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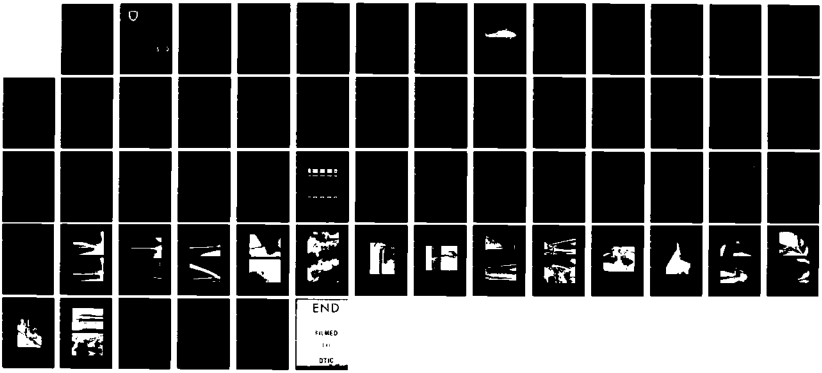

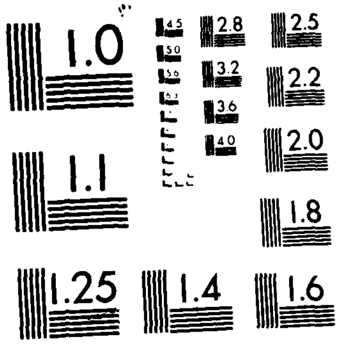

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USAAEFA PROJECT NO. 81-18

UH-60A LIGHT ICING ENVELOPE EVALUATION WITH THE BLADE DEICING KIT INSTALLED BUT INOPERATIVE

FINAL REPORT

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JUNE 1982

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

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

Artificial and natural icing flight tests were conducted on the UH-60A Black Hawk helicopter to verify the existence of a light icing envelope (up to 0.5 grams per cubic meter (gm/m^3) liquid water content (LWC)) with the blade deicing kit (P/N 70070-30003-013) installed but inoperative. The tests were conducted by the United States Army Aviation Engineering Flight Activity at St. Paul, Minnesota from 29 January through 1 April 1982. Testing consisted of 9.0 productive flight hours in the icing environment. The aircraft handling qualities and vibration levels were acceptable throughout the limited artificial and natural icing conditions tested. The UH-60A demonstrated safe operation in light icing conditions up to and including 0.3 gm/m^3 LWC without operating the blade deice system. However, the potential for aircraft damage exists in icing conditions greater than 0.3 gm/m^3. Three deficiencies were identified including aircraft damage from rotor system ice sheds, improper droop stop positions during shutdown, and failure of the blade deice electrical protection system to protect the blades against a heater element short circuit. Two shortcomings were identified: failure of the deice distributor wiring harness protective cover and failure of the distributor wiring harness clamps. UH-60A helicopters without the blade deice kit should be equipped with an ice detector and ice rate meter before they are cleared to fly into forecast icing conditions.

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DEPARTMENT OF THE ARMY
HQ, US ARMY AVIATION RESEARCH AND DEVELOPMENT COMMAND
4300 GOODFELLOW BOULEVARD, ST. LOUIS, MO 63120

DRDAV-D

SUBJECT: Directorate for Development and Qualification Position on the Final Report of USAAEFA Project No. 81-18, UH-60A Light Icing Envelope Evaluation with the Blade Deicing Kit Installed But Inoperative

SEE DISTRIBUTION

1. The purpose of this letter is to establish the Directorate for Development and Qualification Position on the subject report.

a. General Comments. The UH-60A must be airworthy for operation up through and including moderate icing conditions and only the blade deicing kit makes this feasible. Therefore, contrary to the ideas expressed in the report, no requirement exists for UH-60A helicopter that is not equipped with the blade deice kit to fly in light icing conditions. Since many of the delivered aircraft do not have the blade deice kit installed, the objective of this test was to conduct artificial and natural icing flights to explore the feasibility of safe use of UH-60As without the blade deice kit installed in a light icing environment (up to 0.5 gm/m^3 LWC). A by-product of this test is information to provide in the operator manuals instructing flight crews of safe operating procedures in the event of a failure of a blade deice kit when operating under icing conditions. It is not appropriate to document the significant problems that were encountered during this test (damage from rotor system ice sheds and improper droop stop position during shutdown with the deicing system inoperative) as deficiencies in that the aircraft is not, and should not be, expected to operate normally with the deice kit inoperative. Although operation of the UH-60 helicopter in trace and up to near light icing conditions without the blade deice kit was determined to be safe, helicopters without the complete kit should be equipped with the ice detector and ice rate meter portions before they will be cleared to fly into forecast icing conditions.

b. Paragraph 15. This paragraph is misleading in classifying the failure of the unheated droop stops as a deficiency. This classification would be appropriate if UH-60A helicopters without blade deice kits were cleared for flight in icing conditions. The heated droop stop configuration, which was the pacing item in the development of a successful blade deice kit, has been incorporated in the kit to preclude incorrect droop stop position on shut down.

c. Paragraph 18. Since the UH-60A without a blade deice kit is not designed for flight in icing conditions, the aircraft damage due to ice shed is not considered a deficiency. Again, this is only a problem if an unprotected UH-60A is cleared for flight in icing conditions.

d. Paragraph 21. The case of failure of the blade deice protection system is not considered a deficiency. The blade which sustained the damage had undergone flight in a desert environment and had a preexisting discrepancy which was aggravated by the application of power to the blade. The deice system sensed the short in the blade and shut the system down as it was designed to do. The deice system self test did not cause the failure but sensed a problem on the ground and shut the system down thereby performing its intended function. The issue is not the proper functioning of the blade deice system self test, but why the blade failed in the manner it did when the proper amount of power was applied. The Contractor has been apprised of this problem and is investigating.

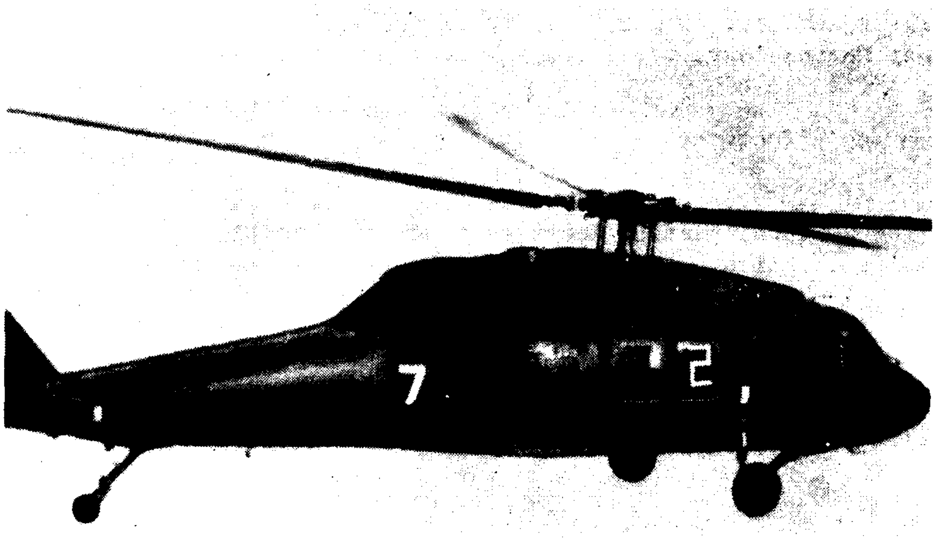
e. Paragraph 28. As previously discussed, these are not considered to be deficiencies.

f. Paragraph 29. The failure of the deice distributor wiring harness protective cover and the failure of the distributor wiring harness clamps are problems which have occurred in previous icing tests. These failures have been caused due to excessive stress on the harness and the clamps because of harness routing. Sikorsky has changed the wire routing and one clamping point has been removed to reduce the stress in both the harness and the clamps. There have been no reports of harness protective cover or clamp failures since the aforementioned changes were implemented.

2. Notwithstanding the differences above regarding special design requirements, this report documented a very important and very successful test program. It did explore the feasibility of safe flight of UH-60s (without blade deice kits) in icing conditions and documented a minimal degree of successful operation. The installation of the ice detector and ice rate meter portions in the deice kit in all BLACK HAWKs will be pursued with the Project Manager in order to capitalize on the results of these tests. Pressure will be kept on the Contractor to insure the adequate quality and maintainability of the deice kit electrical overload protection subsystem.

FOR THE COMMANDER:

CHARLES C. CRAWFORD, JR.
Director of Development
and Qualification



UH-60A Black Hawk Helicopter

TABLE OF CONTENTS

Page

INTRODUCTION

RESULTS AND DISCUSSION

CONCLUSIONS

APPENDIXES

DISTRIBUTION

INTRODUCTION

BACKGROUND

1. The US Army requires the UH-60A helicopter (Black Hawk) to operate safely in a moderate icing environment with a deicing system installed. Artificial icing tests were previously conducted in Alaska in 1976 (ref 1, app A) by the United States Army Aviation Engineering Flight Activity (USAAEFA) using a prototype YUH-60A with main and tail rotor deice system and anti-ice provisions for the pilot and copilot windshields, pitot-static tubes and their support struts, engines and engine inlets. Tests of a production UH-60A with similar deice and anti-ice systems, were conducted in Minnesota in 1979, 1980, and 1981 (refs 2, 3, and 4, app A). The current UH-60A helicopter fleet of approximately 200 aircraft does not have the production deicing kit (P/N 70070-30003-013) which includes an ice detector and rate meter as a part of the configuration. A requirement exists for UH-60A helicopters that are not equipped with the deicing kit to fly under light icing conditions; however, it was essential to first verify a light icing envelope (up to 0.5 grams per cubic meter (gm/m^3) liquid water content (LWC)) for this configuration. The United States Army Aviation Research and Development Command (AVRADCOM) requested USAAEFA to conduct limited artificial and natural icing airworthiness qualification flight tests of the production UH-60A without the blade deicing kit (ref 5) during the winter of 1982. Testing was conducted in accordance with the approved test plan (ref 6) and in conjunction with a logistical evaluation test by the US Army Aviation Development Test Activity (AVNDTA).

TEST OBJECTIVE

2. The objective of this test was to conduct artificial and natural icing flight tests to establish the maximum icing envelope for the UH-60A with an inoperative blade de-icing kit.

DESCRIPTION

3. The UH-60A is a twin-turbine, single-main-rotor configured helicopter capable of transporting cargo, 11 combat troops, or weapons during day and night, visual, and instrument meteorological conditions (IMC). Nonretractable wheel-type landing gear are provided. The main and tail rotors are both four-bladed, with a capability of manual main rotor blade and tail pylon folding. The test aircraft S/N 78-22976 was a production UH-60A, second year buy, with a production deicing kit (P/N 70070-30003-013) modified for this test. The main and tail rotor deice systems

were the same as the production deice systems except the deice controller was modified for flight safety reasons to allow the blades to begin their deice cycle with the heating element ON immediately upon turning the system on rather than starting the deice cycle with the element OFF. The ship's Rosemount ice detector and rate meter were modified to permit their operation with the deice system power switch OFF. An operational description of the test aircraft's modified deice system is contained in appendix B. A breakdown of the serial numbered items in the deice kit and the test items installed by AVNDTA for their logistical evaluation test are also shown in appendix B. A more detailed description of the UH-60A is contained in the operator's manual (ref 7, app A). An anti-ice/deice kit system description may also be found in supplements to the operator's manual. A brief description of the Helicopter Icing Spray System (HISS) is presented in appendix C. A more detailed description of the HISS and a description of the U-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 8, appendix A.

TEST SCOPE

4. In-flight artificial and natural icing tests were conducted in the vicinity of St. Paul, Minnesota, from 29 January to 1 April 1982. A total of 8 icing flights were conducted totaling 16.3 hours. Four artificial icing flights totaling 4.2 productive hours, and 4 natural icing flights, totaling 4.8 productive hours were conducted. Maintenance and logistical support for the test aircraft was provided by AVNDTA. A Black Hawk logistical evaluation test was conducted by AVNDTA in conjunction with the light icing envelope evaluation. The aircraft was flown in the normal utility configuration. Tests were conducted at an average gross weight of approximately 16,300 pounds with average longitudinal center of gravity (cg) location at fuselage station 354. Average density altitude varied from 2800 to 7000 feet. Icing was accomplished at ambient temperatures from -4.0 to -15.0 °C at average liquid water contents (LWC) of 0.15 to 0.5 gm/m^3. Test airspeeds ranged from 97 to 125 knots true airspeed (KTAS) and the main rotor speed was 258 rpm (100 percent). The anti-ice systems were operated continuously while in the icing environment. The main and tail rotor blade deice system was not activated while in the icing environment. A summary of the icing test conditions is presented in table 1, appendix F. Flight limitations contained in the operator's manual and in the airworthiness release (ref 9, app A) were observed during the testing.

TEST METHODOLOGY

5. Artificial icing was conducted by flying in a spray cloud generated by the HISS. The U-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. The UH-60A was immersed in the cloud for the maximum time attainable (limited by HISS fuel and water capacities). A detailed discussion of the test sequence and procedures is contained in reference 6, appendix A.

6. Natural icing tests were conducted by flying in IMC icing conditions under instrument flight rules (IFR). The U-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 U-21A after the test aircraft exited the icing environment. Close coordination with air traffic control, the chase, and test aircraft crews was required to find and stay in the icing environment and to implement in-flight 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. A USAAEFA designed and fabricated visual ice accretion measuring device was used to observe rate of ice accretion on the airframe. Test data were recorded on magnetic tape in pulse code modulation format. 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 severities are presented in appendix E.

RESULTS AND DISCUSSION

GENERAL

9. Artificial and natural icing flight tests were conducted to verify the existence of a light icing envelope (up to 0.5 gm/m^3 LWC) for the UH-60A without a blade deice kit. A summary of the specific test conditions for each flight is presented in table 1, appendix F. Specific icing test conditions are summarized in figure 1, appendix F for the artificial environment and figure 2 for the natural environment. The aircraft handling qualities and vibration levels were acceptable throughout all of the artificial and natural icing conditions tested. Three deficiencies were identified including aircraft damage from rotor system ice sheds, improper droop stop positions during shutdown, and failure of the blade deice electrical protection system to protect the blades against a heater element short circuit. Two shortcomings were identified: failure of the deice distributor wiring harness protective cover and failure of the distributor wiring harness clamps. The UH-60A demonstrated safe operation in light icing conditions up to and including 0.3 gm/m^3 LWC without operating the blade deice system. However, the potential for aircraft damage exists due to rotor system ice sheds and improper droop stop position during shutdown in icing conditions greater than 0.3 gm/m^3 LWC.

FLIGHT CONTROL SURFACE ICE ACCRETION AND SHEDDING CHARACTERISTICS

Main Rotor Blades

10. Main rotor ice sheds occurred in both the artificial and natural icing environments. The ice accretion and shedding characteristics of the main rotor blades was independent of leading edge surface condition. A typical time history of engine torque rise during rotor system ice accretion in natural icing conditions is presented in figure 3, appendix F. The first ice shed during a flight typically occurred from 17 to 52 minutes after entering the icing environment with random and more frequent sheds occurring thereafter. The time required for the first shed to occur and the frequency of subsequent sheds appeared to be a function of the LWC and ambient outside air temperature. Photos 1 through 5, (app G), taken during flight in artificial icing conditions, and photos 6 and 7 (app G), taken after landing, show representative characteristics of main rotor ice accretion and shedding.

11. The main rotor ice sheds resulted in light to moderate increases in airframe vibration which normally lasted less than a minute. This increased vibration level was barely apparent to

an experienced aircrew fully occupied by their tasks and, on occasion, noticeable only if their attention was directed to it or when not otherwise occupied (Vibration Rating Scale (VRS) 3 to 4). One main rotor ice shed occurred (photos 1 and 2, app G) during artificial icing at 0.5 gm/m^3 LWC and -12.5°C which resulted in an airframe vibration immediately apparent to the aircrew but did not significantly affect their workload over the length of time the vibration lasted (approximately 10 minutes) (VRS 6). Significant airframe damage also occurred from main rotor ice hitting the fuselage during this icing encounter (para 16). The increase in airframe vibrations due to main rotor ice shedding was satisfactory.

12. Engine torque increased with ice accretion and decreased when ice was shed from the rotor system. Accurate measurement of torque increase/decrease was not possible while flying in the artificial icing environment due to constant collective control changes required to fly formation and keep the main rotor positioned in the HISS cloud; therefore, an estimate of the percentage of torque rise in the artificial icing environment could not be made. A fixed collective setting was used while in the natural icing environment permitting a more accurate correlation between torque increases/decreases and rotor blades surface ice accretion/shedding. The largest torque rise was observed in natural icing conditions at 0.5 gm/m^3 LWC and -4.0 °C (fig. 4, app F); however, major engine damage occurred during this flight due to ice ingestion from a rotor ice shed as discussed in paragraph 17. The largest torque rise (fig. 3, app F) without airframe damage or droop stops failing to seat properly occurred at conditions of 0.1 and 0.2 gm/m^3 LWC and -15.0 °C. The first main rotor shed began at 43 minutes after entering the icing condition and was completed at 49 minutes resulting in a 3 percent torque decrease per engine, leaving a residual 5 percent torque per engine increase above the pre-immersion cruise torque. A second torque rise of 4 percent occurred during the 30 minutes after the first shed resulting in a 9 percent torque increase above the pre-immersion cruise torque. A subsequent shed caused a 5 percent torque reduction. The maximum torque rise was 9 percent per engine and occurred at 63 minutes after entering the icing environment. Of this 63 minutes, 38 minutes were at 0.1 gm/m^3 and 25 minutes at 0.2 gm/m^3 LWC. The 9 percent torque increase above the trim cruise power will mean reduced range and endurance compared to the aircraft being flown in a non-icing environment and will impact IMC mission planning. The turbine gas temperature (TGT) remained within the normal continuous limits during these power increases at 15,940 pounds gross weight and 5760 feet pressure altitude. However, at heavier gross weights in similar icing conditions, the TGT may be within the 30 minute limit range and could reach the maximum TGT limit.

13. Autorotation rotor speed was evaluated after exiting the icing condition with the residual 5 percent torque increase noted in the above paragraph. The autorotation rpm was within the tolerances specified in the UH-60A Maintenance Test Flight Manual for the ambient conditions. The autorotation revolutions per minute (rpm) was within the proper range when checked after other icing encounters; however, conditions did not permit an autorotation rpm check at the maximum 9 percent or the 18 percent torque increase referenced in paragraph 17. Therefore, no conclusive comment can be made regarding the adequacy of autorotational rpm in an icing environment with an unprotected rotor system.

Tail Rotor Blades

14. Visual observation of the tail rotor blades after icing encounters revealed no significant ice accretions. A high frequency vibration was felt in the cockpit after exiting the natural icing conditions of 0.1 to 0.2 gm/m^3 LWC and -15.0 °C. This vibration was apparent to the crew but did not increase their workload over the short period of time the vibration occurred (VRS 4). A comparison of tail rotor gear box vibrations before and during the high frequency vibration is presented in figure 5, appendix F. The ice accretion and shedding characteristics of the unprotected tail rotor blades appear satisfactory.

Droop Stops and Flap Restrainers

15. Unheated droop stops and flap restrainers were evaluated throughout the icing tests for proper positioning during main rotor shutdown. Government competitive tests (GCT) droop stops (P/N 70105-08051-101) were used during this test because they demonstrated the best ice accretion characteristics of the droop stops tested during previous evaluations (ref 4, app A). Photo 8, appendix G, depicts a droop stop in the correct or "shutdown" position. Photo 9 shows a droop stop after main rotor shutdown in the incorrect or "flight" position after an artificial icing encounter of 60 minutes at 0.49 gm/m^3 LWC and -6.0 °C. Photo 10, appendix G shows one of three droop stops which were only partially seated after a natural icing flight at 0.42 gm/m^3 and -7.0 °C. After landing from this natural icing flight, only 0.5 inches remained of the 3.25 inches in-flight ice accumulation (photos 11 and 12, app G) on the main rotor head due to encountering temperatures above freezing after exiting the icing environment. These droop stops probably would have remained in the "flight" position during shutdown if the outside air temperature had been below freezing. This does not present a significant problem to the ground crew if properly briefed prior to engine shutdown. However, if a shutdown is necessary in high

or gusty wind conditions the main rotor blades may strike the tail rotor drive shaft in the vicinity of the tail rotor intermediate gear box. Photos 13 through 15, appendix G show the static position of a main rotor blade with the droop stop in the "flight" position. The blade may flex more than this in high or gusty winds and cause fuselage or main rotor system damage if the flap restrainers are frozen in the "flight" position. Photos 16 and 17, appendix G show a flap restrainer in the "shutdown" position and frozen in the "flight" position, respectively. This situation occurred after an artificial icing encounter of 60 minutes at 0.49 gm/m^3 LWC and -6.0 °C. The unheated GCT droop stops functioned properly at all icing conditions tested with 0.3 gm/m^3 LWC or less. At all conditions tested with LWCs greater than 0.3 gm/m^3 the potential exists for improper positioning of the droop stops and flap restrainers during shutdown. The production droop stops (P/N 70105-08151-041) demonstrated poorer ice accretion characteristics than did the GCT droop stops (ref 4, app A); therefore, improper droop stop positions may occur at LWCs less than 0.3 gm/m^3. Incorrect GCT droop stop position during shutdown could cause main rotor/fuselage contact and is a deficiency.

Aircraft Damage

16. The aircraft sustained damage during flights under both artificial and natural icing conditions. During an artificial icing flight at 0.49 gm/m^3 LWC and -6.0 °C a tail rotor blade tip cap was damaged, requiring replacement (photo 18, app G). During another artificial icing flight at 0.5 gm/m^3 LWC and -12.5° C, several components were damaged. The white strobe portion of the upper anti-collision light was broken (photo 19, app G) by ice shed from the main rotor. The shattering glass from the anti-collision light was thrown into the tail rotor blades causing damage to the leading edge of all four blades. Additionally, the tail rotor gear box fiberglass cowling was hit by ice shed from the main rotor causing a dent approximately 9 inches in diameter and 4 inches deep. The cowling was split approximately 6 inches (photos 20 and 21, app G).

17. The final test flight was in natural icing conditions of 0.5 gm/m^3 LWC and -4.0 °C. Vibration data from this flight, which is typical of other flights, indicate larger increases in longitudinal vibrations than in the other axes (fig. 6, app F). Photos 22 and 23, appendix G depict the ice formations at these conditions. A 17 percent torque rise per engine occurred after the aircraft had been in the icing environmment 13 minutes (fig. 4, app F). At 29 minutes, a main rotor ice shed occurred and torque decreased to the pre-immersion trim power required

for cruise (collective fixed). Within 5 minutes after this shed the torque had increased 14 percent per engine with random main rotor ice sheds occurring every 3 to 5 minutes, resulting in torque decreases of 3 to 4 percent. No significant increase in vibration level was noted during the ice sheds. After 43 minutes in the icing condition, torque was 18 percent above trim pre-immersion cruise power. At this time, ice was shed from the main rotor and ingested into the No. 2 engine, causing a rumble, similar to that of a compressor stall, accompanied by a high pitched squeal and TGT increase of approximately 40° C. The icing condition was exited immediately and the aircraft was landed at an outlying airport. This flight produced the highest torque rise and most costly aircraft damage of any icing condition tested. A borescope inspection revealed major damage to the compressor section of the No. 2 engine requiring engine replacement.

18. The main rotor ice shedding characteristics discussed in the two preceeding paragraphs resulted in aircraft damage. No aircraft damage occurred at any conditions tested with 0.3 gm/m^3 LWC or less. However, the potential exists for aircraft damage due to ice sheds at LWC's above 0.3 gm/m^3. Aircraft damage occurring from rotor system ice sheds at LWCs of approximately 0.5 gm/m^3 constitutes a deficiency. The UH-60A should not be cleared for operation in icing conditions more severe than 0.3 gm/m^3 LWC without a qualified deice kit installed and operational.

Icing Severity Determination

19. There are no handling qualities, visual, or performance pilot cues which would indicate the severity of the in-flight icing condition on the UH-60A with the blade deicing kit removed. The only way the crew can be made aware of the severity of the icing conditions in which they are flying, before aircraft damage occurs is to have an operable ice detector and ice rate meter installed on the aircraft. The UH-60A helicopters without a blade deice kit should have an ice detector and ice rate meter installed before they are cleared to fly into forecast icing conditions.

RELIABILITY AND MAINTAINABILITY

Deice System

20. Several deice system failures occurred during this program, which included 118 flight hours (16.3 hours for the light icing envelope evaluation and 101.7 for the logistic evaluation test).

Although the icing tests never required using the deice system in an emergency situation, the requirement existed for the deice system to be operationally ready for use in the event of an emergency. A listing of the Equipment Performance Reports submitted by AVNDTA on items of the blade deice kit that failed, is presented in appendix H.

21. During the aircraft instrumentation phase prior to the icing tests, a short circuit occurred in one main rotor blade heating element. The incident happened while performing a functional check of the deice kit using the built-in test equipment (BITE) circuitry. An electrical discharge accompanied by an explosive noise ruptured the lower leading edge of the yellow main rotor blade at station 46.9 (photo 24, app G). The aircraft had undergone desert testing during which time some blade leading edge errosion had occurred. There was no indication that this would preclude satisfactory operation of the deice system. A 50 ampere current limiter designed to protect the system against blade damage was activated but did not prevent physical damage to the blade. This is the first known instance of the blade deice electrical protection system failing to protect the blades against a short circuit. Failure of the blade deice electrical protection system to protect the blades against a heater element short circuit and subsequent blade damage is a deficiency.

22. A second main rotor deice heating element short circuit occurred while on site in St. Paul, Minnesota. The fault was detected during the deice system pre-takeoff BITE check. The black main rotor blade deice blanket was shorted with no blade damage evident.

23. A main rotor blade deice kit distributor malfunction was detected during a pre-takeoff BITE check. The distributor was replaced and the deice blade kit operated normally. It was suspected that the distributor failure resulted from the main rotor blade malfunction (para 22).

24. On one occasion during an operational ground check of the deice system, one main rotor droop stop heater was inoperative. This was caused by a broken wire between the distributor and the droop stop heater.

Main Rotor Distributor Wiring and Clamps

25. The wiring harness protective cover between the distributor and the main rotor blade deice electrical connection cracked and broke numerous times during the tests (photo 25, app G). Shrink tape was used to repair the wiring harness at the recommendation

of Sikorsky Aircraft. The repair was difficult to perform in the area of the wiring harness clamp on the main rotor spindle. On subsequent flights the wiring harness cracked again in this area allowing moisture to get inside the protective covering. The wiring harness clamps on the spindles were removed and the area repaired again. This repair was effective, but it is not known if ice accretion on the now unsupported distributor wiring harness may cause it to break. Failure of the distributor wiring harness protective cover is a shortcoming. An engineering analysis should be performed to determine if ice accretions on the main rotor distributor wiring harness, unsupported at the blade spindles, will cause the harness to fail.

26. During the tests, a total of 4 main rotor distributor wiring harness clamps (manufacturer's part number TA 0230027) on the main rotor blade spindle were broken. These failures occurred on three separate flights. These clamps were removed before completing the icing evaluation at Sikorsky Aircraft's recommendation. If an engineering analysis indicates these clamps are not needed to support the distributor wiring harness (para 25), these failures are insignificant. However, if the distributor wiring harness clamps on the main rotor spindle are required, their frequent failure is unsatisfactory and is a shortcoming.

CONCLUSIONS

GENERAL

27. The UH-60A Black Hawk helicopter demonstrated safe operation in light icing conditions up to and including 0.3 gm/m^3 LWC without using the blade deice kit. The aircraft handling qualities were not significantly degraded and the vibration levels were acceptable at the artificial and natural icing conditions tested.

DEFICIENCIES

28. The following deficiencies are identified and are listed in decreasing order of importance:

a. Aircraft damage resulting from rotor system ice sheds at liquid water contents of approximately 0.5 gm/m^3 (para 18).

b. Incorrect GCT droop stop position during shutdown encountered at liquid water contents above 0.3 gm/m^3 (para 15).

c. Failure of the blade deice electrical protection system to protect the blades against a heater element short circuit and subsequent blade damage (para 21).

SHORTCOMINGS

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

a. Failure of the deice distributor wiring harness protective cover (para 25).

b. Failure of the distributor wiring harness clamps (para 26).

RECOMMENDATIONS

30. The UH-60A should not be cleared for operation in icing conditions more severe than 0.3 gm/m^3 liquid water content without a qualified deice kit installed and operational (para 18).

31. The deficiency listed in paragraph 28c and the shortcomings listed in paragraph 29 should be corrected prior to operating the UH-60A deice system equipped helicopter in an icing environment.

32. The UH-60A helicopters without a blade deice kit should have an ice detector and ice rate meter installed before they are cleared to fly into forecast icing conditions (para 19).

33. An engineering analysis should be performed to determine if ice accretions on the main rotor distributor wiring, unsupported at the blade spindle, will cause the harness to fail (para 25).

APPENDIX A. REFERENCES

1. Final Report, USAAEFA Project No. 76-09-1, *Artificial Icing Test, Utility Tactical Transport Aircraft System (UTTAS). Sikorsky YUH-60A Helicopter.* February 1977.

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

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

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

5. Letter, AVRADCOM, DRDAV-DI, 11 November 1981, subject: UH-60A Light Icing Envelope Evaluation with the Blade Deicing Kit P/N 70070-30003-013 Inoperative.

6. Test Plan, USAAEFA Project No. 81-18, *UH-60A Light Icing Envelope Evaluation with the Blade Deicing Kit, P/N 70070-30003-013 Inoperative,* December 1981.

7. Technical Manual, TM 55-1520-237-10, *Operator's Manual, UH-60A Helicopter,* 21 May 1979, with Change 12, dated 31 December 1981.

8. Letter, USAAEFA, DAVTE-TI, unpublished, subject: Project Report No. 80-04-2, Helicopter Icing Spray System (HISS) Evaluation and Improvement.

9. Letter, AVRADCOM, DRDAV-DI, 21 January 1982, with R-1 25 January 1982, subject: Airworthiness Release for UH-60A Black Hawk Helicopter S/N 78-22976 to Conduct Artificial and Natural Icing Tests with the Blade Deice Kit Inoperative, Project No. 81-18.

APPENDIX B. UH-60A MODIFIED DEICE SYSTEM DESCRIPTION AND LOGISTIC EVALUATION TEST ITEMS

1. The production UH-60A deicing kit (P/N 70070-30003-013) has a heating element ON cycle and a heating element OFF cycle. In normal operation the OFF cycle occurs first when the system is activated. The deice system on the test aircraft was modified so that the ON cycle occurred first. This was accomplished by modifying the deice controller and adding an additional deice control panel in the cockpit. The ship's Rosemount ice detector and rate meter were also modified to permit their operation with the deice system power switch OFF. The additional deice control panel was mounted on the cockpit center console to allow the copilot to operate the modified deice system and consisted of a heater control switch, momentary ON switch, element ON time (EOT) light, and a synchronization (SYNC) light. The function of these switches and lights is described below:

Heater Control Switch - 2 positions: NORM and TEST

In the NORM position, the Deice system will operate as described in the UH-60A Operator's Manual.

In the TEST position the Rosemount Ice Detector will operate to show icing severity with the probe and aspirator heating as long as the ICE DETECTED caution light is illuminated. This will occur with the BLADE DEICE POWER switch ON or OFF. In the TEST position, if the ice rate meter PRESS TO TEST button is pressed and released, the ice rate meter will indicate 1.0 gm/m^3, the ICE DETECTED caution light will illuminate, and the rate meter probe and aspirator will be heated as long as the ICE DETECTED caution light is illuminated.

Momentary On Switch - Depressing this switch with the BLADE DEICE POWER switch ON and the controller synchronized, will bypass the programmed main rotor deice system OFF time and immediately allow power to flow from the controller to the main rotor distributor. The controller should be synchronized prior to requiring immediate main rotor deice cycle activation by turning the BLADE DEICE POWER switch ON for approximately 10-15 seconds. The BLADE DEICE POWER switch should then be turned OFF until main rotor deicing is required. The EOT light will illuminate after the BLADE DEICE POWER switch is turned on and the MOMENTARY ON switch is pressed. The SYNC light will also blink during this time. At the end of the 8-element pulse train, the EOT and SYNC lights will extinguish.

Element On Time Light - The EOT light illuminates when there is current flow from the controller to the distributor.

Synchronization Light - The SYNC light flashes as the controller is being synchronized and then goes out when the controller is in SYNC.

2. The following items were part of the UH-60A deice kit installed for the test:

Rosemount Ice Detector Model 871FF2
P/N 70302-10915-102 S/N 0014

Ice Rate Meter P/N 70550-01124-102 S/N 0179

Blade Deice Control Panel P/N 70902-01099-041 S/N 524

Blade Deice Test Panel P/N X7006-90472-041 S/N 009

Blade Deice Controller (modified for this test)
P/N X7006-91296-104 S/N 0009

Main Rotor Distributor (with provisions for droop stop heaters)
P/N X7006-91293-102

Main Rotor Slip Ring Assembly P/N 70550-02128-041

Tail Rotor Slip Ring Assembly P/N 70550-02129-042 S/N 17

Government Competitive Test (GCT) Droop Stops (P/N 70105-08051-101) with 300 watt heaters

Outside Air Temperature Sensor P/N 70550-01123-101 S/N 980

Insulated Ambient Air Sensing Tube P/N 70306-10017-041

Engine Inlet Anti-ice Modulating Valve P/N 70306-10012-107

3. The following items were on the test aircraft as part of the Logistics Evaluation Test:

No. 1 Engine Pressure and Overspeed Unit
P/N 6043T58G02 S/N 009

No. 1 Engine Anti-ice Starting Bleed Valve
P/N 4046T28 P05

Roll Trim Servo P/N X7006-99943-101

APPENDIX C. HELICOPTER ICING SPRAY SYSTEM (HISS) DESCRIPTION

1. The HISS is installed in a modified CH-47C helicopter and consists of an internally mounted 1800-gallon water tank and an external spray boom assembly suspended 19 feet beneath the aircraft from a cross-tube through the cargo compartment. A schematic is shown in figure 1, and a detailed description is given in references 1 and 2 below. Hydraulic actuators rotate the cross-tube to raise and lower the boom assembly. Both the external boom assembly and water supply can be jettisoned in an emergency. The spray boom consists of two 27-foot center sections, vertically separated by 5 feet, and two 17.6-foot outriggers. The outriggers are swept back 20 degrees and angled downward 10 degrees giving a tip to tip boom width of 60 feet. A total of 97 Sonic Development Corporation Sonicore Model 125-HB nozzles are installed on the two center sections. The spray cloud is generated by pumping water at known flow rates from the tank to the nozzles on the boom assembly, using bleed air from the aircraft engines and an auxiliary power unit to atomize the water.

2. A calibrated outside air temperature probe and a dew point hygrometer provide accurate temperature and humidity measurement. A radar altimeter with aft-facing antenna is mounted on the CH-47 to allow positioning the test aircraft at a known standoff distance. The radar altimeter is wired to red and yellow stationkeeping lights on the underside of the CH-47. These lights provide a visual indication to the test aircraft for maintaining the proper stand-off distance. Because of gross weight limitations, only 1400 gallons of water are carried. To facilitate photographic documentation during icing tests, a chemical is added to the water to impart a yellow color to the ice.

3. At the 150 foot standoff distance used for icing tests, the size of the visible spray cloud is approximately 8 feet high by 36 feet wide. Water flow rates to provide a desired liquid water content (LWC) are established based on a theoretically derived formula assuming no evaporation. The spray cloud is then sampled to determine the actual LWC by a fixed wing, chase/calibration aircraft equipped with particle-measuring devices. The flow rate is adjusted and the cloud sampled until the desired average LWC is attained.

References:

1. Handbook, SM-280B, *Installation, Operation, and Maintenance Instructions with List of Parts, Helicopter Icing Spray System (HISS)*, All American Engineering Co., with Change 1, Nov 74.

2. Letter, USAAEFA, DAVTE-TI, unpublished, subject: Report Project No. 80-04-2, Helicopter Icing Spray System (HISS) Evaluation and Improvements.

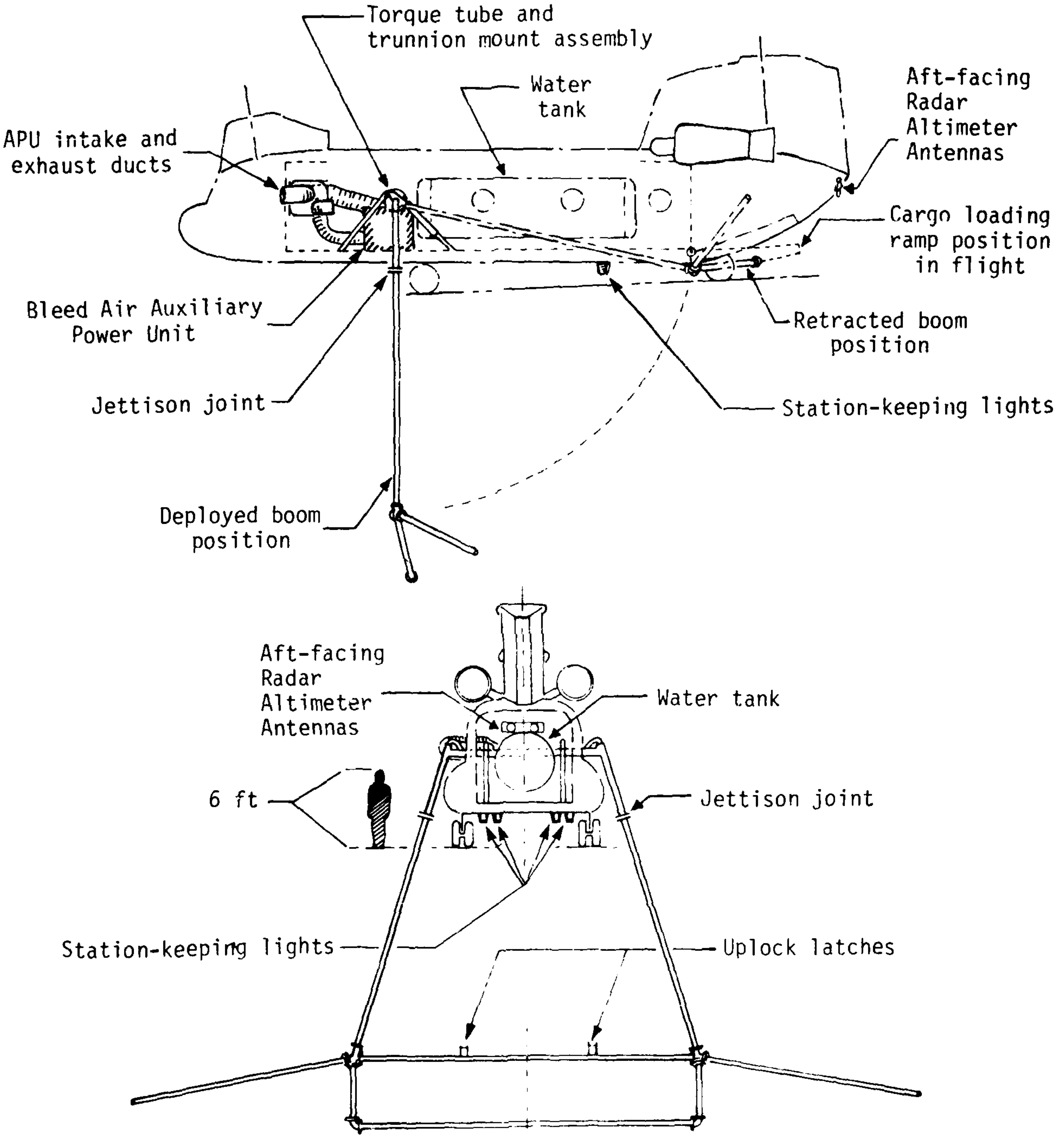


Figure 1. Helicopter Icing Spray System Side and Rear View Schematic

APPENDIX D. INSTRUMENTATION

1. The test instrumentation was installed, calibrated, and maintained by USAAEFA personnel. Data were measured with calibrated instrumentation and displayed or recorded as indicated below. The pulse code modulation (PCM) sampling rate was 200 samples per second.

<u>Pilot's Panel</u>

Liquid water content (Rosemount Probe)

<u>Copilot Panel</u>

Airspeed (ship's system)
Pressure altitude (ship's system)

<u>Engineer Panel</u>

Instrumentation controls
Free air temperature
Time code display
Run number

<u>Digital (PCM) Data Parameters</u>

- Airspeed (ship's system)
- Altitude (ship's system)
- Total air temperature
- Rotor speed
- Gas generator speed*
- Fuel used*
- Engine fuel flow*
- Engine output shaft torque*
- Engine turbine gas temperature*
- Control position
  - Longitudinal cyclic
  - Lateral cyclic
  - Directional
  - Collective
- Aircraft attitude
  - Pitch
  - Roll
  - Yaw
- Icing rate (Rosemount)
- Time of day
- Run number
- Pilot and engineer event pulse

*Both engines

Vibration (accelerometers)
    Pilot station vertical
    Pilot station lateral
    Pilot station longitudinal
    Aircraft cg vertical
    Aircraft cg lateral
    Aircraft cg longitudinal
    Tail rotor gearbox lateral
    Tail rotor gearbox longitudinal
Forward longitudinal main transmission stationary star load

SPECIAL EQUIPMENT

Camera Systems

2. A 16mm high-speed hand-held motion picture camera was located on board the chase and HISS aircraft and was used to document the test aircraft both in the spray cloud and after exit from icing encounters. Additionally, 35mm color slide and color still cameras were used for documentation both in the air and on the ground following icing flights.

Visual Ice Accretion Probe

3. A visual ice accretion indicator probe was fabricated and installed on the test aircraft. It was used to give additional visual cues of ice buildup on the aircraft fuselage. The probe was composed of a small symmetrical airfoil section (OH-6A tail rotor blade section) with a 3/16 inch diameter steel rod protruding forward from the leading edge at the center span. The protruding rod was painted with 1/4-inch stripes of contrasting colors which provide a comparison basis for visual ice measurements. The probe was mounted on the left cockpit door just below the window.

Cloud Sampling Equipment

4. An instrumentation package was installed on the U-21A chase/scout aircraft and used to document both the artificial and natural icing conditions in which the test aircraft flew. This equipment consisted of two laser nephelometers (a forward scattering spectrometer probe (FSSP) and an optical array probe (OAP)), Leigh MK-10 ice detector, calibrated outside air temperature indicator, and a dew point hygrometer. The cloud sample data were presented in near real time to the particle measuring system operator on board the U-21 and also stored on magnetic tape.

APPENDIX E. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. The modified deice system on the production UH-60A helicopter was functionally tested prior to each icing flight. A buildup program was used to gain experience with flight in icing conditions with an unprotected rotor system. The procedure remained the same for each flight up to entry into the cloud. 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 feet behind the spray aircraft. Test and spray aircraft 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 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 spray aircraft. All artificial flights were flown with a predetermined liquid water content (LWC) and OAT. 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 U-21A would locate and document the icing condition and radio the data back to the test aircraft before it entered the icing environment. The U-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 U-21A chase/scout aircraft configured with the particle measuring system instrumentation. The magnetic tape recording system on-board the test aircraft was activated periodically during natural and artificial cloud encounters. Vibration and performance parameters were monitored during each flight.

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, high-speed motion picture 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 and quantitatively assessed by vibration analysis.

WEIGHT AND BALANCE

5. Prior to testing, the aircraft gross weight, longitudinal and lateral cg were determined by using calibrated scales. The aircraft was weighed with instrumentation, fixed ballast and no fuel, and with instrumentation, fixed ballast and full 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.

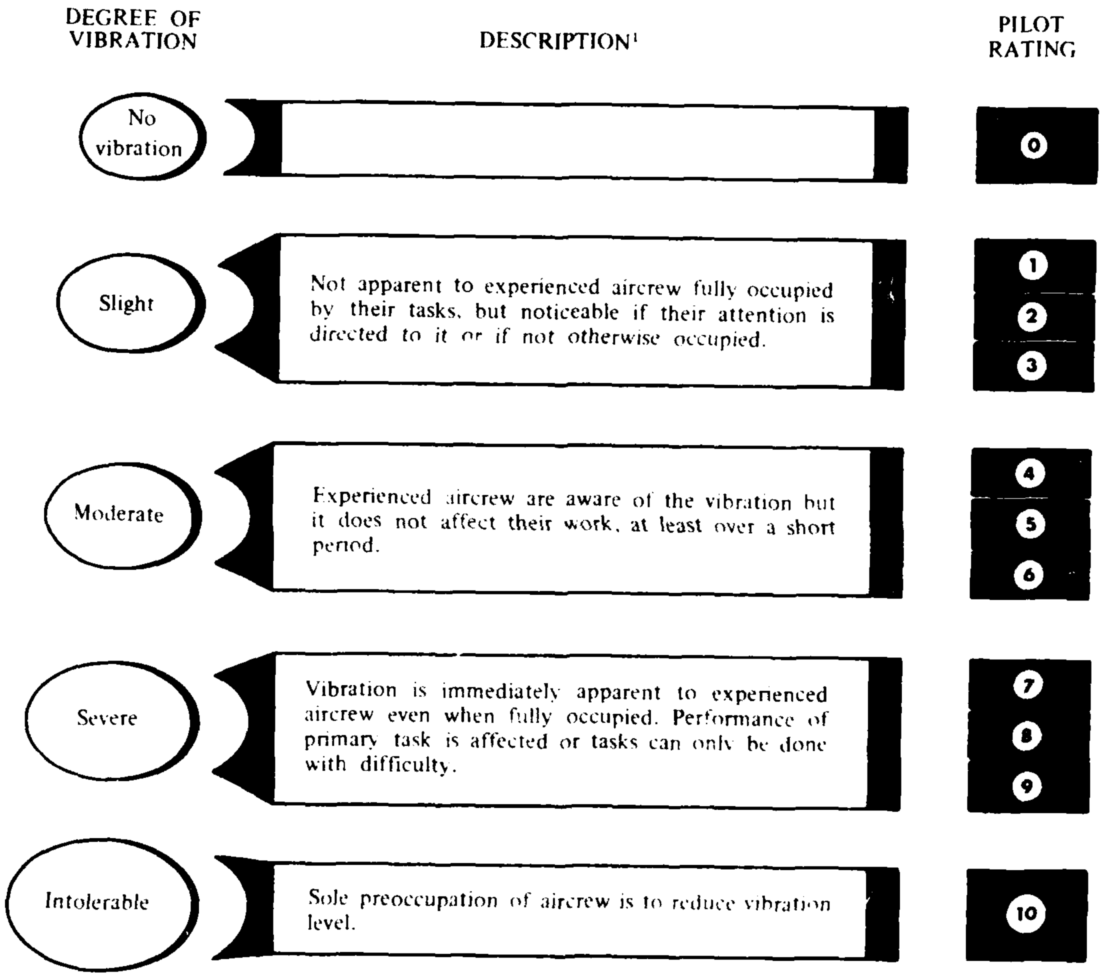
d. Severe/heavy icing. The rate of accumulation is such that deicing/anti-icing equipment fails to reduce or control the hazard. Immediate diversion is necessary. Commonly greater than 1.0 gm/m^3 LWC for the UH-60A helicopter.

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 an item or part, which seriously impairs the equipments operational capability. A deficiency normally disables or immobilizes the equipment; and if occurring during test phases, will serve as a bar to type classification action.

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. If occurring during test phases, the shortcoming should be corrected if it can be done without unduly complicating the item or inducing another undesirable characteristic such as increase cost, weight, etc.

8. A Vibration Rating Scale (VRS) was used to qualitatively assess airframe vibrations resulting from rotor system ice sheds. This scale is presented in figure 1.



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

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

Figure 1. Vibration Rating Scale

APPENDIX F. TEST DATA

Table 1. Specific Test Condition

FLIGHT NO.	ICING CONDITION	AVERAGE L.W.C. (GRAMS/ (CUBIC METER)	MEDIAN VOLUMETRIC DIAMETERS (MICRONS)	AVERAGE RELATIVE HUMIDITY (PERCENT)	AVERAGE O.A.T. (DEC C)	AVERAGE TRUE AIRSPEED (KNOTS)	AVERAGE PRESSURE ALTITUDES (FEET)	TOTAL TIME IN CLOUD (MINUTES)	TOTAL ICE[2] ACCRETED ON VISUAL PROBE (INCHES)	MAXIMUM[3] TORQUE INCREASE PER ENGINE PRIOR TO SHED	RESIDUAL[3] TORQUE INCREASE AFTER SHED	MAXIMUM VIBRATION RATING SCALE
1	Artificial	0.15	27	47	-7.0	111	5660	60	---	--	--	1
2	Artificial	0.21	42	10	-17.0	115	7000	45	---	--	--	4
3	Natural	0.42	20	100	-7.0	115	3120	95	3.25	7	2	4
4	Artificial	0.30	--[4]	95	-12.0	97	8080	81	---	--	--	6
5	Artificial	0.49	82	35	-6.0	115	5040	60	---	--	--	4
6	Natural	0.30	12	100	-6.0	125	2960	59	2.50	8	4	1
7	Natural	0.10	9	100	-15.0	117	5280	38	---	--	--	--
		0.20	9	100	-15.0	117	5760	44	2.50	9	5	3
8	Natural	0.50	19	100	-4.0	113	6680	43	3.50	18	0	1

NOTES:

[1] Average Gross Weight = 16,260 pounds
Average C.G. = FS 354.2
Utility Configuration

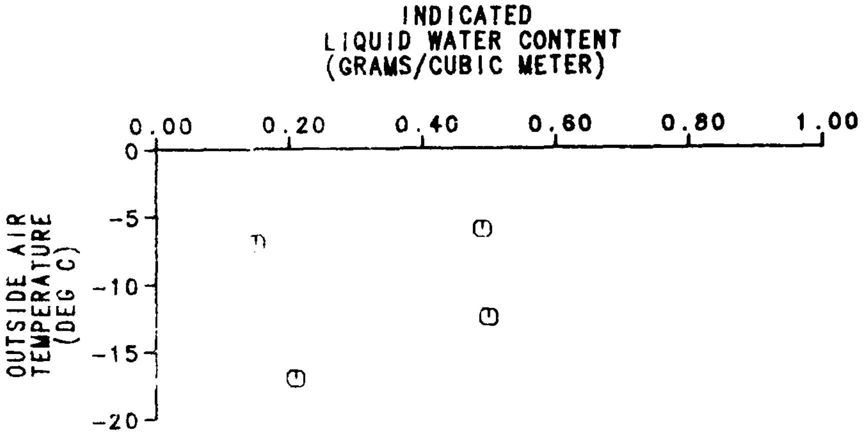
[2] Location of the visual probe precluded it from exposure to the spray cloud during artificial icing.

[3] Accurate mesurements of torque increses and residual torque increase after a rotor ice shed were not possible during artificial icing due to constant power changes required to maintain position in the HISS cloud.

[4] Data not available

FIGURE 1

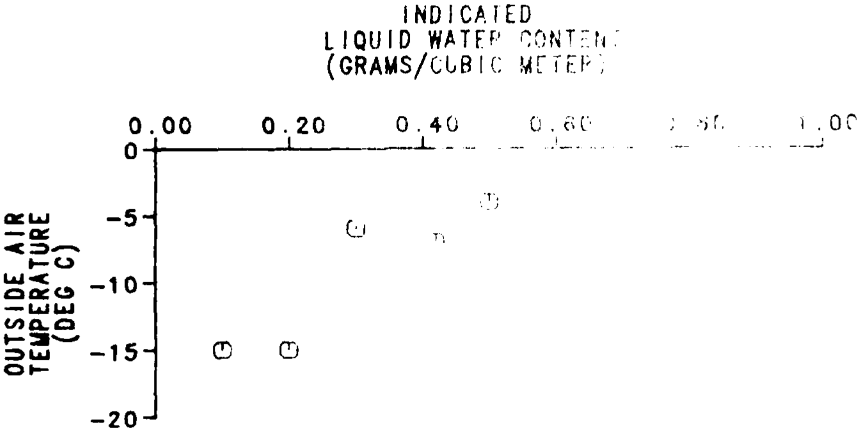
ARTIFICIAL ICING TEST CONDITIONS



NOTE ROTOR SPEED = 258 RPM
AVG GROSS WEIGHT = 16280 LBS
AIR SPEED : 97 TO 115 KTAS
AVG CG FS 354.3 IN
UTILITY CONFIGURATION

FIGURE 2

NATURAL ICING TEST CONDITIONS



NOTE ROTOR SPEED = 258 RPM
AVG GROSS WEIGHT = 16220 LBS
AIR SPEED : 113 TO 125 KIAS
AVG CG FS 354.1 IN
UTILITY CONFIGURATION

FIGURE 3
TORQUE RISE IN NATURAL ICING CONDITIONS
UH-60A USA S/N 77-22976

AVG GROSS WEIGHT (POUNDS)	AVG CG LOCATION LONG. (FS)	AVG CG LOCATION LAT. (BL)	AVG DENSITY ALTITUDE (FEET)	AVG O.A.T. (DEG C)	AVG TRUE AIRSPEED (KNOTS)	MEDIAN VOLUMETRIC DIAMETER (MICRONS)	AVG L.W.C. (GRAMS/ CUBIC METER)
15940	352.9(FWD)	0.1(RT)	2860	-15.0	117	9	0.2

NOTE : 1. CIRCLES DENOTE THE LEFT ENGINE SQUARES DENOTE THE RIGHT
2. DATA TAKEN WITH A FIXED COLLECTIVE POSITION.
3. A MAIN ROTOR ICE SHED WAS OBSERVED BY THE FLIGHT CREW FROM 44 THRU 49 AND 64 THRU 72 MINUTES.

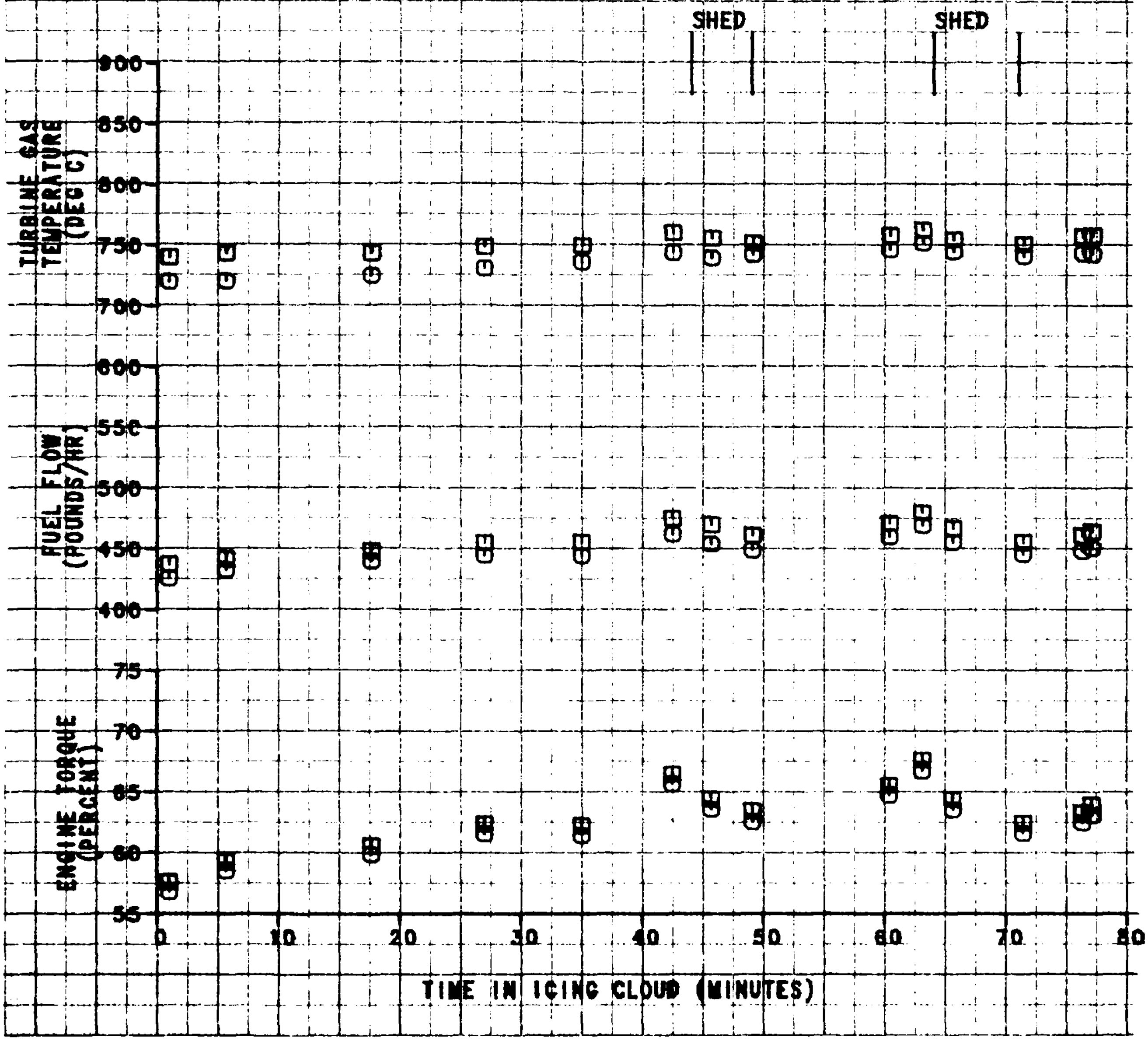


FIGURE 4
TORQUE RISE IN NATURAL ICING CONDITIONS
UH-60A USA S/N 77-22976

AVG GROSS WEIGHT (POUNDS)	AVG CG LOCATION LONG. (FS)	AVG CG LOCATION LAT. (BL)	AVG DENSITY ALTITUDE (FEET)	AVG O.A.T. (DEG C)	AVG TRUE AIRSPEED (KNOTS)	MEDIAN VOLUMETRIC DIAMETER (MICRONS)	AVG L.W.C. (GRAMS/ CUBIC METER)
16460	355.1(FWD)	0.1(RT)	6260	-4.0	113	19	0.5

NOTE : 1. CIRCLES DENOTE THE LEFT ENGINE SQUARES DENOTE THE RIGHT
2. DATA TAKEN WITH A FIXED COLLECTIVE POSITION.
3. A MAIN ROTOR ICE SHED WAS OBSERVED BY THE FLIGHT CREW AT 29 MINUTES.

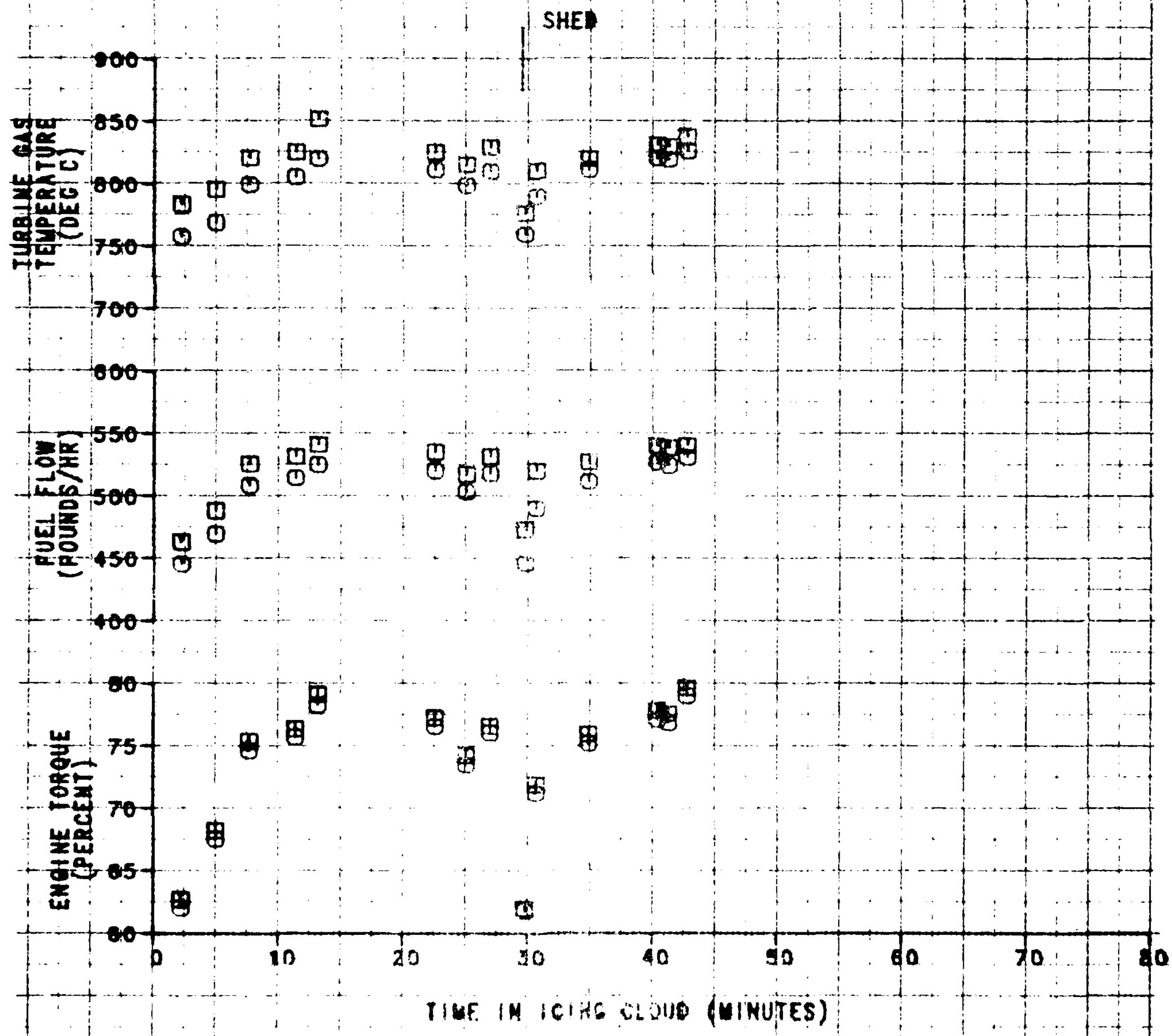


FIGURE 5
VIBRATION CHARACTERISTICS IN NATURAL ICING CONDITIONS
UH-60A USA S/N 77-22976
PILOT STATION
TAIL ROTOR 1/REV (19.8 HZ)

AVG GROSS WEIGHT (POUNDS)	AVG CG LOCATION LONG. (FS)	AVG CG LOCATION LAT. (BL)	AVG DENSITY ALTITUDE (FEET)	AVG F.A.T. (DEG C)	AVG TRUE AIRSPEED (KNOTS)	MEDIAN VOLUMETRIC DIAMETER (MICRONS)	AVG L.W.C. (GRAMS/ CUBIC METER)
15940	352.9(FWD)	0.1(RT)	2860	-15.0	117	9	0.2

NOTE : 1. CIRCLES DENOTE THE LEFT ENGINE SQUARES DENOTE THE RIGHT
2. DATA TAKEN WITH A FIXED COLLECTIVE POSITION.
3. A MAIN ROTOR ICE SHED WAS OBSERVED BY THE FLIGHT CREW FROM 44 THRU 49 AND 64 THRU 72 MINUTES.

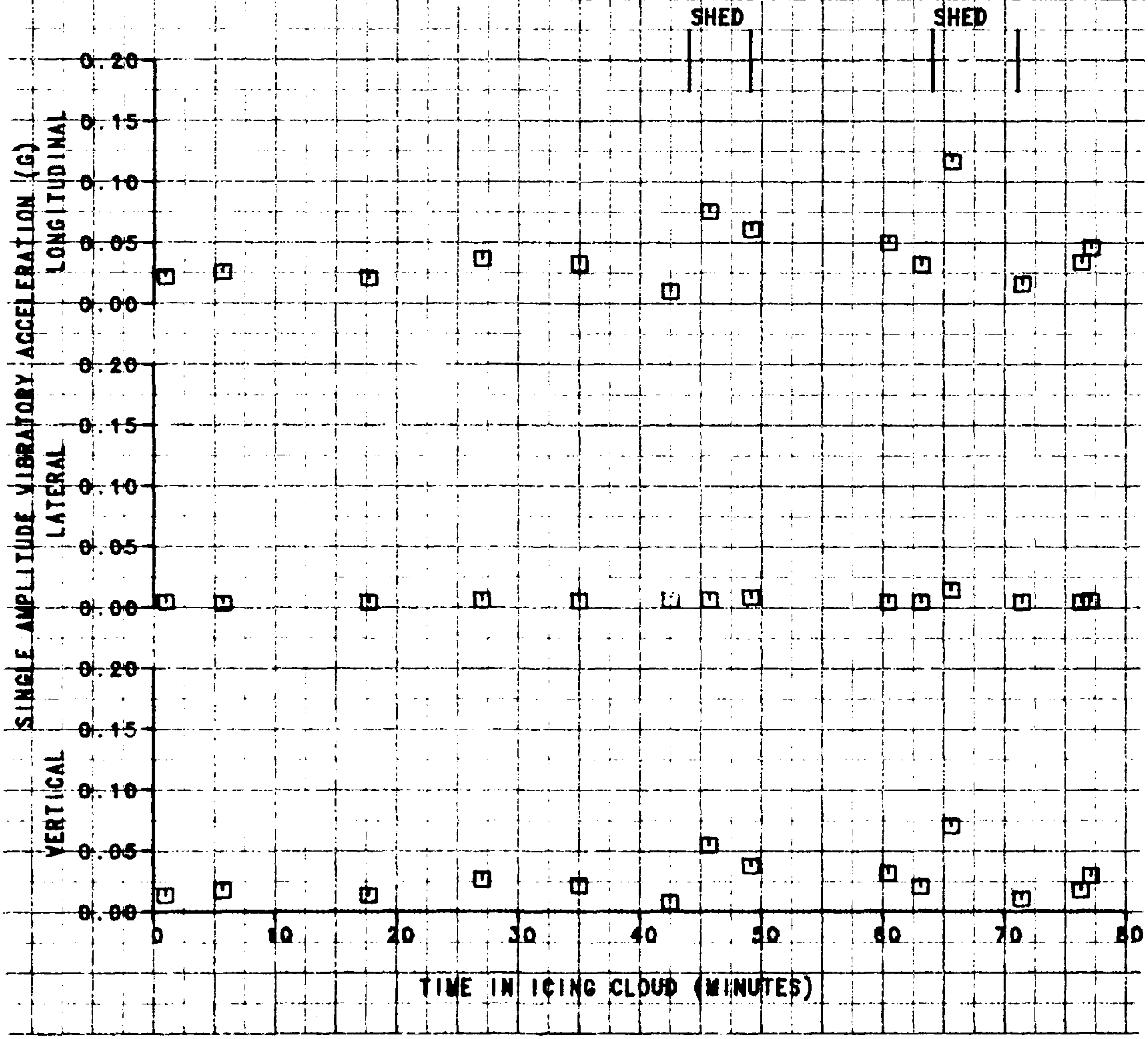
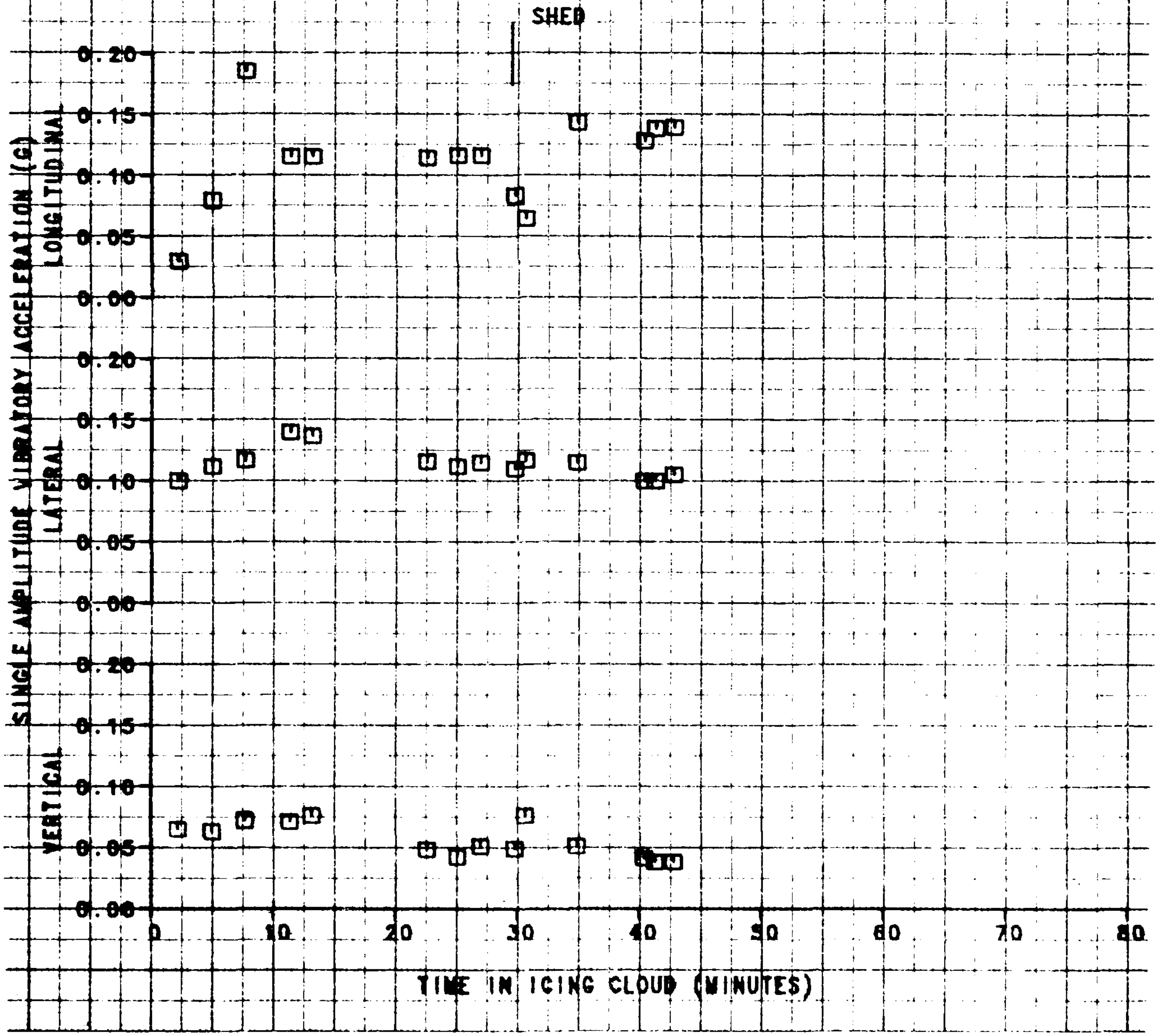


FIGURE 6
VIBRATION CHARACTERISTICS IN NATURAL ICING CONDITIONS
UH-60A USA S/N 77-22976
PILOT STATION
4/REV (17.2 HZ)

AVG GROSS WEIGHT (POUNDS)	AVG CG LOCATION LONG. (FS)	AVG CG LOCATION LAT. (BL)	AVG DENSITY ALTITUDE (FEET)	AVG F.A.T. (DEG C)	AVG TRUE AIRSPEED (KNOTS)	MEDIAN VOLUMETRIC DIAMETER (MICRONS)	AVG L.W.C. (GRAMS/CUBIC METER)
16460	355.1(FWD)	0.1(RT)	6260	-4.0	113	19	0.5

NOTE : 1. CIRCLES DENOTE THE LEFT ENGINE SQUARES DENOTE THE RIGHT
2. DATA TAKEN WITH A FIXED COLLECTIVE POSITION.
3. A MAIN ROTOR ICE SHED WAS OBSERVED BY THE FLIGHT CREW AT 29 MINUTES.



APPENDIX G. PHOTOGRAPHS

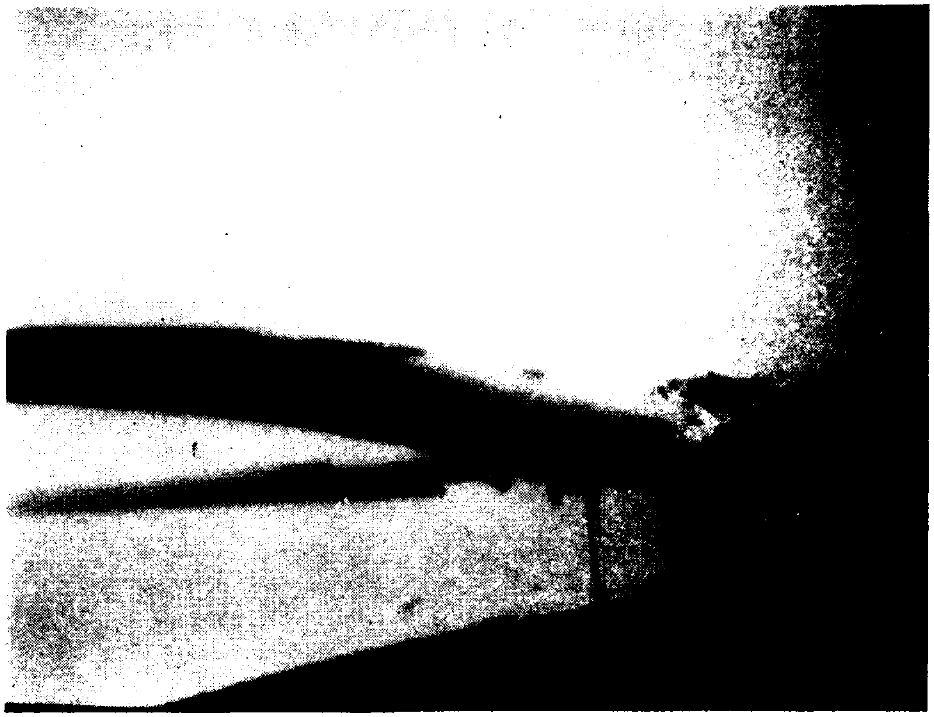


Photo 1. Main Rotor Ice Accretion Artificial Icing: 0.5 gm/m^3 LWC, -12.5° C, 81 Minutes

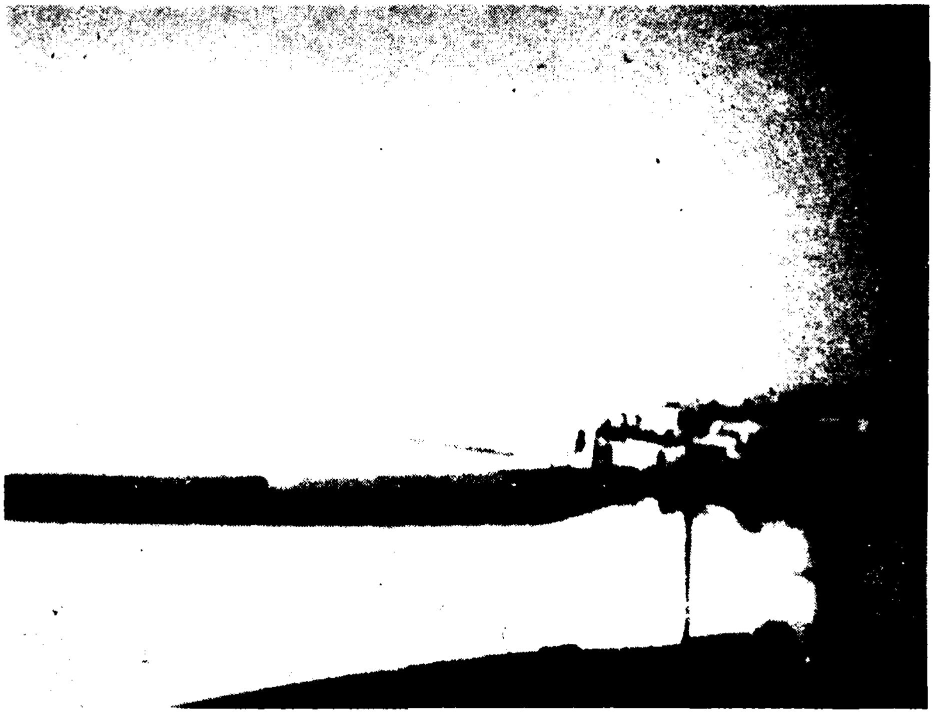


Photo 2. Main Rotor Ice Accretion Artificial Icing: 0.5 gm/m^3 LWC, -12.5°C, 81 minutes

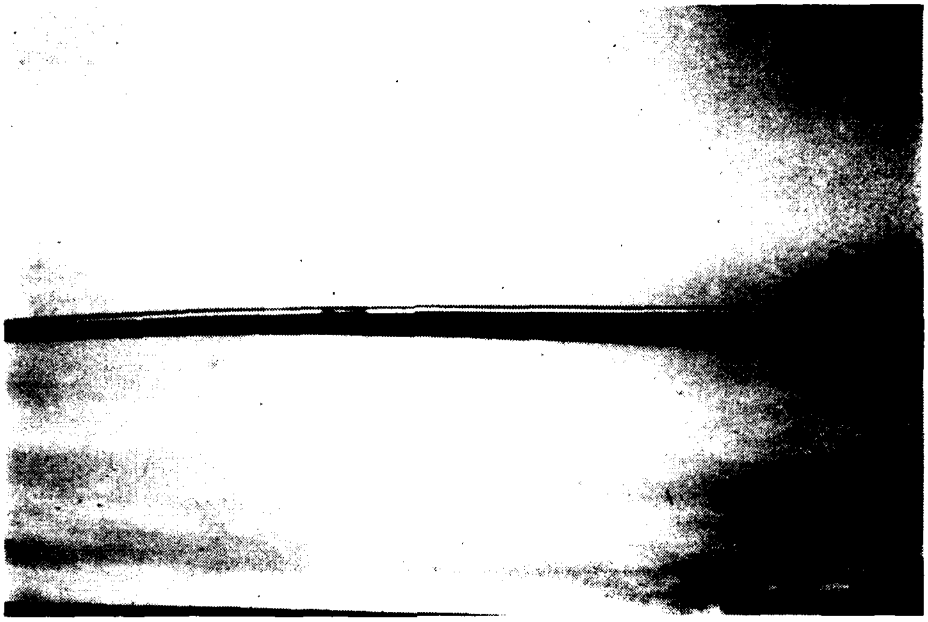


Photo 3. Main Rotor Ice Accretion Artificial Icing: 0.21 gm/m^3 LWC, -17.0° C, 47 Minutes

Photo 4. Main Rotor Ice Accretion Artificial Icing: 0.49 gm/m^3 LWC, -6.0° C, 60 Minutes

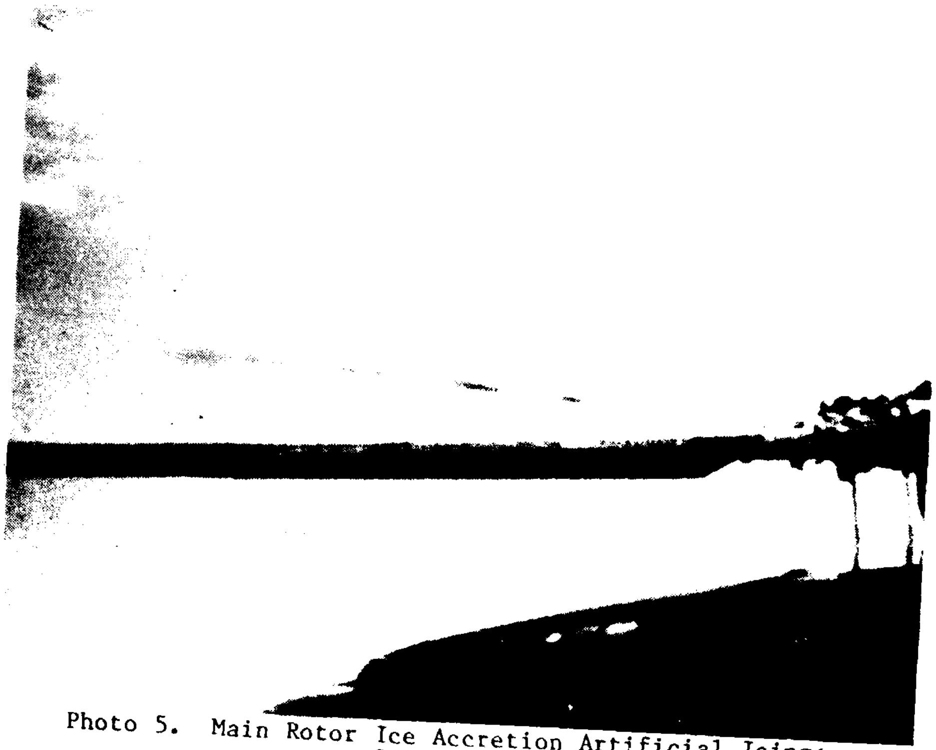


Photo 5. Main Rotor Ice Accretion Artificial Icing:
0.49 gm/m^3 LWC, -6.0° C, 60 Minutes

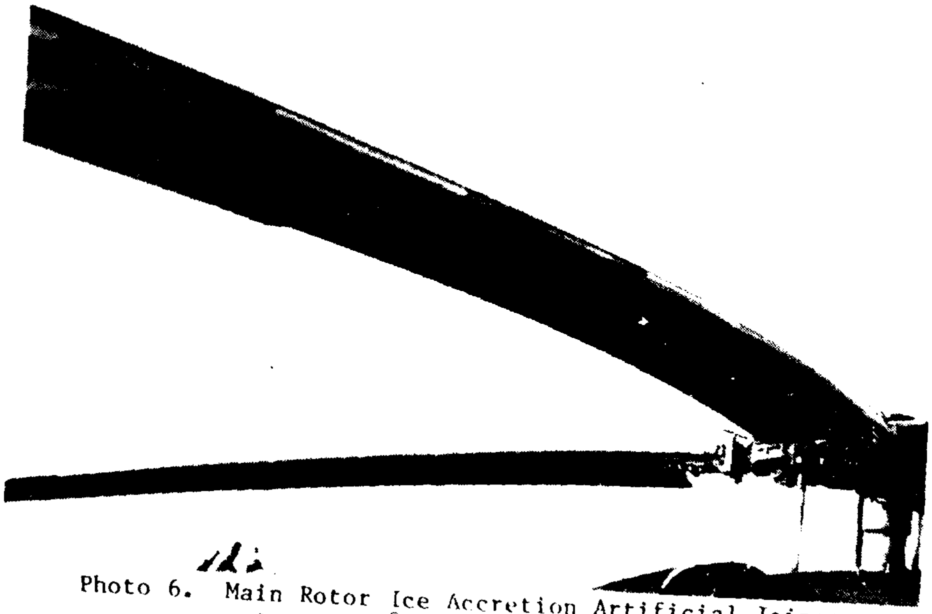


Photo 6. Main Rotor Ice Accretion Artificial Icing:
0.21 gm/m^3 LWC, -17.0° C, 45 Minutes

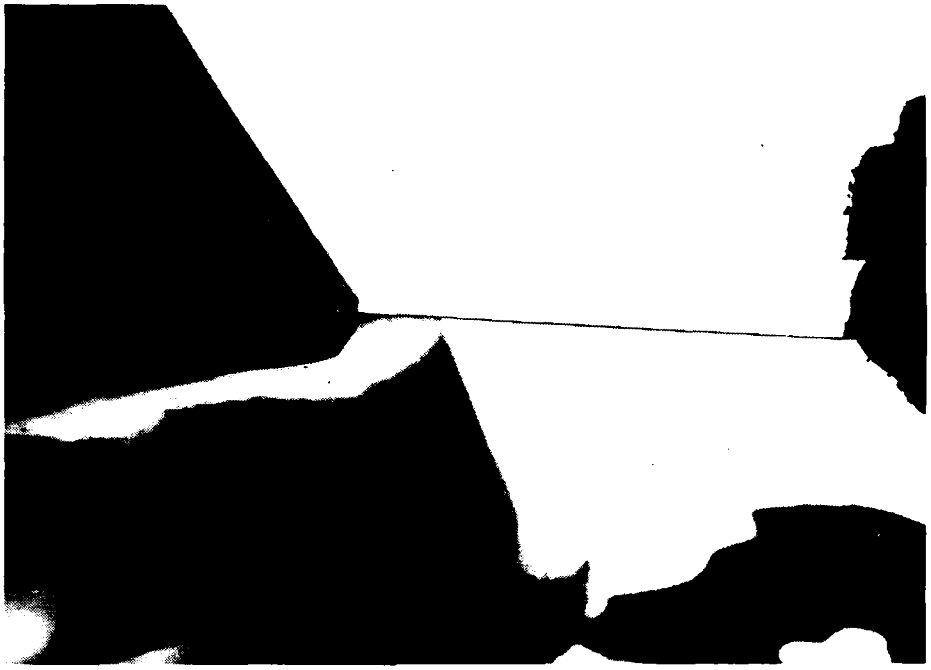


Photo 7. Main Rotor Ice Accretion Artificial Icing: 0.21 gm/m^3 LWC, -17.0°C, 45 Minutes

Photo 8. Droop Stop in the "Shutdown" (Correct) Position

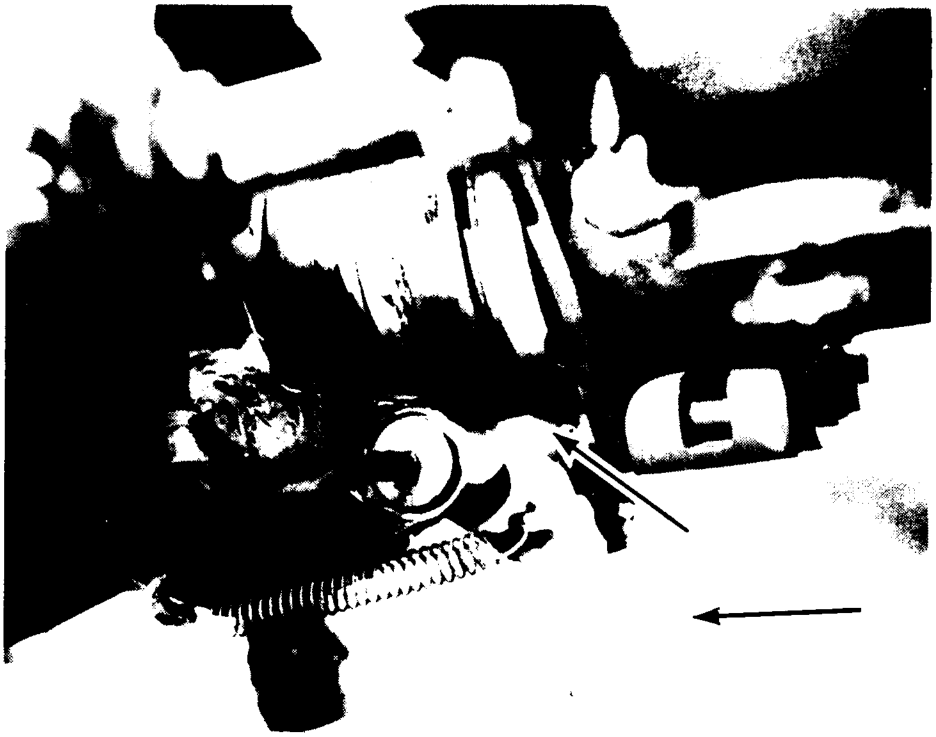


Photo 9. Droop Stop in the "Fly" (Incorrect) Position

Photo 10. Droop Stop Partially Seated Natural Icing: 0.42 gm/m^3 LWC, -7.0° C, 95 Minutes

Photo 11. Ice Accretion on FM Antenna Natural Icing: 0.42 gm/m^3, -7.0° C, 95 Minutes

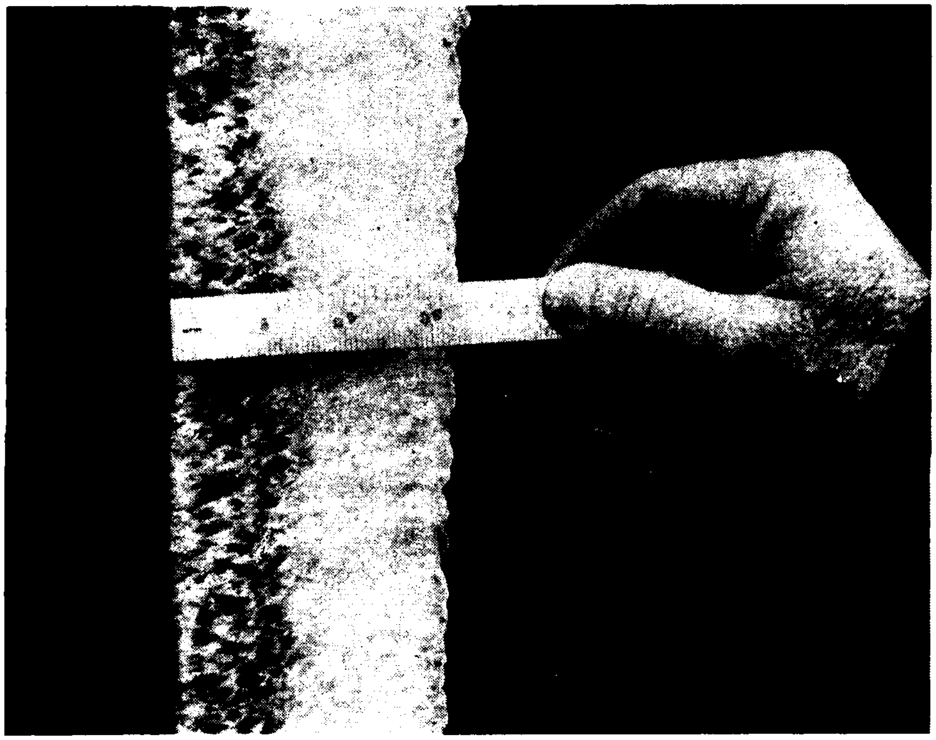


Photo 12. Ice Accretion on FM Antenna Natural Icing: 0.42 gm/m^3 LWC, -7.0° C, 95 Minutes

Photo 13. Droop Stop in the "Fly" (Incorrect) Position

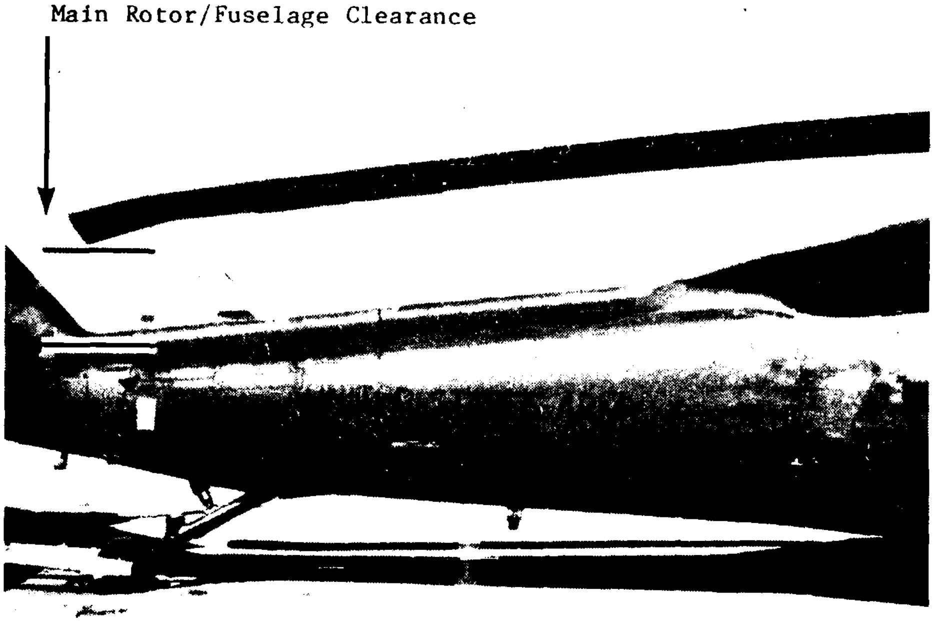


Photo 14. Droop Stop in the "Fly" (Incorrect) Position

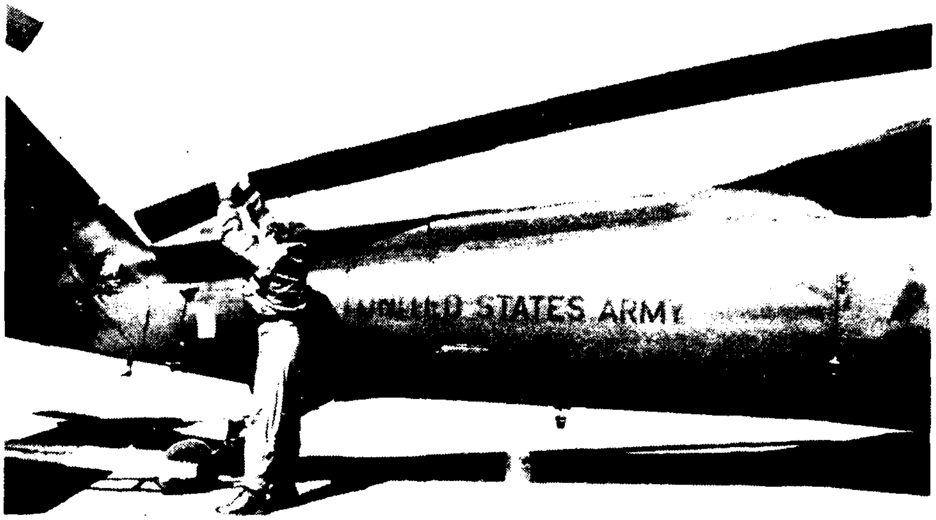


Photo 15. Droop Stop in the "Fly" (Incorrect) Position

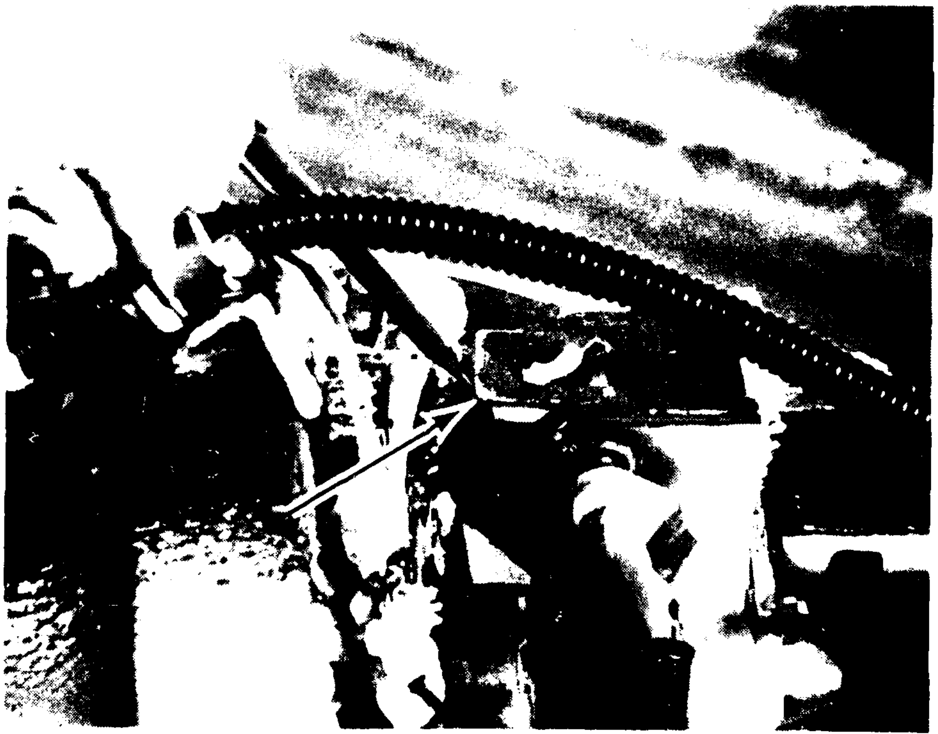


Photo 16. Flap Restrainer in the "Shutdown" (Correct) Position

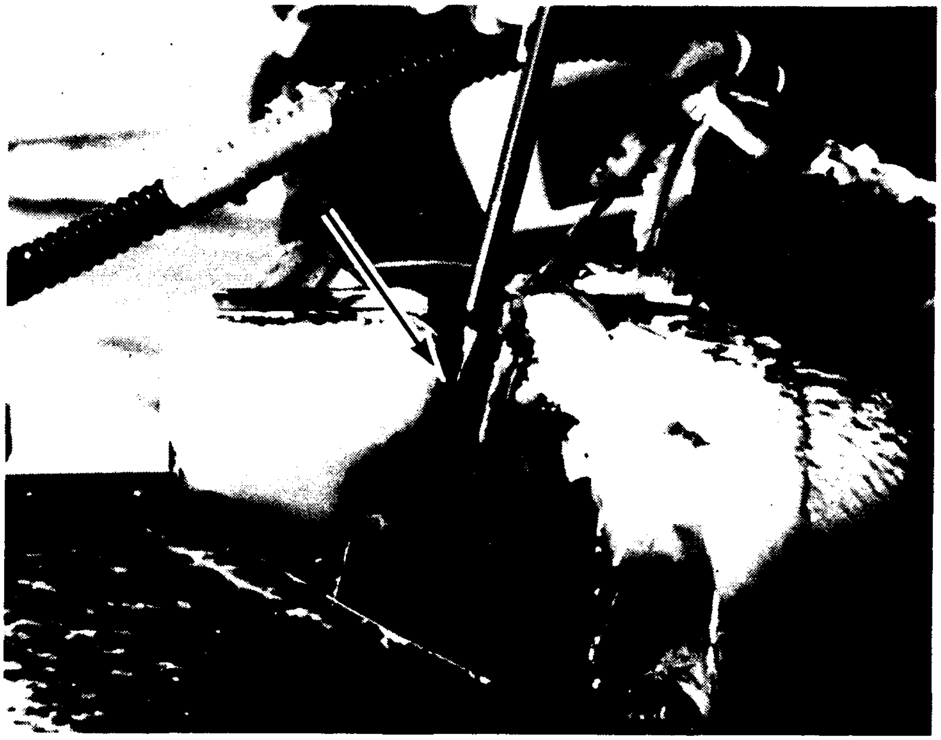


Photo 17. Flap Restrainer in the "Fly" (Incorrect) Position
Artificial Icing: 0.49 gm/m^3 LWC, -6.0° C, 60 Minutes

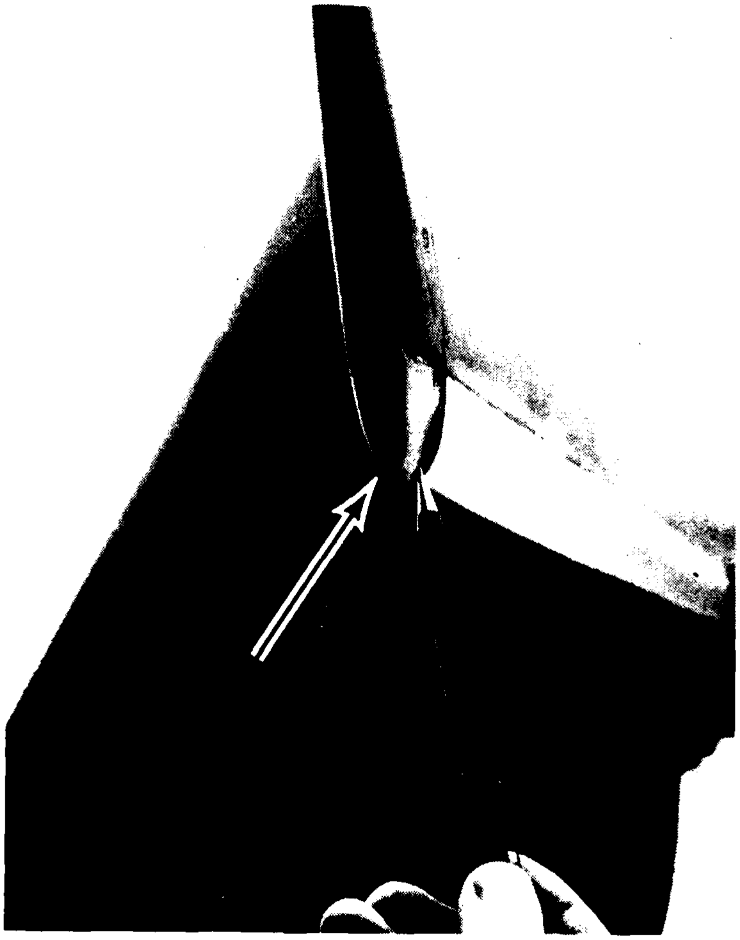


Photo 18. Damaged Tail Rotor Tip Cap Artificial Icing: 0.49 gm/m^3 LWC, -6.0° C, 60 Minutes

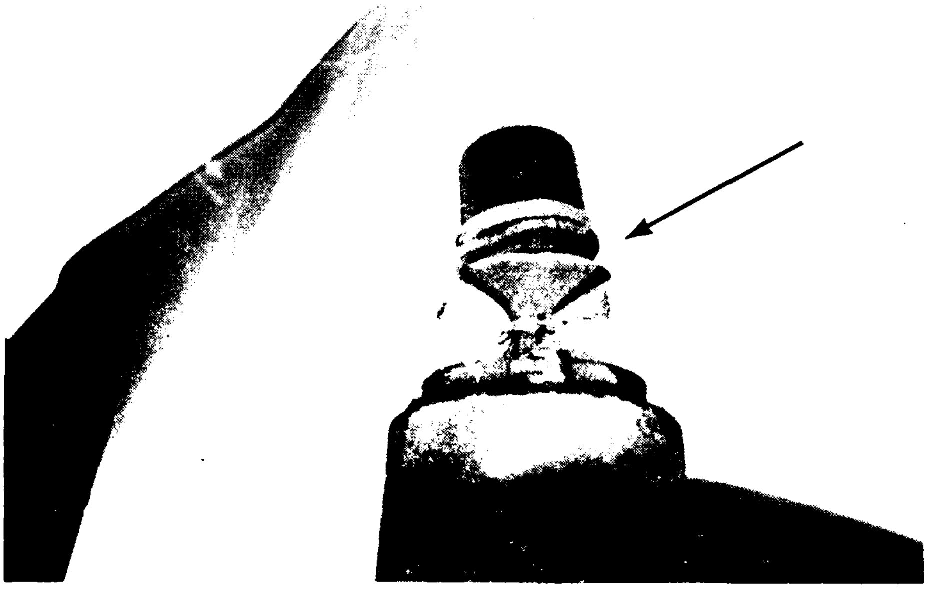


Photo 19. Broken Upper Anti-Collision Light Artificial Icing: 0.5 gm/m^3 LWC, -12.5° C, 81 Minutes

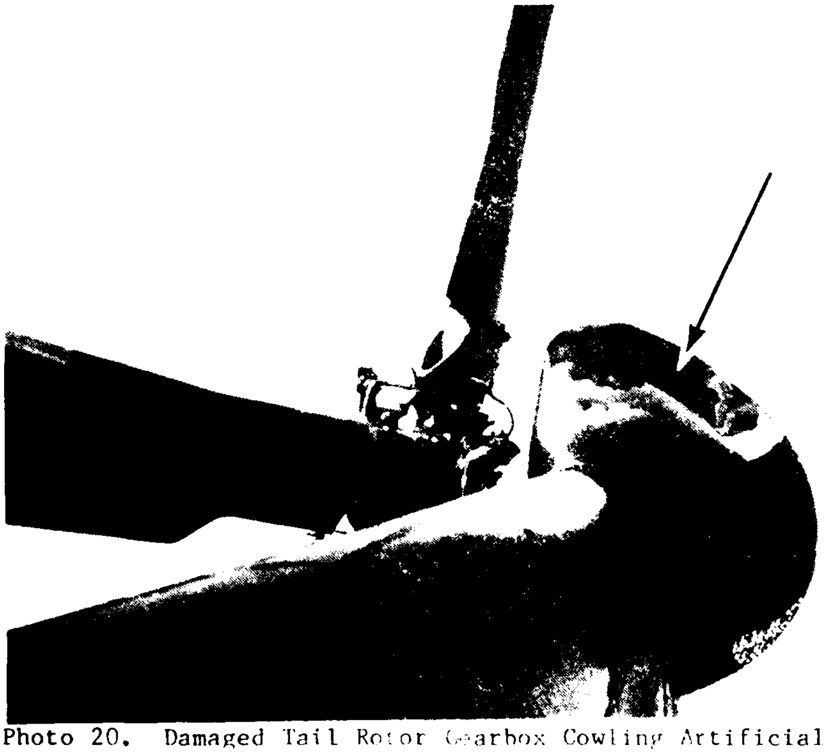


Photo 20. Damaged Tail Rotor Gearbox Cowling Artificial Icing: 0.5 gm/m^3 LWC, -12.5° C, 81 Minutes

Photo 21. Damaged Tail Rotor Gearbox Cowling Artificial Icing: 0.5 gm/m^3 LWC, -12.5°C, 81 Minutes

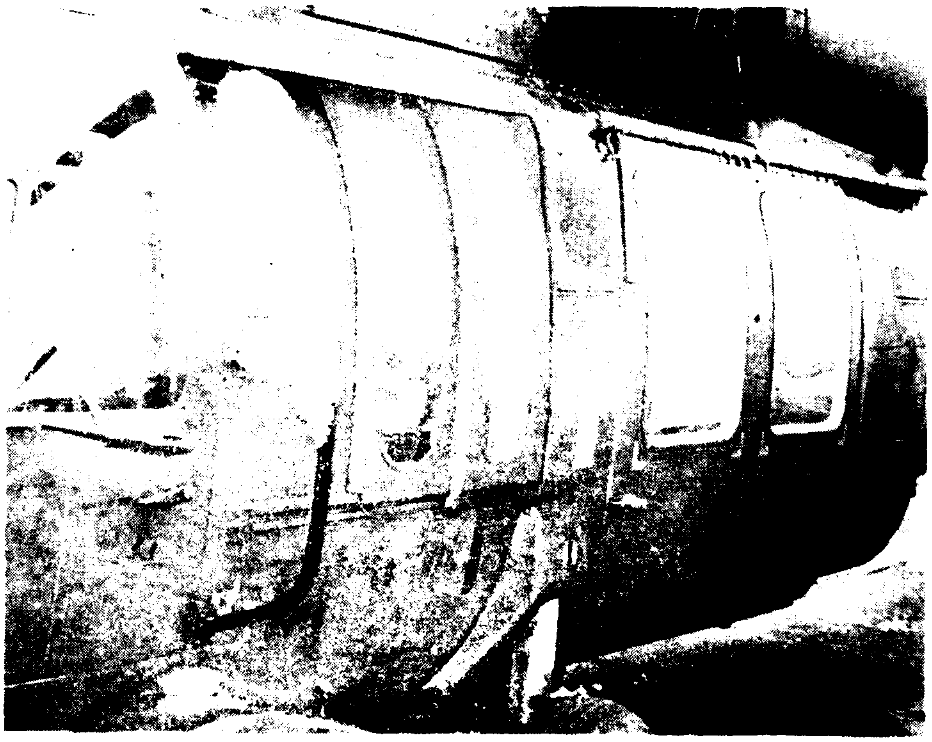
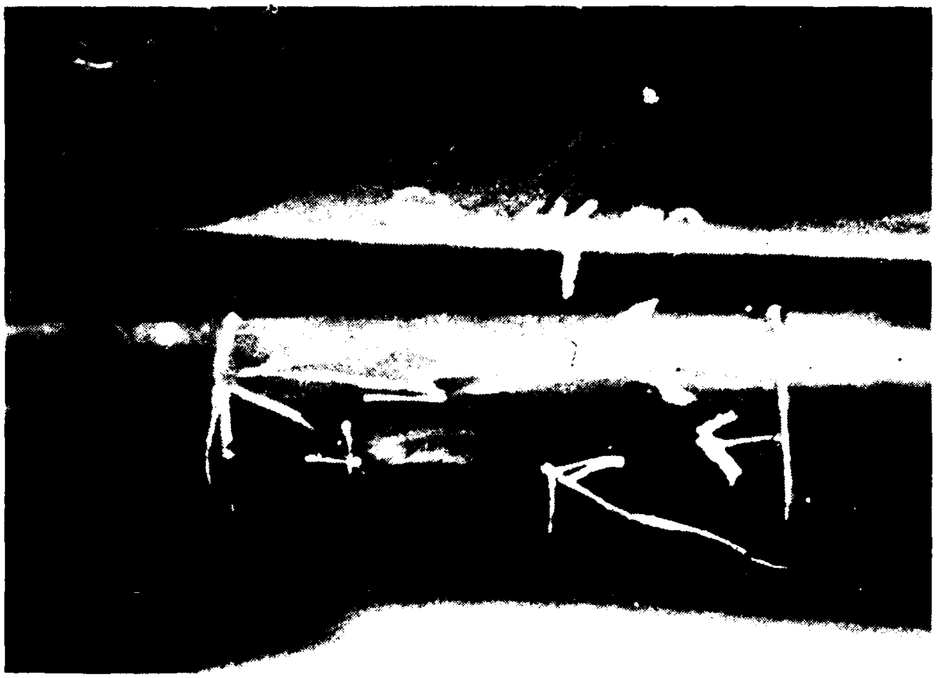


Photo 22. Ice Accretion on FM Antenna Natural Icing: 0.5 gm/m^3 LWC, -4.0° C, 43 Minutes

23. Ice Accretion on FM Antenna Natural Icing:
0.5 gm/m^3 LWC, -4.0°C, 43 Minutes



24. Main Rotor Blade Leading Edge - Electrical Damage

25. Damaged Distributor Wiring Harness

APPENDIX H. EQUIPMENT PERFORMANCE REPORTS

The following Equipment Performance Reports (EPR's), DARCOM Form 2134, 1 September 1976, were submitted by AVNDTA during the light icing envelope and logistics evaluation tests.

EPR Number	Subject
KF-3	Main Rotor Blade Assembly
KF-4	Blade Deice Distributor
KF-5	Deice Distributor Wiring Harness Clamp
KF-6	Blade Deice Distributor
KF-7	Deice Distributor Wiring Harness Clamp
KF-8	Main Rotor Blade Assembly
KF-9	Blade Deice Distributor
KF-10	Droop Stop Heater
KF-11	Deice Distributor Wiring Harness Clamp

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US Army Aviation Center (ATZQ-D-T, ATZQ-TSM-A, ATZQ-TSM-S, ATZQ-TSM-U)	4
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US Army Research and Technology Laboratories/Applied Technology Laboratory (DAVDL-ATL-D, DAVDL-Library)	2
US Army Research and Technology Laboratories/Proplusion Laboratory (DAVDL-PL-D)	1
US Army Research and Technology Laboratories (DAVDL-AS, DAVDL-POM (Library))	2
MTMC-TEA (MTT-TRC)	1
ASD/AFXT	1

3-8

DT