AD A090527

LEVEL II

USAAEFA PROJECT NO. 79-19

ARTIFICIAL AND NATURAL ICING TESTS PRODUCTION UH-60A HELICOPTER

TEST PLAN

BY

MARVIN L. HANKS
CPT, CE
PROJECT OFFICER

OCTOBER 1979

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

TABLE OF CONTENTS

DISCLAIMER NOTICE

INTRODUCTION

BACKGROUND

1. The US Army requires the UH-60A helicopter (Black Hawk) to operate safely in an icing environment up to and including the moderate level of intensity. Artificial icing tests were previously conducted in Alaska in 1976 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 (ref 1, app A). Additional limited tests, with a production UH-60A with similar deice and anti-ice systems, were conducted in Minnesota in 1979 (ref 2, app A). The initial test results indicated that the UH-60A displays the potential for operating in a moderate icing environment. The production UH-60A incorporates a main and tail rotor blade deicing system, anti-icing systems and an ice detection system. Additional artificial and natural icing tests are required to qualify these systems for operational use in a moderate icing environment. The United States Army Aviation Research and Development Command (AVRADCOM) requested USAAEFA to conduct artificial and natural icing tests of the production UH-60A helicopter (app B) during the winter of 1979-1980.

TEST OBJECTIVES

2. The objectives of this test are to conduct artificial and natural icing flight tests of the production UH-60A helicopter to:

a. Substantiate the effectiveness of the production anti-ice/deice systems

b. Determine the effectiveness of the ice detection subsystem

c. Evaluate the effect of ice accumulation on handling qualities and performance. The anti-ice/deice systems will be operating for all tests in the icing environment

d. Provide data for inclusion in the operator's manual.

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). Non-retractable 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. A horizontal stabilator is located on the tail rotor pylon. A more detailed description of the UH-60A is contained in the operator's manual (ref 3, app A). An anti-ice/deice system description may also be found in supplements to the operator's manual and in appendix C.

TEST SCOPE

4. The artificial and natural icing flight tests of the production UH-60A with the ice protection subsystems consist of two phases and will be conducted in the vicinity of St. Paul, MN from 7 January through 4 April 1980.

a. The first phase will be the verification test, starting 7 January 1980, and will require approximately 15 hours of flight testing. During each test flight, the test helicopter will be flown in a cloud generated by the Helicopter Icing Spray System (HISS) at a constant liquid water content (LWC) within the range of 0.25 to 1.0 gm/m^3 and at a constant temperature within the range of 0°C and -20°C. A test matrix of combinations of temperature and LWC will be investigated prior to flight in the natural environment. The exposure time during a single test flight will be limited by the amount of water available on-board the HISS or by flight safety limits, such as excessive power required or excessive vibration.

b. The second phase will be the qualification test, starting after a minimum portion of the verification tests are completed, and will require 30 hours of testing. During each test flight the test helicopter will be flown in instrument meteorological conditions, complying with Instrument Flight Rules (IFR) and attempting to duplicate temperatures and LWC's within the ranges tested during the first phase.

5. Flight restrictions and operating limitations will be established by the airworthiness release to be issued by the AVRADCOM. The tests will be conducted with the infrared (IR) suppressors and M-130 dispenser (chaff made only) installed and with the aircraft at a mid longitudinal and lateral center of gravity (cg). The aircraft will be operated at near design gross weight (16,450 pounds) using normal operating rotor speed (258 rpm), with the stability augmentation system fully operative. Some testing in the normal utility (without IR suppressor and M-130 dispenser (chaff made only)) configuration will be accomplished. In the artificial environment, the aircraft will be tested primarily at 90 knots true airspeed (KTAS). Some data will also be taken at 120 KTAS to determine effects of airspeed on ice accretion and shedding. Test altitudes for the artificial icing test will range from a minimum of 1500 feet above ground level (AGL) to a maximum of 10,000 feet pressure altitude. In the natural environment, tests will be conducted at airspeeds from 60 KTAS to maximum airspeed for level flight (V_H). Test altitudes for the natural icing test will range from minimum vectoring altitude to a maximum of 10,000 feet pressure altitude.

6. The USAAEFA is the responsible agency for the conduct of this test. Installation and maintenance of the instrumentation system and maintenance of the helicopter will be accomplished by the USAAEFA. The Minnesota Army National Guard and the US Army Reserve Aviation Support Facility (USARASF) at the St. Paul Downtown Airport will provide the support requirements as detailed in appendix G. Testing will be conducted according to the test operations plan (app D) and within the safety guidelines of appendix E.

DETAILS OF TEST

GENERAL

7. The icing tests of the production UH-60A will be conducted to provide data to certify the aircraft for flight in icing conditions. The test program is structured to take advantage of the test data generated previously and the development work done by the contractor. Use of the HISS during the anti-ice/deice systems verification is to be viewed as buildup for the qualification tests to be flown in natural icing conditions. Components of the ice protection subsystems will not be adjusted or modified during the test program without prior approval of the project officer and concurrence of the USAAEFA Technical Committee and the AVRADCOM (DRDAV-DI).

8. The test schedule, support requirements and cost estimate are contained in appendixes F, G, and H respectively. A detailed list of the installed instrumentation is contained in appendix I.

PRETEST CHECKS AND CALIBRATIONS

Flight Control Rigging Check

9. Prior to beginning the evaluation, a rigging check of the flight controls will be performed by USAAEFA personnel in accordance with Sikorsky Aircraft Division (SAD), United Technologies recommended procedures.

Weight and Balance

10. Prior to flight test, the instrumented aircraft will be weighed a minimum of two times to accurately determine weight and longitudinal and lateral cg locations. The weighings will be performed with trapped fuel and repeated with full fuel using a calibrated electronic weighing kit.

HUMAN FACTORS

Cockpit Evaluation

11. The cockpit will be qualitatively evaluated throughout the test program with respect to icing systems peculiar controls, switches, procedures, etc. Cockpit assessments will consider the presence of special test instrumentation and equipment which could detract from an opinion rendered on a standard production aircraft. Specific items to be evaluated will include the following:

a. Ease of ingress and egress, both normal and emergency, with ice accreted on the airframe

b. Cockpit arrangements, to include accessibility of controls, switches, circuit breakers, and instrument panel arrangements

c. Cockpit field of view after an icing encounter

d. Adequacy of aircraft heating and ventilating systems

e. Complexity of normal cockpit procedures.

RELIABILITY AND MAINTAINABILITY

12. Specific reliability and maintainability tests will not be conducted during these tests but records will be maintained of all maintenance actions performed on the aircraft. Specific items will include the ease of accomplishing both scheduled and unscheduled maintenance, special tool requirements, and characteristics which enhance or impair maintenance and operation of the aircraft.

SUBSYSTEMS TESTS

General

13. The aircraft ice protection subsystems are the deice systems: main and tail rotor; and the anti-ice systems: windshield, engine inlet, engine and pitot static system. The icing tests will evaluate the entire ice protection system in a simulated icing environment created by the HISS and in the natural environment. Data obtained during these tests will allow for individual evaluation of each of the subsystems. Conditions which may result in the termination of an icing encounter include: excessive engine torque increases (>10%) noted during trim points; loss of ability to maintain rotor speed within limits during autorotation; excessive vibration levels; degraded aircraft handling qualities; ice accretion characteristics (i.e., windshield icing over); shedding characteristics; limits in the airworthiness release; and pilot qualitative assessments. Quantitative handling qualities tests will be conducted.

Simulated Icing Environment:

14. The simulated icing environment will be created by the HISS. The aircraft will be configured with the IR suppressor and the XM-130 (chaff mode only) dispenser installed (doors and windows closed) and tested at the conditions shown in table 1. Some data will be obtained with the aircraft in the normal utility configuration.

15. The sequence for each test point at a particular temperature/LWC combination will be divided into three parts: pre-immersion, cloud immersion, and post-immersion. The sequence of events for each part is detailed below.

a. Pre-immersion:

(1) Anti-ice systems (i.e., pitot heat, windshield anti-ice, engine, and engine air induction system anti-ice) are activated during climb to test altitude and their operation verified prior to entering the icing cloud.

(2) Water flow rate is determined by true airspeed, relative humidity, and distance behind the HISS.

(3) The test aircraft positions approximately 200 feet behind the HISS and approximately 50 feet to the side of the turbulent wake generated by the HISS.

Table 1. Artificial Icing Test Conditions[1]

Temperature (°C)	Liquid Water Content (gm/m³)			
	0.25	0.5	0.75	1.0[2]
-5		X	X[3]	X
-10	X	X[3]	X	~~X~~
-15	X[3]	X	X[4]	~~X~~[4]
-20	X	~~X~~	~~X~~[4]	~~X~~[4]

[1] Tests will be accomplished at near design gross weight (16,450 pounds), mid center of gravity location, normal operating rotor speed (258 rpm), an airspeed of 90 KTAS, and altitudes from 1500 feet AGL to 10,000 feet pressure altitude.

[2] 1.0 gm/m^3 or max flow rate from the HISS, whichever is less.

[3] Release for flight into natural icing conditions is dependent upon successful deice/anti-ice system operation at these test conditions. Sustained flight in natural icing conditions will not be attempted for anticipated conditions more severe than comparable previously tested artificial test conditions.

[4] Conditions will be evaluated for 15 minutes only.

X = Required test conditions
~~X~~ = Desired test conditions

(4) The chase aircraft positions as necessary to provide the desired visual and photographic coverage of the test aircraft.

(5) The HISS establishes desired water flow rate.

(6) Data are recorded with the test aircraft stabilized at test airspeed and altitude.

(7) The test aircraft then positions beneath the spray cloud on center line with the HISS.

(8) The chase aircraft uses the challenge-respond system to confirm that aircraft anti-ice systems are ON and operational prior to the aircraft entering the cloud.

b. Cloud immersion:

(1) Deice system on the test aircraft is activated.

(2) The test aircraft ascends into the spray cloud and establishes stand-off distance.

(3) The HISS copilot provides stand-off distance information to the test aircraft.

(4) The HISS aircraft flies at a constant temperature and test airspeed.

(5) Ice shedding and accumulation observed from the chase aircraft is recorded and reported. The chase aircraft may vary its positions in order to best observe the test aircraft.

(6) The test aircraft descends and moves clear of the cloud after a pre-determined immersion interval. Time in the cloud is based on the accretion rate, previous data, and the effectiveness of the anti-ice/deice system. Immersion may be terminated based on the test pilot's judgment and/or visual observation from any of the aircraft. Excessive increase in power required (approximately 10% torque) or excessive aircraft vibration levels will also be cause to terminate an icing encounter.

c. Post-immersion:

(1) The test aircraft positions clear of the spray cloud and stabilizes at the test altitude and airspeed, and data are recorded.

(2) The chase aircraft positions on the test aircraft to observe and photograph ice accumulation.

(3) The HISS aircraft terminates water flow.

(4) The test aircraft performs specific tests (e.g., autorotational capability, normal instrument flight maneuvers, handling qualities).

(5) At the conclusion of the specific test, the test aircraft repositions on the HISS and the sequence of events is repeated for the next test condition, or the test is terminated.

16. Should significant engine torque increases be observed, autorotational rotor speed will be checked. Prior to accreting the artifical ice at the specified conditions, autorotative rpm and/or collective position will be determined by smoothly entering autorotation and retarding the engine power control levers to obtain an engine/rotor split. This baseline with no ice will be used in comparison with closely duplicated flight conditions after ice accretion.

17. Handling qualities characteristic tests will be accomplished in accordance with the United States Naval Test Pilot School, Helicopter Stability and Control Flight Test Manual (ref 4, app A) if pilot qualitative assessments indicate that a perceivable change has taken place. Emphasis will be placed on qualitative evaluation of instrument flight maneuvers.

18. A thorough post-flight inspection of the test aircraft will be conducted following each flight. In addition to the normal maintenance post-flight items, this inspection will include:

a. Rotor blades for damage

b. Airframe structure for damage

c. Engine inlet and engine compressor for ice ingestion damage

d. Borescope of engine as required to detect any engine ice ingestion damage.

Natural Icing Environment:

19. Natural icing tests will be conducted in IMC regulated by instrument flight rules.The testing is to be conducted with the aircraft in the external configuration (i.e., IR suppressors and M-130 dispenser (chaff made only) installed, or normal utility) determined to be most adverse during the artificial icing tests. Some data will be obtained in the other configuration to verify artificial icing results. The natural testing will initially stay within the temperature and LWC range tested and found to be acceptable in the artificial icing environment. Attempts will be made to duplicate specific conditions tested in the artificial environment for comparative purposes. Safety limitations determined during the artificial icing will be observed. The test condition envelope may be expanded if no limits are reached and if data indicate that the ice protection system is capable of more severe conditions. Natural icing flights will be conducted with ceiling and visibility greater than 2000 feet and 2 miles. The chase helicopter, at the discretion of the project officer, will either be airborne or on standby at a designated airfield.

20. The natural icing test flights will be conducted using radar vectoring to stay in the icing cloud. Normal pre-flight preparations apply to all flights and if specific tests (e.g., static longitudinal stability, control positions, etc.) are to be conducted, they must be briefed at the pre-flight briefing. Specific tests will be attempted only when pilot workload permits as determined by the test aircraft flight crew.

21. Should significant engine torque increases be observed, autorotational rotor speed will be checked. Visual flight conditions will be established and a smooth autorotational entry accomplished by reducing the engine power control levers until an engine/rotor split is accomplished. Flight conditions, aircraft cg and gross weight will be noted so that the test condition can be duplicated at a later date, with no ice accretion, for comparison purposes.

22. Specific handling qualities tests will be accomplished in accordance with the United States Naval Test Pilot School, Helicopter Stability and Control Flight Test Manual (ref 4, app A) if pilot qualitiative assessments indicate that a perceivable change has taken place. These tests will be limited to maneuvers which can be accomplished within normal IFR maneuvering requirements (i.e., 500 fpm climbs and descents, standard rate turns) when accomplished in instrument meteorological conditions. Emphasis will be placed on qualitative evaluations of instrument flight maneuvers.

23. A thorough post-flight inspection of the aircraft will be conducted following each flight, as in paragraph 18.

<u>Rotor Deice System</u>

24. The rotor deice system will be qualitatively and quantitatively evaluated during the test to determine the adequacy of heater mat coverage, effectiveness in removing ice, increased power required due to accreted ice, effectiveness of the ice detection

subsystem, and the effectiveness of the emergency procedures related to the deice system.

Anti-ice Systems

Engines and Engine Inlets:

25. Engine performance data will be obtained with anti-ice systems ON and OFF to determine engine power losses due to use of engine bleed air for anti-ice. The engines and engine inlets will be monitored during the artificial icing tests to determine the effects of icing. (Note: Engine power losses as a function of cabin heater operation will also be assessed.)

Windshields:

26. The windshield anti-ice system will be qualitatively and quantitatively evaluated by recording electrical current and voltage applied to the windshield and observing that ice does not form.

Pitot Tubes:

27. The pitot tubes and supporting struts will be qualitatively evaluated during the artificial icing tests. Observations from the chase aircraft and the HISS will determine if the pitot heads and struts are accreting ice. Photographs will be used to document any accretion.

Unprotected Surfaces

28. The unprotected surfaces will be monitored during the test. If ice accretes during testing, mechanical components (i.e, windshield wipers, cargo hook, sliding gunner window, pilot/copilot's door jettison, fuel system vents, aircraft drains, etc.) will be activated to check their operation in the air or on the ground, as appropriate.

APPENDIX A. REFERENCES

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

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

3. Technical Manual, TM 55-1520-237-10, *Operator's Manual, UH-60A Helicopter*, 21 May 1979, with change 3 dated 3 October 1979.

4. US Naval Test Pilot School Flight Test Manual, *Helicopter Stability and Control*, FTM No. 101, 10 June 1968.

APPENDIX B. TEST REQUEST

DEPARTMENT OF THE ARMY
HQ, US ARMY AVIATION RESEARCH AND DEVELOPMENT COMMAND
P O BOX 209, ST. LOUIS, MO 63166

SEP 14 1979

DRDAV-DI

SUBJECT: Artificial and Natural Icing Tests of the Production UH-60A (Phase 2) (A&FC)

Commander
US Army Aviation Engineering
Flight Activity
ATTN: DAVTE-P
Edwards AFB, CA 93523

This letter transmits AVRADCOM/AEFA Test Request Number 79-19, subject as above.

FOR THE COMMANDER:

1 Incl
as

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

SEP 14 1979

AVRADCOM TEST REQUEST NO. 79-19
ARTIFICIAL AND NATURAL ICING TESTS
OF THE PRODUCTION UH-60A (PHASE 2)
(A&FC)

1. PURPOSE:

This test request tasks the US Army Aviation Engineering Flight Activity (AEFA) to plan, conduct and report on artificial and natural icing Airworthiness Qualification flight tests of the production UH-60A incorporating appropriate ice detection, deicing and anti-icing systems.

2. BACKGROUND:

The UH-60A helicopter requires a capability to safely operate continuously in an icing environment up to and including the moderate level of intensity. Artificial icing tests were previously conducted by AEFA under project no. 76-09-1 using a prototype YUH-60A with a prototype main and tail rotor deice system and anti-ice provisions for the pilot and copilot windshields; pitot-static tubes and their support struts, the engines, and the engines' inlets. The test results substantiated that the YUH-60A displays the potential for operating in a moderate icing environment with the incorporation of adequate deicing and anti-icing systems. The production UH-60A incorporates an improved main and rotor blade deicing system, anti-icing systems and ice detection systems, which require artificial and natural icing tests to substantiate Airworthiness Qualification for operation in a moderate icing environment. AEFA supported contractor PVT-C optimization tests of the production main and tail rotor deicing and anti-icing systems under AEFA project 78-05 (Phase 1) during

May and April 1979. Phase 2 of AEFA project 78-05 was not conducted due to warming weather conditions. Consequently, completion of Phase 2 tests are required for Airworthiness Qualification of the production UH-60A.

3. TEST OBJECTIVES:

The objective of this test is to conduct artificial and natural icing Airworthiness Qualification flight tests to substantiate the effectiveness of the production UH-60A in a moderate icing condition, determine compliance with para 3.7.13.2.1 of Prime Item Description Document AMC-CP-2222-S1000C and provide data for inclusion in the operator's manual. Qualitative test must include as a minimum:

a. Effectiveness of the ice detection systems.

b. Effectiveness of the deicing and anti-icing systems.

c. Impact of ice accumulation on handling qualities and performance.

d. Evaluation of characteristics in natural icing conditions.

4. SPECIAL INSTRUCTIONS:

a. The icing evaluation will consist of artificial and natural icing tests. Flights behind the Helicopter Icing Spray System (HISS) will be used to identify basic icing capabilities of the UH-60A with heated blades, however, natural icing test data only will be considered for qualification unless the current HISS PIP produces significant improvement in the artificial cloud prior to starting flight testing.

b. The intent of this evaluation is to define a continuous moderate icing envelope for liquid water content (LWC) , ambient temperature (OAT). Inclosure 1 provides the accepted atmospheric icing criterion to be used for defining the light and moderate icing envelopes. Inclosure 2 is the recommended matrix of test conditions that are required to fully substantiate a continuous moderate icing envelope. The required and desired test conditions to be flown by AEFA are annotated in Inclosure 2.

c. Priority of testing should be to obtain test conditions first at a LWC of .75 and OAT's of -10, -15, and -20 degrees C behind the HISS in artificial icing conditions before conducting tests in natural icing.

d. Prior to conducting flight tests in natural icing conditions, the UH-60A must first be tested to at least the same conditions behind the HISS. When a test condition is encountered such that flight is unacceptable due to vibration, increased torque, blade stall, significant ice accretion or other limit, an envelope limit will be considered met.

e. AEFA will provide flight crews and test support personnel.

f. AEFA will provide the HISS, chase aircraft support and photographic coverage.

g. AEFA will provide data analysis capability to include onsite/offsite strip out and computer analysis. Additionally, AEFA should use 14 inch tapes to maximize recorded data time.

h. AEFA will provide necessary support during the icing tests to include ferry of the test aircraft to and from the selected test site and maintenance of the test aircraft during tests.

i. AEFA will design, fabricate, install, and maintain the test instrumentation and test equipment per Inclosure 3. AEFA should coordinate directly with the contractor relative to transducer, equipment, and technical support required per inclosure 4.

j. The icing tests will be conducted in the Minneapolis, Minnesota area. AEFA will make the necessary arrangements and coordination with local commercial/military agencies for hangaring and refueling facilities.

5. TEST SCHEDULE:

The time scheduled for the icing tests is January, February, and March 1980. AEFA should plan to support these tests onsite for the full three month schedule and obtain as much natural and artificial icing test data as possible, even if this results in repeating test conditions.

6. DESCRIPTION:

The test helicopter will be production UH-60A equipped with improved main rotor and tail rotor deicing system, ice detection system and improved anti-icing systems.

7. APPLICABLE SPECIFICATIONS:

Prime Item Development Specification, AMC-CP-2222-S1000C, Sikorsky Aircraft Division of United Technologies Corporation, UH-60A, November 1978.

8. POINTS OF CONTACT:

AVRADCOM - Harry W. Chambers, AV 693-1693

BLACK HAWK PMO - LTC John O.Turnage AV 693-6854/6855

Sikorsky Aircraft (Contractor) - Bob Rice (203) 386-5935

9. FUNDING:

A detailed estimate of AEFA reimbursable costs shall be submitted NLT 15 days after receipt of this test request. The cost estimate should be based on sharing common support with AEFA projects 79-02 and 79-07. Additionally, a separate cost based on not sharing common support should be provided.

10. PRIORITY:

AVRADCOM priority 16 is assigned and will be revised when the test period approaches.

11. <u>REPORTS</u>:

a. Eight copies of the advanced test plan are required to be submitted to DRDAV-DI within 30 days after receipt of this test request.

b. AEFA debrief AVRADCOM on test results at earliest possible time following completion of flight tests. A briefing as soon as possible is required so that an early determination can be made relative to establishing an icing envelope.

c. Eight copies of an advanced report are required for review by AVRADCOM within 60 days after flight test completion.

d. AVRADCOM will return report review copies with comments to AEFA NLT 15 days after receipt of review copy.

e. AEFA forwards print copy of report to AVRADCOM NLT 30 days after receipt of review comments.

12. <u>SECURITY CLASSIFICATION</u>: Unclassified.

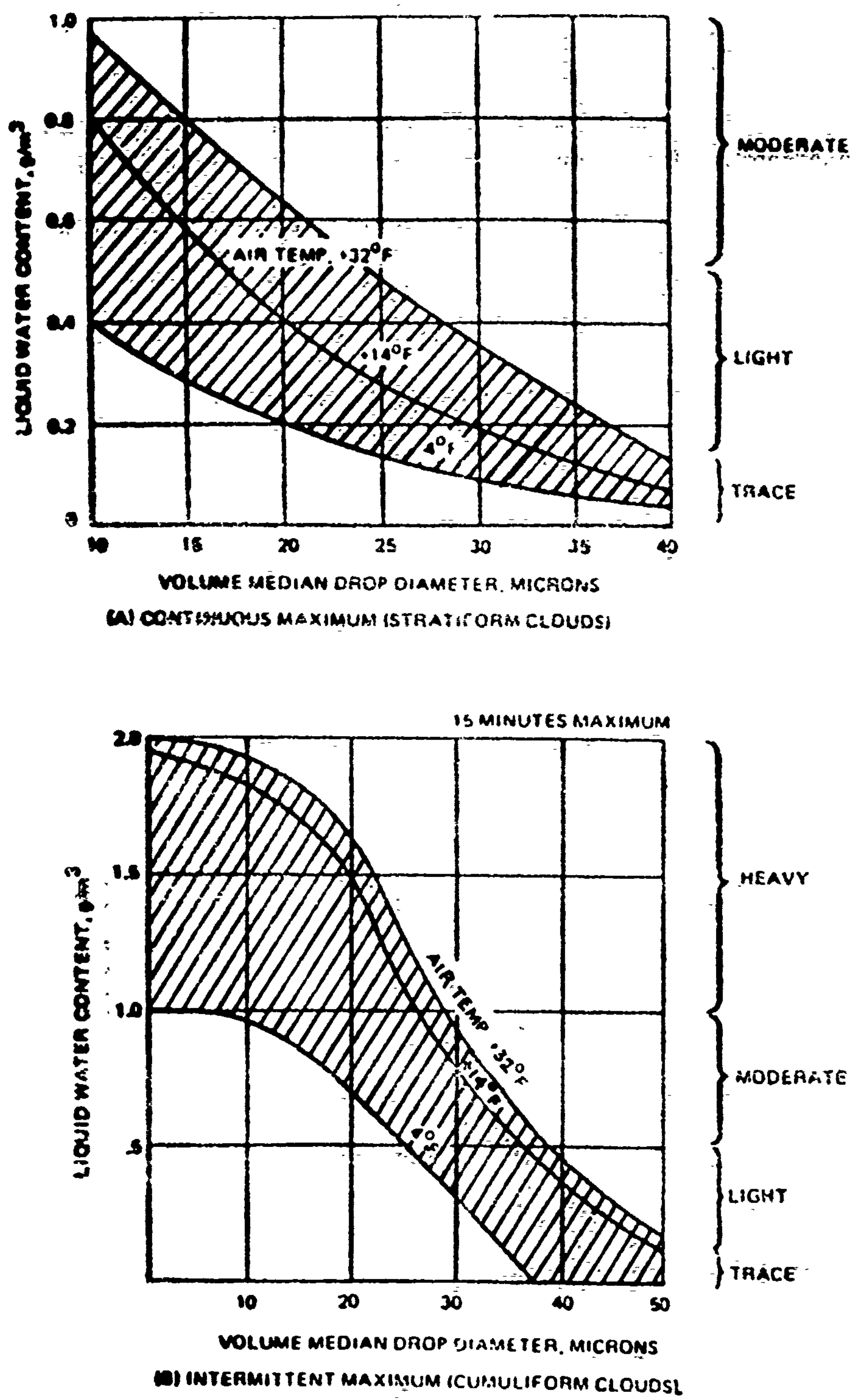
13. <u>EQUIPMENT</u>:

a. AEFA will furnish the JCH-47C HISS.

b. AEFA will furnish a chase JUH-1H for crash/rescue.

c. The test UH-60A S/N 77-12217 will be furnished by the BLACK HAWK Project Manager. The UH-60A will be available for pickup by AEFA at Stratford, CT on approximately 7 November 1979.

14. <u>AIRWORTHINESS RELEASE</u>: An Airworthiness Release is required for this test.



Recommended Atmospheric Icing Criterion.

Figure 4.

TEST CONDITIONS

OAT °C	LWC gm/m³ .25	.50	.75	1.00
-5	*	X	X	X
-10	X	X	X	*
-15	X	X	X	*
-20	X	*	*	*

X REQUIRED TEST CONDITIONS

* DESIRED TEST CONDITIONS

INSTRUMENTATION REQUIREMENTS FOR UH-60A ICING FLIGHT TEST

1. PCM

Airspeed
Altitude (Pressure)
Free Air Temperature
Engine Torque (2)
Engine Fuel Flow Rate (2)
Engine Measured Gas Temperature (2)
Engine Gas Generator Speed (2)
Main Rotor Speed
Longitudinal Stick Position
Lateral Stick Position
Directional Control Position
Collective Position
Longitudinal SAS Actuator Position
Lateral SAS Actuator Position
Directional SAS Actuator Position
Pitch Attitude
Roll Attitude
Yaw Attitude
Pitch Rate
Roll Rate
Yaw Rate
Stabilator Position
Engine Anti-Ice Bleed Air Pressure (2)
Engine Anti-Ice Valve Position (2)
Engine Inlet Duct Anti-Ice Valve Position (2)
No. 1 Generator Voltage
No. 1 Generator Current
No. 2 Generator Voltage
No. 2 Generator Current
APU Generator Voltage
APU Generator Current
De-Ice System Electrical Voltage (Main & Tail)
De-Ice System Electrical Current (Main & Tail)
Windshield Voltage
Windshield Current
Ice Rate (De-Ice System Detector) (DC Voltage to Cockpit Meter)
Ambient Air Temperature (De-Ice System)
Time Code
Event & Status Words
De-Ice Controller "on" Status

2. FM

Main Rotor Fwd Long Stationary Star Load
Main and Tail Rotor 1/Rev & 4/Rev

Vibration

Main Rotor Transmission (3)
Tail Rotor Gearbox (3)
CG (3)
Pilot Seat (3)
Copilot Seat Vertical and Longitudinal
Stabilator Tip Left, Vertical and Longitudinal
Stabilator Tip Right, Vertical and Longitudinal
No. 1 and No. 2 Engine Exhaust Frame, Vertical and Horizontal

TRANSDUCERS, EQUIPMENT AND TECHNICAL SUPPORT REQUIREMENTS
FOR UH-60A ICING FLIGHT TEST

In order to incorporate the parameters required for icing on UH-60A S/N 77-22717 in the time frame 7 November 1979 to 15 December 1979, the following transducers, equpment and technical support will be provided by Sikorsky Aircraft.

1. Voltage sensors:

P/N 108-130 Five (5) each
P/N 103AM200 five (5) each
P/N 108-150 two (2) each
P/N 108-270 two (2) each

2. Current sensors:

P/N 1004-100-C three (3) each
P/N 1004-20-C four (4) each
P/N 1004M7200 four (4) each

3. Main and tail rotor sliprings and hardware associated with icing parameters.

4. Position transducers:

P/N Spectrol 708 Dual six (6) each
P/N 708 Spectrol Single two (2) each
P/N Trans-Teck DCDT 242-000 five (5) each

5. Control position bracketery for the following parameters:

Longitudinal stick position
Lateral stick position
Collective stick position
Directional stick position
Longitudinal SAS actuator position
Lateral SAS actuator position
Directional SAS actuator position

6. Nose "E" bay disconnect with the following parameters available:

Engine torque #1 and #2
Engine measured GAS1 temperature #1 and #2
Engine gas generator speed #1 and #2
Main rotor speed

7. Installation drawings for the Flow-Technology volumetric engine fuel flow rate system.

8. GE velocity vibration system to measure #1 and #2 engine exhaust frame, vertical and horizontal axes.

9. Strain gages and calibrated structure for the following parameters:

Main rotor fwd long stationary star load

APPENDIX C. SYSTEMS DESCRIPTION

DEICE SYSTEM

1. The Black Hawk rotor deice system uses the cyclic electrothermal deicing concept. A prescribed amount of ice is allowed to accrete on the blade surface. Sufficient heat is then applied to the surface to break the ice bond, permitting the ice to be shed by centrifugal force and scavenged away by the airflow.

2. The system uses an opposing blade power cycle (i.e., two blades deiced at a time) thus conserving electric power. The main rotor blade heating elements are embedded in the leading edge sheath and cover 21 to 92 percent spanwise and 12 percent upper to 17 percent lower surface chordwise. These elements are divided into four independent electrical heating zones. Tail rotor blade heating elements are embedded in the leading edge skin and cover 25 to 91 percent spanwise and 12 percent upper and lower surface chordwise. These elements are single electrical heating zones.

3. The systems major components and schematics are shown in figure 1. System operation is initiated as follows. Upon entering an icing environment, the icing rate subsystem will sense the presence of ice and signal the pilot by activation of the ICE DETECTED caution capsule. The pilot will then activate the system by placing the deice system control switch (fig. 2) in the ON position. The pilot then exercises his option to select either automatic or manual OFF TIME control of the system. Placing the mode select switch in automatic results in an icing rate signal from the rate meter to the controller regulating OFF times according to icing intensity. Selection of the manual mode of operation by placing the mode select switch in one of three manual positions replaces the icing rate signal with one of three preset signals corresponding to trace (T), light (L) or moderate (M) icing. The manual mode of operation requires the pilot's assessment of icing intensity, and should only be used if the pilot suspects the icing rate system is malfunctioning. It is important to note that the mode select switch has no effect on heater ON times. The heater element ON time (i.e., the period of power application to each main blade heating zone) is controlled by the system controller and an outside ambient temperature sensor.

4. The main and tail rotor control circuits operate independently. The main rotor control circuit closes the main rotor contactor and produces a pulse train (fig. 3) consisting of eight pulses followed by a waiting period, or OFF time. The counter always resets to zero; that is; the controller always produces a complete train of eight pulses when operation is initiated or when input power is restored after an interruption. The pulse train is supplied to the control input of the main rotor power distributor through the main rotor slipring assembly. The same slipring assembly carries power to the distributor. In response, the distributor supplies power in proper sequence to the rotor blade heating elements (fig. 3). Eight gating pulses are required, since the main blades, each with four independent heating zones, are deiced in pairs. The first gating pulse causes power to be applied to output 1 (zone 1 of blades No. 1 and No. 3); the second pulse energizes output 2 (zone 2 of blades No. 1 and No. 3); . . . . . . the fifth energizes output 5 (zone 1 of blades No. 2 and No. 4), and so on through the sequence of eight pulses. The eight outputs are each powered for the same period of time as the controller gating pulse

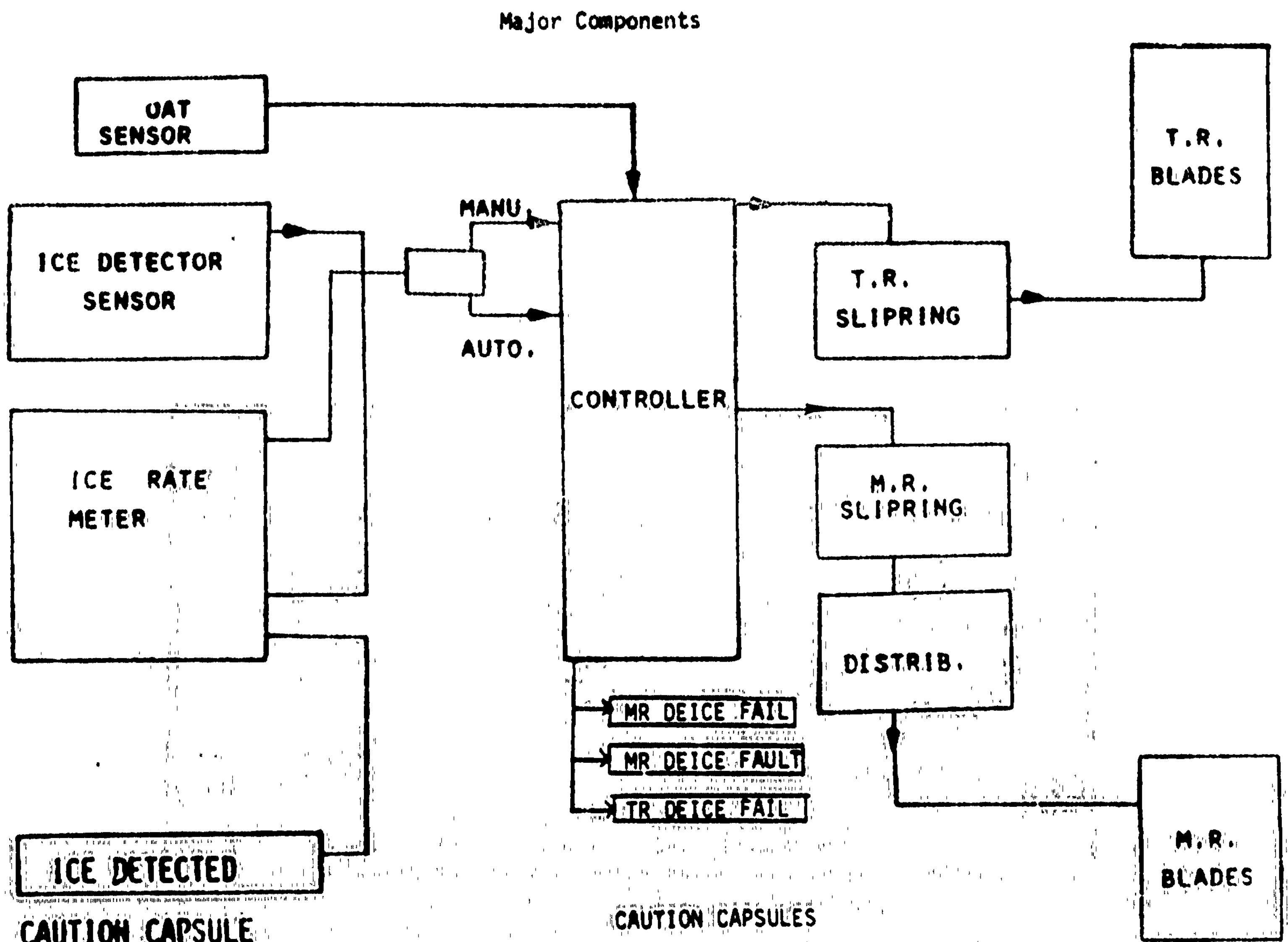


Figure 1. Black Hawk Rotor De-Ice System.

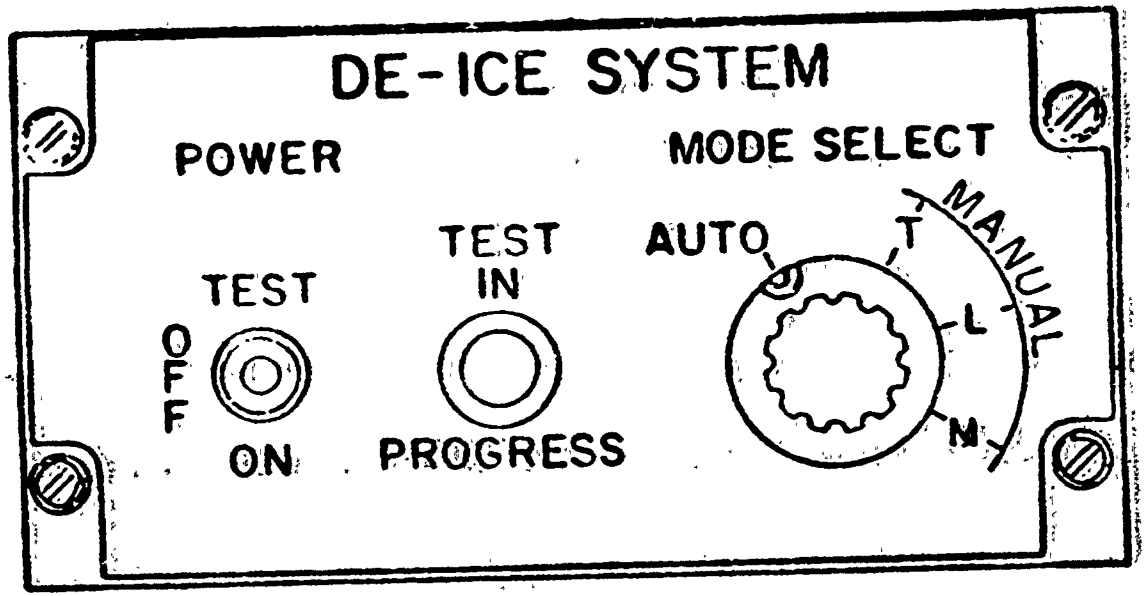


Figure 2. Blade De-Ice Control Panel.

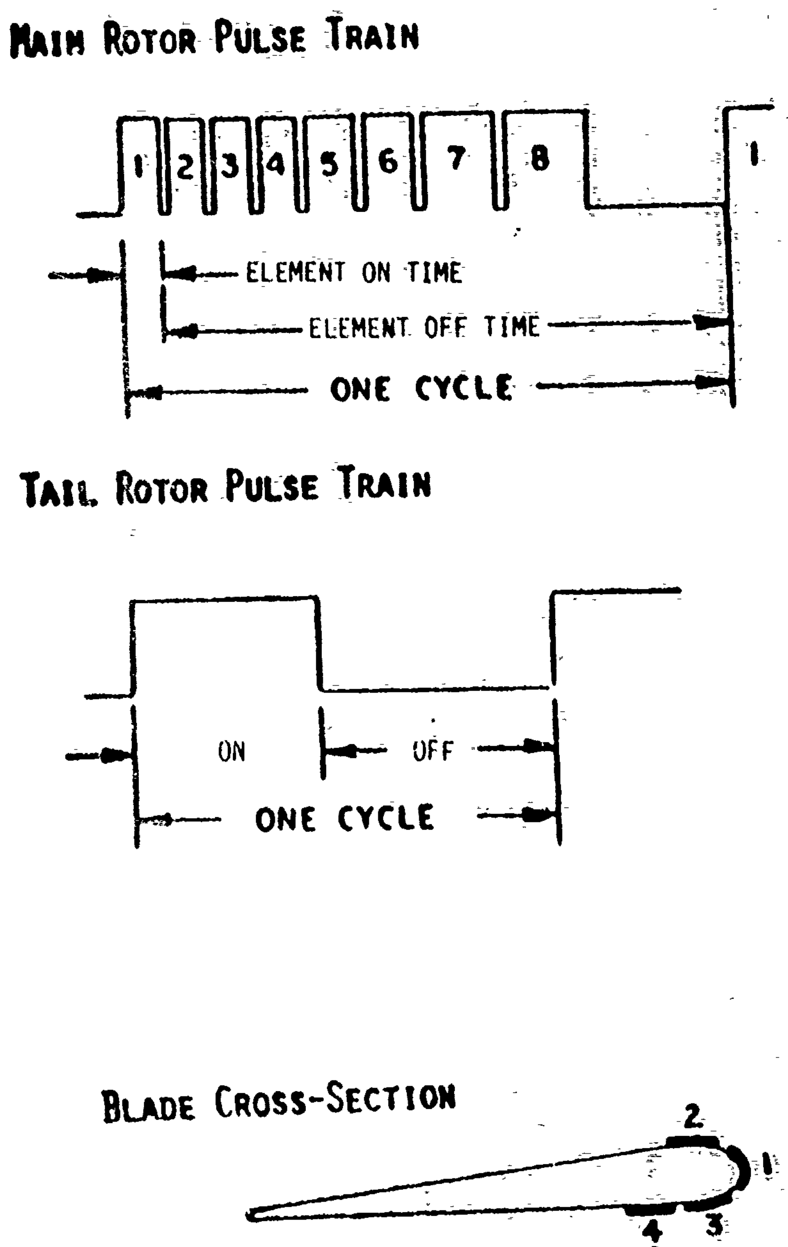


Figure 3. Blade De-Ice Pulse Train and Cross Section.

is applied (element ON time). The sequence counter always resets to output 1 after the OFF time has elapsed or if there is an interruption of power.

5. The tail rotor control circuit provides an output to the tail rotor contactor coil. Energizing the contactor applies power via the tail rotor slipring assembly simultaneously to all the heating elements of the tail rotor; therefore a distributor is not required. The control circuit responds to the outside air temperature (OAT) sensor to determine the ON time of the tail rotor heating elements.

6. The monitor circuits in the controller continuously check the operation of the system. Three-phase current transformers on the main and the tail power leads provide signals corresponding to the actual current delivered to the heaters. By comparing the current delivered with the controller's pulse train, and checking for magnitude balance of the three individual phase currents, the monitor circuits detect such malfunctions as an open circuit heater phase or feeder wire, zero output during a gating pulse, or a short-circuit heater phase. The monitor circuits also detect OAT sensor failure (open- or short-circuit) and an incomplete or improper output pulse train from the controller. Cockpit indicators inform the crew of system fault or failure.

7. A deice system test switch and an icing rate subsystem test switch are provided to enable ground checkout of the system. The deice system test is a preselected duty cycle consisting of a 100-second OFF time followed by approximately 0.5 second element ON times applied to the main and tail rotor blades. Failures resulting from this test will activate the appropriate caution capsule previously described. The icing rate subsystem test is activated by depressing the test button on the ice rate meter (fig. 4). This test conducts a calibration check on the rate meter electronics and checks power application to the ice detector probe heater. Failure of the icing rate subsystem to pass this test will result in the presence of a fail flag on the rate meter assembly.

8. The rotor deice system is powered from the aircraft monitor buss. Loss of one or both of the aircraft primary generators will result in loss of the deice system. With the loss of one primary generator the system can be reactivated by starting the auxiliary power unit (APU) generator, which will supply power to the system.

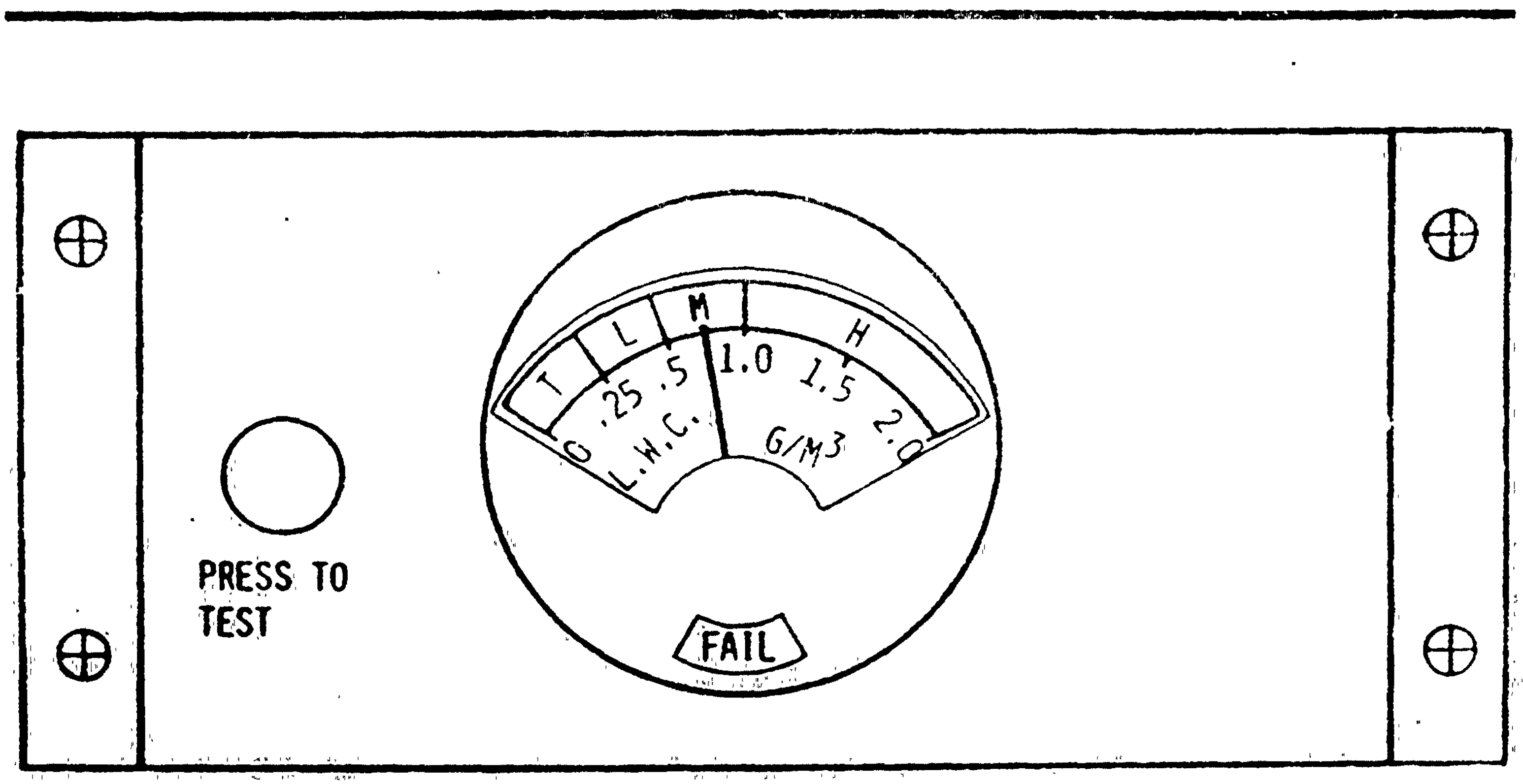


Figure 4. Ice Rate Meter.

APPENDIX D. TEST OPERATIONS PLAN

GENERAL

1. This plan outlines responsibilities and procedures to be followed during the Black Hawk icing test. Current USAAEFA procedures will be in effect throughout the conduct of this test.

RESPONSIBILITY

Project Officer

2. The project officer has overall responsibility for all aspects of the tests. This responsibility includes directing the testing, supervising report writing, and submission of daily progress reports. Additionally, he is the authorized spokesman for the test element to all activities and organizations outside the USAAEFA.

PROCEDURES

Administration

3. All project records will be maintained on a daily basis.

4. Reports will be forwarded to the USAAEFA via the most expedient means and as required by current USAAEFA policies.

5. Administrative support from sources outside the USAAEFA will be coordinated through the project officer.

Flight Test Procedures

6. Takeoff for the first flight of the day will normally be scheduled for sunrise. It is anticipated that maintenance, weather, and hours of daylight will only permit two flights per day; however, when conditions permit, additional flights will be conducted. Flight test operations will be conducted on a six-day-week basis. Generally, all sorties will require smooth air. No aircraft configuration changes will be made to the test aircraft after testing commences without the prior approval of the project officer.

Preflight and Postflight Briefings

7. Pre-flight briefings will be held prior to the scheduled testing. Post-flight briefings can be held in conjunction with the preflight briefings or as required. Personnel required to attend these briefings will be designated by the project officer. Items to be covered during the briefings are contained in the USAAEFA Project Officer's Guidebook. Items to be briefed will be added or deleted as required.

Crew Requirements

8. Normal crew for the test aircraft will be two test pilots and one flight test engineer. No passengers/observers will be permitted on the test aircraft during testing except as authorized by the project officer. Sufficient seats and crash restraint systems will be provided for the crewmembers, with the flight test engineer's accommodations providing visual access to cockpit instruments and test instrumentation for data recording.

Chase Aircraft

9. A UH-1H chase aircraft will be used during all artificial icing tests; and during the natural icing tests, at the discretion of the project officer, the chase/rescue aircraft will be airborne or on standby at a designated airfield. The chase aircraft will provide for airborne photographic coverage. The anticipated crew for the chase aircraft is shown below.

Pilot - USAAEFA
Copilot - USAAEFA
Medic (1) - USAF
Firemen (2) - USAF
Photographer - USAAEFA/USAF

TEST SUPPORT

Aircraft Maintenance

10. The test aircraft will be maintained by the USAAEFA during the test program.

Instrumentation

11. Flight test instrumentation will be installed and maintained by the USAAEFA and will have current calibrations during the flight testing. Functional checks will be performed on the test aircraft instrumentation prior to testing to verify proper operation of the instrumentation data package.

Photography

12. Photographic coverage will be used for documentation and monitoring of the flight test program. Photographic coverage will include 16mm color movies, 35mm color slides, and color and black and white stills. USAAEFA will provide personnel, equipment, film and processing for all photographic coverage.

Test Data

13. All data collected during the icing tests will be the property of the United States Army. Data processing techniques will be reviewed and priority for reduction of data will be established by the project officer.

APPENDIX E. SAFETY

GENERAL

1. Safety is the primary consideration during the conduct of this test and will be maintained at the highest possible level throughout the testing. Human and materiel resources will be protected and conserved by early identification, evaluation, and correction of any system or flight hazard which may appear during the test. The USAAEFA safety officer will act as a monitor on this test and will provide guidance and advice where required. Parachutes will be worn by the crews of the test aircraft and the HISS. Test team crewmembers will get a cold weather survival briefing.

TEST LIMITATIONS

2. The conduct of this test requires specific test limitations. These limitations will be based on the requirements set forth in the airworthiness release, the operator's manual, past icing test experience (ref 1 and 2, app A), and a thorough analysis of the test data.

TEST SITE

3. Testing will be conducted at St. Paul, Minnesota. A safety survey has been performed and will be reviewed and updated by the project officer prior to testing. A chase helicopter with adequate crash rescue personnel and equipment will be required for all artificial icing test flights. Additionally, all testing will be conducted over terrain suitable for an emergency landing. A chase/rescue helicopter, at the discretion of the project officer, will be airborne or on standby at a designated airfield. Positive radar coverage will also be required for all test flights into natural icing conditions.

AIRCRAFT

4. The test helicopter will be inspected by the project pilot to ensure ingress/egress routes are not impaired by test equipment installation and that helicopter records are up to date. Maintenance procedures for both the test and support helicopters will be according to established procedures.

RISK LEVELS

5. The following risk levels were used to evaluate specific tests to be conducted:

a. Risk Level I - High probability of damage to equipment and/or injury to personnel

b. Risk Level II - Moderate probability of damage to equipment and/or injury to personnel

c. Risk Level III - Low probability of damage to equipment and/or injury to personnel.

6. The risk levels assigned to the test are as follows:

Artificial icing	II
Natural icing	II

7. Tests designated as Risk Level II require chase/rescue coverage with firemen and medic crew. During natural icing tests, the chase/rescue helicopter, at the discretion of the project officer, will be airborne or on standby at a designated airfield. During aircraft shutdown, after flight in the icing environment, all ground personnel will be cautioned to remain clear of the aircraft until the rotor has come to a complete stop, in order to prevent personal injuries due to ice shedding.

8. If, during the conduct of this test, a situation arises which increases the risk level, completion of the test will be delayed until a thorough review is completed by the USAAEFA project officer and the safety officer.

APPENDIX F. TEST SCHEDULE

1980 TIME FRAME

JAN: 6 13 20 27 · FEB: 3 10 17 24 · MAR: 2 9 16 23 30 · APR: 6 13 20 27 · MAY: 4 11 18 25

EVENT	1980 TIME FRAME
Black Hawk arrival at St. Paul, MN	7 Jan
Artificial icing test	7 Jan - 31 Mar
Natural icing test	21 Jan - 4 Apr
Data reduction and analysis	7 Jan - 2 May
Report preparation	4 Feb - 9 Jun
Advance report submitted	9 Jun △

APPENDIX G. SUPPORT REQUIREMENTS

GENERAL

1. The following requirements are based on the USAAEFA's anticipated needs to conduct the approximately 45 flying hours of icing tests. The USAAEFA will maintain both aircraft and instrumentation systems (app D). Other organizations providing support include the contractor; Edwards AFB, CA (EAFB); USARASF, St. Paul (STP); and the Minnesota National Guard (MN NG).

2. The contractor will provide the following personnel:

   Aircraft technical representative
   Deice system technical representative
   Engine technical representative
   Aircraft maintenance personnel (2).

3. The USAAEFA will provide the following personnel :

   Project officer (1)
   Test pilot (2)
   Flight test engineer (1)
   Aircraft maintenance personnel (3)
   Data systems/instrumentation personnel (3)
   Other support personnel as required.

4. Edwards AFB will furnish two firemen and one medic.

5. The MN NG will provide heated hangar space for the HISS.

6. The USARASF, STP, will provide the following:

   Chase aircraft, UH-1H
   Heated hangar space
   Office space.

APPENDIX H. COST ESTIMATE

1. The following cost estimate is for the USAAEFA direct costs only, assuming the UH-60A is the only aircraft involved in an icing program. This cost estimate does not include the costs of other agencies:

Civilian overtime	$ 27,072
Civilian hazard pay	3,375
Travel cost	12,884
Per diem	107,724
Rental cars	8,530
Photographic cost	3,425
Flying hour cost	78,875
Miscellaneous cost	45,500
Uncorrected total	$287,385

2. This cost estimate was established on the same basis as above with the exception that support costs are shared with two other icing test programs:

Civilian overtime	$ 4,988
Travel cost	10,324
Per diem	58,598
Rental cars	8,100
Photographic cost	2,000
Flying hour cost	48,695
Miscellaneous cost	36,192
Uncorrected total	$168,907
5% inflation factor	8,445
Grand total	$177,352

APPENDIX I. INSTRUMENTATION

INSTRUMENTATION

1. In addition to standard aircraft instruments, calibrated instrumentation will be installed on the test aircraft and maintained by the USAAEFA. Data from the cockpit instrumentation will be recorded on flight data cards, and the specially installed instrumentation system will record pulse code modulated (PCM) and frequency modulated (FM) data on magnetic tape.

2. The ship's system instrumentation and test instrumentation are listed below.

Pilot/Copilot Panel

Airspeed (ship's system)
Altitude (ship's system)
Altitude (radar)
Rate of climb/descent (ship's system)
Free air temperature (ship's system)
Free air temperature (sensitive)
Rotor speed (sensitive)
Engine torque (both engines)
Engine turbine gas temperature (both engines)
Engine gas generator speed (both engines)
Engine power turbine speed (both engines)
Stabilator position (sensitive)
Control Position:
- Longitudinal
- Lateral
- Directional
- Collective

Icing rate (ship's system)

Digital (PCM) Data Parameters

Airspeed
Altitude (pressure)
Free air temperature
Engine torque (2)
Engine fuel flow rate (2)
Engine fuel temperature (2)
Engine measured gas temperature (2)
Engine gas generator speed (2)
Main rotor speed
Longitudinal stick position
Lateral stick position
Directional control position
Collective position
Longitudinal SAS actuator position
Lateral SAS actuator position
Directional SAS actuator position
Pitch attitude

Roll attitude
Yaw attitude
Pitch rate
Roll rate
Yaw rate
Stabilator position
Engine anti-ice bleed air pressure (2)
Engine anti-ice valve position (2)
Engine inlet duct anti-ice valve position (2)
No. 1 generator voltage
No. 1 generator current
No. 2 generator voltage
No. 2 generator current
APU generator voltage
APU generator current
Deice system electrical voltage (main and tail)
Deice system electrical current (main and tail)
Windshield voltage
Windshield current
Ice rate (deice system detector) (DC voltage to cockpit meter)
Ambient air temperature (deice system)
Time code
Event and status words
Deice controller "ON" status
Engine inlet surface temperature (2)
Main and tail rotor 1/Rev

Analog (FM) Data Parameters

Main rotor forward long stationary star load
Main and tail rotor 1/Rev
Laser nephalometer output
Vibration
- Main rotor transmission (3)
- Tail rotor gearbox (3)
- CG (3)
- Pilot seat (3)
- Copilot seat vertical and longitudinal
- Stabilator tip left, vertical and longitudinal
- Stabilator tip right, vertical and longitudinal
- No. 1 and No. 2 engine exhaust frame, vertical and horizontal
- Main transmission support beam left (3)
- Main transmission support beam right (3)

3. In addition to standard aircraft instruments, calibrated instrumentation is installed aboard the CH-47C spray aircraft. This instrumentation will be used to establish the desired test conditions during the icing flights and is listed below.

Airspeed
Altitude
Free air temperature
Dew point
Water flow rate
Bleed air pressure
Radar distance (separation between test and spray aircraft)

DISTRIBUTION

Assistant Secretary of the Army (R&D), Deputy for Aviation	1
Deputy Chief of Staff for Research, Development, and Acquisition (DAMA-WSA, DAMA-RA, DAMA-PPM-T)	4
US Army Materiel Development and Readiness Command (DRCPM-BH, DRCDE-DW-A, DRCQA)	4
US Army Aviation Research and Development Command (DRDAV-DI, DRDAV-EO, DRDAV-EG)	11
US Army Training and Doctrine Command (ATCD-CM-C)	1
US Army Test and Evaluation Command (DRSTE-TO, DRSTE-CT, USMC LnO)	3
Research & Technology Laboratory/Aeromechanics (DAVDL-AL-D)	2
Research & Technology Laboratory/Propulsion (DAVDL-PL-D)	2
Research & Technology Laboratories/Applied Technology Lab (DAVDL-ATL-D, Tech Library)	1
US Army Aeromedical Research Laboratory (SGRD-UAC)	1
US Army Infantry School (ATSH-TSM-BH)	1
US Army Aviation Center (ATZQ-D-MT)	1
US Army Aviation Test Board (ATZQ-OT-C)	2
US Army Aviation School (ATZQ-AS)	1
US Army Aviation Development Test Activity (STEBG-CO-T, STEBG-PM, STEBG-CT)	5
US Army Safety Center (IGAR-TA, IGAR-Library)	2
US Army Transportation School (ATSP-CD-MS)	1
US Army Logistics Management Center (ATCL-M)	1
US Naval Air Test Center	1

US Army Materiel Systems Analysis Activity (DRXSY-CM)	1
Defense Documentation Center (DDC-TCA)	2