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Documentation of Ice Shapes Accreted on the Main Rotor of a UH-1H Helicopter in Level Flight

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SUMMARY

Icing tests were conducted on a UH-1H helicopter in level flight behind a spray tanker near Duluth, Minnesota, during the winter of 1983-84 as part of the joint NASA / Army HIFT program. On landing, the ice formations on the main rotor were documented by casting a set of ten-inch molds on the blade using a Dow-Corning silicone rubber compound which was initially liquid at sub-freezing temperatures. Such documentation was accomplished for eight flights in which the temperature ranged from -11°C to -22°C and the in-cloud flight times ranged from 5 to 9 minutes.

INTRODUCTION

The joint NASA/Army Helicopter Icing Flight Test (HIFT) Program has been outlined in reference 1 while the hover documentation phase and the subsequent dry wind tunnel test program have been described in some detail in references 2 and 3. The techniques previously developed were applied to phase 2, in attempting to document the ice formations accreted on a UH-1H helicopter in level flight behind the Army CH-47C spray tanker. This phase of the program was conducted near Duluth, Minnesota, during the months of February and March, 1984, and the details are presented in reference 4. The documentation of the ice formations on the main rotor was performed by personnel from FluiDyne Engineering Corporation, Minneapolis, and that aspect has been reported in reference 5.

This report summarizes the ice documentation; a dry wind tunnel test program to determine the section characteristics by using castings from the molds will follow, as for the hover phase.

TEST FACILITIES AND PROCEDURES

The focal point of the operation was the Air Force Base at the Duluth Airport, Minnesota, with the aircraft and operational personnel from the U.S. Army Aviation Engineering Flight Activity (USAAEFA), and the documentation equipment and personnel from the FluiDyne Engineering Corporation, Minneapolis. The test aircraft was a UH-1H helicopter equipped with instrumentation to record the performance; the spray was supplied by a CH-47C helicopter equipped with a water tank and a retractable spray bar; a U-21 aircraft was used to measure the humidity, the liquid water content and the droplet size in the cloud; a UH-1H helicopter flew chase to provide photographic coverage and emergency support. The equipment for molding the ice formations was that assembled for the hover test phase a year earlier. FluiDyne also supplied a scissor-lift van (Figure 1) with a work area of 7 feet by 10 feet and the other miscellaneous support equipment.

The molding compound, as for the hover experiments, was Dow-Corning silicone rubber compound DC3110, diluted with Dow-Corning DC200 silicone oil and Catalyst number 4. This was poured into the mold-boxes (reference 2) which were fixed to the rotor blade after the aircraft had landed and the rotor was stopped (Figure 2).

A project engineer on the hover program, Mr. Rory Harding of Hovey and Associates, Ottawa, assisted in the initial test run to familiarize the FluiDyne personnel with the molding technique.

RESULTS AND DISCUSSION

As with the hover phase of the HIFT program, the level flight case was regarded as a feasibility study and the degree of success achieved can be attributed to the careful perseverence of all those involved. A variety of problems were overcome and these are described in references 4 and 5; at the beginning of the flight tests, the possibility of molding any significant amount of rotor ice after the helicopter had landed was uncertain and so the first flights were regarded as tentative as far as documentation was concerned. However, some to most of the ice formations were successfully molded for eight flights and the pertinent information has been assembled in the Table I. The various details of each flight have been recorded in reference 5.

Figures 3 and 4 show the results from two such flights (G and H) for which the reference data are included in the Table I. The spanwise distributions of ice thickness have been plotted in Figure 5.

The differences in shapes from those of the hover case are obviously considerable by comparison with reference 3; these differences may be due to the fact that, although the hover is an almost steady-state condition, forward flight presents an unsteady flow field to any section, both in speed and attack angle. Figure 6 shows typical excursions for the same four sections that were treated in hover, with a full excursion occurring every revolution. These variations, particularly in attack angle, may prevent the kind of formations observed in hover. On the other hand, the combinations of time and weather conditions may have produced some erosion of both detail and shape. In an attempt to answer the last question, the in-flight performance measurements were bypassed for flight H and the aircraft brought to the documentation site as quickly as possible. It was noted that the ice formation and condition were quite similar to those of the other flights; however, the differences are not small and may be attributed only in part to the flight conditions.

A wind tunnel test program is planned for at least one flight from the level-flight phase in a manner similar to that conducted for the hover phase. A study of Figure 5 suggests that such a program must should require a much larger data base than that generated for a hover flight and that some attempt should be made to acquire unsteady data, particularly if the steady-state tests indicate a stall onset at the higher attack angles.

However, the regularity of the shapes as illustrated in Figures 3 and 4 suggests that airfoil analysis codes might be used to aid in determining the aerodynamic characteristics. The combination of code application together with a selected set of points in wind tunnel tests for comparison to "tune" the code for this situation, especially for drag, is proposed as the most effective (and most economical) technique for obtaining a useable data base.

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4. Abbott, W. Y.; Lockwood, R. A.; Linehan, J. L.; and Todd, L. L.: Evaluation of UH-1H Level Flight Performance Degradation Caused By Rotor Icing. USAAEFA Report No. 83-23, July 1984.

5. Hanson, M.K.: Documentation of Ice Accretion Shapes from Helicopter Icing Flight Tests at Duluth, Minnesota During February and March, 1984. FluiDyne Engineering Corporation Report.

TABLE 1

SUMMARY OF FLIGHT AND MOLD DATA

Run Number	A	B	C	D	E	F	G	H
Date	2-27-84	2-29-84	3-1-84	3-2-84	3-6-84	3-7-84	3-8-84	3-9-84
Time of Flight	1000-1130	1050-1200	1045-1145	0930-1045	1335-1445	0830-0930	0830-0930	1050-1130
Time in Cloud (minutes:seconds)	5:20	5:00	5:00	6:35	8:00	8:40	9:10	8:00
Time Cast	1200	1230-1245	1215-1230	1110-1115	1515-1600	1020 & 1515	1000	1200
Time of Initial Set	1300	1400	1355	1245	1700	1145 & 1630	1130	1330
Time Molds Removed	1430	1530	1520	1445	1900	1830	1345	1445
Temperature, In-Flight, °C	-12	-13	-14	-11	-21	-19	-22	-21
Temperature, Landing, °C	-2.2	-5	-4	-9	-15.7	-18	-14.5	-8
Weather	bright sun	bright sun	bright sun	bright sun	bright sun	light haze	light haze	bright sun
Relative Humidity, %	-	60	23	55	55	70	70	70
Liquid Water Content, gm/m^3	0.5	0.5	0.5	0.47	0.5	0.5	0.5	0.5
Particle Size, µm	30	38	38	35	42	65	43	64
Amount of Base Material, gm	5000	7500	7500	7700	9500	7000	10000	10000
Amount of Oil, gm	555	832	832	855	1055	778	1111	1111
Amount of Calalyst, gm	33.3	50	50	51	63.5	53	70	70.5
Number of Molds	3	5	5	5	6	4	6	6

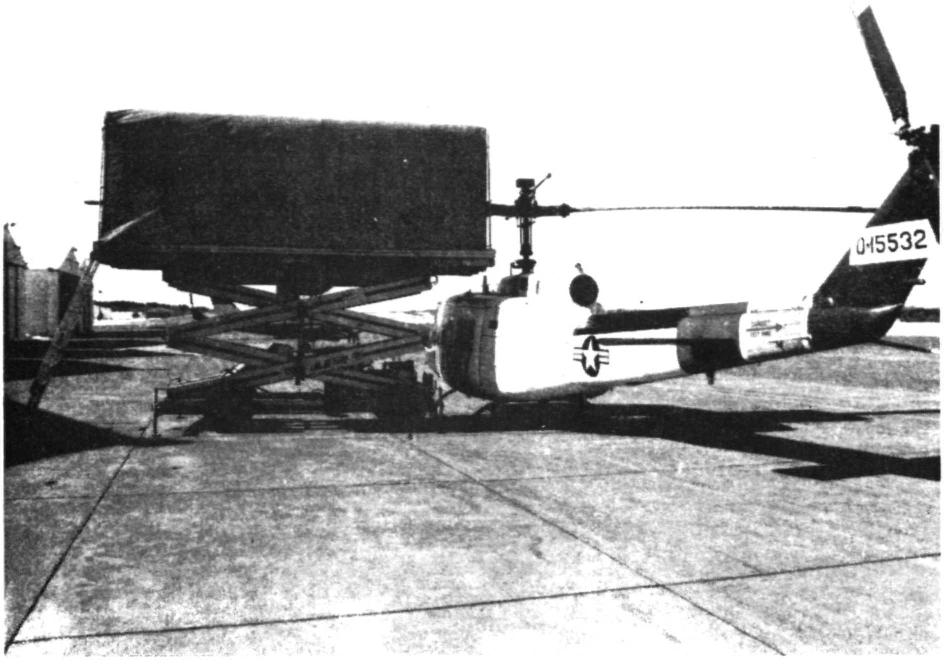

FIGURE 1. LIFT PLATFORM DURING CASTING

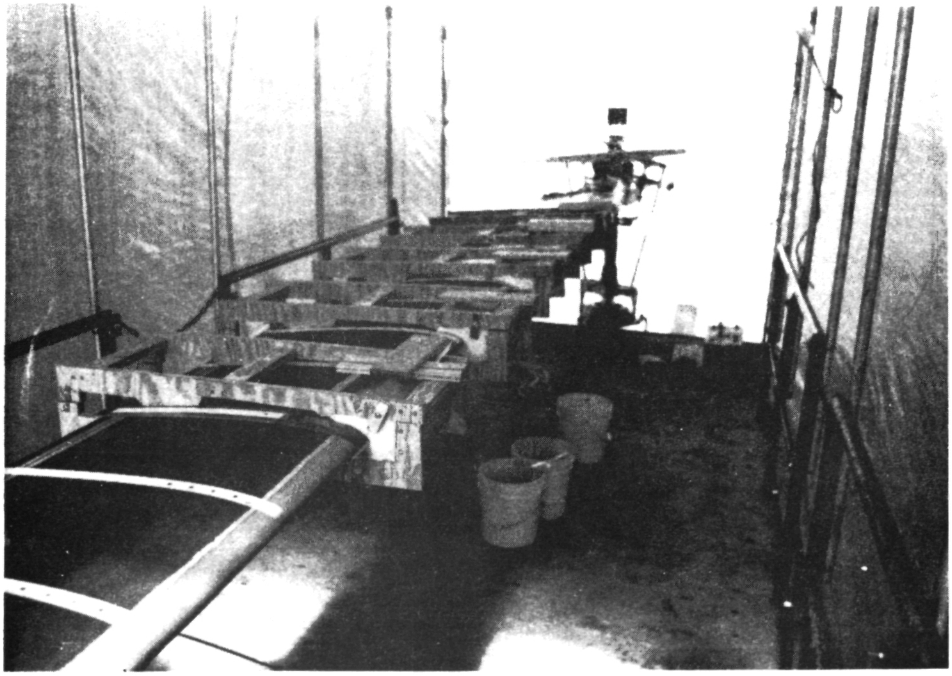

FIGURE 2. ROTOR BLADE AND MOLDING BOXES

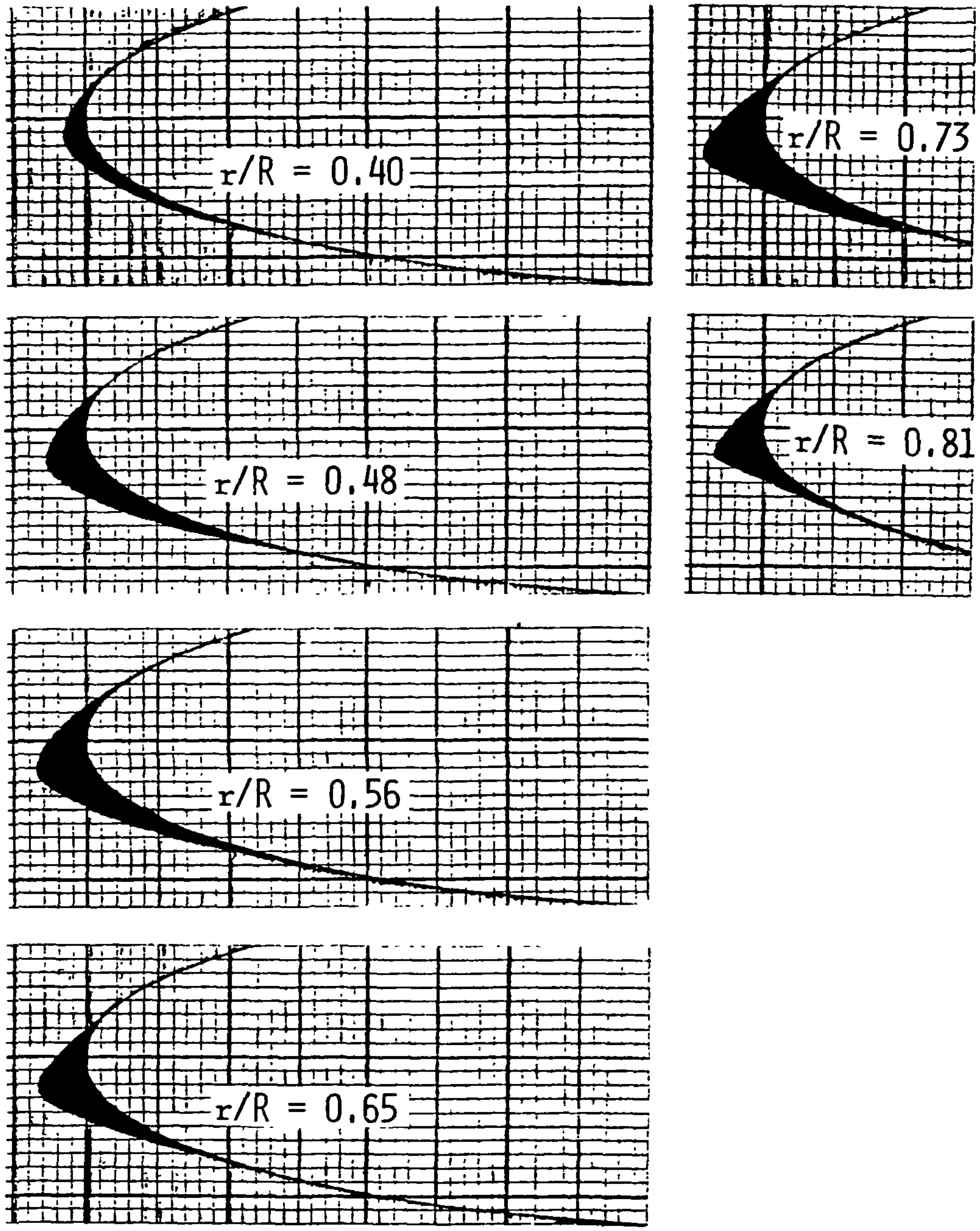

FIGURE 3. PROJECTIONS OF MOLDS OF ICE ACCRETIONS IN LEVEL FLIGHT (FLIGHT G)

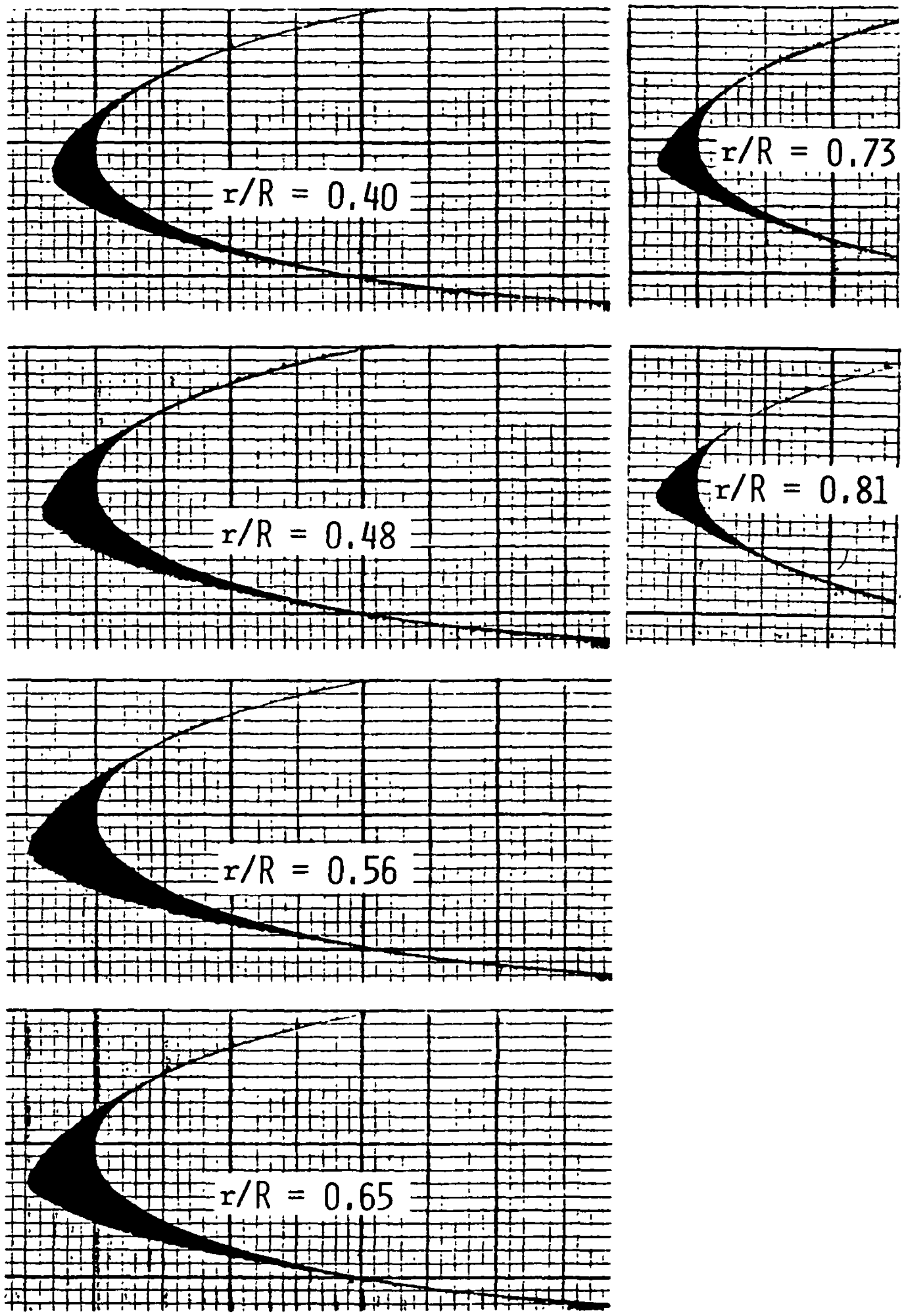

FIGURE 4. PROJECTIONS OF MOLDS OF ICE ACCRETIONS IN LEVEL FLIGHT (FLIGHT H)

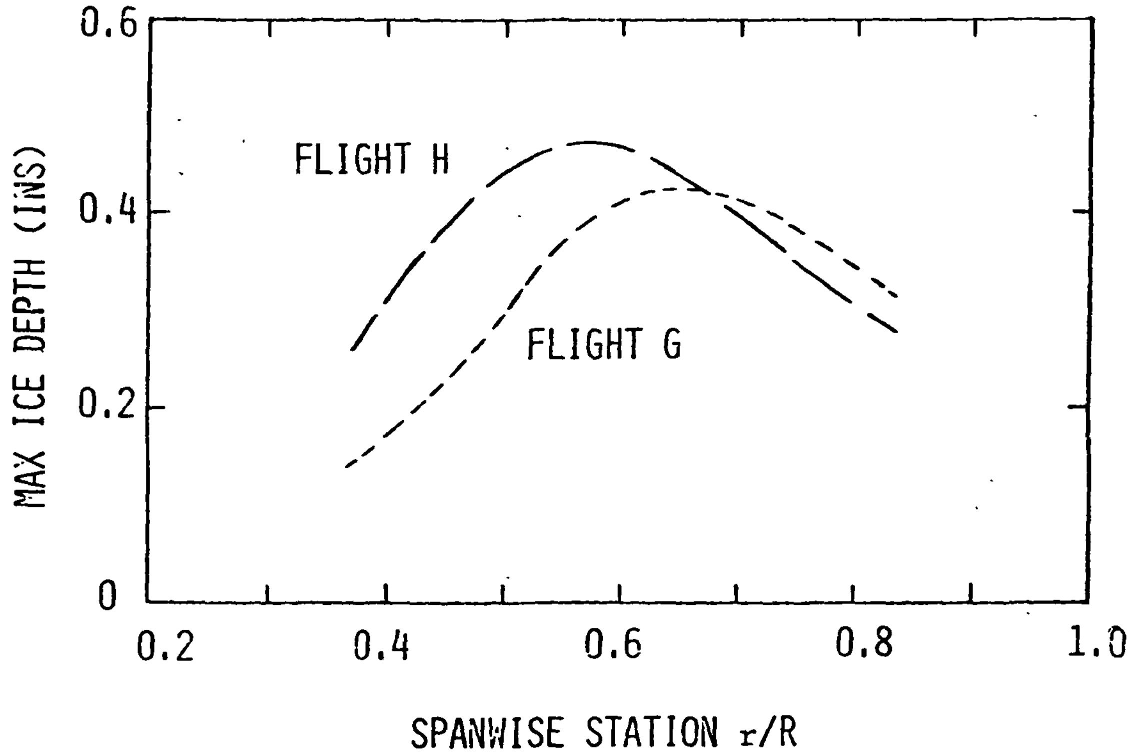

FIGURE 5. DEPTH OF ICE ACCRETED IN LEVEL FLIGHT (FLIGHTS G AND H)

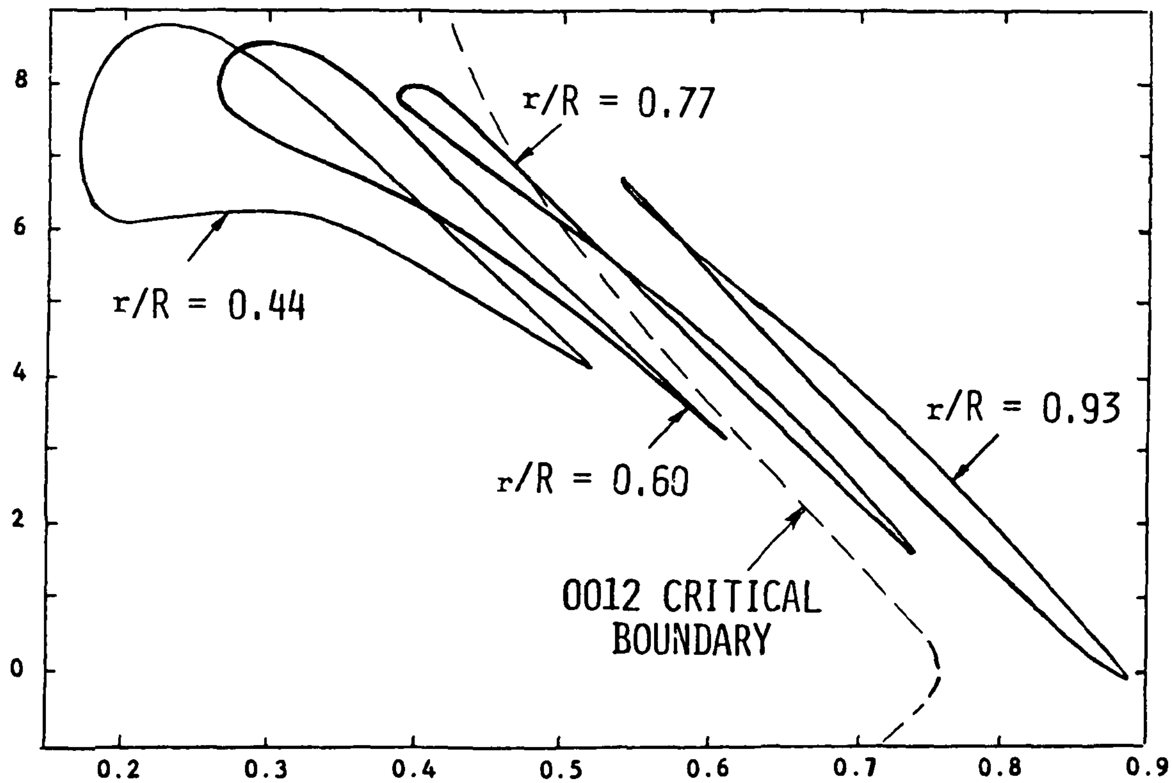

FIGURE 6. TYPICAL RANGES OF CONDITIONS EXPERIENCED BY FOUR SELECTED BLADE STATIONS FOR THE LEVEL FLIGHT CASES.

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16 Abstract
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