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AEFA Project No. 87-19

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ARTIFICIAL AND NATURAL ICING TESTS OF THE UH-60A HELICOPTER CONFIGURED WITH THE XM-139 MULTIPLE MINE DISPENSING SYSTEM (VOLCANO)

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March 1988

Final Report

"Original contains color plates: All DTIC reproductions will be in black and white"

AVIATION ENGINEERING FLIGHT ACTIVITY
Edwards Air Force Base, California 93523-5000

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

AD-A204 031

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY U.S. ARMY AVIATION SYSTEMS COMMAND	3. DISTRIBUTION/AVAILABILITY OF REPORT
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AEFA PROJECT NO. 85-15	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION U.S. ARMY AVIATION ENGINEERING FLIGHT ACTIVITY 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) EDWARDS AIR FORCE BASE, CALIFORNIA 93523-5000	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION U.S. ARMY AVIATION SYSTEMS COMMAND 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) 4300 GOODFELLOW BLVD. ST. LOUIS, MO 63120-1798	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO.: 1A7BF7Z11A PROJECT NO.: EC TASK NO.: WORK UNIT ACCESSION NO.:

11. TITLE (Include Security Classification)

ARTIFICIAL AND NATURAL ICING TESTS OF THE UH-60A HELICOPTER CONFIGURED WITH THE XM-139 MULTIPLE MINE DISPENSING SYSTEM (VOLCANO)

12. PERSONAL AUTHOR(S)

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13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
FINAL	FROM 01/10/88 TO 02/22/88	MARCH 1988	60

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	ANTI-ICING SYSTEMS, ICE ACCRETION CHARACTERISTICS, ICING ENVIRONMENT, MINE DISPENSING SYSTEM (VOLCANO), UH-60A HELICOPTER

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

A limited evaluation of the UH-60A helicopter with the XM-139 Multiple Delivery Mine Dispensing System (VOLCANO) was conducted to determine the capability to operate safely in a moderate icing environment. Artificial and natural icing tests were conducted at Duluth, Minnesota from 10 January through 22 February 1988. Testing was conducted by the U.S.Army Aviation Engineering Flight Activity and consisted of 16.4 productive flight hours. One deficiency related to inadequate procedures in the operator's and crewmember's checklist was identified. The checklist does not contain procedures to activate anti-icing systems. Two shortcomings were identified that involved the ice accretion characteristics of the VOLCANO. Ice accretion on the mounting hardware kit interferes with reinstalling the launcher rack jettison safety pins due to ice covering the safety pin holes. Ice accretion on the forward end of the launcher racks interferes with movement of the arming levers and locking levers to the safe and unlocked positions, respectively. The probability of damage to rotating components, due to impact with shed ice particles in descents is increased with the installation of the VOLCANO. The UH-60A helicopter with the VOLCANO system installed can safely operate in moderate icing conditions.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL SHEILA R. LEWIS	22b. TELEPHONE (Include Area Code): (805) 277-2115 22c. OFFICE SYMBOL: SAVTE-PR

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

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INTRODUCTION

BACKGROUND

1. The UH-60A helicopter with the production anti-icing and deicing equipment installed has undergone natural and artificial icing airworthiness qualification flight tests (refs 1 through 3, app A) and has been cleared for flight into moderate icing conditions. The XM-139 Multiple Mine Dispensing System (VOLCANO) is a rapid deployment system for launching a mix of antitank and antipersonnel mines from the UH-60A helicopter and ground vehicles. The airborne system was developed by the U.S. Army Aviation Research Development and Engineering Center in conjunction with the Program Manager-Mines, Countermines and Demolition in response to an urgent requirement of the High Technology Light Division for a helicopter mine dispensing system. The prime contractor is Honeywell Inc. The U.S. Armament, Munitions, and Chemical Command has been tasked with system production and has in turn requested the U.S. Army Aviation Systems Command (AVSCOM) support for qualification of the airborne system. AVSCOM requested (ref 4) the U.S. Army Aviation Engineering Flight Activity (AEFA) to conduct artificial and natural icing tests on the XM-139 VOLCANO configured UH-60A during the winter of 1987-1988 in accordance with the approved test plan (ref 5).

TEST OBJECTIVE

2. The objective of this test was to conduct a limited artificial and natural icing evaluation to provide AVSCOM the results from which to establish a moderate icing envelope for a UH-60A helicopter configured with the XM-139 VOLCANO system.

DESCRIPTION

3. The VOLCANO is a modification of the UH-60A helicopter designed to provide the capability for aerial mine dispensing missions. The UH-60A is a twin-turbine, single main rotor configured helicopter capable of day or night operations in visual or instrument meteorological conditions (IMC). The main and tail rotors are both four-bladed with a capability of manual main rotor blade folding. A UH-60A with the deicing kit installed incorporates a main and tail rotor deicing system and an ice detection system as well as anti-ice provisions for the pilot, copilot and center windshields, droop stops, pitot-static tubes and their support struts, engines, and engine inlets. A movable horizontal stabilator is located on the lower portion of the tail rotor pylon. The helicopter is powered by two T700-GE-700 turboshaft engines having an uninstalled thermodynamic rating (30 minute) of 1553 shaft horsepower (shp) (power turbine speed of 20,900 rpm) each at sea level, standard day static conditions. Installed dual-engine power is transmission limited to 2828 shp. A more detailed description of the standard UH-60A is contained in the operator's manual (ref 6 and app B).

4. The XM-139 VOLCANO weapons system with related equipment is produced by Honeywell, Inc. The VOLCANO is an automated, scatterable mine delivery system capable of launching mines from host ground and air vehicles (5 ton dump and cargo trucks and the UH-60A helicopter). The mine dispenser system is modular and consists of four major components: (1) mounting hardware kits, (2) four launcher racks, (3) 160 mine canisters,

and (4) a dispenser control unit. The XM-139 VOLCANO for the UH-60A uses the "go-around" switches on the pilot's and copilot's cyclic grips and the airframe fixed provisions for the External Stores Support System (ESSS). The airframe fixed provisions include permanent structural modifications, attachment points, and electrical harnesses. The mounting hardware kit contains components unique to the airborne system and allows mounting to the UH-60A ESSS fixed provision mounting points without any aircraft modifications. This hardware accepts up to four launcher racks (two per side), with each rack holding up to 40 individual XM-87 Mine Canisters. Each canister contains a stack of six mines giving the system a total delivery capability of 960 mines. For this test, a fully operational XM-139 VOLCANO system was utilized, configured with either 160 empty mine canisters or with canisters removed. A more detailed description of the VOLCANO system is contained in the system operator and technical manuals (refs 7 and 8, app A) and appendix B.

5. A description of the JCH-47C helicopter icing spray system (HISS) configured to generate the artificial icing cloud is presented in appendix C. A more detailed description of the HISS is presented in reference 9, appendix A. A description of the JU-21A configured with the cloud particle measuring system, used to document the icing environment in which the test aircraft was flown, is presented in reference 10.

TEST SCOPE

6. The artificial and natural icing flight tests of the UH-60A configured with the XM-139 VOLCANO were conducted in the vicinity of Duluth, Minnesota (field elevation 1430 ft) from 10 January to 22 February 1988 and required 13 flights and 16.4 hours of productive flight testing. Of these flights, 5 were in the artificial environment, totaling 5.2 hours, and 8 flights were in natural icing environment, totaling 11.2 hours. Maintenance support was provided by civilian contract maintenance personnel from the U.S. Army Aviation Development Test Activity, Ft. Rucker, Alabama. The test aircraft was flown in three configurations: (1) with mounting kit sideboards and launcher racks installed without canisters; (2) with mounting kit sideboards, launcher racks and canisters installed and the interlaced strap protruding from 20 canisters in the post launch external condition; and (3) with mounting kit sideboards and launcher racks installed and 160 expended XM-88 inert mine canisters installed. A summary of specific test conditions is presented in figure F-1. Flight limitations contained in the operator's manual and the airworthiness release (ref 11) were observed.

TEST METHODOLOGY

7. 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 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. During each artificial flight, the VOLCANO system was immersed in the cloud approximately 60 minutes. A detailed discussion of the test sequence and procedures is contained in the test plan (ref 5, app A).

8. Natural icing tests were conducted by flying in IMC 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. Photographs 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 find and stay 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 was used. Time in the clouds was limited by the availability of the natural icing conditions and aircraft IFR fuel requirements.

9. Instrumentation and special equipment used during this test are presented in appendix D. Test techniques, data analysis methods, methods used to determine cloud parameters, and definitions of icing types and severities are presented in appendix E.

RESULTS AND DISCUSSION

GENERAL

10. Artificial and natural icing tests were conducted to provide data to establish a moderate icing envelope (up to 1.0 gm/m³ liquid water content (LWC)) for the UH-60A helicopter with the VOLCANO installed. The VOLCANO and helicopter ice accretion and shedding characteristics were documented. A summary of test conditions is presented in table 1. A more detailed presentation of the specific test conditions for each flight is presented in figure F-1.

Table 1. Test Conditions

Flt[1] No.	Icing Environment	VOLCANO Configuration	Average OAT[2] (deg C)	Average LWC[3] (gm/m)	MVD[4] (μm)	Total Time In Cloud (min)
03	Artificial	No Canisters	-9.7	0.5	46	58
04	Artificial	Canisters[5]	-14.9	0.5	([6])	60
05	Artificial	No Canisters	-5.2	0.9	([6])	61
06	Artificial	Canisters[5]	-5.1	0.9	37	61
07	Natural	Canisters	-11.9	0.2	09	75
08	Natural	Canisters	-12.5	0.3	12	91
09	Artificial	Canisters	-20.1	1.0	50	60
10	Natural	Canisters	-21.6	0.1	13	44
11	Natural	Canisters[5]	-12.2	0.3	22	87
12	Natural	No Canisters	-11.2	0.5	17	84
13	Natural	Canisters	-10.9	0.2	12	79
14	Natural	Canisters	-6.3	0.5	14	81
15	Natural	Canisters	-10.4	0.3	17	104

Notes:

[1]Flight No. 1 and 2 were maintenance aborts.
[2] OAT: Outside air temperature.
[3]LWC: Liquid water content.
[4]MVD: Mean volumetric diameter.
[5]Indicates certain canisters in post firing configuration.
[6]Data not available due to instrumentation failure.

The UH-60A helicopter with the VOLCANO system installed can be safely operated in moderate icing conditions. One deficiency related to inadequate procedures in the operator's and crewmember's checklist was identified. The checklist does not contain procedures to activate anti-icing systems. Two shortcomings related to the ice accretion characteristics of the VOLCANO were identified. The two shortcomings are ice accretion characteristics of the mounting hardware kit and the launcher racks. Ice on the mounting hardware kit safety pin holes interferes with installation of the jettison safety pins. Ice on the forward end of the launcher racks interferes with movement of the arming levers and locking levers to the safe and unlocked positions, respectively. Although these discrepancies are safety related, proper operational procedures will reduce risk of injury to an acceptable level. No discrepancies related to the ice shedding characteristics of the VOLCANO were identified. However, the probability of shed ice particles causing foreign object damage (FOD) to the helicopter could be increased during rapid descents with the VOLCANO installed. Seven additional helicopter related shortcomings were identified. Nine previously identified shortcomings were also noted.

11. The UH-60A has numerous documented shortcomings that are potential sources of engine FOD. The FOD to three engines during previous icing tests have required engine replacement. The whole front of the aircraft, forward of the engine inlets should be closely evaluated to reduce the likelihood of FOD hazards to the engines. Consideration should be given to provide additional engine FOD protection.

XM-139 VOLCANO

General

12. The ice accretion and shedding characteristics of the VOLCANO were evaluated in three configurations shown in figures H-1 through H-3. Configuration 1 consisted of mounting racks and launcher racks without mine canisters installed. Configuration 2 added 160 expended XM-88 inert mine canisters . Eighteen of these canisters were sealed on the outboard end to simulate the external appearance of a loaded canister. Twenty of the canisters had the interlaced strap protruding in the post launch external appearance. The interlaced straps in the remaining 122 canisters were stored inside the canister. Configuration 3 was identical to configuration 2 except that the 20 protruding interlaced straps were also stored inside of the canisters. The canister pattern was symmetrical between left and right side in all configurations. No firings of the VOLCANO system were conducted. Ice accretion characteristics of the mine canisters did not indicate that ice would in any way impede mine firings.

Mounting Hardware Kit

13. The ice accretion and shedding characteristics of the air VOLCANO mounting hardware kit were evaluated at the specific test conditions shown in table 1. Photographs of typical ice accretions are presented in figures H-4 through H-6. The primary locations for ice accretion were on the forward facing ends of the side panel assemblies and the side panel struts. The largest formations of ice at these locations were approximately three inches (flt 9). Much smaller formations of ice were accreted on the inboard sides and tops of the side panel assemblies and on the exposed cable assemblies. Ice also accreted on the launcher rack mounting hardware on the outboard side of the side panels, preventing re-installation of some of the jettison safety pins. Ice accretions on the mounting hardware kit were essentially unaffected by the test configuration. Ice accretion characteristics of the mounting hardware kit interfere with installation of the jettison safety pins and are a shortcoming. The information contained in paragraph 15 should be included in paragraph 8-62 of the operator's manual.

14. No ice shedding from the mounting hardware kit was observed. However, ice shed from adjacent areas during level flight and partial power descents was observed moving aft and down by the resultant airflow under the rotor. The ice shedding characteristics of the mounting hardware kit are satisfactory.

Launcher Racks

15. The ice accretion and shedding characteristics of the launcher racks were evaluated with and without canisters installed at the specific tests conditions shown in table 1. Photographs of typical ice accretions are presented in figures H-4 and H-5. The primary locations for ice accretion were on the forward facing ends of the launcher racks including the latching levers, arming levers, lever guards, and handles. Ice formations of up to approximately 3.5 inches were observed in these frontal areas. During flight in moderate icing conditions (flight 12) without canisters installed, only a light "frosting" of ice was accreted on the outboard sides of the launcher racks near the aft end of the racks. These light accretions on the side of the racks did not interfere with mine canisters installation. However, ice formations of the forward latching levers and arming levers will interfere with mine canister installation and removal on the forward half of the launcher racks. Ice accretion characteristics of the launcher racks that interfere with movement of the forward latching levers and arming levers are a shortcoming. The following information should be included in paragraph 8-62 of the operator's manual:

> c. After flight in icing conditions with the VOLCANO system installed, the jettison safety pins may be difficult to install due to ice in and around the safety pin holes. The forward launcher rack latching levers and arming levers may also be covered with ice making it difficult to move the arming levers to the safe position. Use of an external heater to remove ice from these areas is recommended. Do not use foreign objects to break ice from these areas as this may cause damage to the system.
>
> **WARNING**
>
> All personnel will remain clear of the outboard side of the launcher racks until the arming levers are safed and the jettison safety pins are installed, or until the helicopter is shutdown and power removed.

Future designs of the air VOLCANO should include provisions to prevent ice accretions on the forward locking and arming levers.

16. Natural shedding of the launcher racks was essentially limited to flight into warmer air temperatures. Ice on the forward lever guards were the most frequently shed formations on the launcher racks. Ice shed from the area of the launcher racks was observed moving aft and down during level flight and partial power descents. No evidence of damage to the VOLCANO system or to the helicopter was documented. The ice shedding characteristics of the launcher racks are satisfactory.

Mine Canisters

17. The ice accretion and shedding characteristics of the XM-88 mine canisters were evaluated in the pre-launch and post-launch configuration at conditions shown in table 1. Photographs of typical ice accretions are presented in figures H-2 through H-5. Essentially no ice accreted on the exposed canister straps. The primary locations of ice accretion were on the front radius of the first column of canisters and the upper radius of the top row of

canisters installed on both the upper and lower launcher racks. Ice formations of up to approximately five inches were observed in these locations. None of these accretions extended around the outboard end of the canister. Only a light "frosting" of ice was noted on the end caps of the canisters installed near the aft columns. These ice accretions will not interfere with mine launch operations. The ice accretion characteristics of the mine canisters are satisfactory.

18. Ice shedding was observed more frequently from the mine canisters than from other parts of the VOLCANO system. All ice sheds observed went aft and down, away from the helicopter. Due to the shedding characteristics, firing of the mines was not deemed necessary since the shedding should be similar. The ice shedding characteristics of the mine canisters are satisfactory. However, this test did not include high rates of descent into air temperatures warmer than freezing. It is possible that the air flow under these conditions could result in shed ice particles causing FOD to the helicopter, most probably the tail rotor. The following information should be included in paragraph 8-61 of the operator's manual:

> d. During flight in icing conditions, shed ice particles may cause FOD to the helicopter, especially main rotor and tail rotor blades and engine compressors. Flight tests have shown that this FOD is difficult to detect during flight. Minimizing descent rates after ice has accumulated on the helicopter or external stores should reduce the probability of FOD because the airflow will carry particles aft and down, away from the helicopter. Normal instrument procedure descents of approximately 1000 fpm or less are preferable. During shutdown, crewmember's should be alert for unusual engine damage. The helicopter should be alert for unusual engine noise (high pitched whine) that indicate engine compressor damage. The helicopter should be visually inspected prior to further flight.

AIRCRAFT ICE PROTECTION SYSTEMS

Engine and Engine Inlet Anti-Ice Systems

19. The engine and engine inlet anti-ice systems on the test helicopter were identical to systems previously tested. These systems were activated prior to entering the icing environment except for flight 10. On this flight the ENG ANTI-ICE switches were not placed in the ON position due to a human error caused partly by the checklist (ref 12). Neither the "BEFORE TAKEOFF" nor the "AFTER TAKEOFF" checks include a step to remind the pilot to activate anti-icing systems in accordance with (IAW) the WARNING in paragraph 8-27 of the operator's manual (ref 6). Only small ice formations accreted on the engine inlet assembly (fig. H-7) because this flight was for a relatively short duration in trace icing conditions. Had this error occurred during a flight in more severe icing conditions, one or both engines could have been damaged by FOD. The omission of steps in the Operator's and Crewmember's Checklist to remind pilots to activate anti-icing systems IAW the operator's manual is a deficiency. The following step should be placed in the "BEFORE TAKEOFF" and the "AFTER TAKEOFF" checks immediately:

> PITOT HEAT, ENG ANTI-ICE, and WINDSHIELD ANTI-ICE switches - ON as required.

20. Ice accretions were noted on the forward inboard lip of the heated number two engine air inlet fairing assembly (bullet cowling) on flights 4, 7, and 8. Photographs of typical ice formations on the number two inlet faring are presented in figures H-7 through H-9. These small formations were shed prior to landing. One of these ice sheds was documented on video tape, but the evaluation of where the ice went was inconclusive. The shed ice either went inboard behind the fairing assembly or into the engine inlet. Ice accretion forward of the engine inlet increases the probability of engine FOD. Ice accretion on the inboard lip of the number two engine inlet assembly is a shortcoming. An engine inlet anti-icing system improvement should be made on the UH-60 helicopter to prevent ice accretions on the inboard lip of the engine inlet assembly.

Engine Inlet Particle Separator

21. The engine inlet particle separators on the test helicopter were identical to separators previously tested. These separators are designed to remove sand, dust, and other foreign materials from the inlet air. There was no conclusive evidence that ice shed from the helicopter entered the engine inlet during this test. However, engine FOD from ice ingestion was documented during previous icing tests on the UH-60A helicopter (refs 3 and 13) and during the recent EH-60A helicopter icing test (ref 14). None of the incidents resulted in a catastrophic failure of the engine, and no abnormal engine indications were detected in the cockpit except for unusual engine compressor noise. Engine FOD did require an engine change in these incidents. The probability of future engine FOD can be reduced by improvements in the ice accretion and shedding characteristics of the helicopter. However, there will always be ice shed in front of the helicopter from the rotor system that can enter the engine inlet. The design of the engine inlet particle separator does not prevent ingestion of ice and is a shortcoming. The design of the inlet particle separator on the UH-60 helicopter should be improved to prevent ingestion of airframe and rotor system ice.

Windshield Anti-Ice System

22. The windshield anti-ice system was different from systems previously tested, in that, the center windshield was also heated. The windshield and anti-ice system was activated prior to entering the icing environment. Photographs of typical ice accretions are presented in figures H-8 through H-10. The pilot and copilot windshields were kept essentially clear of ice at all conditions tested, but ice did accrete around the sides of the windshields. The center windshield was also kept essentially clear of ice except for flight 15 where ice accretions were observed on the lower half of the windshield. This ice accreted from the sides and bottom of the center windshield. Ice also accreted on the windshield wipers as previously reported in reference 2. Ice formations of up to approximately 5 x 20 x 1/4-inches were observed on the wipers. These ice formations frequently shed during flight. Ice sheds were observed moving up over the windshield. Ice shedding from the windshields and wipers increase the probability of engine and rotor system FOD. The ice accretion and shedding characteristics of the windshield anti-ice system and wipers cause large ice accretions increasing the probability of FOD to the helicopter and are a shortcoming. A design improvement on the UH-60 helicopter windshield anti-icing system should be accomplished to prevent ice accretions on the center windshield and the windshield wipers.

AIRFRAME ICE ACCRETION AND SHEDDING CHARACTERISTICS

General

23. The airframe ice accretion and shedding characteristics of the UH-60A helicopter configured with the VOLCANO system were evaluated at conditions shown in table 1. Most of the airframe ice accretion and shedding characteristics identified as shortcomings in previous evaluations were noted during this evaluation. These shortcomings will be listed later in a miscellaneous paragraph. Two additional airframe shortcomings were identified during this evaluation.

Free-Air Temperature Indicators

24. The free-air temperature (FAT) indicator ice accretion and shedding characteristics were evaluated at conditions presented in table 1. The cockpit FAT indicators were different from the FAT indicator installed in previous test helicopters. The test helicopter had a FAT indicator installed in both the pilot's and copilot's overhead windows. Photographs of typical ice accretions on these indicators are presented in figures H-1, and H-8 through H-10. Ice formations of up to approximately 5 x 2-1/4 x 3/8-inches were observed on the FAT indicators. Similar ice formations were observed on the protective shield for the blade deice FAT sensor (element on time (EOT) sensor). Ice formations on the FAT indicators shed on several occasions even when the air temperature was below freezing. Ice accretion and shedding from the FAT indicators increases the probability of engine FOD and is a shortcoming. The FAT indicators in the UH-60 helicopter could be replaced with remote FAT sensors that are located in a less critical area, e.g., the ambient air sensing tube on the outboard side of the engine inlet assembly. The EOT sensor should also be relocated.

Control Access Fairing

25. The control access fairing ice accretion and shedding characteristics were evaluated at conditions presented in table 1. Photographs of typical ice accretions on the control access fairing are presented in figures H-8 and H-9. Ice accreted in the heater air intake port and on the rear alignment pin bracket hardware. The location of these ice formations, directly in front of the engine inlet, increases the probability of engine FOD from ice shedding. However, no ice shedding was documented from these locations and no evidence of engine FOD was detected during this test. The ice accretion characteristics of the control access fairing are a shortcoming because of an increased probability of engine FOD. The design of the control access fairing on the UH-60 helicopter should be improved to eliminate ice accretion in front of the engine inlets.

PERFORMANCE

26. Level flight performance characteristics of the VOLCANO equipped UH-60A helicopter were quantitatively evaluated to determine degradation when operating in an icing environment. Power required to maintain level unaccelerated flight was recorded from cockpit gauges and compared to a baseline value obtained prior to or immediately upon entering icing conditions. As the aircraft operated in these conditions, ice accreted on the VOLCANO system, airframe, and rotor system. Power required increased as ice accumulated until the rotor deice system initiated a shed of rotor system ice, thus reducing power required. The power required decrease following rotor system shed did not typically return to pre-immersion power levels but was 2 to 8% higher. This cycle of accretion and

shed continued throughout the flights with the maximum power required being encountered just prior to rotor system shed. The maximum increase in indicated torque observed was 18%. The data for these flights is summarized in table F-2. The increased drag did not present an immediate hazard to aircraft or crew. The following sentence should be added to paragraph 8-61C of reference 5, appendix A:

> Engine indicated torque increases of up to 20% can be expected during cruise flights in icing conditions with the VOLCANO system installed.

RELIABILITY AND MAINTAINABILITY

27. The UH-60A helicopter deicing kit was evaluated throughout the test period. At the initiation of testing, the aircraft total flight time was 164.7 hours. During this flight test program, which consisted of 16.4 flight hours, there were three total failures of the deice system and numerous instances when deice system functional checks had to be repeated several times to obtain the correct results (item 17, para 8-21 and item 6, para 8-23, ref 5). Test incidence reports are included in appendix G.

MISCELLANEOUS

28. No corrective action was accomplished for the following previously identified shortcomings on the UH-60A helicopter in icing conditions. The following discrepancies remain:

a. The large increases in power required with ice accumulation on the rotor system (ref 2, app A).

b. The large decrease in power available with the engine and engine inlet anti-ice systems on (refs 2 and 3).

c. The poor location of the deice system circuit breakers (ref 2).

d. The poor reliability of the deice system (ref 2).

e. The insufficient main transmission drip pan drain capacity (ref 2)

f. The ice accumulation on the FM homing antennas which interferes with cockpit door opening (ref 2)

g. The large ice accretions on the wire strike protection system components which subsequently shed and cause FOD to the aircraft (ref 15).

h. The large ice accretions on the forward portion of the improved airspeed system pitot-static tube support strut fairings (ref 16).

i. The inadequate anti-ice provisions on the pitot-static tube support struts as installed with the improved airspeed system fairings (ref 16).

29. The following recommendations still apply from previous UH-60A helicopter icing tests since no corrective action has been accomplished or the corrective action taken was inadequate to warrant deletion of the previous recommendations:

a. The windshield anti-ice switches should be labeled to indicate the reset feature of the OFF position (ref 2).

b. The following NOTE should be placed in the operator's manual immediately (ref 2):

NOTE

Moderate accumulations (approximately one inch) of ice on the FM homing antennas can interfere with normal cockpit door opening. A slight amount of pressure on the door will normally break the ice from the antenna.

c. The following CAUTION should be placed in the operator's manual immediately (ref 3):

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 foreign object damage if the ice should shed from the windshield.

d. The following NOTE should be placed in the operator's manual immediately (ref 3):

NOTE

Some ice impact damage to the aircraft can be expected during flight in icing conditions. The aircraft should be closely inspected following icing encounters.

CONCLUSIONS

GENERAL

30. The UH-60A helicopter with the VOLCANO system installed can safely operate in moderate icing conditions. However, the probability of rotating component FOD, due to impact with shed ice particles during descents, is increased with the installation of the VOLCANO. Consideration should be given to provide additional engine FOD protection (para 11). One deficiency and 7 shortcomings were identified regarding the operation of the UH-60A helicopter in an icing environment.

DEFICIENCY

31. The omission of steps in the operator's and crewmember's checklist to remind pilots to activate anti-icing systems IAW the operator's manual is a deficiency (para 19).

SHORTCOMINGS

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

a. The ice accretion characteristics of the air VOLCANO mounting hardware kit interfere with installation of the jettison safety pins (para 13).

b. Ice accretion characteristics of VOLCANO launcher racks interfere with movement of the arming levers and locking levers to the safe and unlocked position, respectively (para 15).

c. The design of the engine inlet particle separator does not prevent ingestion of airframe and rotor system shed ice (para 21).

d. The ice accretion and shedding characteristics of the windshield anti-ice system and wipers does not prevent large ice accretions which cause an increased probability of FOD to the helicopter (para 22).

e. The ice accretion and shedding characteristics of the cockpit FAT indicators increases the probability of engine FOD (para 24).

f. The ice accretion characteristics of the control access fairing increases the probability of engine FOD (para 25).

g. Ice accretion on the inboard lip of the number two engine inlet assembly increases the probability of engine FOD (para 20).

33. The following ice related shortcomings have been previously identified:

a. The large increases in power required with ice accumulation on the rotor system (para 28a).

b. The large decrease in power available with the engine and engine inlet anti-ice systems on (para 28b).

c. The poor location of the deice system circuit breakers (para 28c).

d. The poor reliability of the deice system (para 28d).

e. The insufficient main transmission drip pan drain capacity (para 28e).

f. The ice accumulation on the FM homing antennas which interferes with cockpit door opening (para 28f).

g. The large ice accretions on the wire strike protection system components which subsequently shed and cause FOD to the aircraft (para 28g).

h. The large ice accretions on the forward portion of the improved airspeed system pitot-static tube support strut fairings (para 28h).

i. The inadequate anti-ice provisions on the pitot-static tube support struts as installed with the improved airspeed system fairings (para 28i).

RECOMMENDATIONS

34. The deficiency presented in paragraph 31 should be corrected immediately (para 19). The following steps should be addded to the "BEFORE TAKEOFF" and the "AFTER TAKEOFF" checks:

> PITOT HEAT, ENG ANTI-ICE, and WINDSHIELD ANTI-ICE switches - ON as required.

35. The shortcomings listed in paragraphs 32a and 32b should be corrected in future design changes to the air VOLCANO system. Future designs of the air VOLCANO could include an aerodynamic shield or cover to prevent ice accretions on the forward arming and latching levers. This shield could be attached to mounting hardware to continue compatibility of air and ground vehicle system (para 15).

36. The following information should be included in paragraph 8-61 of the operator's manual (para 18):

> d. During flight in icing conditions shed ice particles may cause FOD to the helicopter, especially main rotor and tail rotor blades, and engine compressors. Flight tests have shown that this FOD is difficult to detect during flight. Minimizing descent rates after ice has accumulated on the helicopter or external stores should reduce the probability of FOD because the airflow will carry particles aft and down away from the helicopter. Normal instrument procedure descents of approximately 1000 fpm or less are preferable. During shutdown, crewmember's should be alert for unusual engine noise (high pitched whine) that indicates compressor damage. The helicopter should be visually inspected prior to further flight.

37. The following sentence should be added to paragraph 8-61.c of the operator's manual (para 26):

> Engine torque increases of up to 20% can be expected during cruise flights in icing conditions with the VOLCANO system installed.

38. The following information should be included in paragraph 8-62 of the operator's manual (para 15):

> c. After flight in icing conditions with the VOLCANO system installed, the jettison safety pins may be difficult to install due to ice in and around the safety pin holes. The forward launcher rack locking levers and arming levers may also be covered with ice making it difficult to move the arming levers to the safe position. Use of an external heater to remove ice from these areas is recommended. Do not use foreign objects to break ice from these areas as this may cause damage to the system.

WARNING

All personnel will remain clear of the outboard side of the launcher racks until the arming levers are safed and th jettison safety pins are installed, or until the helicopter is shutdown and power removed.

39. The shortcomings listed in paragraphs 32c through 32g shou.d be corrected in future designs of the UH-60 helicopter.

40. Consideration should be given to provide additional engine FOD protection (para 30).

41. The following recommendations still apply from previous UH-60A helicopter icing tests since no corrective action has been accomplished or the corrective action taken was inadequate to warrant deletion of the revious recommendations:

a. The windshield anti-ice switches should be labeled to indicate the reset feature of the OFF position (para 29).

b. The following NOTE should be placed in the operator's manual immediately (para 29):

NOTE

Moderate accumulations (approximately one inch) of ice on the FM homing antennas can interfere with normal cockpit door opening. A slight amount of pressure on the door will normally break the ice from the antenna.

c. The following CAUTION should be placed in the operator's manual immediately (para 29):

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 foreign object damage if the ice should shed from the windshield.

d. The following NOTE should be placed in the operator's manual immediately (para 29):

NOTE

Some ice impact damage to the aircraft can be expected during flight in icing conditions. The aircraft should be closely inspected following icing encounters.

APPENDIX A. REFERENCES

1. Letter, AEFA, DAVTE-TB, 12 October 1979, subject: Letter Report, AEFA Project No. 78-05, Artificial and Natural Icing Tests Production UH-60A.

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

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

4. Memorandum, AVSCOM, AMSAV-8, 3 December 1987, subject: Icing Test of the UH-60A Heicopter Equipped with the VOLCANO Mine Dispensing System.

5. Test Plan, AEFA Project No. 87-19, *Artificial and Natural Icing Tests of the UH-60A Helicopter Configured with the XM-139 VOLCANO Mine Dispensing Subsystem*, December 1987

6. Technical Manual, TM 55-1520-237-10, *Operator's Manual, UH-60A Helicopter*, 21 May 1979 with change 43 dated 23 October 1987.

7. Draft Equipment Publication, DEP 9-1095-208-10, *Operator's Manual for Multiple Delivery Mine System (VOLCANO)*, June 1987.

8. Draft Equipment Publication, DEP 9-1095-208-23&P (Manuscript), *Technical Manual Organizatational and Direct Support Maintenance Manual (Including Repair Parts and Special Tools List) for Multiple Delivery Mine System (VOLCANO)*, June 1987.

9. Final Report, AEFA Project No. 82-05-3, *Helicopter Icing Spray System (HISS) Evaluation and Improvements*, April 1986.

10. Final Report, AEFA Project No. 83-01, *Verification of U-21A Cloud Parameter Measurement Equipment and Comparison of Natural and Artificial Ice Accretion Characteristics on Rotor Blade Airfoil Sections*, May 1987 (to be published).

11. Memorandum, AVSCOM, AMSAV-E, 6 January 1988, subject: Airworthiness Release for the Conduct of an Artificial and Natural Icing Test of S/N 86-24483 UH-60A, Configured with the VOLCANO XM-139 Universal Mine Dispenser System, with revision 1 dated 7 January 1988, revision 2 dated 11 January 1988.

12. Technical Manual, TM-1520-237-1OCL, *Operator's and Crewmember's Checklist, UH-60A Helicopter*, 7 February 1986 with change 7, 25 September 1987.

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

14. Final Report, AEFA Project No. 88-06, *Artificial and Natual Icing Tests, EH-60A Helicopter*, to be published.

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

APPENDIX B. DESCRIPTION

GENERAL

1. The UH-60A (Black Hawk) is a twin-turbine, single main rotor helicopter with nonretractable wheel-type landing gear. A movable horizontal stabilator is located on the lower portion of the tail rotor pylon. The main and tail rotor are both four-bladed with a capability of manual main rotor blade and tail pylon folding. The cross-beam tail rotor with composite blades is attached to the right side of the pylon. The tail rotor shaft is canted 20 degrees upward from the horizontal. Primary mission gross weight is 16,260 lb and maximum alternate gross weight is 20,250 lb. The proposed maximum gross weight is 22,000 lb and the XM-139 Multiple Mine Dispensing System (VOLCANO) configured helicopter design gross weight is 20,572 lb. The UH-60A is powered by two General Electric T700-GE-700 turboshaft engines having an installed thermodynamic rating (30 minute) of 1553 shaft horsepower (shp) (power turbine speed of 20,900 revolutions per minute) each at sea level, standard-day static conditions. Installed dual-engine power is transmission limited to 2828 shp. The aircraft also has an automatic flight control system and a command instrument system. The test helicopter, UH-60A U.S. Army S/N 86-24483, was manufactured by Sikorsky Aircraft Division of United Technologies Corporation and is a production Black Hawk equipped with fixed provision mounting points. These points provide the mounting for the VOLCANO system hardware. A more complete description of the UH-60A helicopter can be found in reference 6, appendix A.

XM-139 VOLCANO MINE DISPENSER

2. The XM-139 VOLCANO weapons system with related equipment is produced by Honeywell, Inc. The VOLCANO is an automated, scatterable mine delivery system capable of launching mines from host ground and air vehicles (5 ton dump and cargo trucks and the UH-60A helicopter). The mine dispenser system is modular and consists of four major components: (1) mounting hardware kits, (2) four launcher racks, (3) 160 mine canisters, and (4) a dispenser control unit (DCU). Dimensions and weights of these components are summarized in table B-1 and aircraft mounting locations are shown in figure B-1.

Table B-1. XM-139 Component Dimensions

	Dimensions (in.)			Weight
Component	Height	Length	Width	Pounds
UH-60A Side Panel (each)	58.5	57.25	6.25	238
Launcher Rack (each)	25.0	79.0	9.0	225
XM-88 Canisters (each)		24.0	5.0 (dia)	30
DCU	19	21	21	70

The mounting hardware is the only application-unique system element and allows mounting to the Black Hawk fixed provision mounting without any aircraft modifications. This hardware accepts up to four launcher racks (two per side) with each rack holding up to 40 individual XM-87 mine canisters. Each canister contains a stack of five BLU-91/B antitank and one BLU-92/B anti-personnel GATOR mines giving the system a total delivery

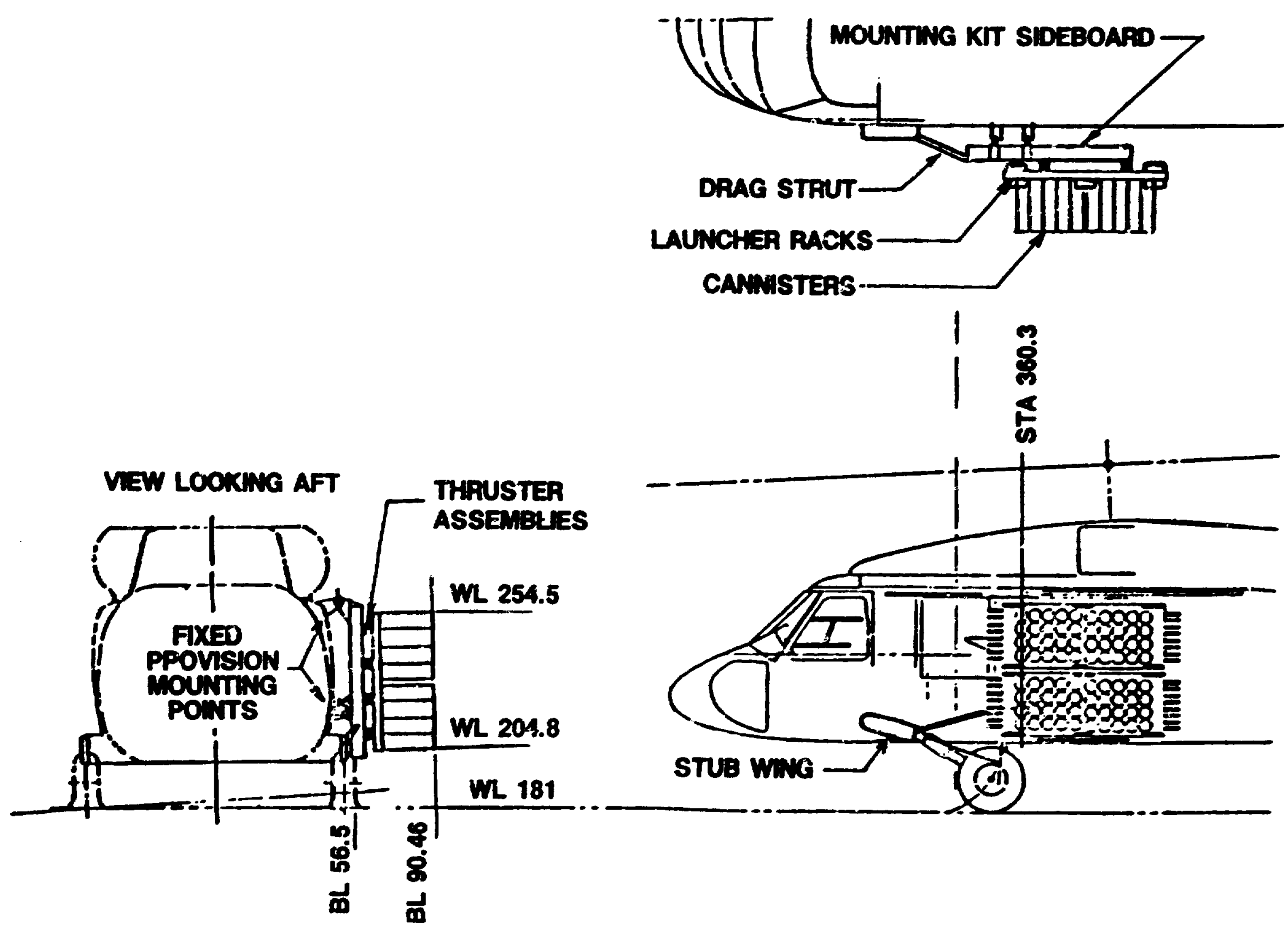


Figure B-4. XM-139 VOLCANO Mine Dispensing System, UH-60A Black Hawk capability of 960 mines. A web assembly is interlaced between the mines providing lateral dispersal during firing. Once the canister has been fired, the webbed strap assembly hangs out of the canister. The post firing configuration does not impede subsequent canister firings. Empty inert XM-88 mine canisters were used for this test. The XM-139 DCU mounted in the cargo compartment, is programmed by the operator with the selected dispensing speed and mine self-destruct time. It is designed to control firing of one to four racks in a prescribed sequence on alternating sides of the aircraft. The interface control panel mounted on the center instrument console, and the go-around switch, located on both pilot and copilot cyclic controls, control the arming, firing and jettison of the launcher racks. The interface control panel allows the pilot to conduct a continuity test of the jettison system. A more complete description of the system can be found in references 7 and 8, appendix A.

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 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 foot distance from the booms used for icing tests, the size of the visible spray cloud cross-section is approximately 8 ft high and 36 ft 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:

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

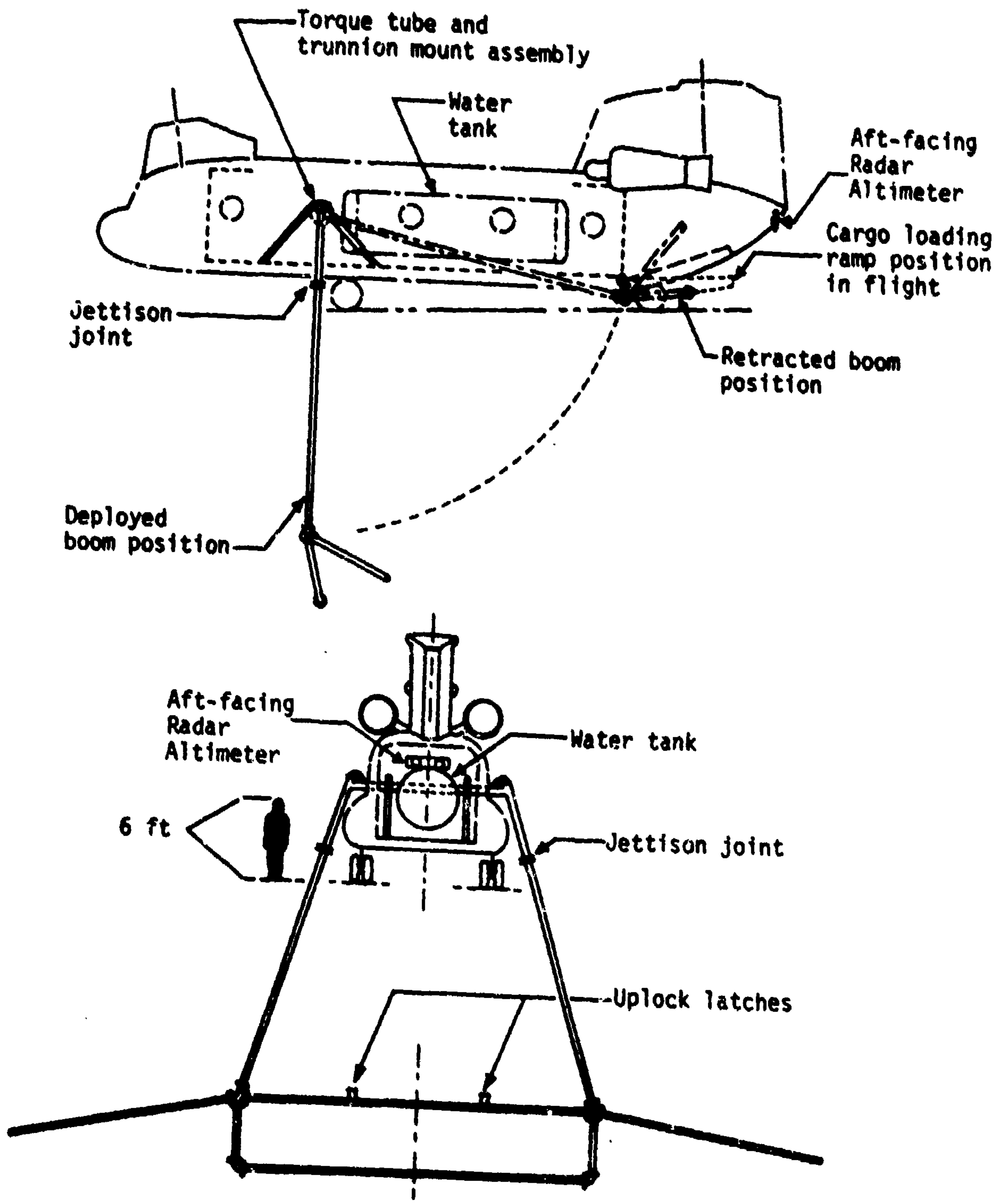


Figure C-1. Helicopter Icing Spray System
Side and Rear View Schematic

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 [illegible] ambient temperature and humidity measurement. To enhance photographic [illegible] 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. A video camera was located onboard the chase aircraft and was used to document the test aircraft in the spray cloud, after exit from icing encounters, and on the ground. Single lens reflex 35mm cameras and 2-1/4-in. Hasselblad camera were used for still photo documentation both in the air and on the ground following icing flights.

VISUAL ICE ACCRETION PROBE

2. Two visual ice accretion indicator probes were fabricated and installed on the test aircraft. These were used to give additional visual cues of ice build-up on the aircraft fuselage. One 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-in. 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. The other probe was mounted on the left upper launcher racks front row of canisters. The probe was a 2-in. long, 3/16-in. diameter screw afixed to a stainless steel circular clamp which mounted to the canister 6in. from the outboard edge.

CLOUD SAMPLING EQUIPMENT

3. Icing conditions were measured in both the natural and artificial environments, by a 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), Rosemount outside air temperature 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).

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 (deg C)

e. dew point (deg 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 (μm)

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. All anti-ice systems (i.e., pitot heat, windshield anti-ice, engine, and engine air induction system anti-ice) were activated while enroute to the test area. For artificial icing the test aircraft then entered the artificial spray cloud from a position below and approximately 150 ft behind the spray aircraft. Test and spray aircraft separation distance was maintained during the icing flight by observing yellow (greater than 160 ft) and red (closer than 140 ft) lights mounted on the bottom of the spray aircraft. The visual indications were supplemented as required by information relayed from the spray aircraft. Airspeed and outside air temperature (OAT), were established with the calibrated instrumentation system of the Helicopter Icing Spray System aircraft. All artificial flights were flown with a predetermined liquid water content (LWC) and OAT. For natural icing the JU-21A would locate and document the icing condition and radio the data back to the test aircraft before it entered the icing environment. The JU-21A would then loiter in the area to facilitate a post-immersion rapid in-flight join-up with the test aircraft for photographic documentation. The 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. The Rosemount icing rate meter in the test aircraft was also used to monitor LWC in natural clouds.

WEIGHT AND BALANCE

2. Prior to the test, the aircraft gross weight, longitudinal and lateral center of gravity were determined by using calibrated scales. The aircraft was weighed with full fuel, side panels, dispenser control unit, and launchers racks with canisters OFF and ON.

ICE ACCRETION AND SHEDDING

3. Ice accretion on the test aircraft was documented using hand held video and still cameras photographing from both the chase aircraft and spray aircraft. Post-flight photographs were made to document the ice remaining on the individual components of the airframe and the XM-139 Multiple Mine Dispensing System subsystem.

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

DEFINITIONS

5. Icing characteristics were described using the following definitions of icing severity. These definitions may be found in FM 1-230 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/m³ 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/m³ 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.

6. 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 an item or part, which seriously impairs the equipments 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 material or end product.

APPENDIX F. TEST DATA

Table F-1 Specific Test Conditions

Flt No.	Date	Icing Environment	Volcano Configuration	Average Gross Weight (lb)	Average Longitudinal Center of Gravity (FS)	Average Density Altitude (ft)	Average OAT[1] (deg C)	Average True Airspeed (kts)	Average LWC[2] (gm/m^3)	MVD[3] (µm)	Total Time In Cloud (min)
03	10 Jan 88	Artificial	No Canisters	14,720	356.3	3,990	-9.7	100	0.5	46	58
04	14 Jan 88	Artificial	Canisters[4]	15,570	355.6	3,340	-14.9	101	0.5	([5])	60
05	17 Jan 88	Artificial	No Canisters	14,740	356.4	5,500	-5.2	100	0.9	([5])	61
06	17 Jan 88	Artificial	Canisters[4]	15,580	355.7	5,410	-5.1	100	0.9	37	61
07	20 Jan 88	Natural	Canisters	15,570	355.7	1,180	-11.9	97	0.2	09	75
08	21 Jan 88	Natural	Canisters	15,440	354.8	910	-12.5	99	0.3	12	91
09	25 Jan 88	Artificial	Canisters	15,610	356.3	2,480	-20.1	100	1.0	30	60
10	08 Feb 88	Natural	Canisters	15,700	356.6	9,840	-21.6	126	0.1	13	44
11	14 Feb 88	Natural	Canisters[4]	15,730	355.2	3,140	-12.2	97	0.3	22	87
12	16 Feb 88	Natural	No Canisters	14,530	356.7	5,100	-11.2	110	0.5	17	84
13	17 Feb 88	Natural	Canisters	15,530	356.2	2,750	-10.9	98	0.2	12	79
14	19 Feb 88	Natural	Canisters	15,510	356.1	2,290	-6.3	97	0.5	14	81
15	22 Feb 88	Natural	Canisters	15,320	355.2	5,430	-10.4	104	0.3	17	104

NOTES:

[1]OAT: Outside air temperature.
[2]LWC: Liquid water content.
[3]MVD: Mean volumetric diameter.
[4]Indicates Certain Canisters In Post Firing Configuration.
[5]Data not available due to instrumentation failure.

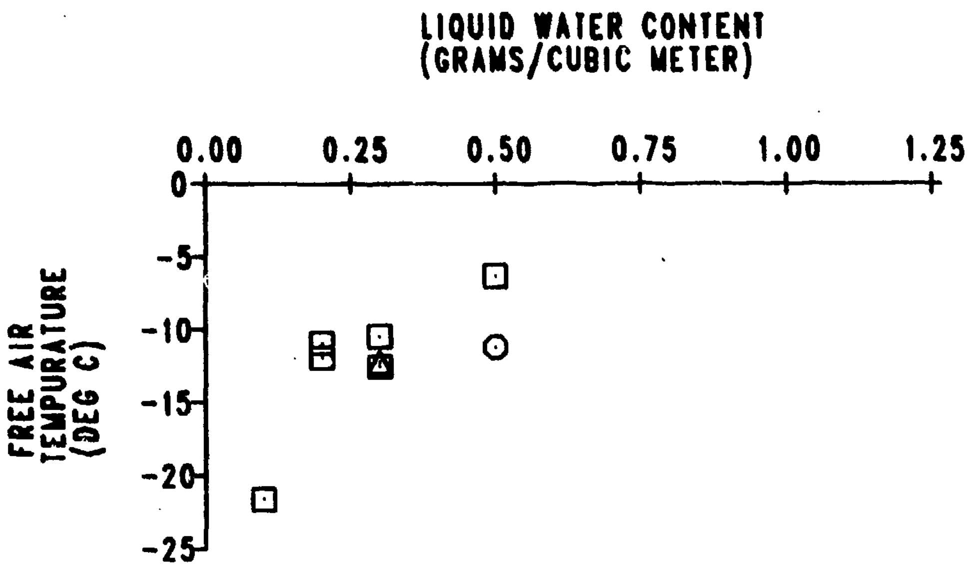
Table F-2. Requirements for Level Unaccelerated Flight In Natural Icing Conditions

Flt	Baseline Power Required (% trq)	Maximum Power Required (% trq)	Maximum Power Change (% trq)	True Airspeed (knots)	Density Altitude (ft)	Free Air Temp. (deg C)	Liquid Water Content (g/m^3)
07	50	61	11	97	1,180	-11.9	0.2
08	58	73	15	99	910	-12.5	0.3
10	68	76	8	126	9,840	-21.6	0.1
11	52	67	15	97	3,140	-12.2	0.3
12	56	74	18	110	5,100	-11.2	0.5
13	DATA	NOT AVAIL	ABLE	98	2,750	-10.9	0.2
14	56	68	12	97	2,290	-6.3	0.5
15	53	65	12	104	5,430	-10.4	0.3

NOTE:

[1]Baseline power required obtained prior to or immediately upon entering icing conditions.

FIGURE F-3. NATURAL ICING CONDITIONS

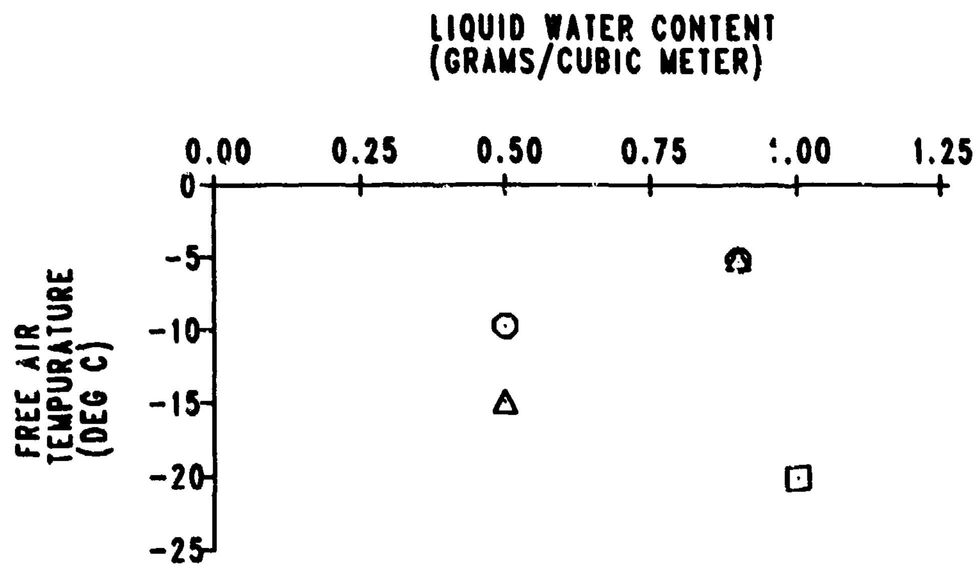


NOTE: ⊙ VOLCANO SYSTEM WITH CANISTERS REMOVED
AVERAGE GROSS WEIGHT = 14,530 LB
AVERAGE LONGITUDINAL CG LOCATION = FS 356.7 (MID)
AVERAGE DENSITY ALTITUDE = 3100 FT

⊡ VOLCANO SYSTEM WITH CANISTERS INSTALLED
AVERAGE GROSS WEIGHT = 15,510 LB
AVERAGE LONGITUDINAL CG LOCATION = FS 355.8 (MID)
AVERAGE DENSITY ALTITUDE = 3730 FT

△ VOLCANO SYSTEM WITH CANISTERS INSTALLED
(CERTAIN CANISTERS IN POST FIRING CONFIGURATION)
AVERAGE GROSS WEIGHT = 15,730 LB
AVERAGE LONGITUDINAL CG LOCATION = FS 355.2 (MID)
AVERAGE DENSITY ALTITUDE = 3140 FT

FIGURE F-4. ARTIFICIAL ICING CONDITIONS



NOTE:

⊙ VOLCANO SYSTEM WITH CANISTERS REMOVED
AVERAGE GROSS WEIGHT = 14730 LB
AVERAGE LONGITUDINAL CG LOCATION = FS 356.4 (MID)
AVERAGE DENSITY ALTITUDE = 4750 FT

⊡ VOLCANO SYSTEM WITH CANISTERS INSTALLED
AVERAGE GROSS WEIGHT = 15610 LB
AVERAGE LONGITUDINAL CG LOCATION = FS 356.[illegible] (MID)
AVERAGE DENSITY ALTITUDE = 2480 FT

Δ VOLCANO SYSTEM WITH CANISTERS INSTALLED
(CERTAIN CANISTERS IN POST FIRING CONFIGURATION)
AVERAGE GROSS WEIGHT = 15,570 LB
AVERAGE LONGITUDINAL CG LOCATION = FS 355.6 (MID)
AVERAGE DENSITY ALTITUDE = 4370 FT

APPENDIX G. TEST INCIDENT REPORTS

TEST INCIDENT REPORT (AMCR 70-13)		1. Release Date: 10 February 1988
2. Test Title: Artificial and Natural Icing Tests, UH-60A Helicopter Configured w/XM-139 VOLCANO Mine Disp. Sys.	3. Test Project # 87-19	4. TIR # EJ-A871901
5. Test Agency: AEFA		6. Test Sponsor AVSCOM

I MAJOR ITEM DATA

10. Model: Helicopter, UH-60	Test Life: Units:
11. Serial#: 86-24483	21.
12. USA#:	22.
13. Mfr: Sikorsky	23.
14. Contract#:	24. (Not Used)

II INCIDENT DATA

30. Title Main Rotor De-ice Failure	40. Data & Time: 10 Jan 88, 0840
31. Subsystem:	41. FD/SC Step#:
32. Incident Class: Major	42. FD/SC Class:
33. Category: Performance	43. Chargeability:
34. Observed During: Operation	44. Preliminary CA Status:
35. Action Taken: Operated	45. Asgd Resp:

48. Test Environment: Aircraft run-up.
49. Defective Materiel: Turned all in to supply.

III INCIDENT SUBJECT DATA

50. Name Capacitor (1.0 MFD ±20% 400 VDC)	60. FGC:
51. Serial#:	61. LSA#:
52. FSN/NSN:	Part Life: Units:
53. Mfr: West Cap	63.
54. Mfr Part#: M39022?01-1464	64.
55. Drawing#:	65.
56. Quantity: 1	66. Next Assy:
57. Action: Replaced	67. Serial#:

IV MAINTENANCE DATA

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

V INCIDENT DESCRIPTION

Full Description of Incident:

90. Aircraft failed de-ice preflight/operational BIT check repeatedly, but would eventually pass BIT check without fault indications.

Name, Title & Phone of Preparer: 98. DAVID A. DOWNEY, CPT, AV Project Officer, 277-4992	FOR THE COMMANDER: 99. AUSTIN R. OMLIE, MAJ, AV Chief, Plans & Programs

TEST INCIDENT REPORT (AMCR 70-13)

TEST INCIDENT REPORT (AMCR 70-13)	1. Release Date: 10 February 1988	
2. Test Title: Artificial & Natural Icing Tests, UH-60A Helicopter Configured w/XM-139 VOLCANO Mine Dispensing System	3. Test Project # 87-19	4. TIR # EJ-A871902
5. Test Agency: AEFA	6. Test Sponsor AVSCOM	

I MAJOR ITEM DATA

10. Model: Helicopter, UH-60	Test Life: Units:
11. Serial#: 86-24483	21.
12. USA#:	22.
13. Mfr: Sikorsky	23.
14. Contract#:	24. (Not Used)

II INCIDENT DATA

30. Title	40. Date & Time: 28 Jan 88, 0915
31. Subsystem:	41. FD/SC Step#:
32. Incident Class:	42. FD/SC Class:
33. Category:	43. Chargeability:
34. Observed During:	44. Preliminary CA Status:
35. Action Taken:	45. Asgd Resp:

48. Test Environment: Aircraft run-up.
49. Defective Materiel: Turned in to supply.

III INCIDENT SUBJECT DATA

50. Name Distributor, Blade De-ice	60. FGC:
51. Serial#: 0946	61. LSA#:
52. FSN/NSN: 1680-01-102-6015	Part Life: Units.
53. Mfr: Dynamic Controls Corp.	63.
54. Mfr Part#: 78286-70550-02127-103	64.
55. Drawing#: TM 55-1520-237-23P2,	65.
56. Quantity: 1 page 1993, fig. 654,	66. Next Assy:
57. Action: Replaced Item 10	67. Serial#:

IV MAINTENANCE DATA

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

V INCIDENT DESCRIPTION

Full Description of Incident:

90. Aircraft failed blade de-ice system test (item 17, para 8021, pg 8-8.2, TM 55-1520-237-10) and DE-ICE EOT check (item 6, para 8-23, pg 8-11) repeatedly. De-ice system would only pass test with % N_R at 100%. Per trouble shooting charts, blade de-ice distributor was changed. After replacement of the blade de-ice distributor the aircraft passed the blade de-ice system test.

Name, Title & Phone of Preparer:	FOR THE COMMANDER:
98. DAVID A. DOWNEY, CPT, AV Project Officer, 277-4992	99. AUSTIN R. OMLIE, MAJ, AV Chief, Plans & Programs

TEST INCIDENT REPORT (AMCR 70-13)	1. Release Date: 1 February 1988
2. Test Title: Artificial & Natural Icing Tests, UH-60A Helicopter Configured w/XM-139 VOLCANO Mine Dispensing System	3. Test Project # 87-19 / 4. TIR # EJ-A871903
5. Test Agency: AEFA	6. Test Sponsor AVSCOM

I MAJOR ITEM DATA

10. Model: Helicopter, UH-60	Test Life: Units:
11. Serial#: 86-24483	21.
12. USA#:	22.
13. Mfr: Sikorsky	23.
14. Contract#:	24. (Not Used)

II INCIDENT DATA

30. Title Icing Rate Meter out of Calibration	40. Data & Time: 5 Feb 88, 1200
31. Subsystem:	41. FD/SC Step#:
32. Incident Class: Major	42. FD/SC Class:
33. Category:	43. Chargeability:
34. Observed During: Operation	44. Preliminary CA Status:
35. Action Taken: Cleared	45. Asgd Resp:

48. Test Environment: Aircraft run-up.
49. Defective Materiel: Turned in to supply.

III INCIDENT SUBJECT DATA

50. Name Icing Rate Meter	60. FGC:
51. Serial#: 1331	61. LSA#:
52. FSN/NSN: 1680-01-111-0187	Part Life: Units:
53. Mfr: Rosemount	63.
54. Mfr Part#: 70550-01124-103	64.
55. Drawing#:	65.
56. Quantity: 1	66. Next Assy:
57. Action: Replaced.	67. Serial#:

IV MAINTENANCE DATA

70. Diagnostic Clockhours:	80. Type:
71. Diagnostic Manhours:	81. Level Use:
72. Active Maint Clockhours:	82. Level Presc:
73. Active Maint Manhours:	83. Level Recm:

V INCIDENT DESCRIPTION

Full Description of Incident:
90. Icing rate meter failed BIT during initial run-up.

Name, Title & Phone of Preparer:	FOR THE COMMANDER:
98. DAVID A. DOWNEY, CPT, AV Project Officer, 277-4992	99. AUSTIN R. OMLIE, MAJ, AV Chief, Plans & Programs

TEST INCIDENT REPORT (AMCR 70-13)

1. Release Date: 10 February 1988

2. Test Title: Artificial & Natural Icing Tests, UH-60A Helicopter Configured w/XM-139 VOLCANO Mine Dispensing System

3. Test Project #: 87-19

4. TIR #: EJ-A871904

5. Test Agency: AEFA

6. Test Sponsor: AVSCOM

I MAJOR ITEM DATA

10. Model: Helicopter, UH-60
11. Serial#: 86-24483
12. USA#:
13. Mfr: Sikorsky
14. Contract#:

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

II INCIDENT DATA

30. Title
31. Subsystem:
32. Incident Class:
33. Category:
34. Observed During:
35. Action Taken:

40. Data & Time: 5 Feb 88, 1200
41. FD/SC Step#:
42. FD/SC Class:
43. Chargeability:
44. Preliminary CA Status:
45. Asgd Resp:

48. Test Environment: Aircraft run-up.
49. Defective Materiel: Turned in to supply.

III INCIDENT SUBJECT DATA

50. Name Blade De-ice Controller Assembly
51. Serial#: 0862
52. FSN/NSN: 1680-01-115-3568
53. Mfr:
54. Mfr Part#: 70550-2126-106
55. Drawing#: TM 55-1520-237-230-2, pg 2014, fig. 662, Item 24
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:
71. Diagnostic Manhours:
72. Active Maint Clockhours:
73. Active Maint Manhours:

80. Type:
81. Level Use:
82. Level Prsc:
83. Level Recm:

V INCIDENT DESCRIPTION

Full Description of Incident:

90. Aircraft failed blade de-ice system test (item 17, para 8-21, pg 8-8.2, TM 55-1520-237-10) and DE-ICE EOT check (item 6, para 8-23, pg 8-11) repeatedly. As blade de-ice system test was initiated, the main rotor power fault light (de-ice test panel, fig 2-16, pg 2-41, TM 55-1520-237-10) would illuminate. The fault light should illuminate for approximately 5 sec at the end of the test cycle. Test cycle duration is 105 to 135 seconds. Blade de-ice controller was replaced in accordance with maintenance trouble shooting charts (TM 55-1520-237-23-3). After replacement of the de-ice controller, the aircraft passed the blade de-ice system test.

Name, Title & Phone of Preparer:
98. DAVID A DOWNEY, CPT, AV
Project Officer, 277-4992

FOR THE COMMANDER:
99. AUSTIN R. OMLIE, MAJ, AV
Chief, Plans & Programs

TEST INCIDENT REPORT (AMCR 70-13)	1. Release Date: 10 February 1988	
2. Test Title: Artificial & Natural Icing Tests, UH-60A Helicopter Configured w/XM-139 VOLCANO Mine Dispensing System	3. Test Project # 87-19	4. TIR # EJ-A871905
5. Test Agency: AEFA	6. Test Sponsor AVSCOM	

I MAJOR ITEM DATA

10. Model: Helicopter, UH-60	Test Life: Units:
11. Serial#: 86-24483	21.
12. USA#:	22.
13. Mfr: Sikorsky	23.
14. Contract#:	24. (Not Used)

II INCIDENT DATA

30. Title Main Rotor De-ice Fault Light	40. Data & Time: 8 Feb 88, 1600
31. Subsystem:	41. FD/SC Step#:
32. Incident Class: Major	42. FD/SC Class:
33. Category:	43. Chargeability:
34. Observed During: Operation	44. Preliminary CA Status:
35. Action Taken: Cleared	45. Asgd Resp:

48. Test Environment: Aircraft run-up.
49. Defective Materiel: Turned in to supply.

III INCIDENT SUBJECT DATA

50. Name K2 No. 2 Generator Contactor	60. FGC:
51. Serial#: CG-54097	61. LSA#:
52. FSN/NSN: 6110-01-105-6615	Part Life: Units:
53. Mfr: Hartman Electrical Manufacturing	63.
54. Mfr Part#: D-56B	64.
55. Drawing#:	65.
56. Quantity: 1	66. Next Assy:
57. Action: Replaced	67. Serial#:

IV MAINTENANCE DATA

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

V INCIDENT DESCRIPTION

Full Description of Incident:

90. Main rotor de-ice faults have persisted for the last 30 days. Parts have been replaced IAW the trouble shooting guide per TM 55-1570-237-23-3. During the last 30 days the followi[ng] parts have been replaced: capacitor (TIR # EJ-A871901); blade de-ice distributor (TIR # EJ-A871902); Blade de-ice controller assembly (TIR # EJ-A871904). The KZ No.2 generator contactor (also known as K60 relay per TM 55-1520-237-23-3) was replaced and blade de-ice system successfully passed blade de-ice system test.

98. Name, Title & Phone of Preparer: DAVID A. DOWNEY, CPT, AV Project Officer, 277-4992	99. FOR THE COMMANDER: AUSTIN R. OMLIE, MAJ, AV Chief, Plans & Programs

TEST INCIDENT REPORT (AMCR 70-13)	1. Release Date: 10 February 1988	
2. Test Title: Artificial & Natural Icing Tests, UH-60A Helicopter Configured w/XM-139 VOLCANO Mine Dispensing System	3. Test Project # 87-19	4. TIR # EJ-A871906
5. Test Agency: AEFA	6. Test Sponsor AVSCOM	

I MAJOR ITEM DATA

10. Model: Helicopter, UH-60	Test Life: Units:
11. Serial#: 86-24483	21.
12. USA#:	22.
13. Mfr: Sikorsky	23.
14. Contract#:	24. (Not Used)

II INCIDENT DATA

30. Title External Power Failure	40. Data & Time: 8 Feb 88, 1600
31. Subsystem:	41. FD/SC Step#:
32. Incident Class: Minor	42. FD/SC Class:
33. Category:	43. Chargeability:
34. Observed During: Operation	44. Preliminary CA Status:
35. Action Taken: Cleared	45. Asgd Resp:

48. Test Environment: Troubleshooting electrical problem.
49. Defective Material: Returned to supply.

III INCIDENT SUBJECT DATA

50. Name Switch, Toggle	60. FGC:
51. Serial#: N/A	61. LSA#:
52. FSN/NSN: 5730-00-581-8137	Part Life: Units:
53. Mfr:	63.
54. Mfr Part#: M524524-31	64.
55. Drawing#:	65.
56. Quantity: 1	66. Next Assy:
57. Action switch would not activate	67. Serial#:

IV MAINTENANCE DATA

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

V INCIDENT DESCRIPTION

Full Description of Incident:

90. The faulty toggle switch is a 3 position ON-OFF-RESET switch (panel B, fig 206 (sheet 1 of 2), pg 2-8.1, TM 55-1520-237-10) that allows ground/external power source of 115 VAC, three-phase, 400 Hz to be connected to the aircraft. Failure of this switch precludes ground maintenance of various sytems. Replacement of switch corrected failure.

Name, Title & Phone of Preparer: 98. DAVID A. DOWNEY, CPT, AV Project Officer, 277-4784	FOR THE COMMANDER: 99. AUSTIN R. OMLIE, MAJ, AV Chief, Plans & Programs

APPENDIX H. PHOTOGRAPHS

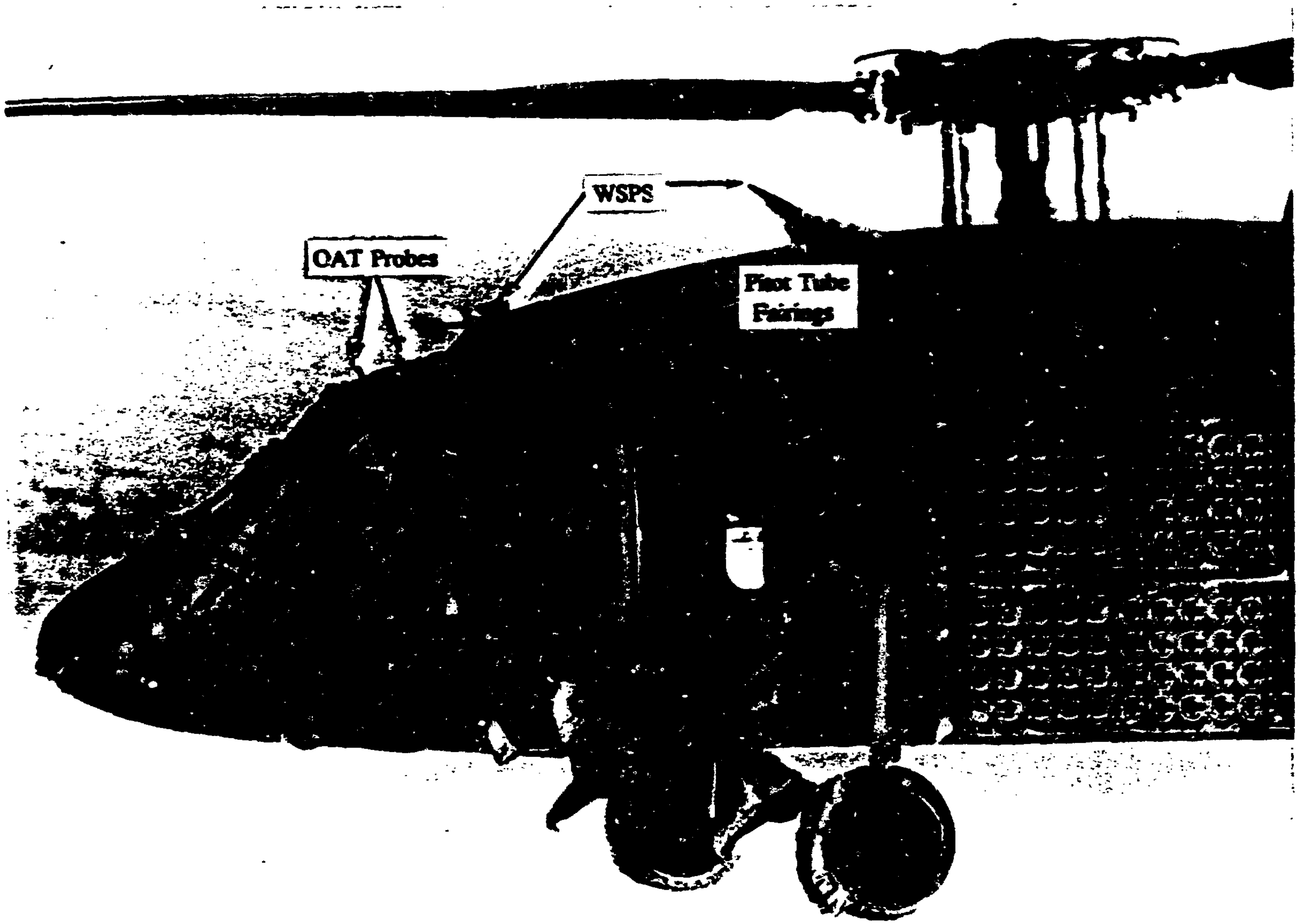


Figure H-1. XM - 139 VOLCANO without Canisters

Figure H-2. XM - 139 VOLCANO with XM - 88 Inert Canisters Installed

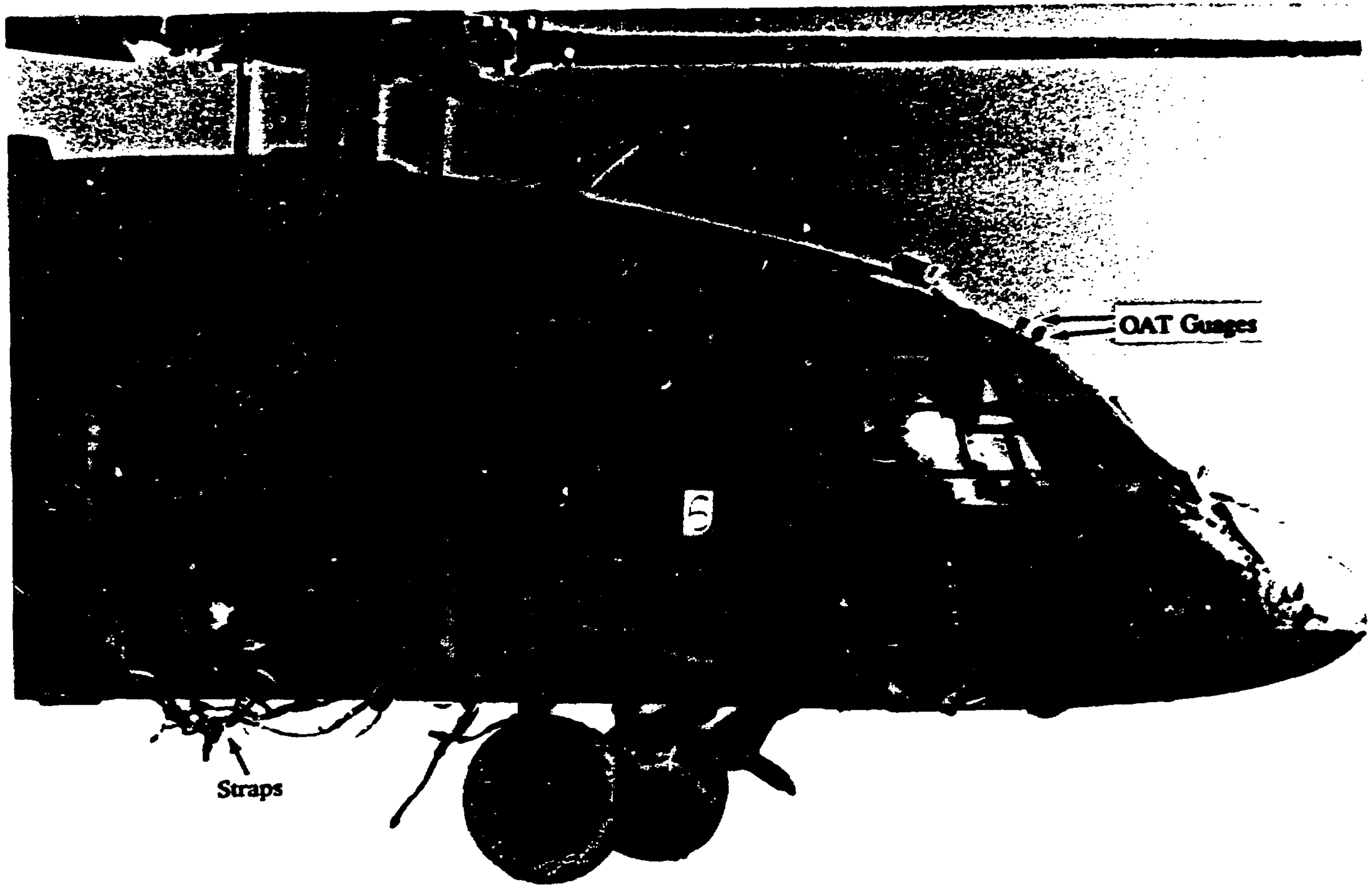


Figure H-3. XM – 139 VOLCANO with Certain Canisters in Post-Launch Configuration

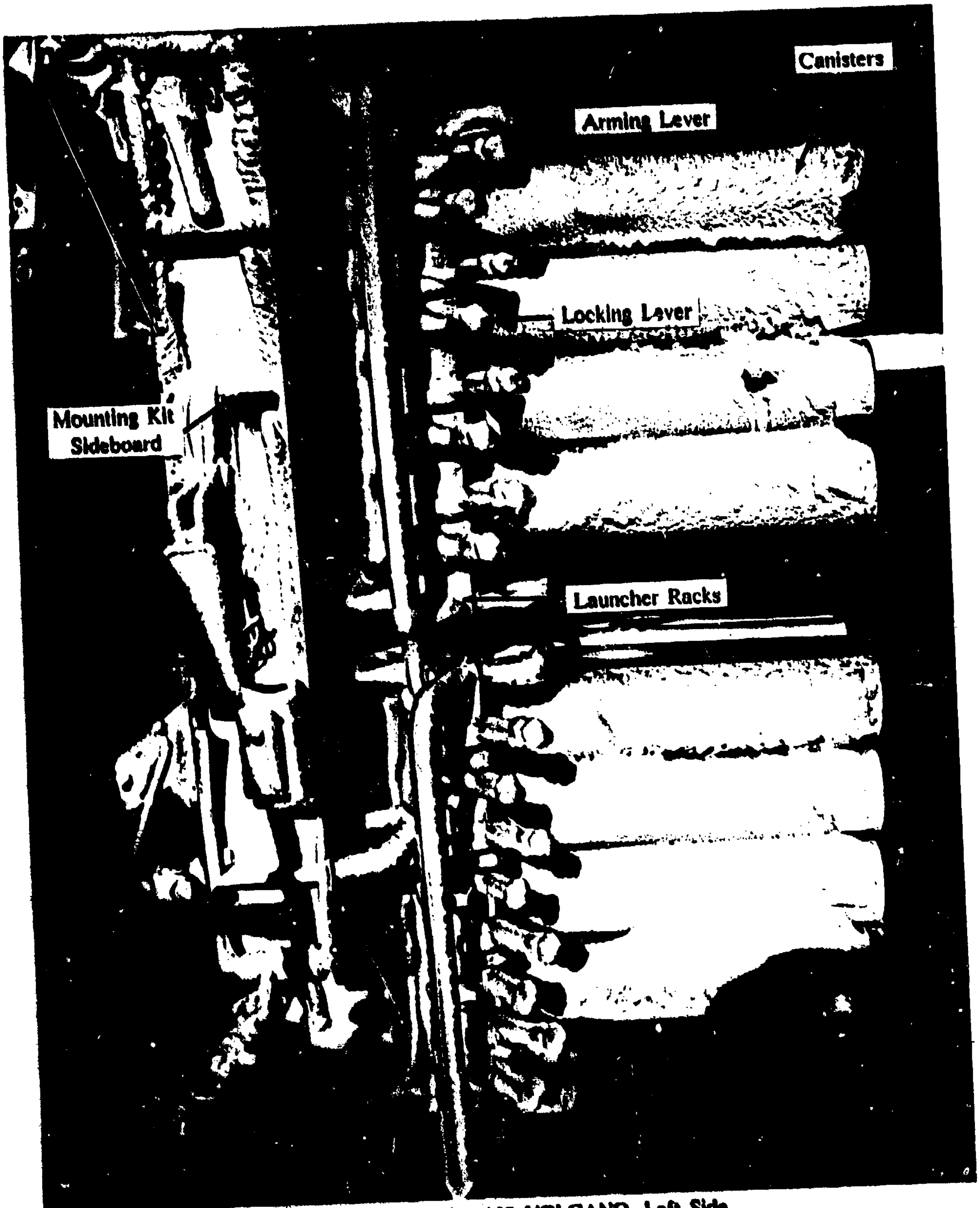


Figure H-4. XM - 139 VOLCANO, Left Side

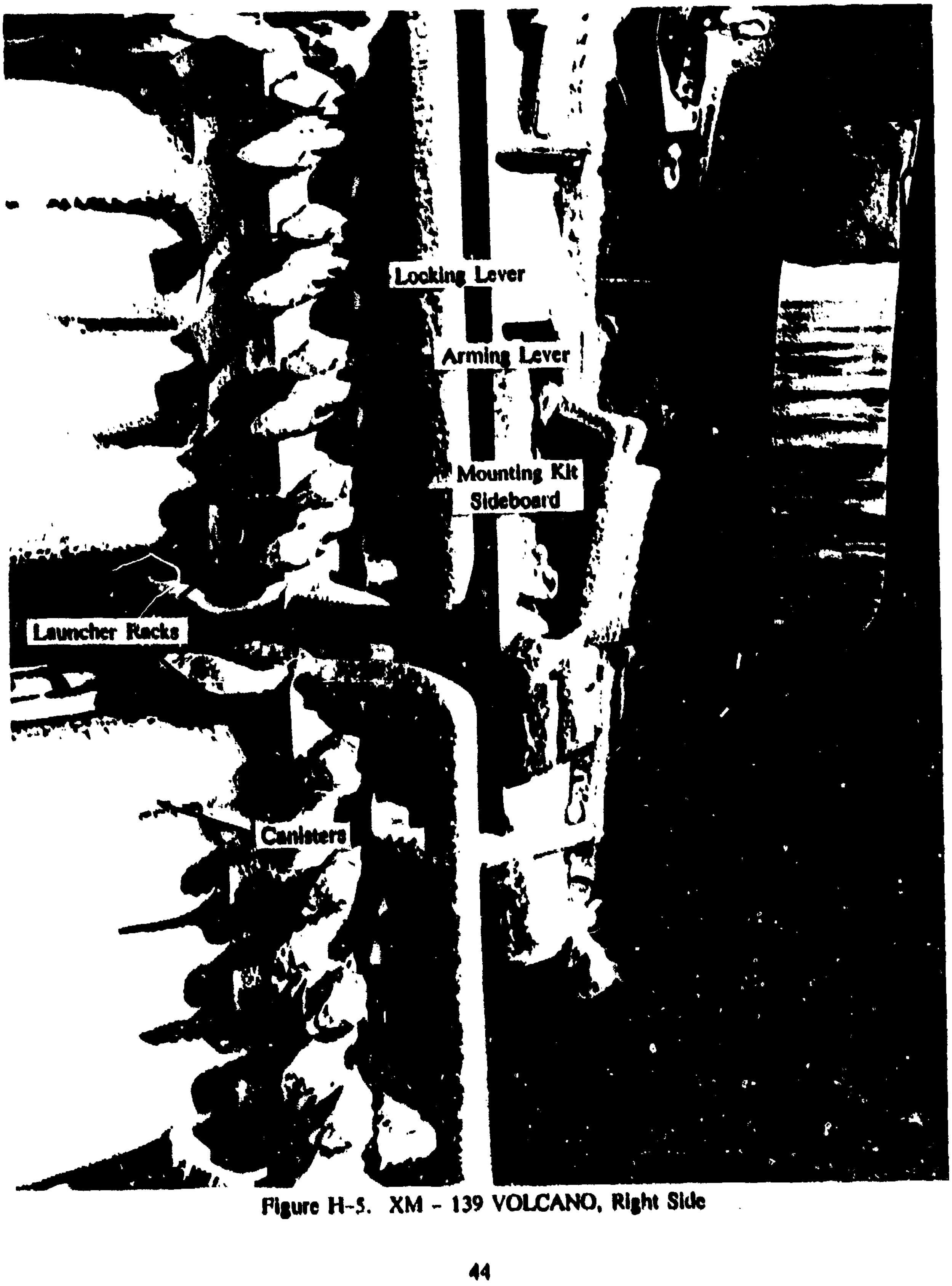


Figure H-5. XM - 139 VOLCANO, Right Side

Figure H-6. XM - 139 VOLCANO, Right Mounting Kit Sideboard

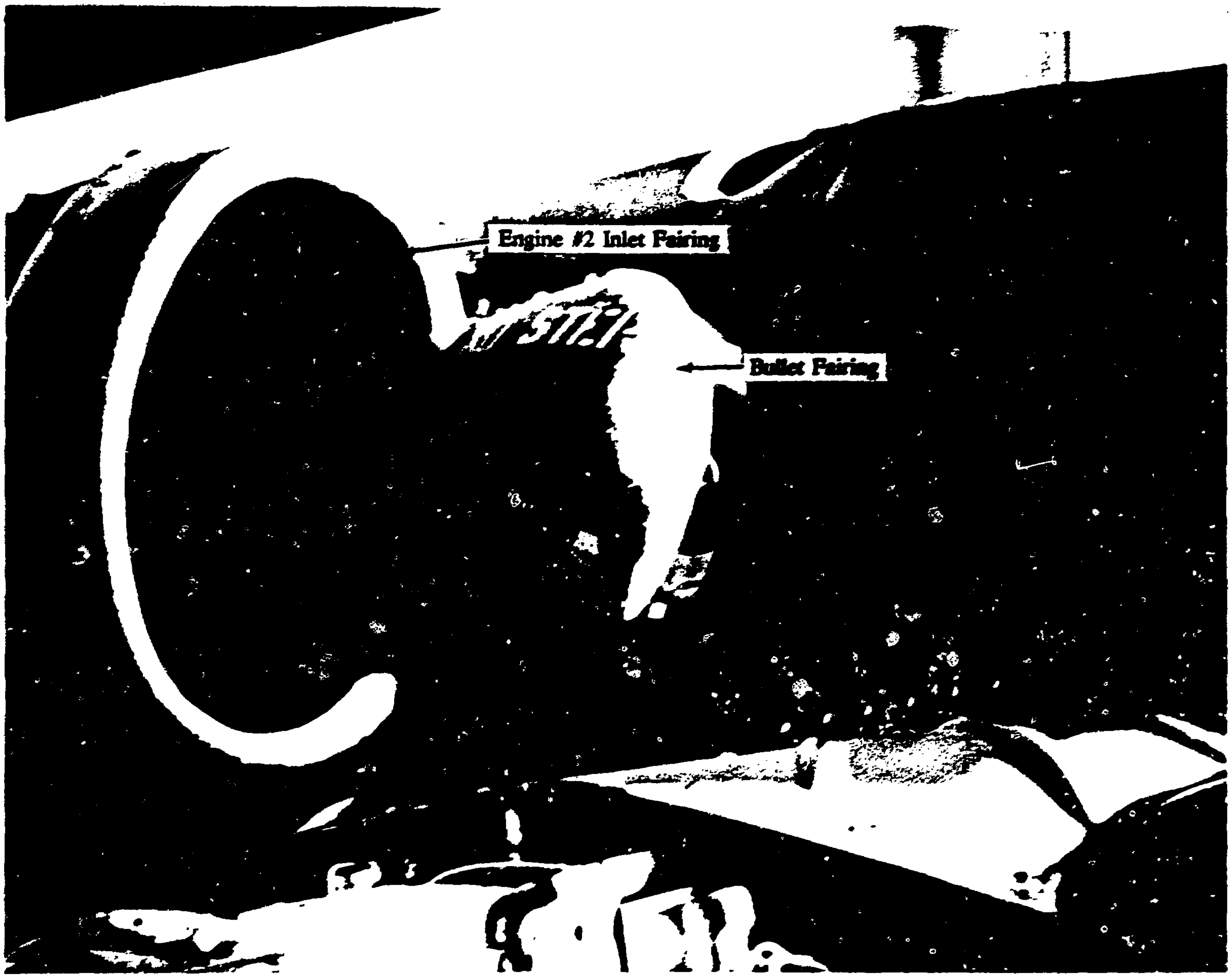


Figure H-7. No. 2 Engine Inlet Fairing (Flt 10)

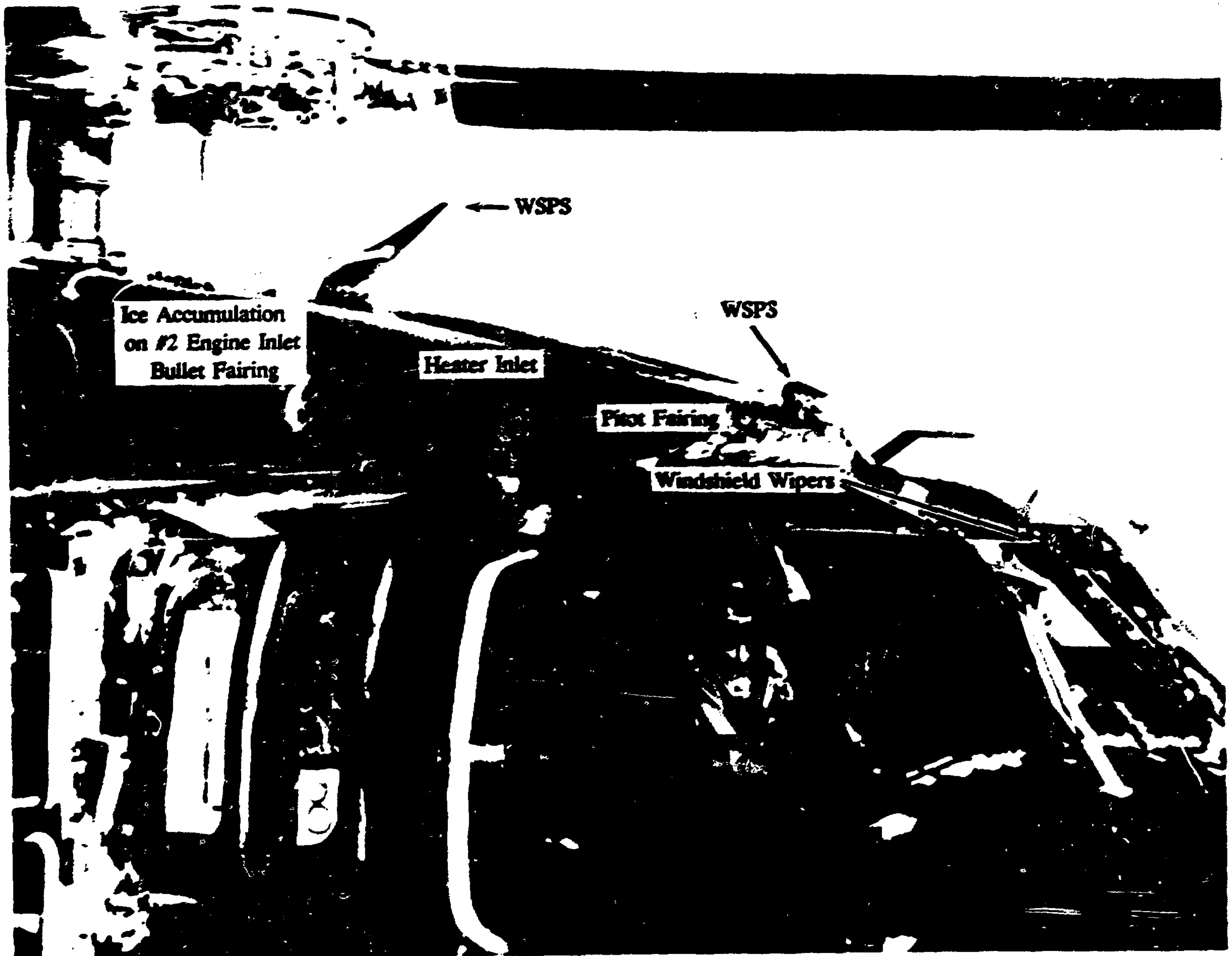


Figure H-8. Typical Natural Icing Forward Fuselage (Flt 8)

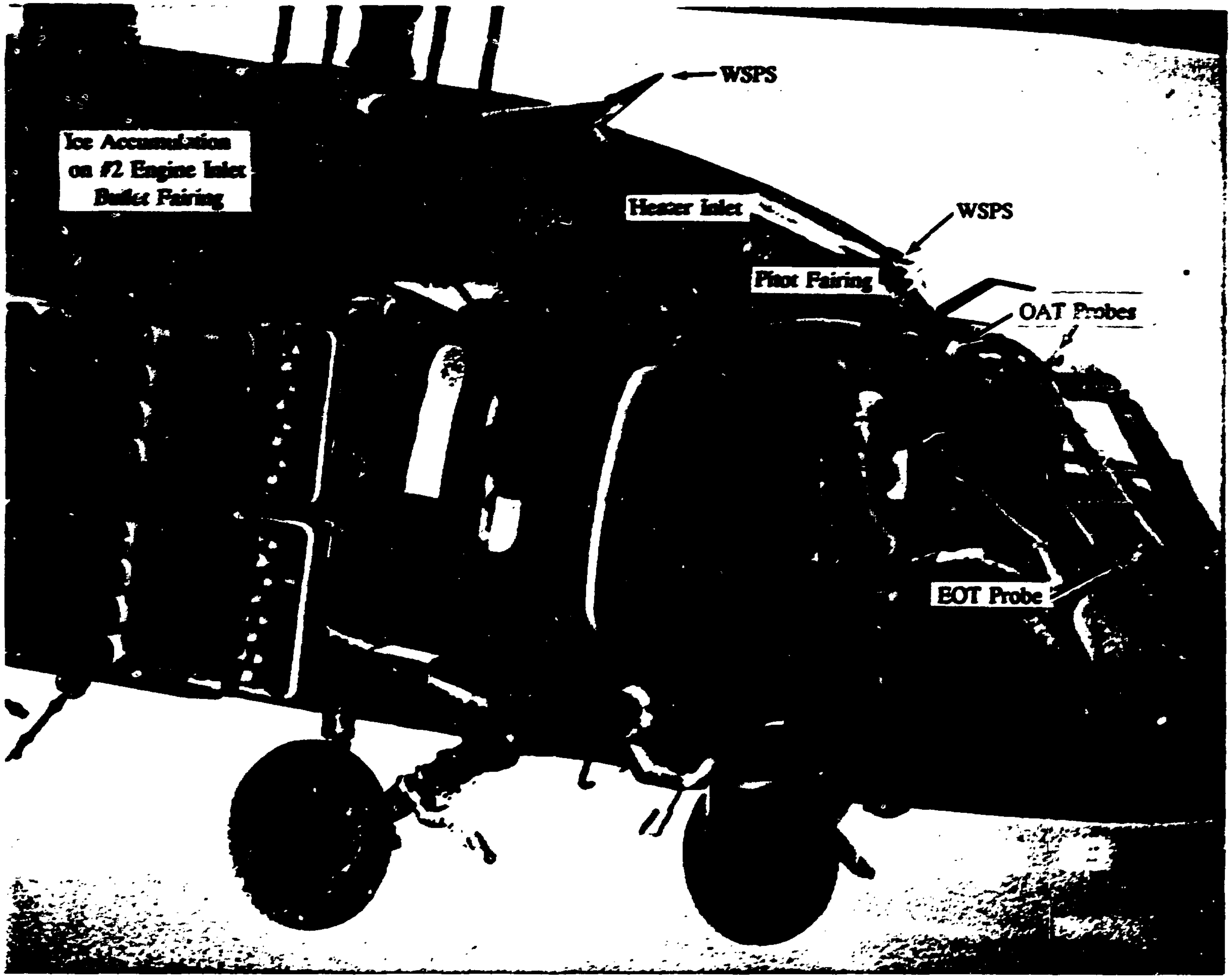


Figure H-9. Typical Natural Icing Forward Fuselage (Flt 4)

Figure H-10. Frontal View of UH-60A

DISTRIBUTION

HQDA (DALO-AV)	1
HQDA (DALO-FDQ)	1
HQDA (DAMO-HRS)	1
HQDA (SARD-PPM-T)	1
HQDA (SARD-RA)	1
HQDA (SARD-WSA)	1
US Army Material Command (AMCDE-SA, AMCDE-P, AMCQA-SA, AMCQA-ST)	4
US Training and Doctrine Command (ATCD-T, ATCD-B)	2
US Army Aviation Systems Command (AMSAV-8, AMSAV-Q, AMSAV-MC, AMSAV-ME, AMSAV-L, AMSAV-N, AMSAV-GTD)	8
US Army Test and Evaluation Command (AMSTE-TE-V, AMSTE-TE-O)	2
US Army Logistics Evaluation Agency (DALO-LEI)	1
US Army Materiel Systems Analysis Agency (AMXSY-RV, AMXSY-MP)	8
US Army Operational Test and Evaluation Agency (CSTE-AVSD-E)	2
US Army Armor School (ATSB-CD-TE)	1
US Army Aviation Center (ATZQ-D-T, ATZQ-CDC-C, ATZQ-TSM-A, ATZQ-TSM-S, ATZQ-TSM-LH)	5
US Army Combined Arms Center (ATZL-TIE)	1
US Army Safety Center (PESC-SPA, PESC-SE)	2
US Army Cost and Economic Analysis Center (CACC-AM)	1
US Army Aviation Research and Technology Activity (AVSCOM) NASA/Ames Research Center (SAVRT-R, SAVRT-M (Library)	3
US Army Aviation Research and Technology Activity (AVSCOM)	2

Aviation Applied Technology Directorate (SAVRT-TY-DRD, SAVRT-TY-TSC (Tech Library)	
US Army Aviation Research and Technology Activity (AVSCOM) Aeroflightdynamics Directorate (SAVRT-AF-D)	1
US Army Aviation Research and Technology Activity (AVSCOM Propulsion Directorate (SAVRT-PN-D)	1
Defense Technical Information Center (FDAC)	2
US Military Academy, Department of Mechanics (Aero Group Director)	1
ASD/AFXT, ASD/ENF	2
US Army Aviation Development Test Activity (STEBG-CT)	2
Assistant Technical Director for Projects, Code: CT-24 (Mr. Joseph Dunn)	2
6520 Test Group (ENML)	1
Commander, Naval Air Systems Command (AIR 5115B, AIR 5301)	3
Defense Intelligence Agency (DIA-DT-2D)	1
School of Aerospace Engineering (Dr. Daniel P. Schrage)	1
Headquarters United States Army Aviation Center and Fort Rucker (ATZQ-ESO-L)	1