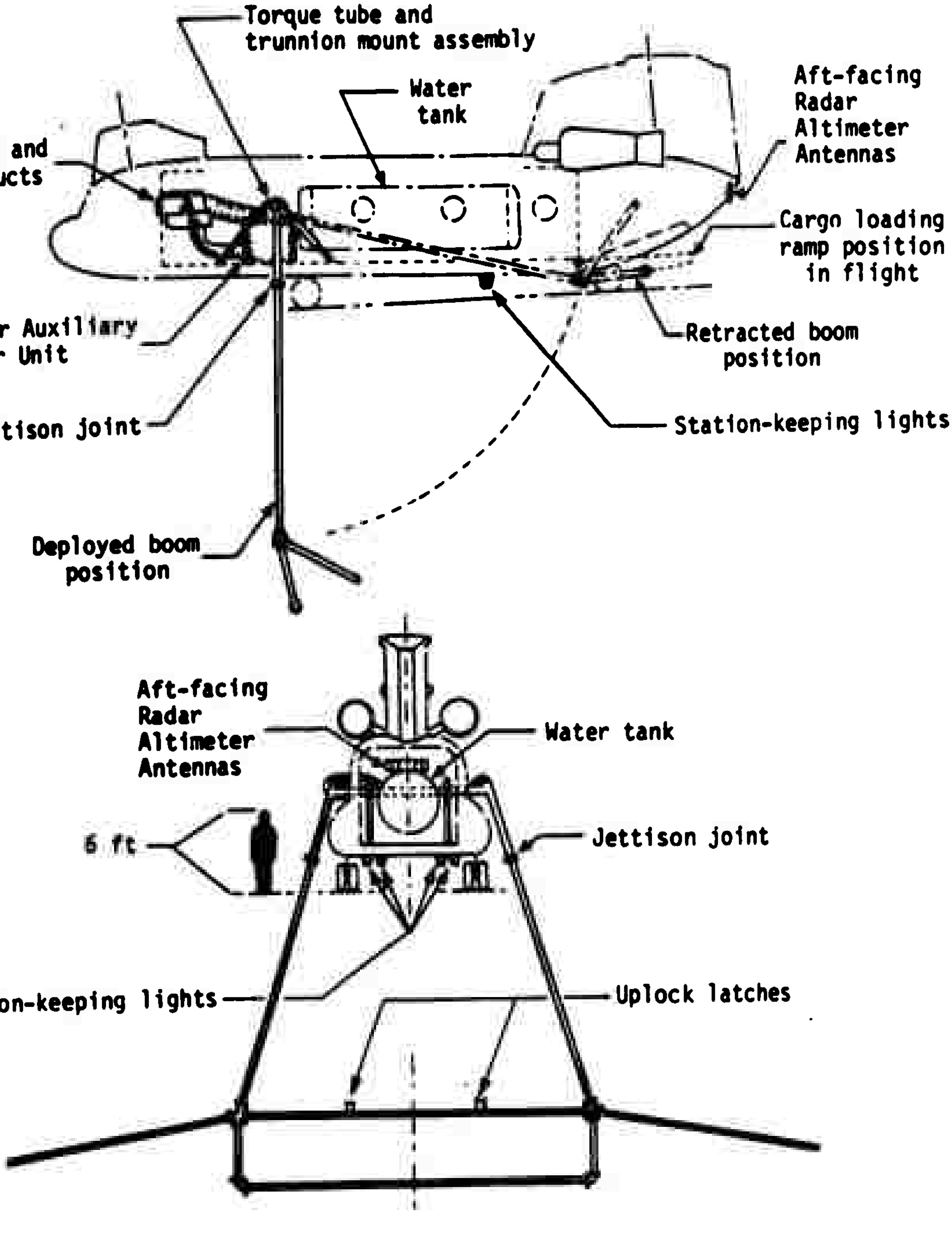

Figure C-1. Helicopter Icing Spray System
Side and Rear View Schematic

Where:

LWC = liquid water content of drops within a volume of air, gm/m^3

Flow rate = gallons/minute

Airspeed = knots true airspeed

Cross-sectional cloud area = ft^2 (288 ft^2 for the 8 x 36 ft HISS spray)

1320.06 = conversion factor for units shown; water density taken as 1 gm/cm^3

This function provides a calculated average of LWC over the entire cloud cross-sectional area. Adjustments to the flow rate are made after the instrumented JU-21A samples the spray and obtains a measured value for LWC.

5. To provide visual cues to the test aircraft for maintaining standoff position, aft-facing radar altimeter antennas are mounted at the rear of the HISS which activate red and yellow lights on the fuselage. A calibrated Rosemount air temperature probe and a Cambridge dew point hygrometer with cockpit displays provide ambient temperature and humidity measurement. To enhance photographic detail during icing operations, yellow dye is added to the water (calcocid uranine yellow No. 73, in approximate proportions of 7 ounces per 1500 gallons).

APPENDIX D. INSTRUMENTATION AND SPECIAL EQUIPMENT

CAMERA SYSTEMS

1. Two video cameras were located on the test aircraft to monitor and document accretion characteristics on the #2 and #3 Direction Finding dipole antennas and the Electronic Countermeasure (ECM) antenna (figs. D-1 and D-2). Each camera was controlled and powered by a separate battery powered recorder. Both cameras were monitored using a split screen during the first five flights. During the last three flights, a switch enabled the engineer to select which camera output was displayed on the single color video monitor mounted at the ECM operator's position. Additionally, a video camera was located on board the chase and Helicopter Icing Spray System (HISS) aircraft and were used to document the test aircraft both in the spray cloud and after exit from icing encounters. Single lens reflex 35mm cameras were used for still photo (color prints and slides) documentation both in the air and on the ground following icing flights.

VISUAL ICE ACCRETION PROBE

2. A visual ice accretion indicator probe was fabricated and installed on the test aircraft. It was used to give additional visual cues of ice build-up on the aircraft fuselage and correlate LWC readings. The probe was composed of a small symmetrical airfoil section (OH-6A tail rotor blade sections) with 3/16-inch diameter steel rod protruding outward from the leading edge of the center span. The protruding rod was painted with 1/4-inch stripes of contrasting colors which provided a means of measuring ice accumulation. The probe was mounted on the left cockpit door just below the window as shown in figure D-3.

CLOUD SAMPLING EQUIPMENT

3. Icing conditions were measured in both the natural and artificial environments, by a U.S. Army Aviation Enginering Flight Activity (AEFA) JU-21A fixed-wing aircraft, US Army S/N 66-18008. This aircraft was equipped with the following equipment: a Particle Measuring System (PMS), forward scattering spectrometer probe (model FSSP-100), a PMS optical array cloud droplet spectrometer probe (model OAP-200X), Rose-mount outside air temperature (OAT) sensor and display, Cambridge model 137 chilled mirror dew point hygrometer and display, Leigh Mk 10 ice detector unit with digital display, Cloud Technology ice detector unit, and a Small Intelligent Icing Data System (SIIDS).

4. The FSSP-100 sizes particles by measuring the amount of light scattered into the collecting optics aperture during particle interaction through a focused helium-neon high order, multimode laser beam. The signal pulses are alternating current coupled to a pulse height analyzer which compares their maximum amplitude with a reference voltage derived from a separate measurement of the direct current light signal illuminating the particles. The output of the pulse height analyzer is encoded to give the particle size in binary code. The probe is set up to size particles from 2 to 47 microns having velocities between 20 and 125 m/sec (39 to 243 knots).

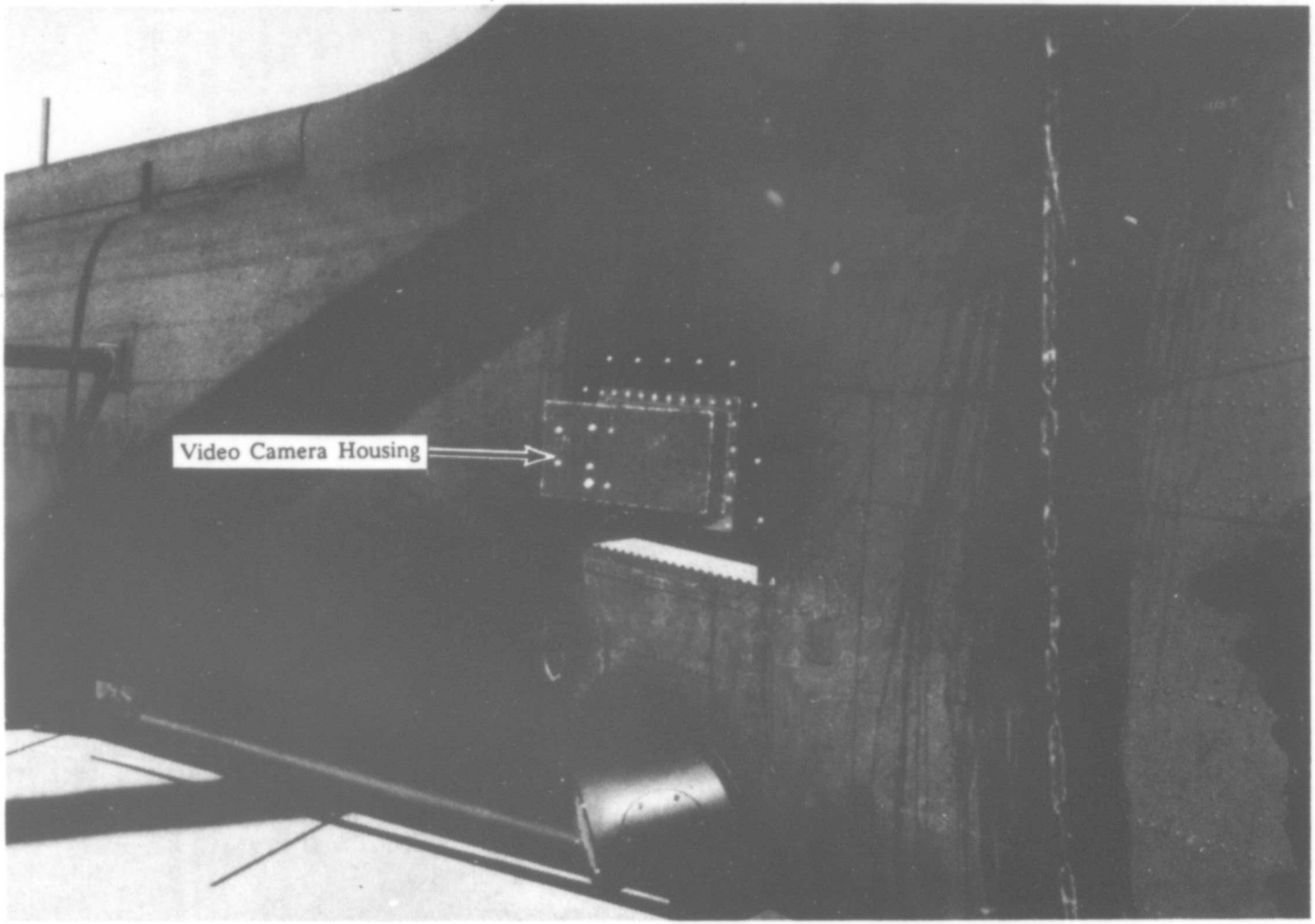

Figure D–1. Direction Finding Antenna Camera

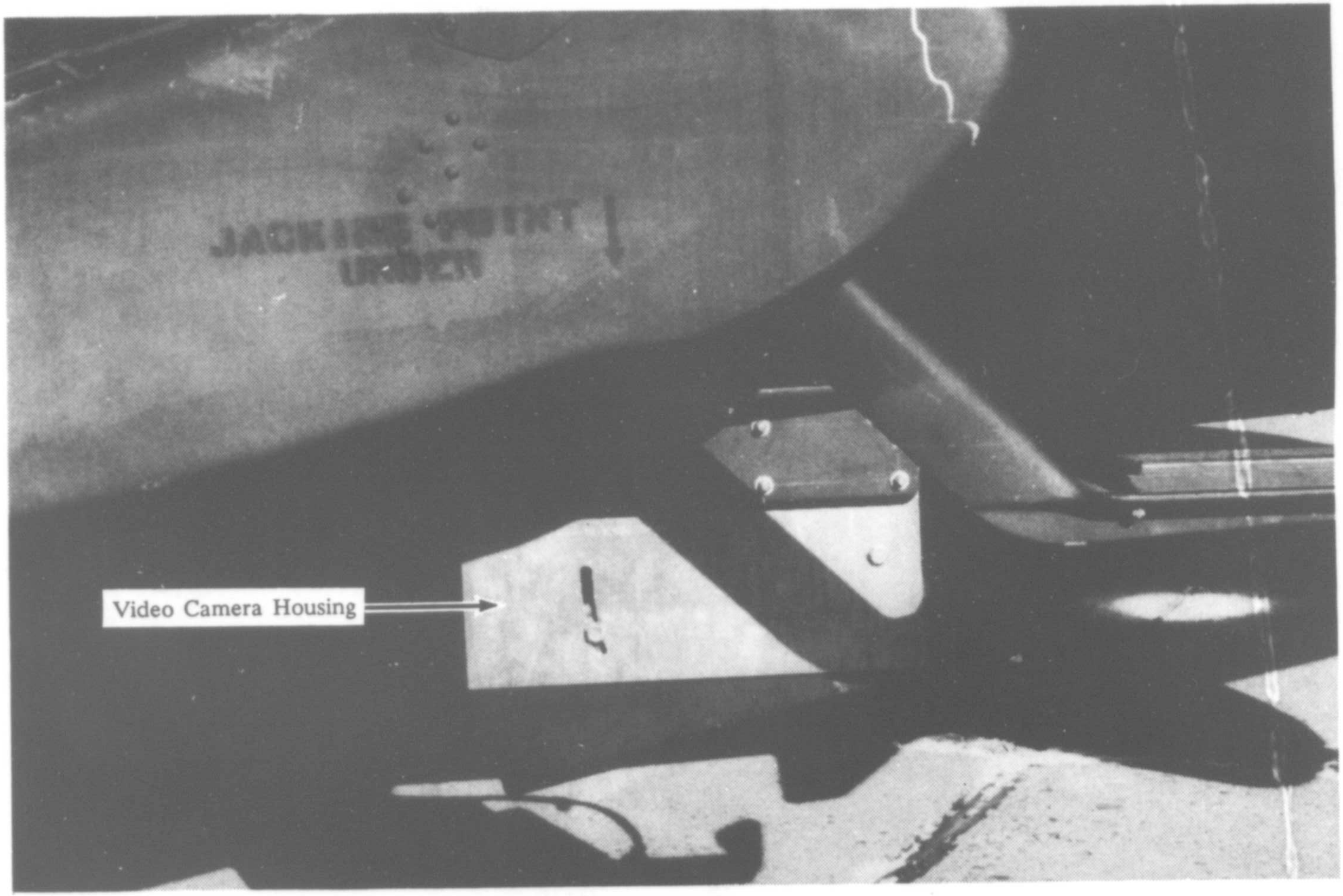

Figure D-2. Electronic Countermeasures Antenna Camera

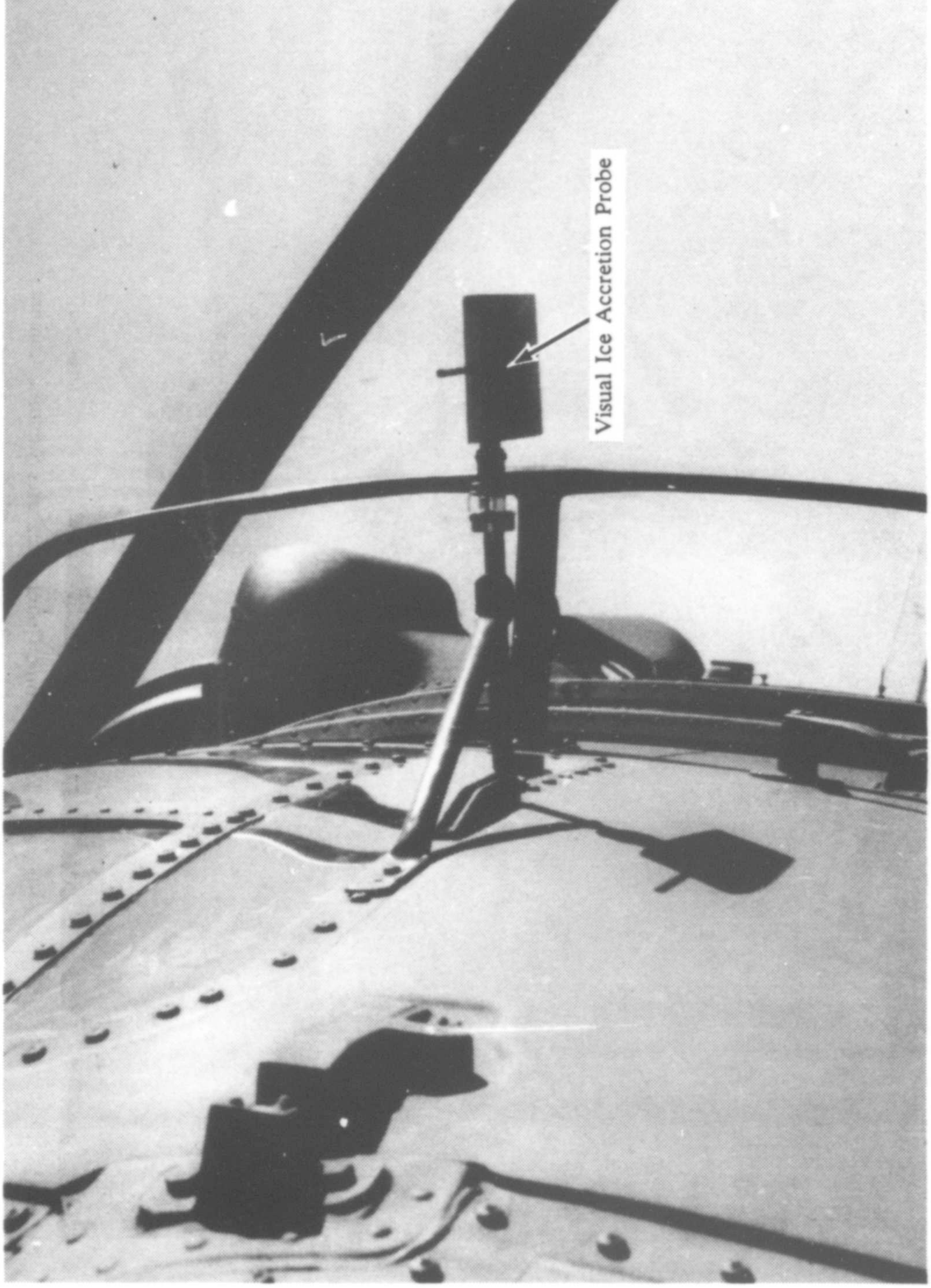

Figure D–3. Visual Ice Accretion Probe

5. The OAP-200X sizes using a linear array of photodiodes to sense the shadowing of array elements by particles passing through its field-of-view. Particles are illuminated by a helium-neon laser and imaged as shadowgraphs on the photodiode array. If the shadowing of each photodiode element is dark enough a flip-flop element is set. The particle size is determined by the number of elements set by a particle's passage, the size of each array element, and the magnification of the optical system. This probe contains 24 active photodiode elements capable of sizing into 15 size channels with a magnification set for a size range of 20 to 300 microns.

6. The SIIDS is a compact data acquisition system designed and programmed specifically for icing studies. It consists of four main components: a microprocessor, Techtran data cassette recorder, Axiom printer, and an operator control panel. The SIIDS has three operational modes: (1) data acquisition, in which averaged raw data are recorded on cassette tape and averaged engineering units are displayed on the printer, (2) a playback mode in which raw averaged data read from the cassette are converted to average engineering units which are displayed on the printer, (3) monitor mode used to set the calendar clock and alter programmed constants. During data acquisition, the operator may select an averaging period of 1/2, 1, 2, 5, or 10 seconds.

7. The following parameters are displayed on the SIIDS printer in engineering units.

a. calendar: year, month, day, hour, minute and second

b. pressure altitude (feet)

c. airspeed (knots)

d. outside air temperature (degree C)

e. dew point (degree C)

f. total liquid water content observed by the FSSP (g/m^3)

g. total liquid water content observed by both the FSSP and OAP (g/m^3)

h. median volumetric diameter (mm)

i. amount of liquid water content observed for each channel (total 30) of both probes (g/m^3)

APPENDIX E. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. The production deice system on the EH-60A helicopter was functionally tested prior to each icing flight. All anti-ice systems (pitot heat, windshield, engine, and engine inlet) and rotor deice systems were activated while enroute to the test area. A build-up program was used to gain experience with flight in icing conditions. For artificial icing the test aircraft entered the artificial spray cloud from a position below and approximately 150 feet behind the spray. Test and spray aircraft horizontal separation distance was maintained during the icing flight by observing yellow (greater than 160 feet) and red (closer than 140 feet) lights mounted on the bottom of the spray aircraft. The visual indication was supplemented as required by information provided from the spray aircraft. Because of the limited depth of the icing cloud, the Direction Finding (DF) dipole antennas and the Electronic Countermeasures (ECM) whip antenna could not be immersed simultaneously. Information from the chase aircraft was used to position the test aircraft vertically so as to ice either the DF or ECM antenna. All artificial icing flights were flown with a predetermined liquid water content (LWC) and outside air temperature (OAT). Airspeed and OAT were established with the calibrated instrumentation of the spray aircraft. Flight continued in the cloud condition until a test aircraft limitation was reached or until the spray aircraft fuel or water limit was reached. For natural icing the JU-21A would locate and document the icing condition and radio the data to the test aircraft before it entered the icing environment. The JU-21A would then orbit in the area to facilitate a post-immersion rapid in-flight join-up with the test aircraft for photographic documentation. The liquid water content (LWC), particle size in the icing cloud, OAT, and relative humidity were documented by the JU-21A chase/scout aircraft configured with the particle measuring system instrumentation.

ICE ACCRETION AND SHEDDING

2. Ice accretion in the natural icing environment was determined in flight using the visual ice accretion probe indicator. The visual probe was monitored by the copilot. The Rosemount icing rate meter was used to monitor LWC.

3. Ice accretion on the test aircraft was documented using hand-held motion picture and video tape cameras photographing from both the chase aircraft and spray aircraft. Postflight photographs were made to document the ice remaining on the individual components of the airframe and rotors. A description of the camera systems is presented in appendix D.

4. Ice shedding characteristics were qualitatively assessed by crew members in the test, spray, and chase aircraft.

WEIGHT AND BALANCE

5. Prior to the test, the aircraft gross weight and longitudinal and lateral centers of gravity were determined by using calibrated scales. The aircraft was weighed with instrumentation, fixed ballast and trapped fuel.

DEFINITIONS

6. Icing characteristics were described using the following definitions of icing severity. These definitions may be found in FM 1-30 and the UH-60A operator's manual.

a. **Trace icing**: Ice becomes perceptible. Rate of accumulation slightly greater than rate of sublimation. It is not hazardous even though deicing equipment is not used, unless encountered for an extended period of time (over 1 hour). Commonly 0 to 0.15 gm/m^3 LWC for the UH-60A helicopter.

b. **Light icing**: The rate of accumulation may create a problem if flight is prolonged in this environment (over 1 hour). Occasional use of deicing/anti-icing equipment removes/prevents accumulation. It does not present a problem if the deicing/anti-icing equipment is used. Commonly 0.15 to 0.5 gm/m^3 LWC for the UH-60A helicopter.

c. **Moderate icing**: The rate of accumulation is such that even short encounters become potentially hazardous and use of deicing/anti-icing equipment or diversion is necessary. Commonly 0.5 to 1.0 gm/m^3 LWC for the UH-60A helicopter.

d. **Severe/heavy icing**: The rate of accumulation is such that deicing/anti-icing equipment fails to reduce or control the hazard. Immediate diversion is necessary. Commonly greater than 1.0 gm/m3 LWC for the UH-60A helicopter.

7. Results were categorized as deficiencies or shortcomings in accordance with the following definitions.

Deficiency: A defect or malfunction discovered during the life cycle of an item of equipment that constitutes a safety hazard to personnel; will result in serious damage to the equipment if operation is continued; or indicates improper design or other cause of failure of an item or part, which seriously impairs the equipment's operational capability.

Shortcoming: 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 materiel or end product.

APPENDIX F. SPECIFIC TEST CONDITIONS

Table F-1. Specific Test Conditions[1]

Flt	Date	Icing Environment	Average Gross Weight (lb)	Average Longitudinal Center of Gravity (FS)	Average Density Altitude (ft)	Average OAT[2] (deg C)	Average True Airspeed (kts)	Average LWC[3] (gm/m^3)	MVD[4] (μm)	Total Time In Cloud (min)
04	04-Mar	Artificial	16,060	360.7	1,590	-10.4	121	.62	26	60
02	04-Mar	Artificial	16,100	361.0	7,690	-9.9	118	.99	49	56
03	05-Mar	Artificial	16,100	360.7	2,830	-5.1	123	.95	38	57
04	08-Mar	Natural	16,170	361.2	9,440	-7.2	109	.70	N/A	61
05	13-Mar	Artificial	15,970	360.6	1,630	-15.0	121	.52	34	63
06	13 Mar	Artificial	16,010	360.7	6,490	-19.6	121	.45	31	60
07	16-Mar	Natural	15,900	360.1	3,450	-9.3	122	.20	18	92
08[5]	17-Mar	Natural	16,580	362.8	5,160	-13.0	109	.55	17	21

NOTES:

[1]Main rotor speed = 258 rpm, mid lateral center of gravity location, ECM antenna extended.
[2]OAT: Outside air temperature.
[3]LWC: Liquid water content.
[4]MVD: Mean Volumetric Diameter.
[5]ECM antenna removed.

APPENDIX G. TEST INCIDENT REPORTS

The following Test Incident Reports (TIR's), AMC Form 2134, November 1987, were submitted by AEFA during this evaluation.

TIR Number	Subject
EJ-B 880601	Engine Ice Ingestion
EJ-B 880602	Sheared Retaining Screws
EJ-B 880603	Tail Rotor Ice Damage
EJ-B 880604	Sheared Retaining Screws
EJ-B 880605	Sheared Pivot Stud
EJ-B 880606	Cracked Phenolic Block

TEST INCIDENT REPORT (AMCR 70-13)	1. Release Date: 10 March 1988	
Test Title: 2. Artificial and Natural Icing Tests, EH-60A	Test Project # 3. 88-06	TIR # 4. EJ-B 880601

5. Test Agency: AEFA — 6. Test Sponsor PM SEMA

I MAJOR ITEM DATA

10. Model: Helicopter, EH-60A
11. Serial#: 84-24019
12. USA#:
13. Mfr: Sikorsky
14. Contract#:

Test Life: Units:
21.
22.
23.
24. (Not Used)

II INCIDENT DATA

30. Title Engine Ice Ingestion
31. Subsystem:
32. Incident Class: MAJOR (P)
33. Category: R&D
34. Observed During: Operation
35. Action Taken: Remove and Replace

40. Data & Time: 8 March 1988, 1235
41. FD/SC Step#:
42. FD/SC Class:
43. Chargeability:
44. Preliminary CA Status:
45. Asgd Resp:

48. Test Environment: Transition to hover, approximately 10 - 20 KIAS
49. Defective Materiel:

III INCIDENT SUBJECT DATA

50. Name Engine, Aircraft, Turbine T700-GE-700
51. Serial#: GE-E-306941
52. FSN/NSN: 2840-01-070-1003
53. Mfr: General Electric
54. Mfr Part#: 70000-10100-014
55. Drawing#: TM 55-1520-237-23P, Index 2, Fig. 49
56. Quantity: 1
57. Action: Replaced

60. FGC:
61. LSA#:
Part Life: Units:
63.
64.
65.
66. Next Assy:
67. Serial#:

IV MAINTENANCE DATA

70. Diagnostic Clockhours: LCF1 067
71. Diagnostic Manhours: LCF2 0156
72. Active Maint Clockhours: 01507
73. Active Maint Manhours: 0117

80. Type: Unscheduled
81. Level Use: Organizational
82. Level Prsc: AVUM
83. Level Recm: AVUM

V INCIDENT DESCRIPTION

Full Description of Incident:

90. Test flight was a natural icing flight at 9800 ft PA, -7.2 °C and an average liquid water content of 0.75 gram per cubic meter resulting in mixed ice accumulations of approximately 2 - 2.5 inches on the FM antennae, OAT probe, wirestrike protection system, and rotor hub. While transitioning from forward flight to a hover (approximately 10 - 20 KIAS) with surface temperatures of ±1 °C, ice began to shed from several areas of the aircraft. A loud, high pitched whine was heard from the right side of the aircraft. Aircraft was landed immediately and #2 engine control lever was placed in the idle detent. As engine RPM decreased, the whine diminished. (CONTINUED ON REVERSE)

Name, Title & Phone of Preparer:	FOR THE COMMANDER:
98. WILLIAM D. LEWIS, MAJ, AV Project Officer, 277-4784	99. AUSTIN R. OMLIE, MAJ, AV Chief, Plans & Programs ARO

Coordination Stamp on Reverse

Post-flight inspection (borescope, para 1-143, page 1-272.23, TM 55-2840-248-23) revealed six first stage compressor blades bent/chipped beyond limits (para 1-144, page 1-272.26.1, Table 1-15).

USA AVN ENGR FLT ACTV			
		INIT	DATE
DRAFTER			
3	C2	[illegible]	
	C ___		
	A		
	D		
	M		
4	P	[illegible]	8/11
	SM		
2	T	[illegible]	11 Mar
1	-TB	[illegible]	
ADJUTANT			
READ FILE		YES	NO

TEST INCIDENT REPORT (AMCR 70-13)	1. Release Date: 21 March 1988	
2. Test Title: Artificial and Natural Icing Tests, EH-60A	3. Test Project # 88-06	4. TIR # EJ-B880602

5. Test Agency: AEFA

6. Test Sponsor PM SEMA

I MAJOR ITEM DATA

10. Model: Helicopter, EH-60A	Test Life: Units:
11. Serial#: 84-24019	21.
12. USA#:	22.
13. Mfr: Sikorsky	23.
14. Contract#:	24. (Not Used)

II INCIDENT DATA

30. Title Sheared Retaining Screw	40. Data & Time:13 March 1988, 1150
31. Subsystem: Quick Fix	41. FD/SC Step#:
32. Incident Class: Minor (P)	42. FD/SC Class:
33. Category: R&D	43. Chargeability:
34. Observed During:Post-flight inspection	44. Preliminary CA Status:
35. Action Taken: Replaced	45. Asgd Resp:

48. Test Environment: Artificial icing test flight at -15 °C, LWC 0.5, for one hour.

49. Defective Materiel: Scrapped

III INCIDENT SUBJECT DATA

50. Name Screw, retaining	60. FGC:
51. Serial#: UNK	61. LSA#:
2. FSN/NSN: 5305-00-253-5614	Part Life: Units:
53. Mfr:	63.
54. Mfr Part#: UNK	64.
55. Drawing#: UNK	65.
56. Quantity: 1	66. Next Assy:
57. Action: Replaced	67. Serial#:

IV MAINTENANCE DATA

70. Diagnostic Clockhours:	80. Type: Unscheduled
71. Diagnostic Manhours:	81. Level Use: Organizational
72. Active Maint Clockhours:	82. Level Prsc: AVUM
73. Active Maint Manhours:	83. Level Recm: AVUM

V INCIDENT DESCRIPTION

Full Description of Incident:

90. Following an artificial icing flight of 1 hour duration at -15 °C with a liquid water content of 0.5 grams per cubic meter, post-flight inspection revealed a sheared dipole retaining screw. The screw was located on the right front lower dipole retaining block, the upper left screw as viewed from the right side of the aircraft. The shear occurred just below the screw head. The screw head was missing upon post flight.

Name, Title & Phone of Preparer:	FOR THE COMMANDER:
3. WILLIAM D. LEWIS, MAJ, AV Project Officer, (805)277-4784	99. AUSTIN R. OMLIE, MAJ, AV Chief, Plans & Programs

TEST INCIDENT REPORT (AMCR 70-13)	1. Release Date: 21 March 1988	
Test Title: Artificial and Natural 2. Icing Tests, EH-60A	Test Project # 3. 88-06	TIR # 4. EJ-B880603

5. Test Agency: AEFA

6. Test Sponsor PM SEMA

I MAJOR ITEM DATA

10. Model: Helicopter, EH-60A	Test Life: Units:
11. Serial#: 84-24019	21.
12. USA#:	22.
13. Mfr: Sikorsky	23.
14. Contract#:	24. (Not Used)

II INCIDENT DATA

30. Title Tail Rotor Ice Damage	40. Data & Time: 13 March 1988, 1410
31. Subsystem: Tail rotor paddle	41. FD/SC Step#:
32. Incident Class: Minor (P)	42. FD/SC Class:
33. Category: R&D	43. Chargeability:
34. Observed During: Post-flight inspection	44. Preliminary CA Status:
35. Action Taken: Replaced	45. Asgd Resp:

48. Test Environment: Artificial icing flight at -20°C, 0.5 LWC for one hour.

49. Defective Materiel: Returned to Red River Army Depot

III INCIDENT SUBJECT DATA

50. Name Blade, rotor, rudder	60. FGC:
51. Serial#: A009-0215	61. LSA#:
2. FSN/NSN: 1615-01-088-3230	Part Life: Units:
53. Mfr:	63.
54. Mfr Part#: 70101-11200-044	64.
55. Drawing#: TM55-1520-237-23-10, Fig. 29-2	65.
56. Quantity: 1	66. Next Assy:
57. Action: Replaced	67. Serial#:

IV MAINTENANCE DATA

70. Diagnostic Clockhours:	80. Type: Unscheduled
71. Diagnostic Manhours:	81. Level Use: Organizational
72. Active Maint Clockhours:	82. Level Prsc: AVUM
73. Active Maint Manhours:	83. Level Recm: AVUM

V INCIDENT DESCRIPTION

Full Description of Incident:

90. Following an artificial icing flight of one hour duration at -20 °C with a liquid water content of 0-5 grams per cubic meter, post-flight inspection revealed a cut and dented area on the red tail rotor blade. The tail rotor was inspected IAW TM55-1520-237-10, task 29, page 29-11, and determined to be unacceptable for continued operation (table 29-1, page 29-15).

Name, Title & Phone of Preparer:	FOR THE COMMANDER:
8. WILLIAM D. LEWIS, MAJ, AV Project Officer (805)277-4784	99. AUSTIN R. OMLIE, MAJ, AV Chief, Plans & Programs

TEST INCIDENT REPORT (AMCR 70-13)	1. Release Date: 21 March 1988	
2. Test Title: Artificial and Natural Icing Tests, EH-60A	3. Test Project # 88-06	4. TIR # EJ-B880604

5. Test Agency: AEFA

6. Test Sponsor PM SEMA

I MAJOR ITEM DATA

10. Model: Helicopter, EH-60A	Test Life: Units:
11. Serial#: 84-24019	21.
12. USA#:	22.
13. Mfr: Sikorsky	23.
14. Contract#:	24. (Not Used)

II INCIDENT DATA

30. Title Sheared retaining screw	40. Data & Time: 16 March 1988, 0840
31. Subsystem: Quick Fix	41. FD/SC Step#:
32. Incident Class: Minor (P)	42. FD/SC Class:
33. Category: R&D	43. Chargeability:
34. Observed During: Post-flight inspection	44. Preliminary CA Status:
35. Action Taken: Replaced	45. Asgd Resp:

48. Test Environment: Natural icing test flight of -9.3 °C with 0.2 LWC

49. Defective Materiel: Scrapped

III INCIDENT SUBJECT DATA

50. Name Screw, retaining	60. FGC:
51. Serial#: N/A	61. LSA#:
52. FSN/NSN: 5305-00-253-5614	Part Life: Units:
53. Mfr:	63.
54. Mfr Part#: UNK	64.
55. Drawing#: UNK	65.
56. Quantity: 1	66. Next Assy:
57. Action: Replaced	67. Serial#:

IV MAINTENANCE DATA

70. Diagnostic Clockhours:	80. Type: Unscheduled
71. Diagnostic Manhours:	81. Level Use: Organizational
72. Active Maint Clockhours:	82. Level Prsc: AVUM
73. Active Maint Manhours:	83. Level Recm: AVUM

V INCIDENT DESCRIPTION

Full Description of Incident:

90. Following a natural icing test flight of 1.5 hours duration at -9.3 °C with a liquid water content of 0.2 grams per cubic meter, post-flight inspection revealed a sheared dipole retaining screw. The screw was located on the right front lower retaining block, the upper right screw as viewed from the right side of the aircraft. The sheer occurred approximately 3/8 inch from the screw head. The screw head was missing upon post flight.

Name, Title & Phone of Preparer:	FOR THE COMMANDER:
WILLIAM D. LEWIS, MAJ, AV Project Officer, (805)277-4784	99. AUSTIN R. OMLIE, MAJ, AV Chief, Plans & Programs

TEST INCIDENT REPORT (AMCR 70-13)	1. Release Date: 21 March 1988	
Test Title: Artificial and Natural 2. Icing Tests, EH-60A	Test Project # 3. 88-06	TIR # 4. EJ-B880605

5. Test Agency: AEFA

6. Test Sponsor PM SEMA

I MAJOR ITEM DATA

10. Model: Helicopter, EH-60A
11. Serial#: 84-24019
12. USA#:
13. Mfr: Sikorsky
14. Contract#:

Test Life: Units:

21.
22.
23.
24. (Not Used)

II INCIDENT DATA

30. Title Sheared Pivot Stud
31. Subsystem: ECM antenna actuator assy
32. Incident Class: Minor (P)
33. Category: R&D
34. Observed During: Post-flight inspection
35. Action Taken: Removed

40. Data & Time: 16 March 1988, 0840
41. FD/SC Step#:
42. FD/SC Class:
43. Chargeability:
44. Preliminary CA Status:
45. Asgd Resp:

48. Test Environment: Natural icing test flight of -9.3 °C with 0.2 LWC
49. Defective Materiel: Returned to Flight Systems Inc.

III INCIDENT SUBJECT DATA

50. Name Stud, Pivot
51. Serial#:
2. FSN/NSN: UNK
.3. Mfr:
54. Mfr Part#: C507 47 25-1
55. Drawing#: TM 55-1520-237-23P, Fig. 1
56. Quantity: 1
57. Action: Removed

60. FGC:
61. LSA#:

Part Life: Units:

63.
64.
65.
66. Next Assy:
67. Serial#:

IV MAINTENANCE DATA

70. Diagnostic Clockhours:
71. Diagnostic Manhours:
72. Active Maint Clockhours:
73. Active Maint Manhours:

80. Type: Unscheduled
81. Level Use: Organizational
82. Level Prsc: AVUM
83. Level Recm: AVUM

V INCIDENT DESCRIPTION

Full Description of Incident:

90. At termination of a natural icing test flight of 1.5 hours duration at -9.3 °C with a liquid water content of 0.2 grams per cubic meter, ECM antenna failed to fully retract. Aircraft was brought to hover and ECM antenna was removed from mount to permit landing without damage to aircraft. Post-flight inspection revealed a sheared pivot stud (TM 55-1520-237-23P Figure 1, item 22) causing mount to jam against housing. The opposite pivot stud was bent. The ECM actuator (figurel, item 4) was bent at the connecting point to the stud arm subassembly.

Name, Title & Phone of Preparer:

9. WILLIAM D. LEWIS, MAJ, AV
Project Officer, (805)277-4784

FOR THE COMMANDER:

99. AUSTIN R. OMLIE, MAJ, AV
Chief, Plans & Programs

TEST INCIDENT REPORT (AMCR 70-13)	1. Release Date: 21 March 1988	
2. Test Title: Artificial and Natural Icing Tests, EH-60A	3. Test Project # 88-06	4. TIR # EJ-B880606

5. Test Agency: AEFA

6. Test Sponsor PM SEMA

I MAJOR ITEM DATA

10. Model: Helicopter, EH-60A	Test Life: Units:
11. Serial#: 84-24019	21.
12. USA#:	22.
13. Mfr: Sikorsky	23.
14. Contract#:	24. (Not Used)

II INCIDENT DATA

30. Title Cracked Phenolic Block	40. Data & Time: 17 March 1988, 0755
31. Subsystem: AN/ASN 151, Quick Fix	41. FD/SC Step#:
32. Incident Class: Minor (P)	42. FD/SC Class:
33. Category: R&D	43. Chargeability:
34. Observed During: Post-flight inspection	44. Preliminary CA Status:
35. Action Taken: Replaced	45. Asgd Resp:

48. Test Environment: Natural icing test flight of 20 min at -13 °C, LWC 0.6.

49. Defective Materiel: Returned to Flight Systems Inc.

III INCIDENT SUBJECT DATA

50. Name Block, Phenolic	60. FGC:
51. Serial#:	61. LSA#:
52. FSN/NSN: UNK	Part Life: Units:
53. Mfr:	63.
54. Mfr Part#: UNK	64.
55. Drawing#:	65.
56. Quantity: 1	66. Next Assy:
57. Action: Replaced	67. Serial#:

IV MAINTENANCE DATA

70. Diagnostic Clockhours:	80. Type: Unscheduled
71. Diagnostic Manhours:	81. Level Use: Organizational
72. Active Maint Clockhours:	82. Level Prsc: AVUM
73. Active Maint Manhours:	83. Level Recm: AVUM

V INCIDENT DESCRIPTION

Full Description of Incident:

90. Helicopter was flown in natural icing conditions on 17 March 1988. Total time in the icing cloud was 20 minutes. Airspeed was 108.7 KTAS. Vibrations of approximately ±4 inches were monitored on the right front dipole antenna. Vibrations stopped abruptly and aircraft returned to base. Post-flight inspection revealed a cracked phenolic block at the lower dipole attachment point. The crack occurred at the lower right attachment screw. The lower right attachment screw was missing and the lower left screw had pulled the helicoil approximately 1/16 inch out of the phenolic block. Both upper attachment screws were loose. Only small vibrations of approximately ±1 inch were noted on the other dipole antennae.

Name, Title & Phone of Preparer:	FOR THE COMMANDER:
98. WILLIAM D. LEWIS, MAJ, AV Project Officer, (805)277-4784	99. AUSTIN R. OMLIE, MAJ, AV Chief, Plans & Programs

APPENDIX H. PHOTOGRAPHS

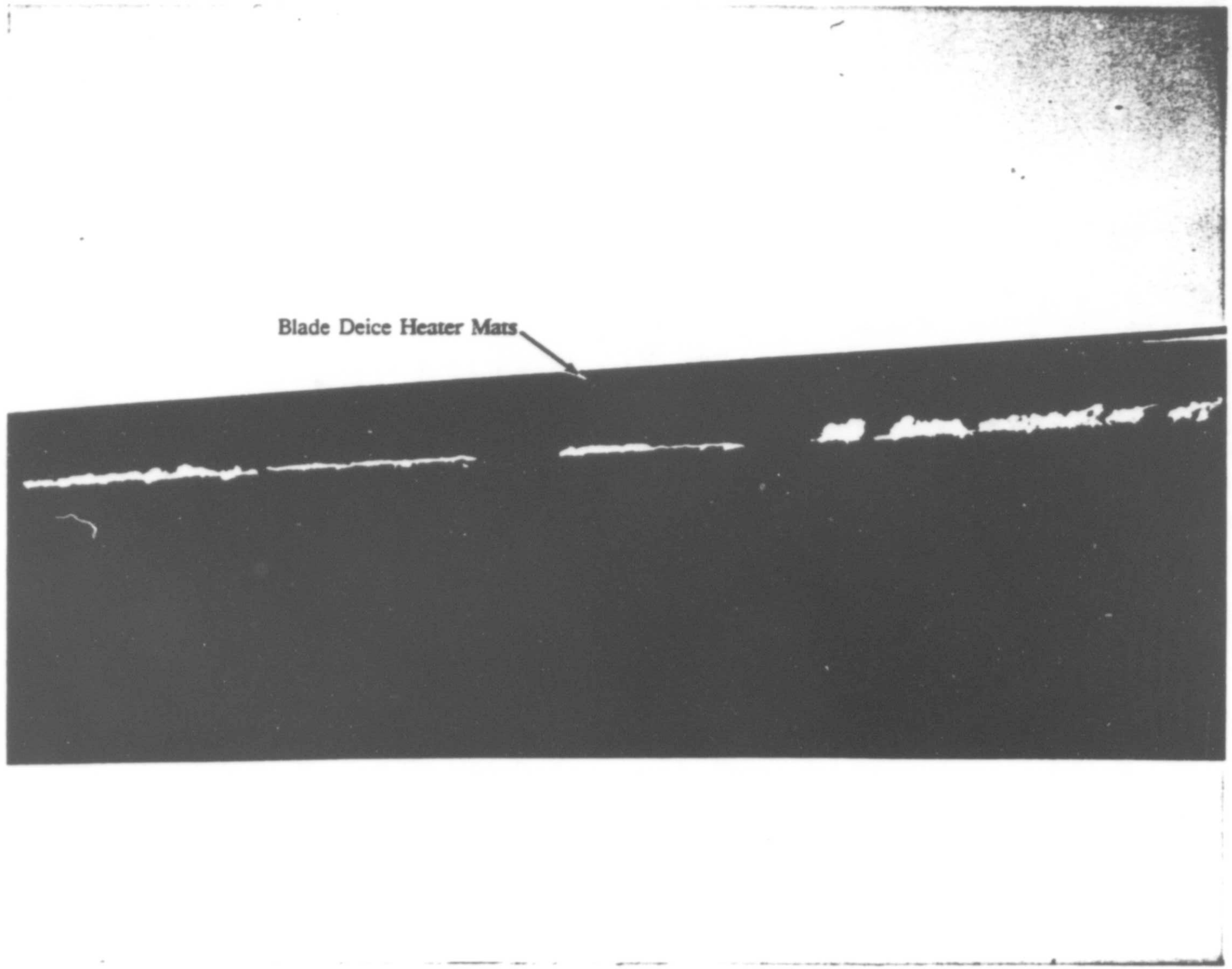

Figure H-1. **Main Rotor Blade Ice Accumulation**
Natural Icing - .55 gm/m3 LWC, -13°C OAT, 21 min

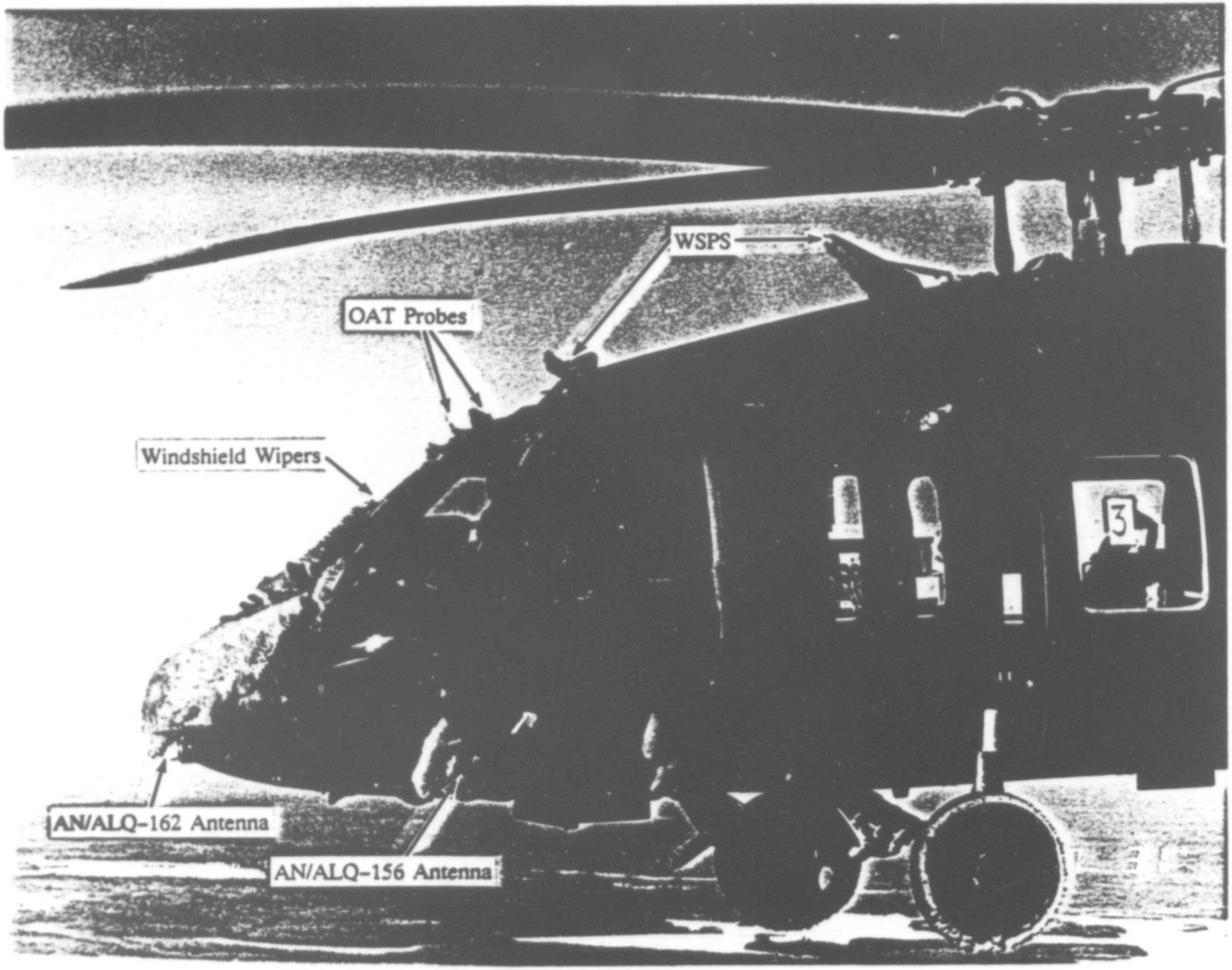

Figure H-2. Airframe Ice Accumulation
Artificial Icing - .95 gm/m3 LWC, -5.1°C OAT, 57 min

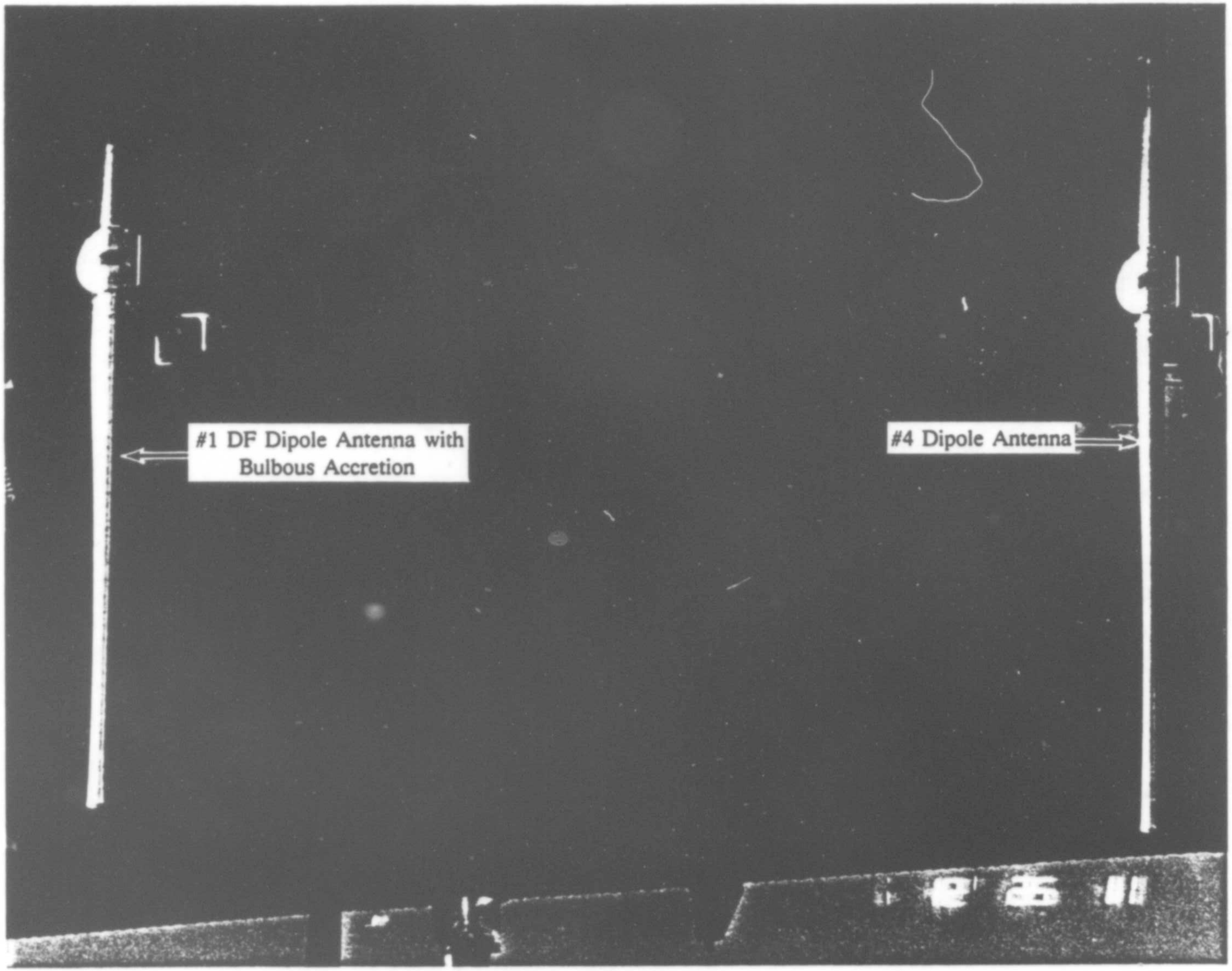

Figure H-3. Dipole Antenna Ice Accumulation
Artificial Icing - .99 gm/m3 LWC, -9.9°C OAT, 38 min

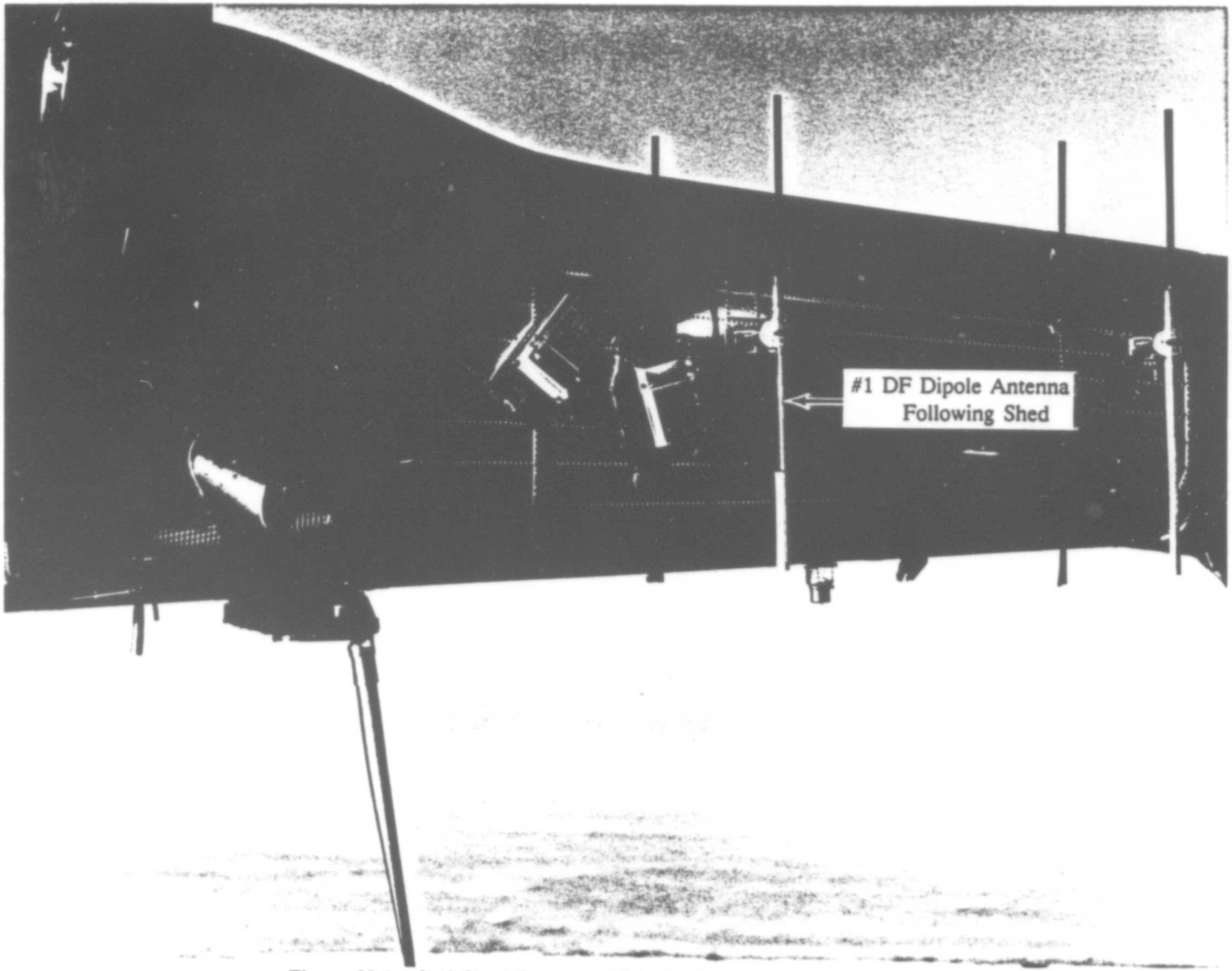

Figure H-4. Self Shed Pattern of Dipole Antennas
Artificial Icing - .99 gm/m^3 LWC, -9.9°C OAT, 38 min

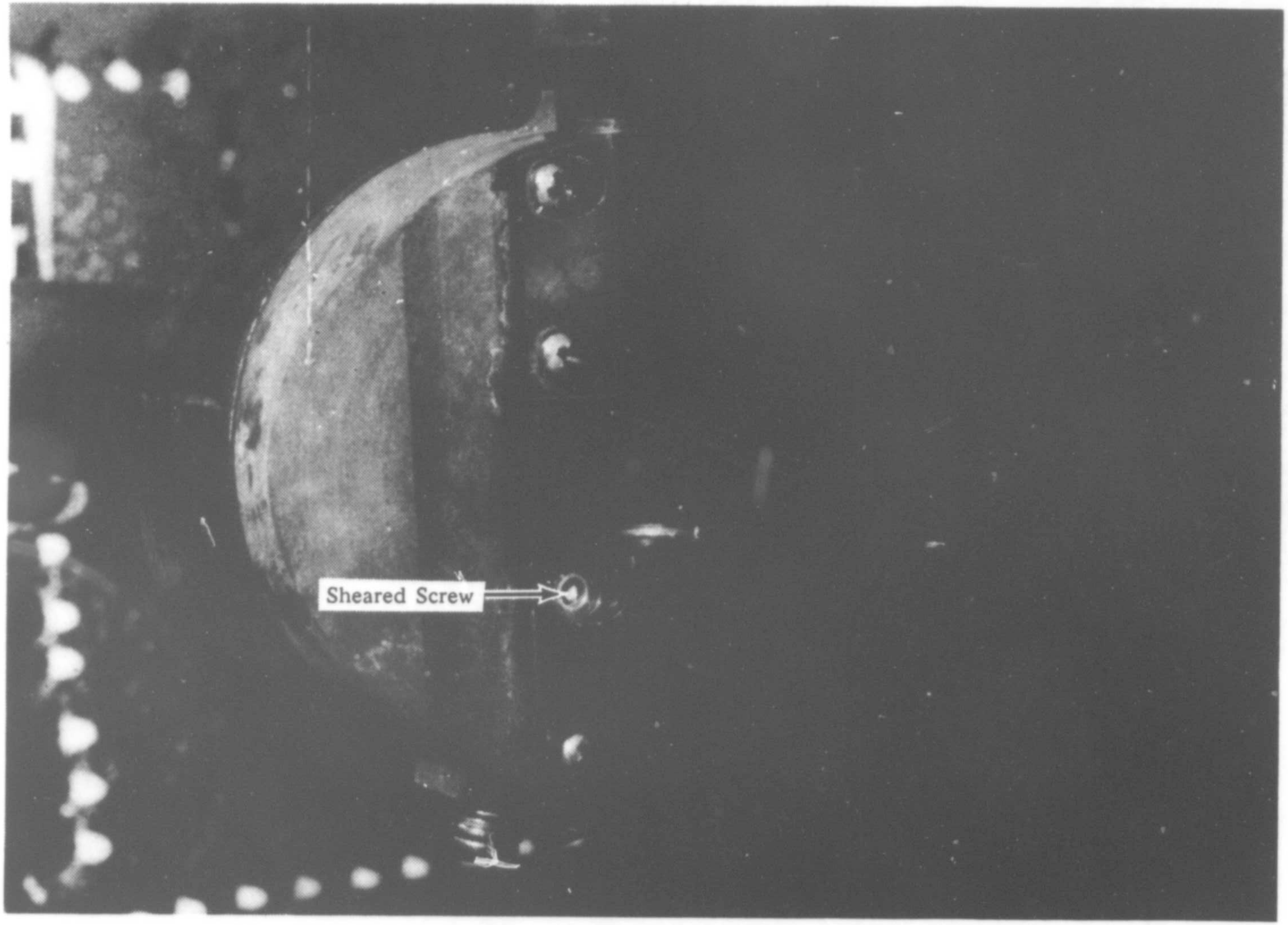

Figure H-5. Sheared Dipole Retaining Screw
Artificial Icing – .52 gm/m³ LWC, –15°C OAT, 44 min

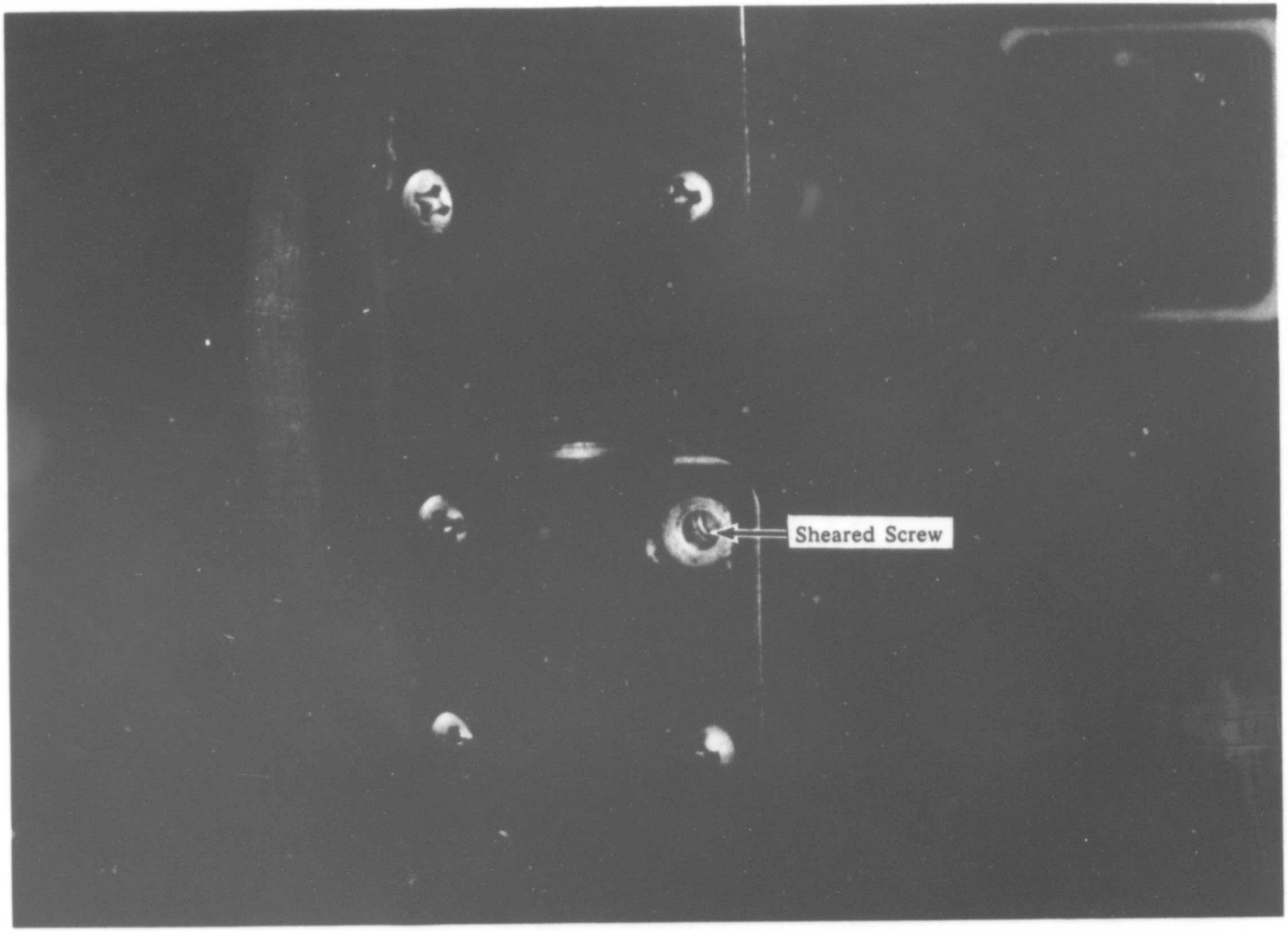

Figure H-6. Sheared Dipole Retaining Screw
Natural Icing – .20 gm/m³ LWC, –9.3°C OAT, 21 min

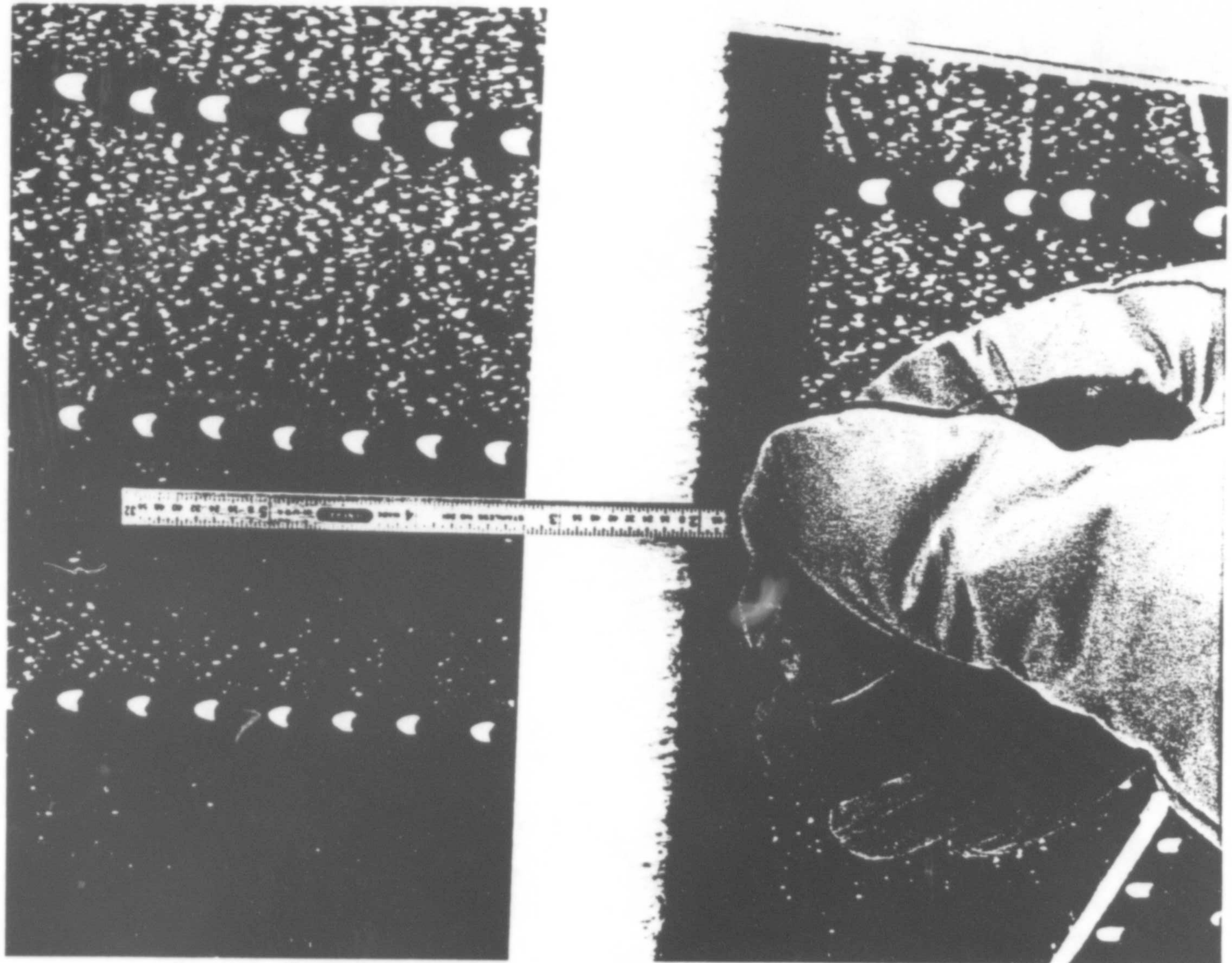

Figure H-7. Ice Accumulation on DF Antennas
Artificial Icing – .52 gm/m3 LWC, –15.0°C OAT, 60 min

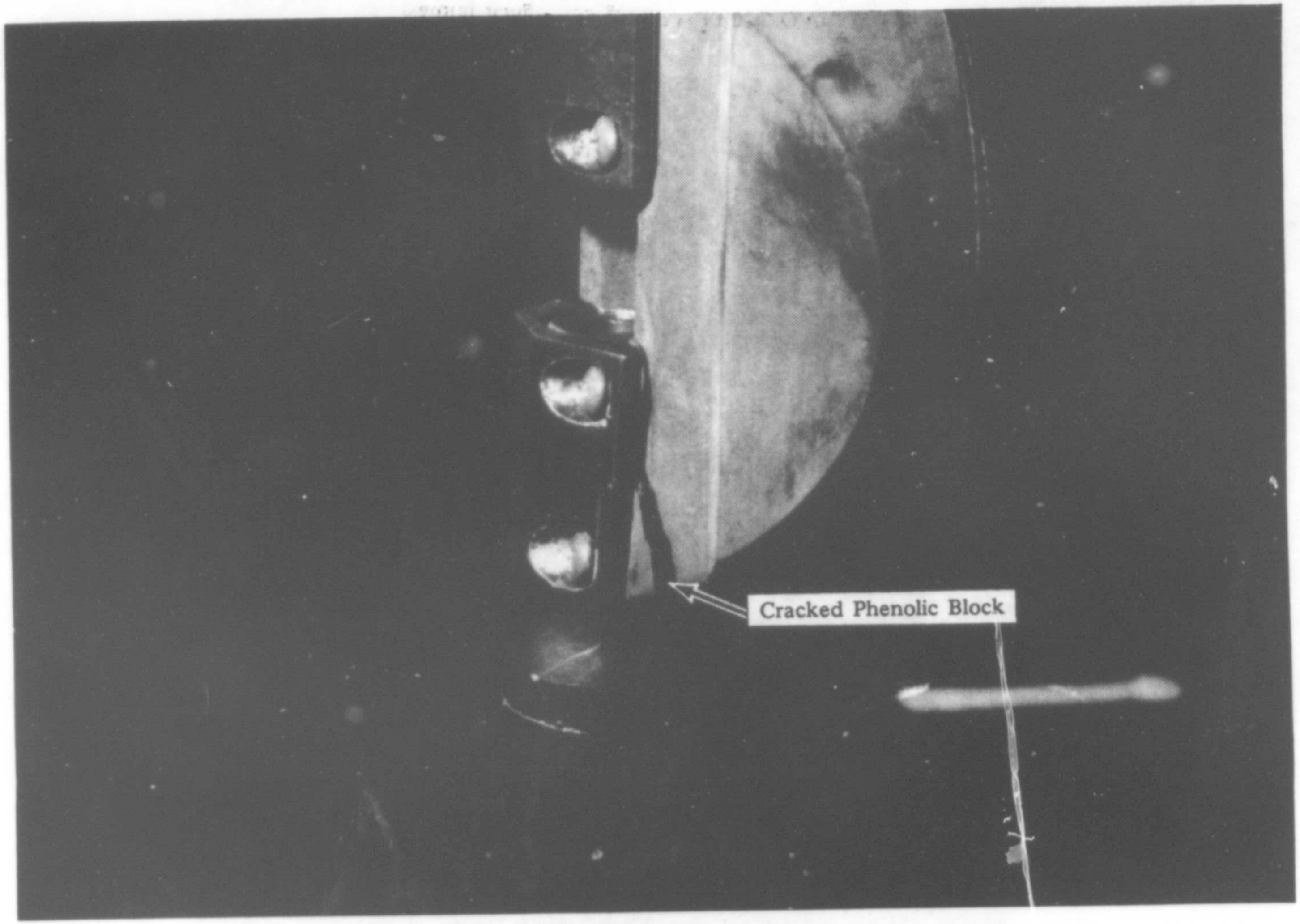

Figure H-8 #2 Dipole Antenna Cracked Phenolic Block
Natural Icing – .55 gm/m^3 LWC, –13.0°C OAT, 21 min

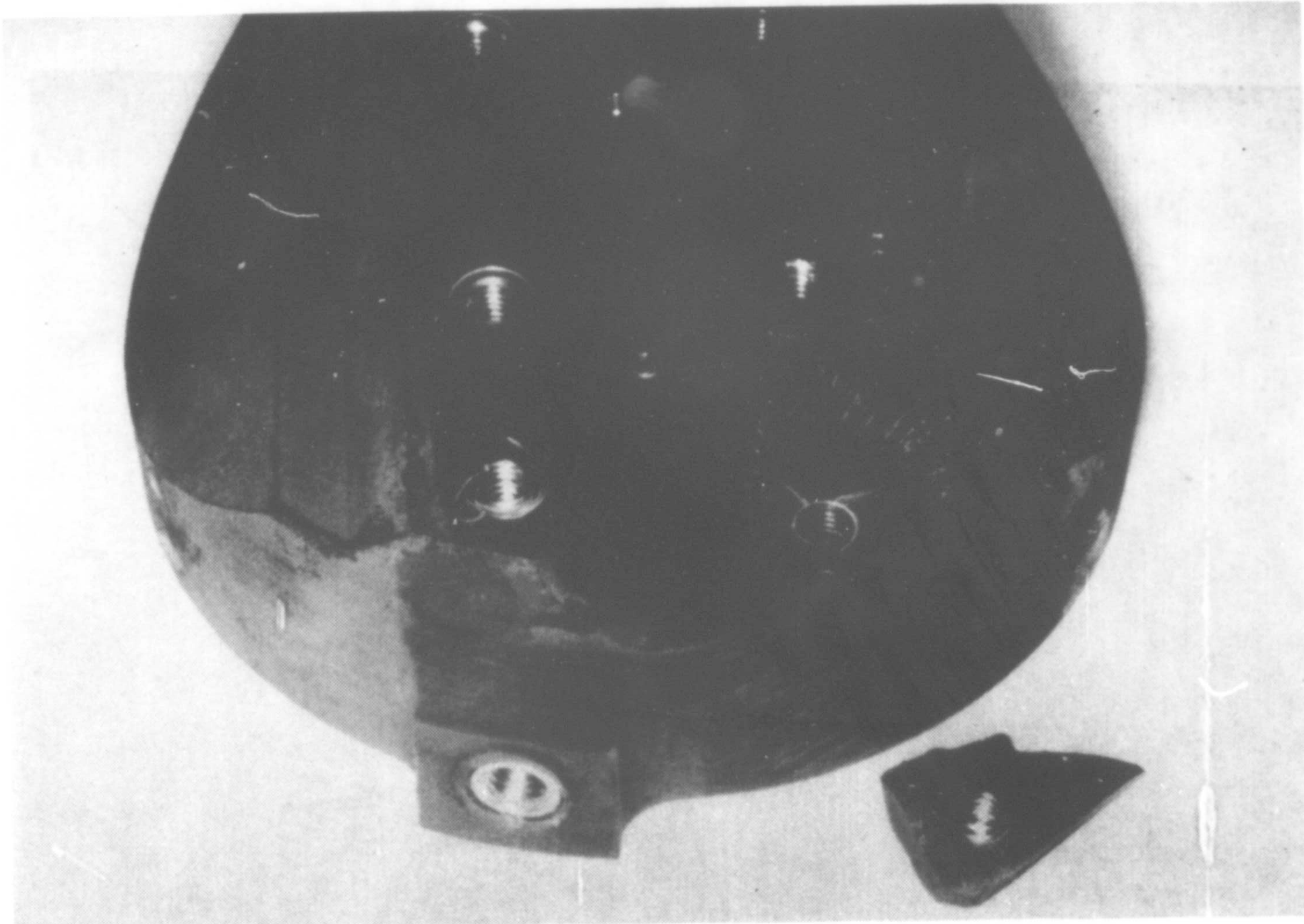

Figure H-9. Cracked Phenolic Block
Natural Icing - .55 gm/m³, -13.0°C OAT, 21 min

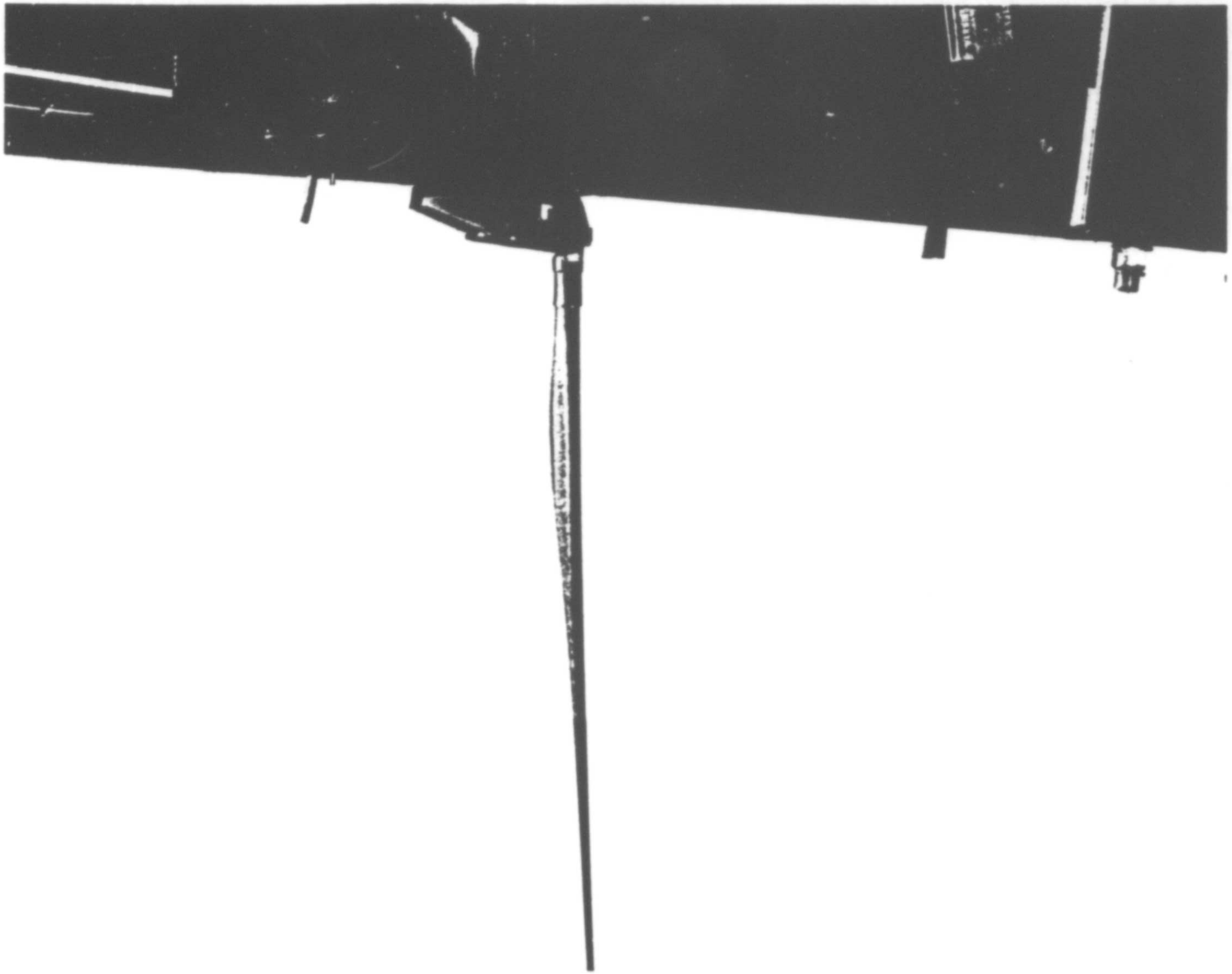

Figure H-10. ECM Antenna: Artificial Icing
Artificial Icing - .95 gm/m3 LWC, -5.1°C OAT, 57 min

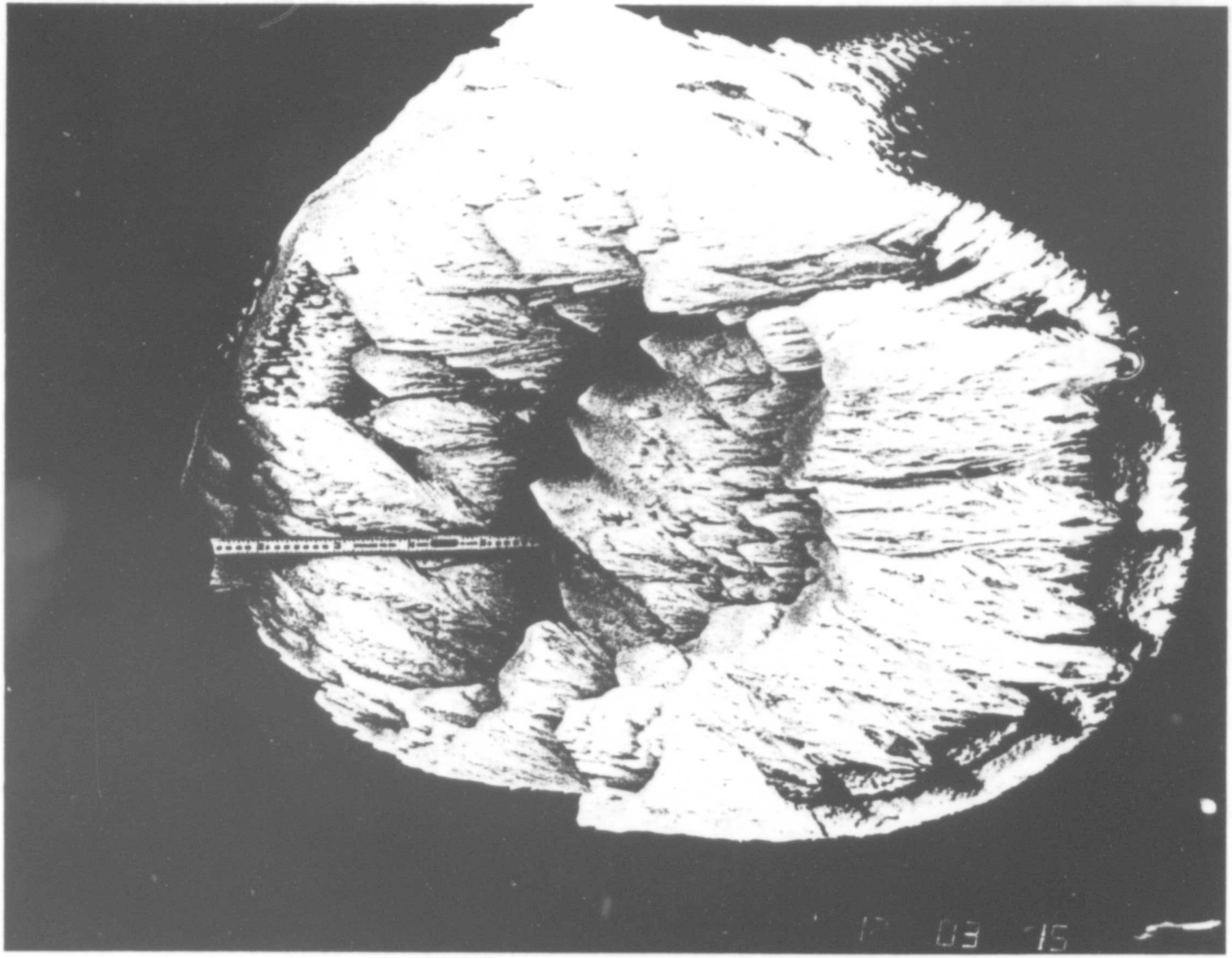

Figure H-11. AN/ALQ – 156 Antenna Accumulation
Artificial Icing – .52 gm/m3 LWC, –15.0 °C OAT, 60 min

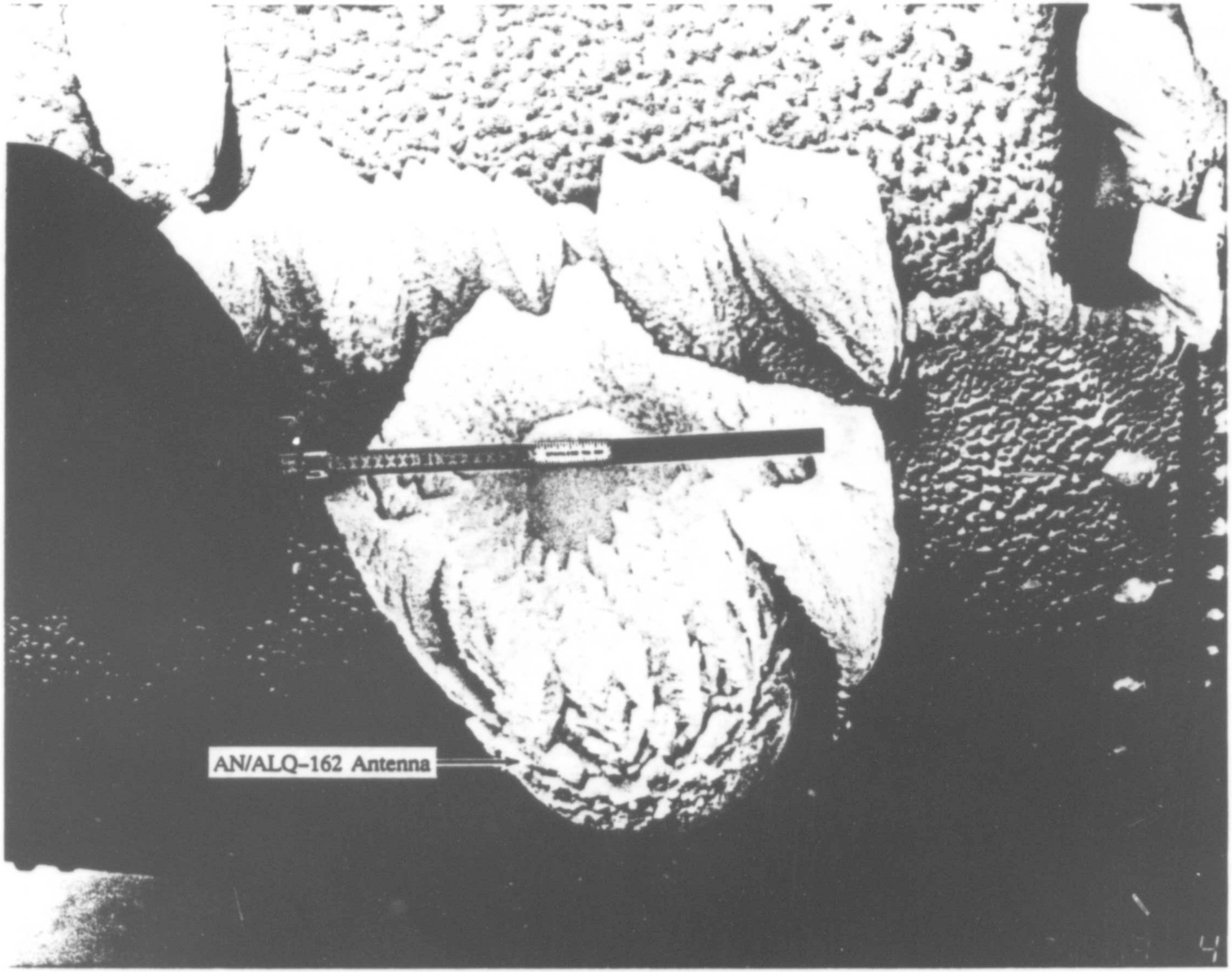

Figure H-12. AN/ALQ-162 Antenna Accumulation (Front View)
Artificial Icing - .52 gm/m3 LWC, -15.0°C OAT, 60 min

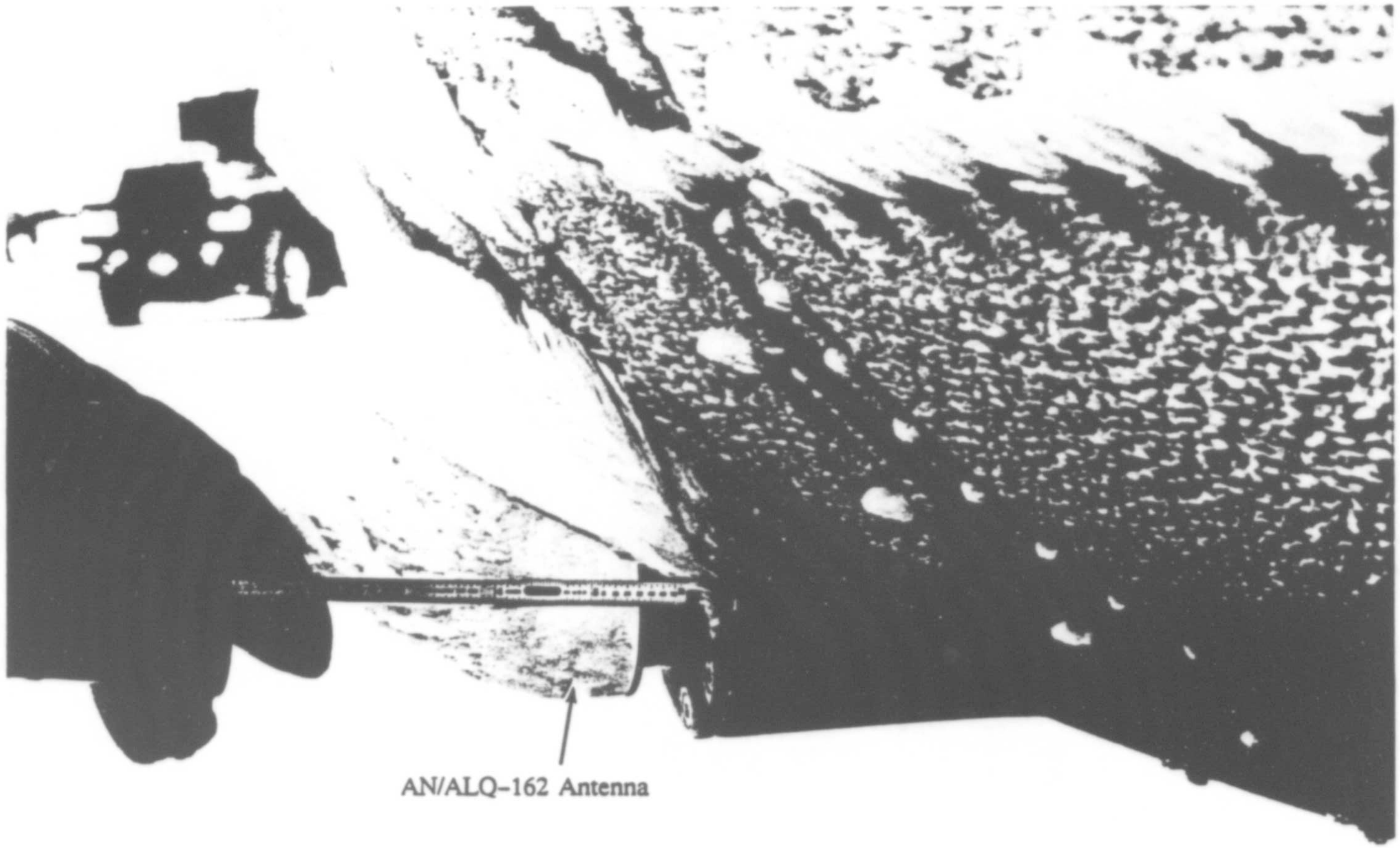

Figure H-13. AN/ALQ-162 Antenna Accumulation (Side View)
Artificial Icing - .59 gm/m3 LWC, -15.0°C OAT, 60 min

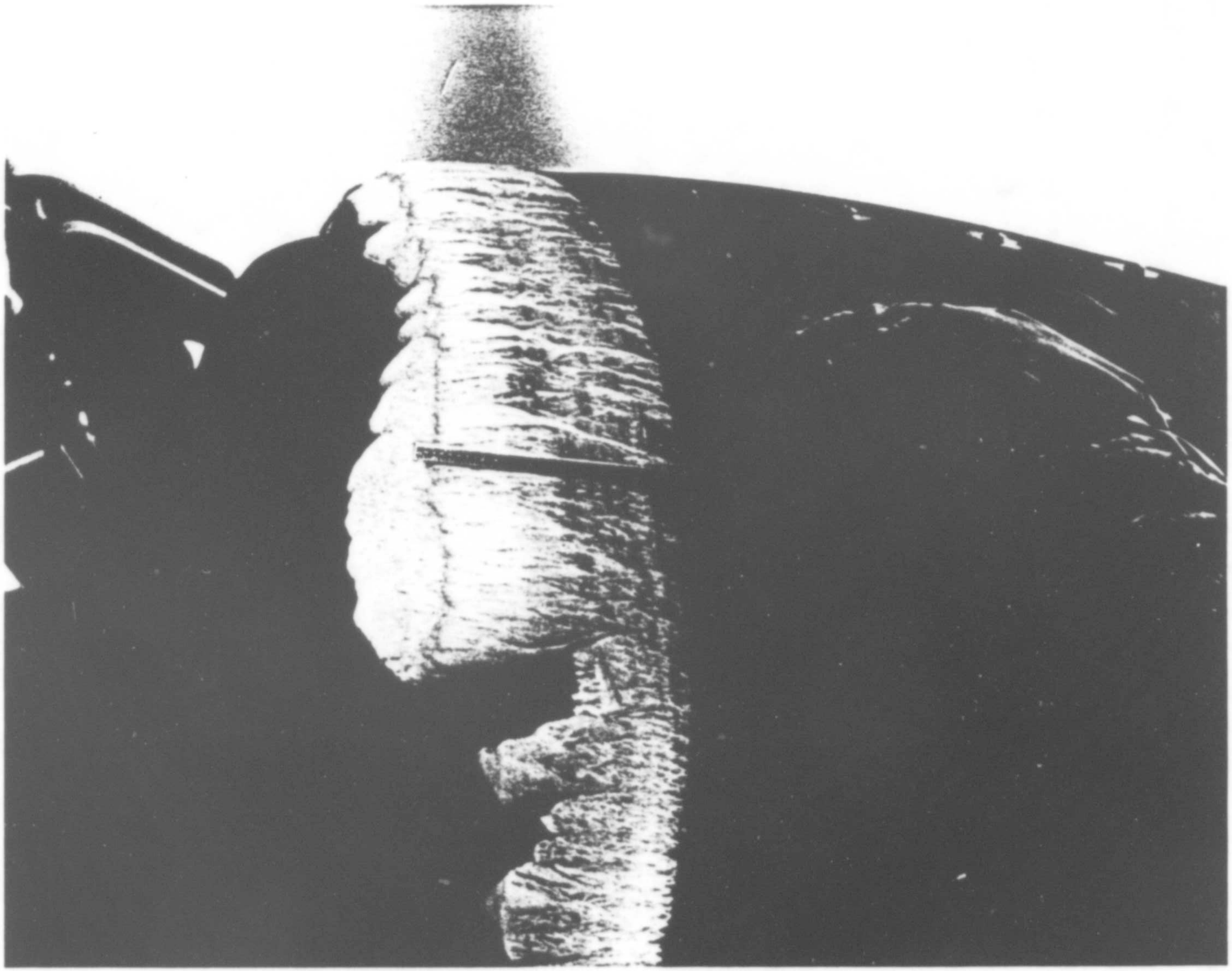

Figure H-14. HIRSS Engine Cooling Air Inlet Fairing
Artificial Icing - .52 gm/m3 LWC, −15.0°C OAT, 60 min

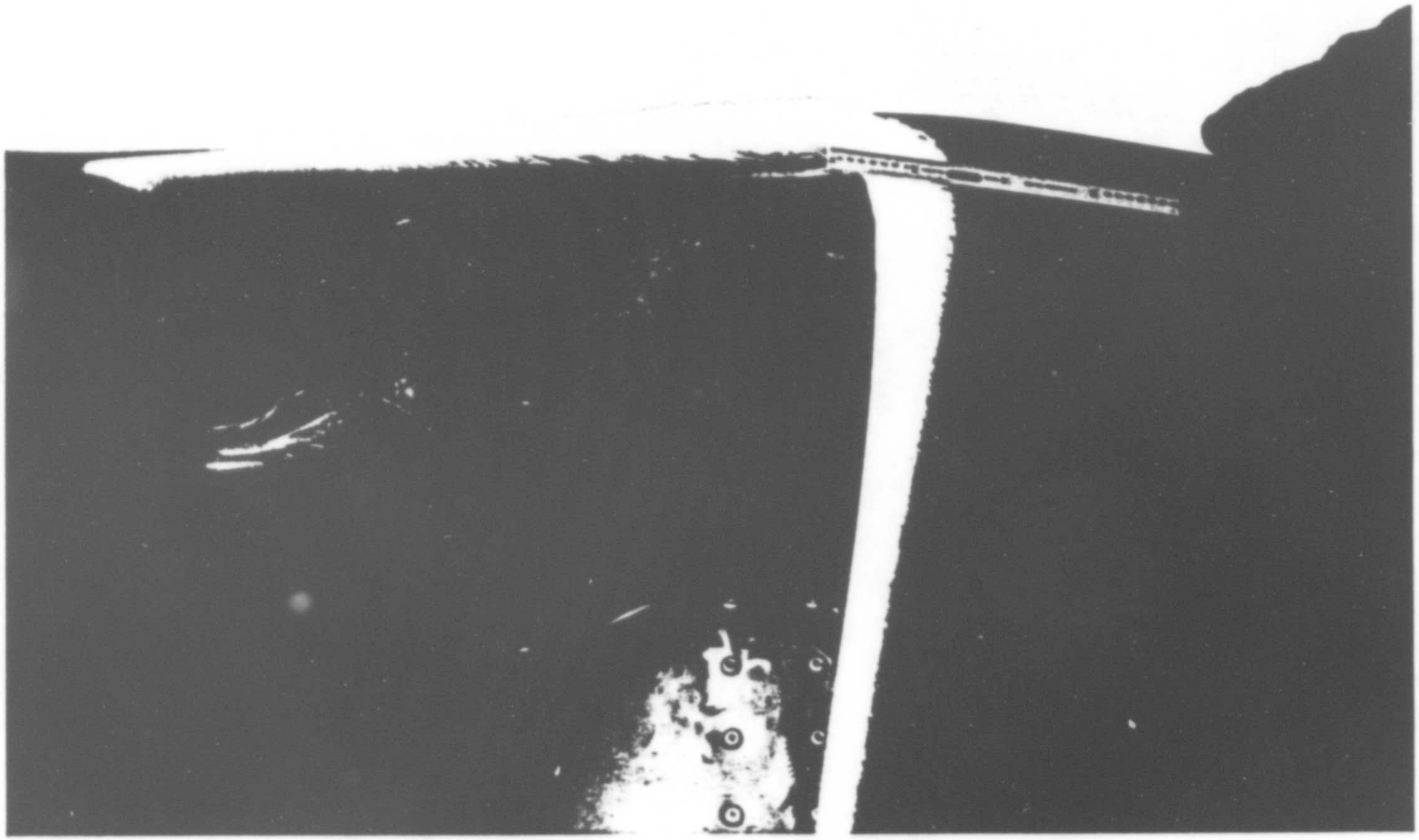

Figure H-15. HIRSS Exhaust Ram Inlet Scoop
Artificial Icing - .52 gm/m3 LWC, -15.0°C OAT, 60 min

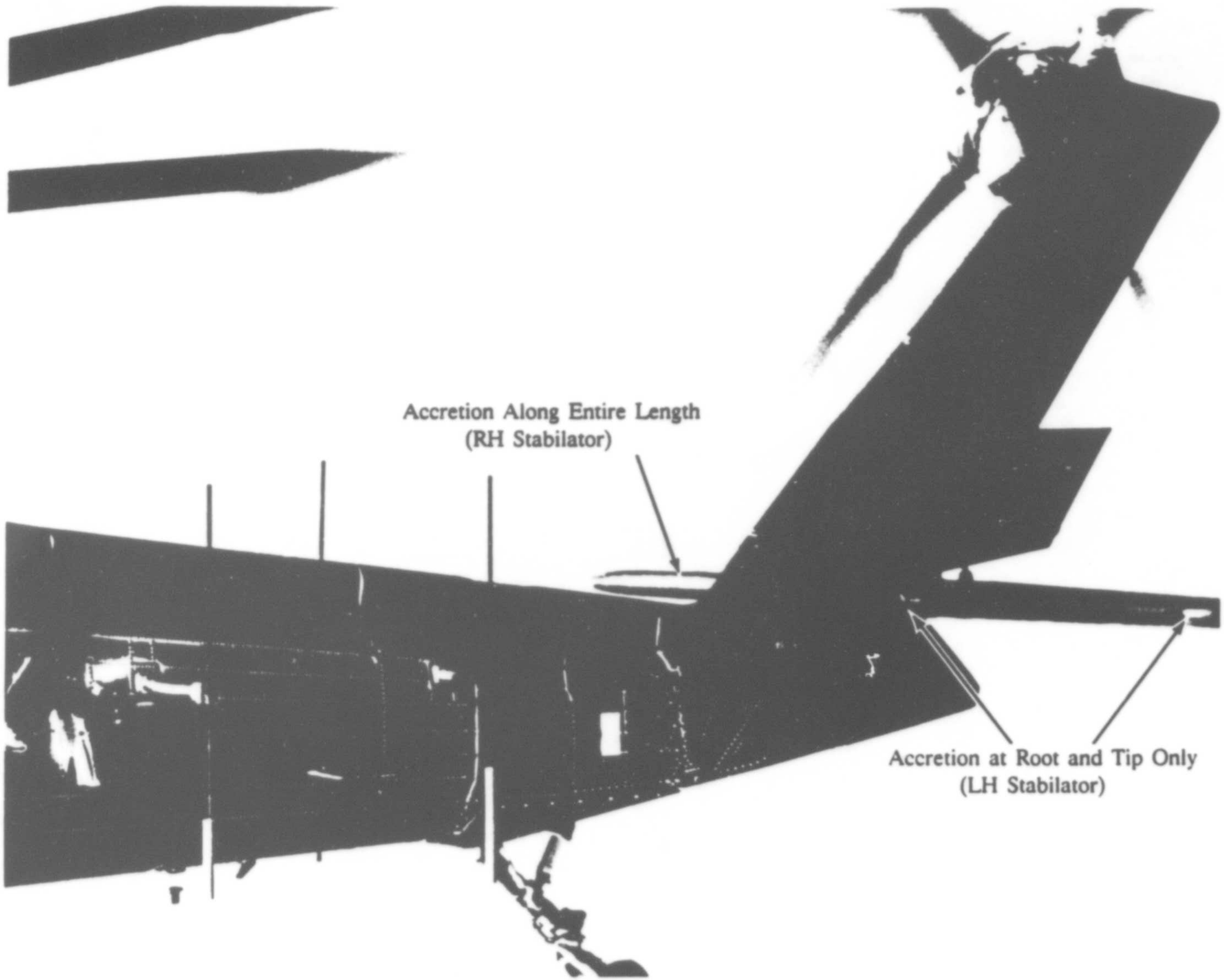

Figure H-16. Stabilator Ice Accumulation
Natural Icing - .20 gm/m3 LWC, -9.3°C OAT, 92 min

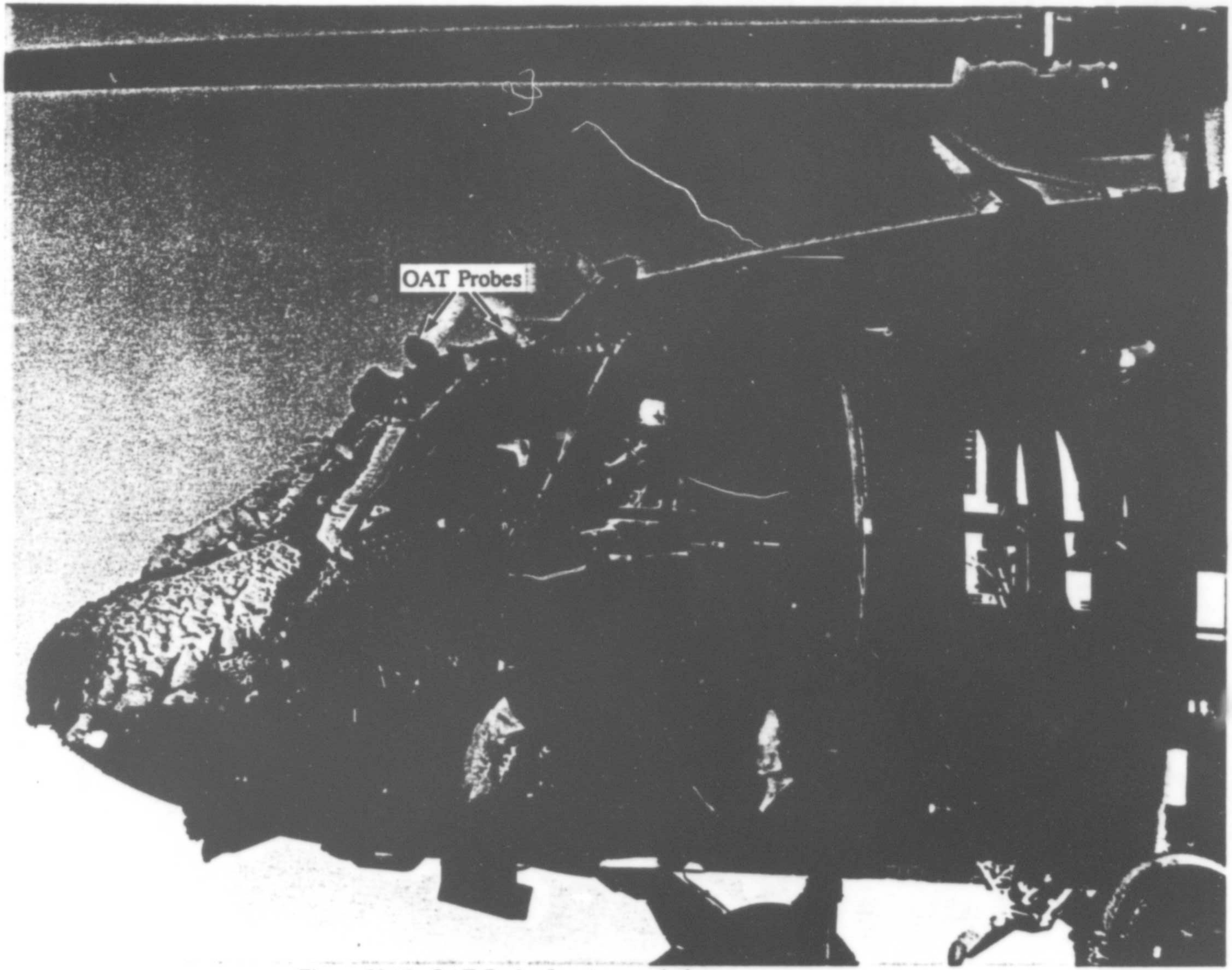

Figure H-17. OAT Probe Ice Accumulation
Artificial Icing – .95 gm/m3 LWC, –5.1°C OAT, 57 min

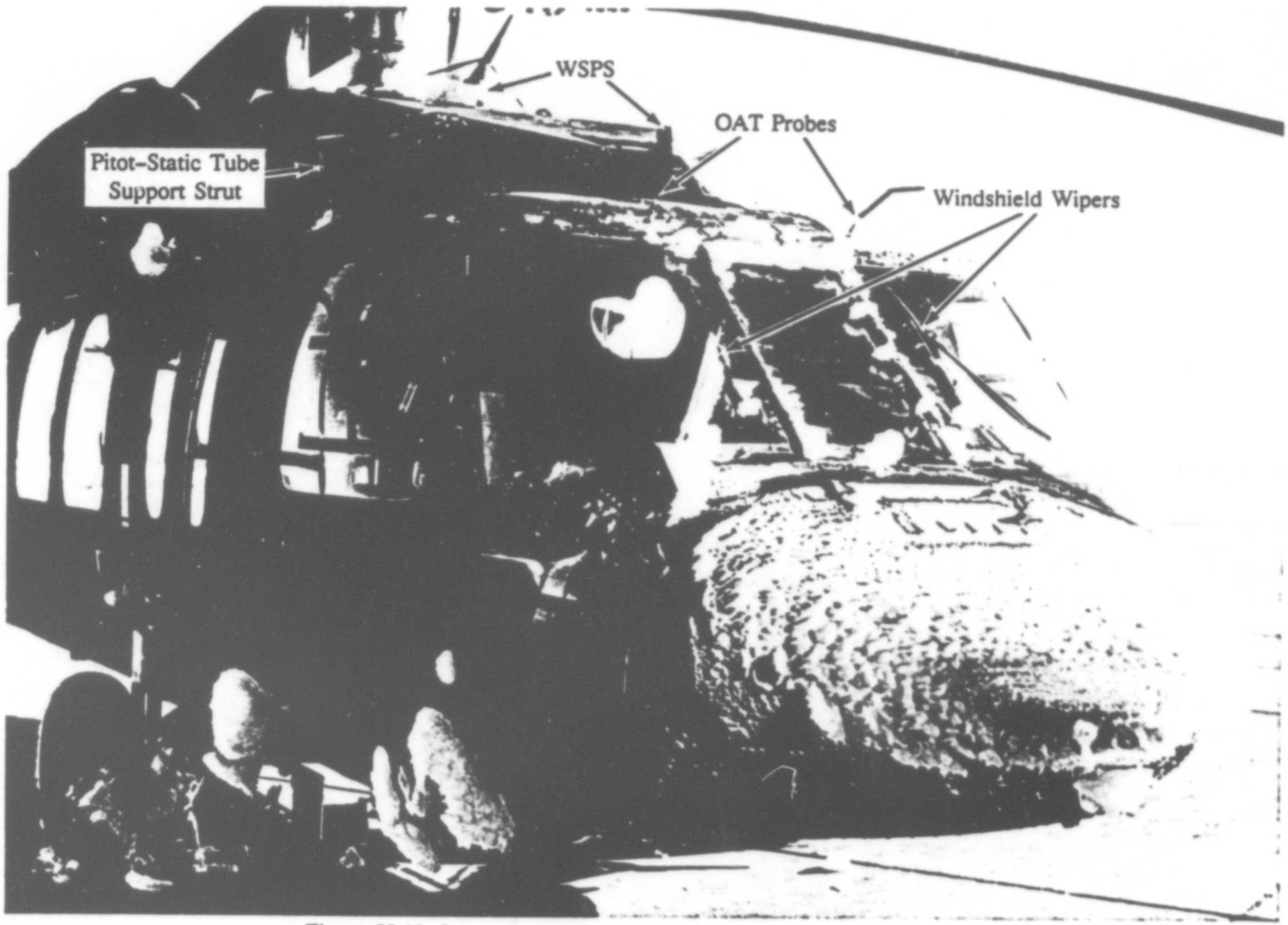

Figure H-18. Ice Accumulation on Front of Aircraft
Artificial Icing – .95 gm/m3 LWC, –5.1°C OAT, 57 min

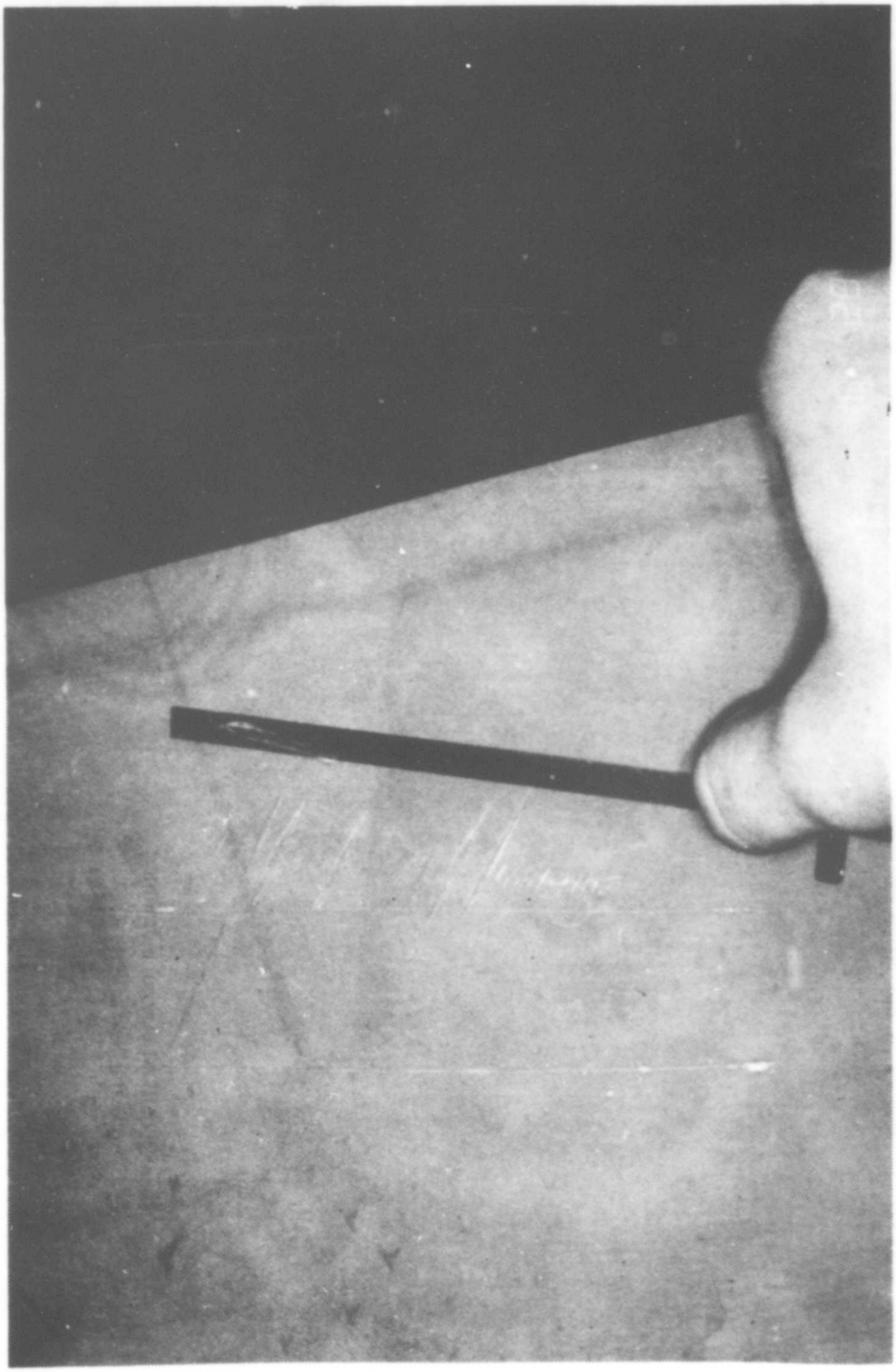

Figure H-19. Damaged Tail Rotor Paddle
Natural Icing – .45 gm/m^3 LWC, –19.6°C OAT, 60 min

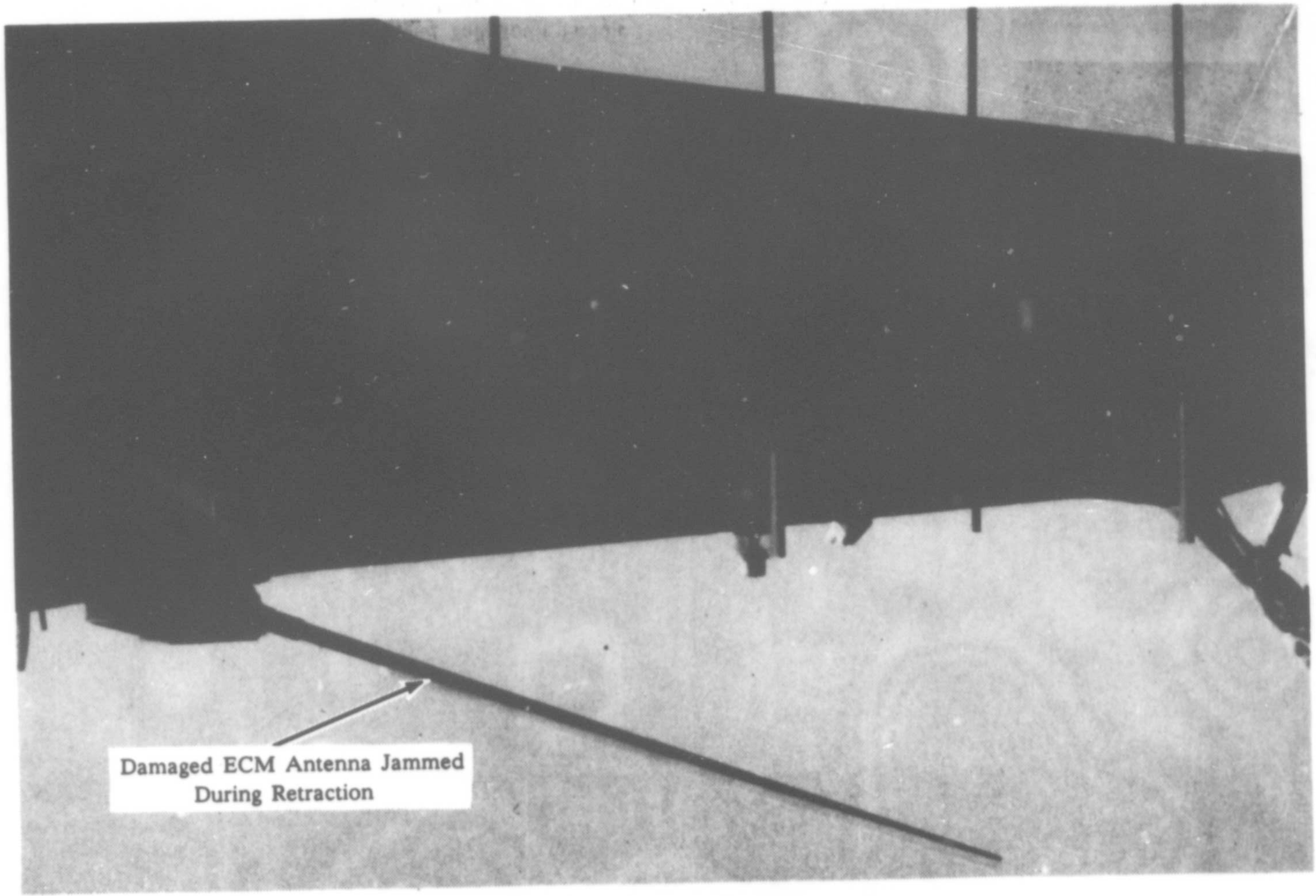

Figure H-20. Jammed ECM Antenna
Natural Icing – .20 gm/m³ LWC, –9.3°C OAT, 92 min

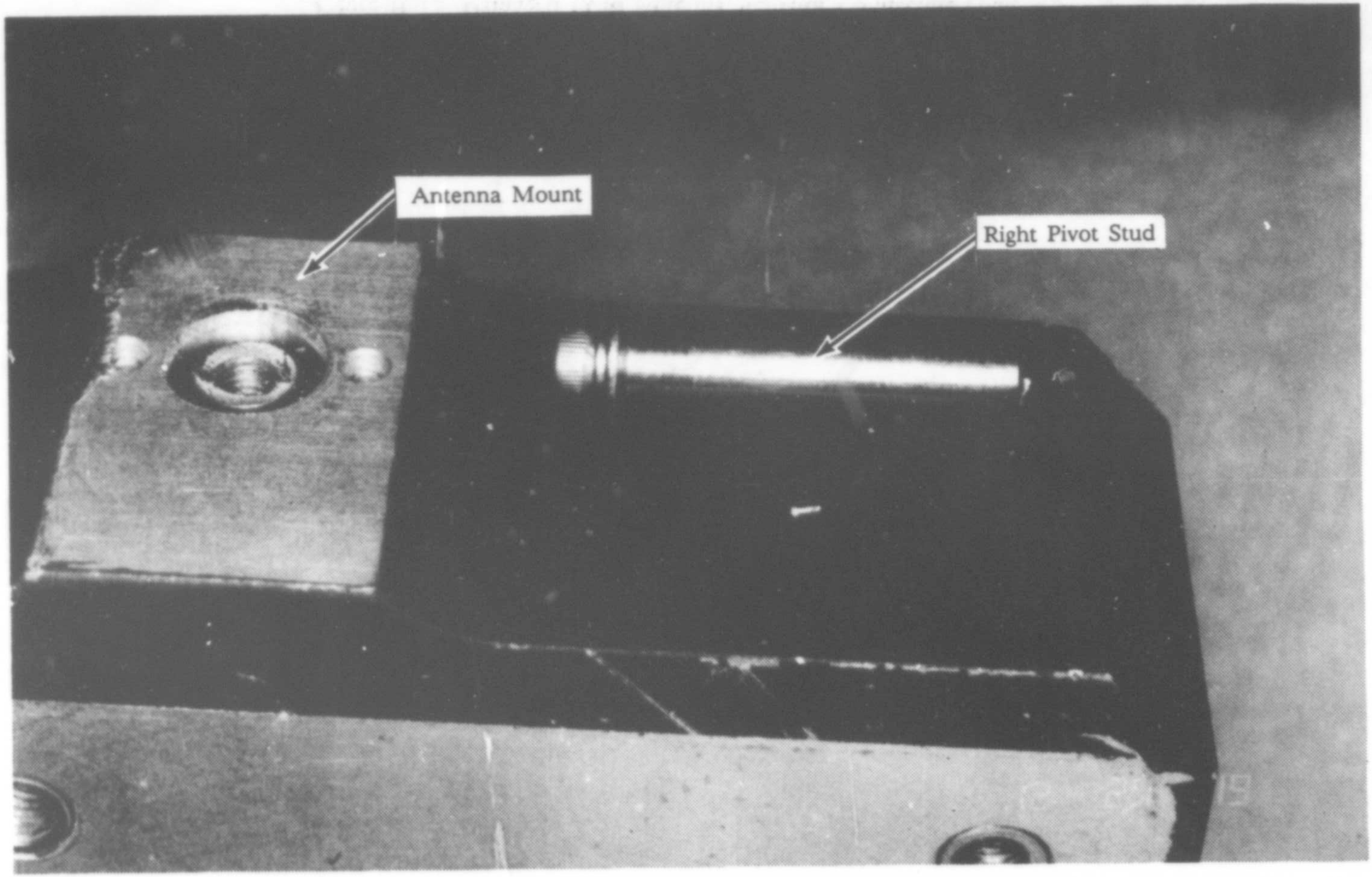

Figure H-21. ECM Antenna Mount and Sheared Pivot Stud
Natural Icing – .20 gm/m³ LWC, –9.3°C OAT, 92 min

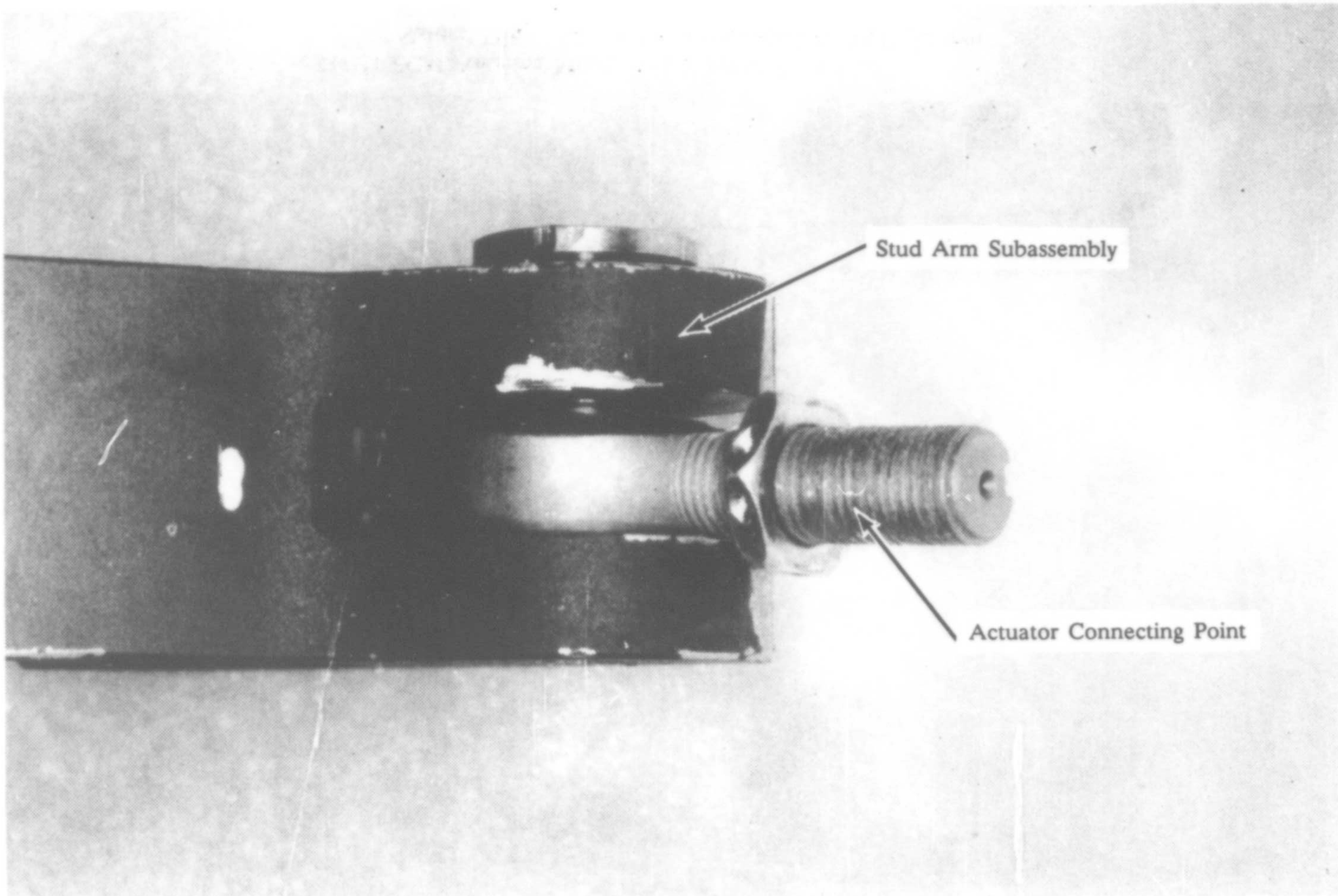

Figure H-22. Damaged ECM Antenna Actuator Connecting Point
Natural Icing – .20 gm/m^3 LWC, –9.3°C OAT, 92 min

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