SEG-TR-65-53

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EVALUATION OF RAIN-EROSION-RESISTANT MATERIALS TO PROTECT THE HH-43B/F HELICOPTER ROTOR

MATTHEW H. CHOPIN

TECHNICAL REPORT SEG-TR-65-53

AUGUST 1966

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SYSTEMS ENGINEERING GROUP
RESEARCH AND TECHNOLOGY DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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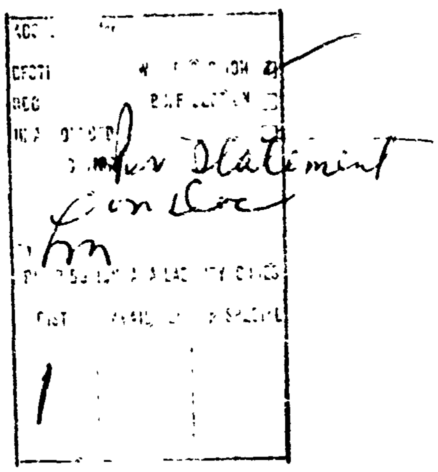

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FOREWORD

This report was prepared as the result of an in-house program to select a suitable material to protect the servo-flap of the HH-43B/F helicopter rotor system from rain erosion. Work was initiated by the HH-43B/F Helicopter System Program Office under System No. 976Z. The test report was prepared by Mr. M. H. Chopin of the V/STOL Propulsion Branch, Systems Engineering Group, which provided engineering support to the project office. Test facilities were provided by the Propulsion Branch of the AF Aero Propulsion Laboratory. Both support organizations are under the Research and Technology Division.

During a subsequent series of tests, the test club separated from the shaft and completely destroyed itself and the spray rig. This report, therefore, also serves to describe the RTD rain erosion test facility in detail and the tests performed on it prior to its destruction.

This report covers work from 30 July 1963 to 26 December 1964.

The report was submitted by the author in August 1965.

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This technical report has been reviewed and is approved.

JAMES G. BARRETT
Technical Director
Directorate of Propulsion & Power
Subsystems Engineering
Systems Engineering Group

ABSTRACT

This report describes the tests of various materials to determine a suitable protective covering for the HH-43B/F helicopter servo-flap leading edge when operating in rain.

Nineteen materials were tested and compared on a rain erosion spray rig in the electric motor whirl stand facility at WPAFB Ohio. Impact velocity varied from 330 to 730 ft per second.

A description of the facility, test procedures, results and recommendations is presented. Photographs of the spray rig and test specimens are also included.

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ILLUSTRATIONS

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SECTION I
INTRODUCTION

Propulsion and lift of the HH-43B/F rescue helicopter are provided by twin, intermeshing, counter-rotating, two-blade rotor assemblies controlled by aerodynamic action of the blade-mounted servo flaps (see Figure 1). The cyclic and collective pitch controls are linked directly to the blade-mounted servo flaps.

The servo flap of the production models of these helicopters is constructed of high-quality spruce and maple wood, birch plywood, and nylon rip-stop cloth, and the leading edge is sprayed with a layer of neoprene rubber over the rip-stop cloth. The primary objective of this test program was to determine a suitable material for protecting the HH-43 B/F helicopter servo-flap leading edge from rain erosion when operating in a rain environment. Typical damage to the servo flaps when operating in rain is illustrated in Figure 2.

Comparative tests of 19 materials were run under the same simulated rain conditions of 2 mm droplets and a water flow rate of 1 inch per hour. During initial tests, which were run at 700 rpm (500 mph tip speed), failure times were found to be very rapid. Later tests, which were run at varying rpm's from hover to red line tip speeds, produced curves similar to conventional S-N curves and failure times were more meaningful.

Many of the materials tested were known to provide excellent protection when applied over a hard surface. The leading edge of the servo flap for the HH-43 helicopter, however, consists of a spruce core covered with a 1/32-inch 3-ply plywood, which provides a relatively soft surface. This made the selection of a suitable protective material very difficult. The failure of the materials during this test program, therefore, should not reflect upon their usefulness when used under the conditions for which they were intended. Based upon these test results, a material was selected which provided the best protection for the given flight conditions.

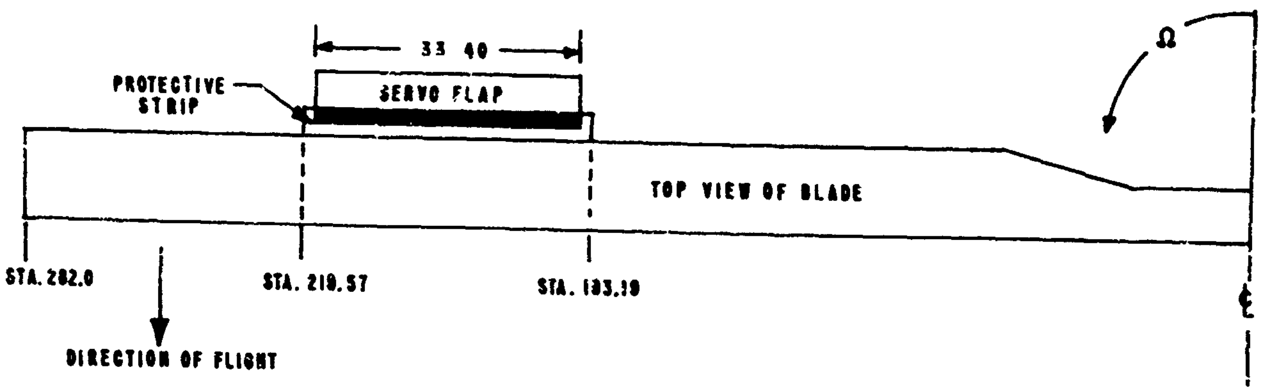


Figure 1. Flap Spanwise Location on HH-43 Helicopter Blade

Figure 2. Typical In-Flight Servo Flap Damage From Operation in Rain

SECTION II

TEST PREPARATION, INSTRUMENTATION, AND EQUIPMENT

Construction of the RTD rain erosion rig resulted from a 1957 study conducted by Cornell Aeronautical Laboratory under Contract AF33(616)-3267. The study concluded the use of the 30,000 HP propeller electric whirl rig (already in existence at Wright-Patterson AFB) was a feasible and economical approach to obtain high-velocity (up to Mach 2) rain-erosion test conditions.

RTD personnel designed and fabricated the 20-foot-diameter test club for use in the test facility. (See Figures 3, 4, and 5.) The test club was a two-blade solid steel section, symmetrical both chordwise and in planform, and having no camber, twist, or pitch. The test samples were attached in a slot machined in each blade tip, and were retained by a combination of a wedge fit of the sample mount and small diameter pins through the sample. (See Figure 6 and 7.)

The circular spray rig system as designed by Cornell contained 16 modified spray nozzles around the circumference of the ring. These nozzles were obtained commercially. The rig was later modified to hold 32 hypodermic needles, 1-1/4 inches long and 0.030 inch inside diameter, to provide the proper droplet size.

Sixteen solenoid valves (2 needles per valve) were installed upstream of the hypodermic needles to provide accurate off-on control of the water flow. (See Figure 4.) These solenoid valves were connected to an electric timer and a common switch which measured water spray "on" time. Pressure at each pair of spray needles was adjusted by a small restriction type valve.

Rain intensities shown in Table I are specified in AFSCM 80-1, Handbook of Instructions for Aircraft Designers (HIAD). The 2 mm droplet size and 1 inch/hour flow rate are equivalent to rainfall classified between "heavy" and "excessive" and represent a world-wide average.

The method used to produce the desired 2 mm droplet size was established during a prior series of tests. Droplets from hypodermic needles of different sizes were photographed as they passed in front of a screen marked off in a millimeter grid. Individual needles were mounted slightly in front of and parallel to the plane of the grid. A camera was mounted in front of the screen with a spotlight positioned on each side. As the spray passed across the grid, the individual droplets were clearly defined and the diameter could be determined by comparing the droplets with the grid in the background. A 0.030 inch ID needle was found to produce a 2 mm droplet consistently. Droplet size could be varied by using different ID size needles.

The desired water flow rate for this test was 1 in./hr; the flow actually exceeded this rate but the exact amount of excess is not known. Measurements indicated that the flow rates ranged from excessive to cloudburst. All tests run on this spray rig were of the comparative type and the time to failure under test conditions is not the same as actual service time.

Before a test was run the water lines, spray needles, filters, and spray frame were cleaned and flushed to remove sediment. Each day the hypodermic needles were cleaned and adjusted for spray impingement. Line water pressure range from 25 to 30 psig. Pressure for individual needle pairs was adjustable at the spray frame. The spray

Figure 3. Closeup View of Damaged Plywood Leading Edge and Peeled Away Nylon Rip-Stop Cloth

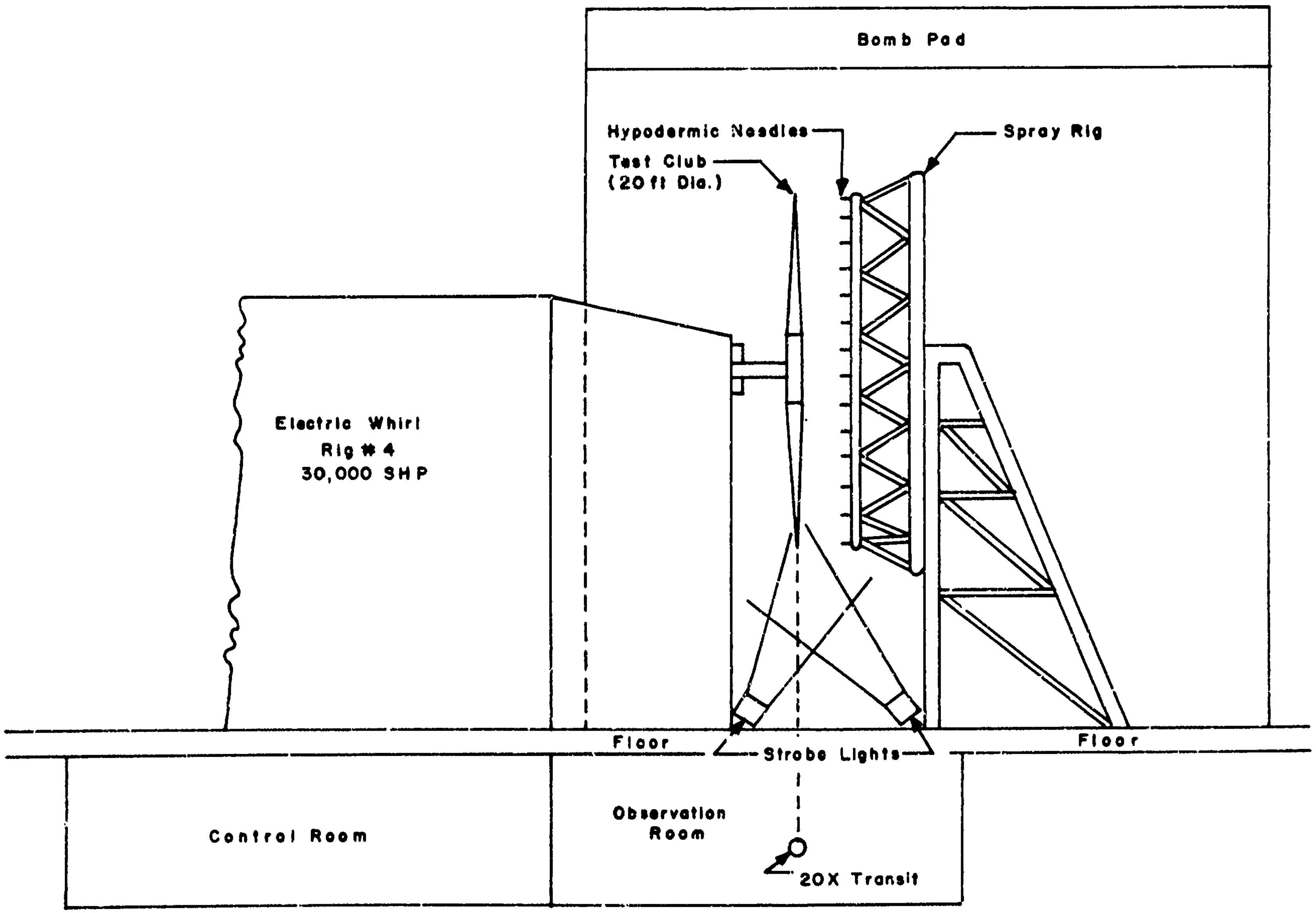


Figure 4a. Photograph and Schematic of RTD 30,000 HP Test Rig With Spray Apparatus, Side View

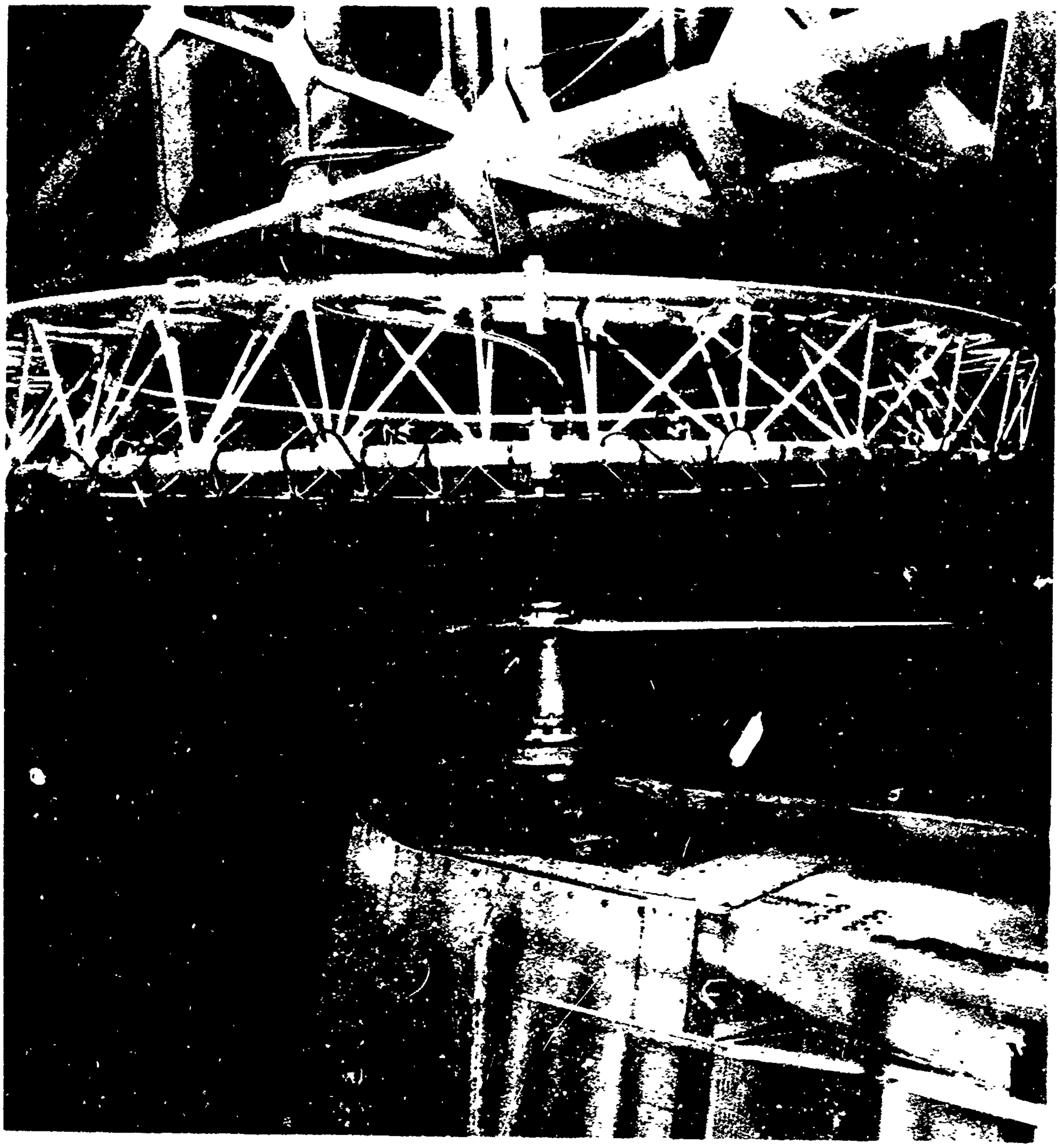


Figure 4b. Photograph and Schematic of RTD 30,000 HP Test Rig With Spray Apparatus, Side View

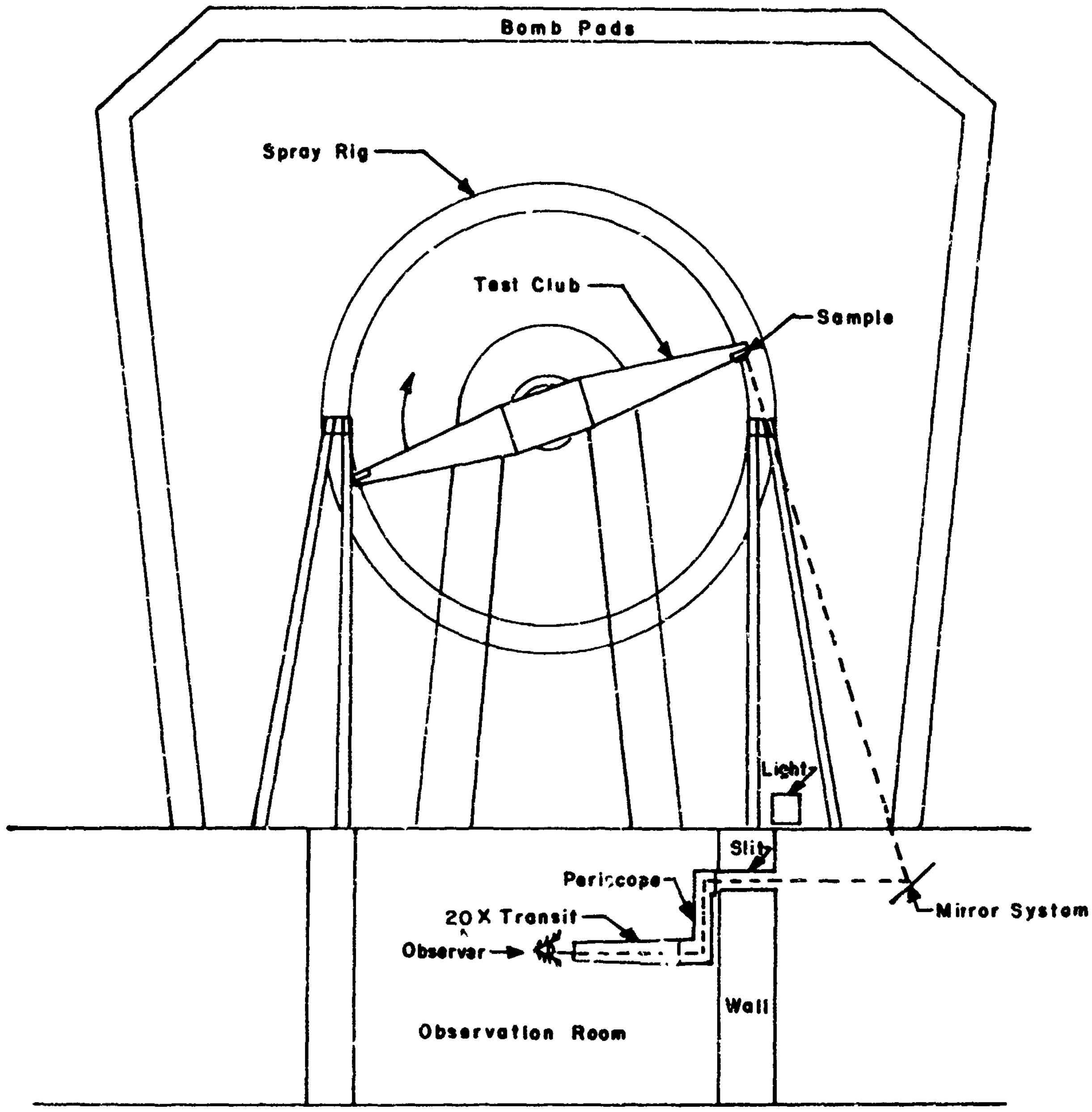


Figure 5a. Photograph and Schematic of RTD 30,000 HP Test Rig With Spray Apparatus, Front View

Figure 5b. Photograph and Schematic of RTD 30,000 HP Test Rig With Spray Apparatus, Front View

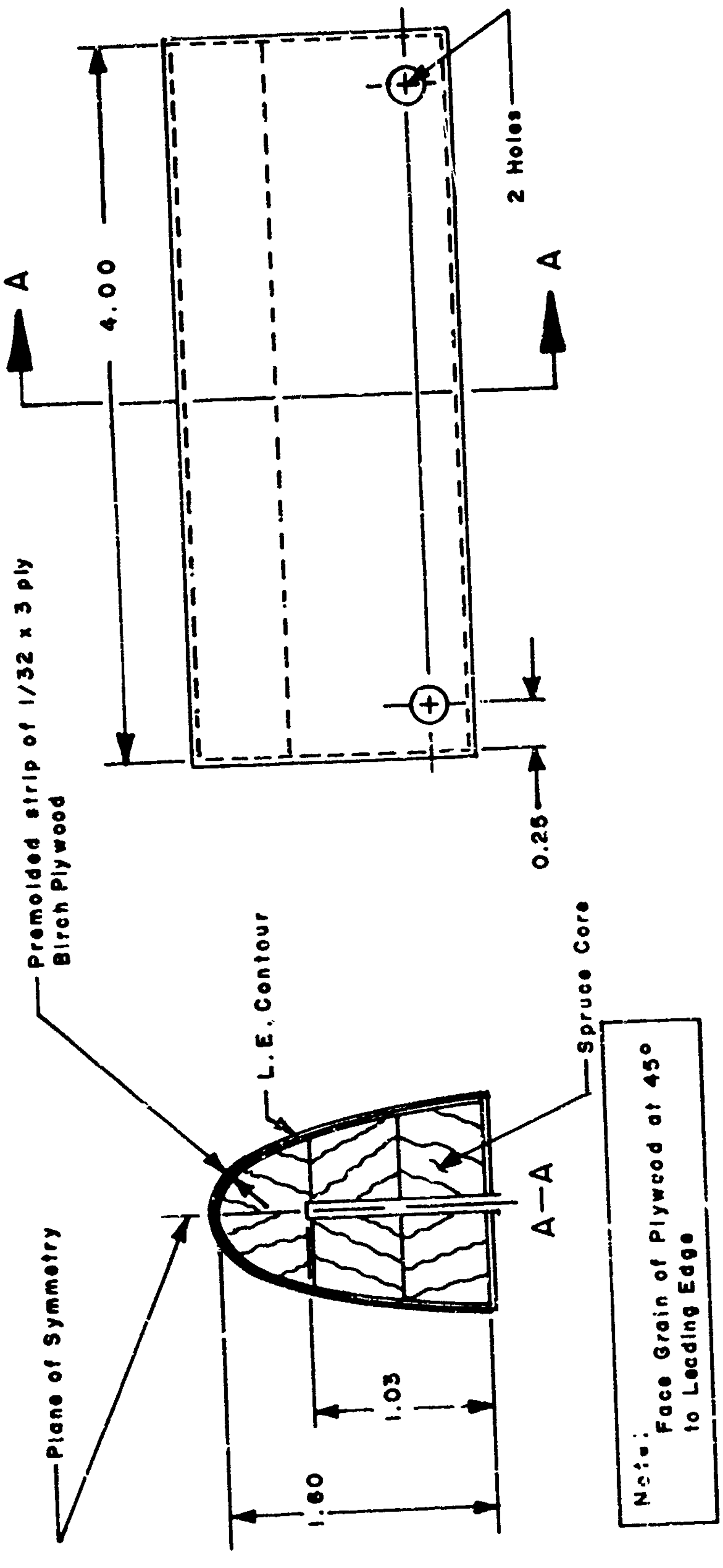


Figure 6. Detail Diagram of Test Sample Block

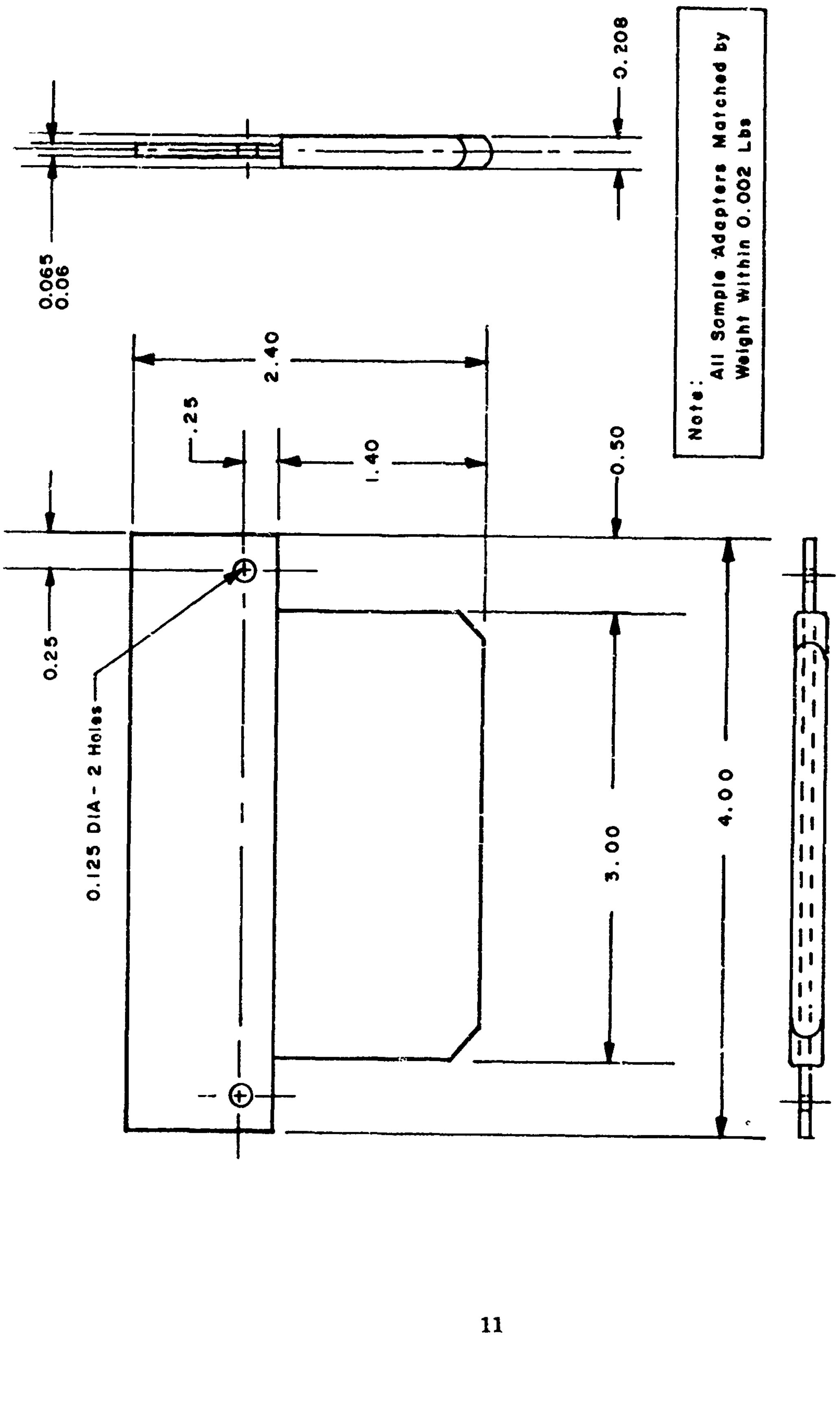


Figure 7. Detail Diagram of Sample Adapter

TABLE I

HiAD RAIN INTENSITIES

Popular Name	Precipitation Intensity		Droplet Diameter	Velocity of Fall	Milligrams of Liquid Water Per Cu. Meter of Air	Grains of Liquid Water Per Cu. Ft. of Air
	mm/Hr	In/Hr	mm	Meters/Se		
Clear	0.00	—	---	—	0.00	—
Fog	Trace	—	0.01	0.003	6.0	0.002
Mist	0.05	0.002	0 10	0.25	55.5	0.024
Drizzle	0.25	0.01	0.20	0.75	92.6	0.04
Light Rain	1.00	0.04	0.45	2.00	138.9	0.06
Moderate Rain	4.00	0.16	1.0	4.00	277.8	0.12
Heavy Rain	15.00	0.59	1.5	5.00	833.3	0.365
Excessive Rain	40.00	1.6	2.1	6.00	1851.9	0.81
Cloudburst	100 to 1000	4.0 to 50.0	3 0	7.00	4000 to 35,000	1.75 to 15.30

(Standard Density at 0°C and 740 mm Pressure) frame, supported by two large steel "A" frames, was positioned parallel to and approximately 30 inches before the plane of the test club.

The 30,000 HP spray rig was equipped with a precision optical viewing system and a high-speed stroboscopic light which allowed continuous viewing of the test club tips at any speed. While a test was being conducted, an observer in the observation room below the rig could watch the progress of a test through a 20X transit and periscope. The observer was protected by a series of bends in the wall. Light was transmitted to the transit by a series of mirrors and prisms. Two stroboscopes were mounted below the blade to provide sufficient light for viewing the test, as shown in Figures 4 and 5. The light was not adequate for taking movies through the transit, however, so only still pictures were made of the spray passing over the sample. (See Figure 8.) Synchronization of the strobe lights, relative to the rotating test club, could be varied during operation, allowing observation of alternate blades during any test run.

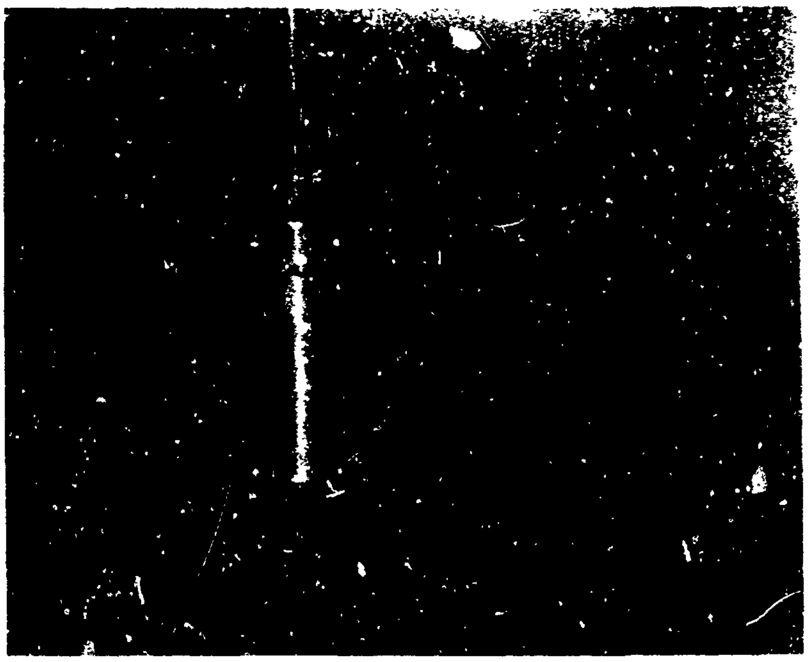


Figure 8. Club Tip, Sample and Water Spray Photographed Through the Transit

SECTION III
TESTING PROCEDURES AND FINDINGS

The test program was divided into three phases -- 1. high speed, 2. variable speed, and 3. comparison tests. The test samples were considered to have failed when the backup material, either wood or fabric, showed through the protective material covering enough for the observer to detect it through the transit.

The test materials were applied over spruce blocks shaped in accordance with Figure 6. Early blocks did not have the molded plywood leading edge and presented a softer backing for the test sample. A sample consisted of a soft spruce block covered with a sheet of pre-molded birch plywood. This was then covered with a sheet of nylon rip-stop cloth and the protective material was then sprayed, bonded, or brushed over the nylon cloth. For exact construction details of particular samples, see the Appendix. None of the materials were aged prior to testing.

1. HIGH SPEED TESTS (500 MPH)

The tip speed selected for this part of the program was 733 ft/sec (equivalent to 500 mph) which was produced by a whirl rig speed of 700 rpm. Various Speeds vs Whirl Rig RPM are shown in Figure 9. 500 mph is generally considered a standard for rain tests as most rain erosion studies in the past have been conducted at this speed.

Samples -101 through -113 (see Appendix) were tested at 733 ft/sec tip speed and the time to failure was noted. All of these materials were applied over the bare spruce blocks and the results are shown plotted in Figure 10.

In general, these high speed tests revealed that the materials failed within a very short time. One sample -101 failed in less than 10 seconds, and no material lasted longer than 12-1/2 minutes. Samples -101 and -103 after only 4 seconds exposure to simulated rain are shown in Figure 11. Stainless steel -105 was expected to provide good protection but it also failed after 4 to 12 minutes of exposure. Typical failures of Stainless steel samples are illustrated by Figure 12 and they appeared to fail from fatigue after the soft spruce back-up material deformed. Typical failure patterns of -109 Neoprene sheet and precured Urethane sheet -111 are illustrated by Figure 13.

After initial tests had shown that rapid failures were primarily due to deformation of the soft spruce back-up material, new blocks were constructed with a "hard" leading edge, duplicating the construction used on the servo flap of the helicopter. This "hard" block consisted of the same spruce core but covered with a 1/32 inch thick 3-ply molded birch plywood leading edge. The significance of this change is apparent from Figure 14. The -103 curve represents the "soft" block and the -115 curve represents the "hard" block - both were covered with the exact same neoprene. The difference between the two curves is attributed to the increased hardness of the backing for the -115 sample.

Analysis of these high speed tests indicated that the test conditions were too severe and unrealistic. The 500 mph tip speed is above the speed of the advancing servo-flap when the helicopter is flying at its 105 knot red line, and therefore would not be encountered in normal operation. The tests did, however, serve to eliminate from further testing several of the materials that had demonstrated low time-to-failure.

2. VARIABLE SPEED TESTS

All samples for this portion of the test were backed by the 1/32 inch 3-ply birch plywood leading edge. Test rig speeds were varied from 465 rpm to 700 rpm, which are equivalent to servo-flap speeds just slightly below hover to above aircraft red line (105 knots), as shown by Figure 9 The majority of the test points were run at a servo-flap speed corresponding to an approximate helicopter speed of 50 knots, 85 knots, and 105 knots. Only two points

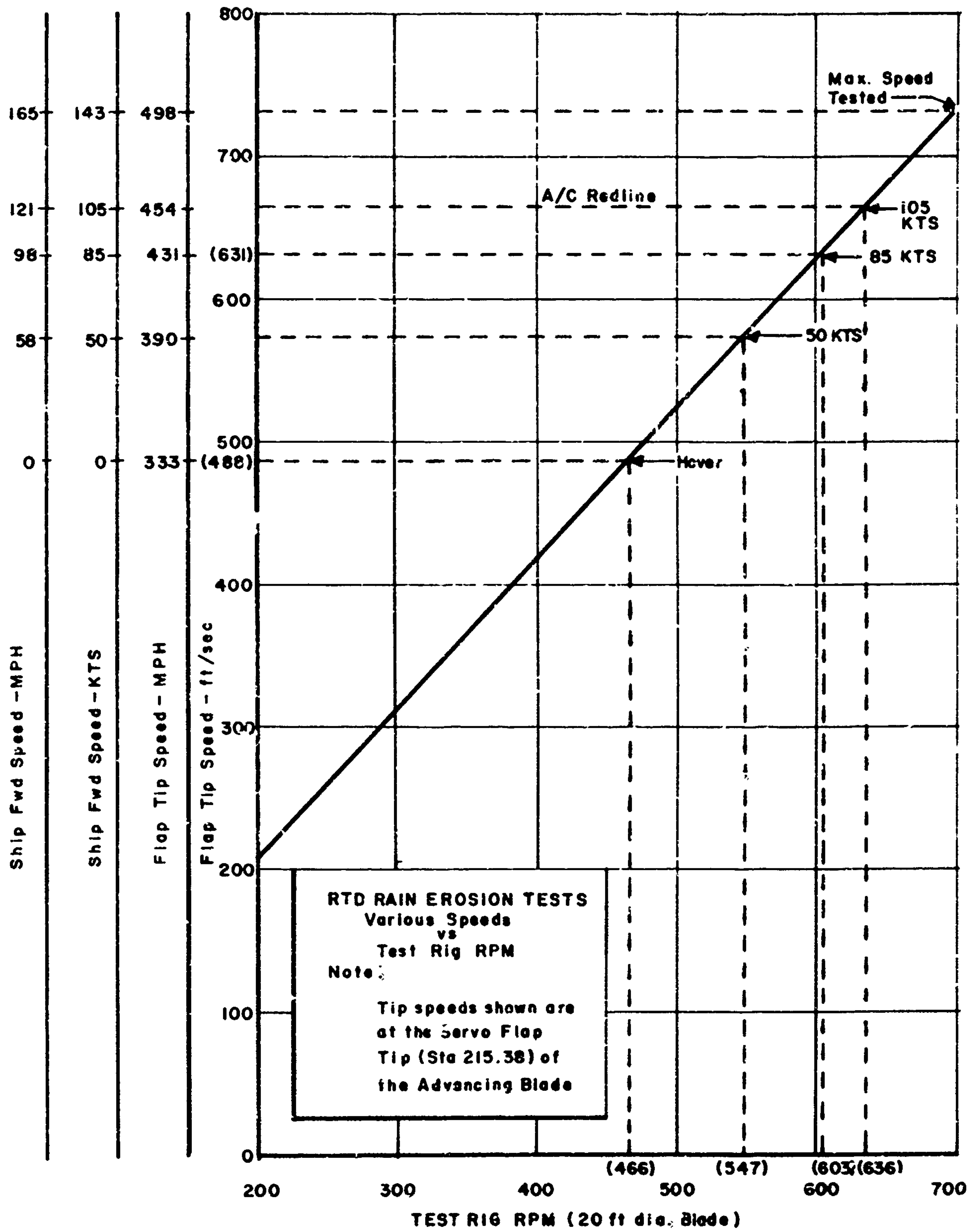


Figure 9. Various Speeds Versus Test Rig RPM

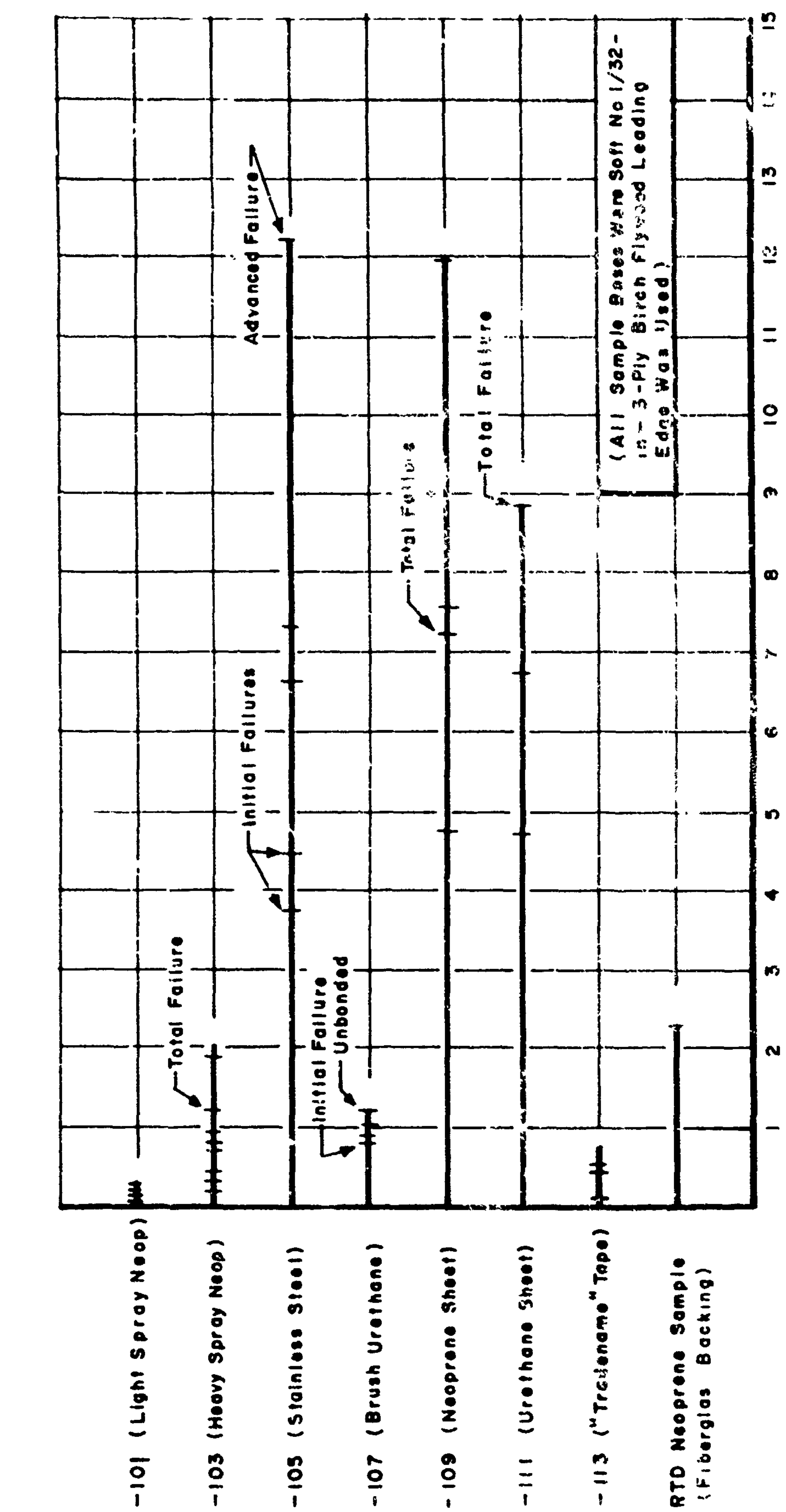


Figure 10. Time-to-Failure for Samples Tested at High Speed (500 mph)

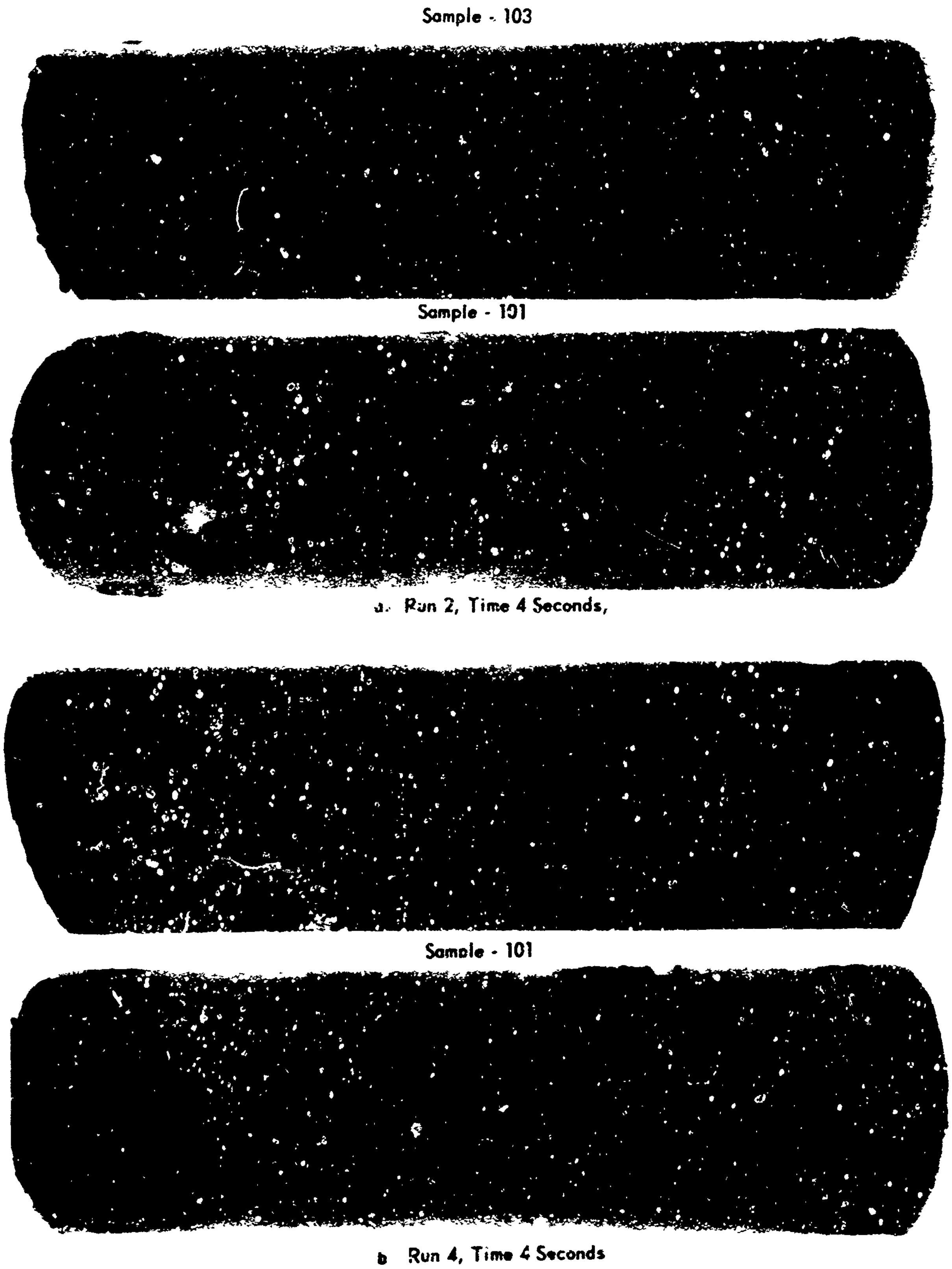
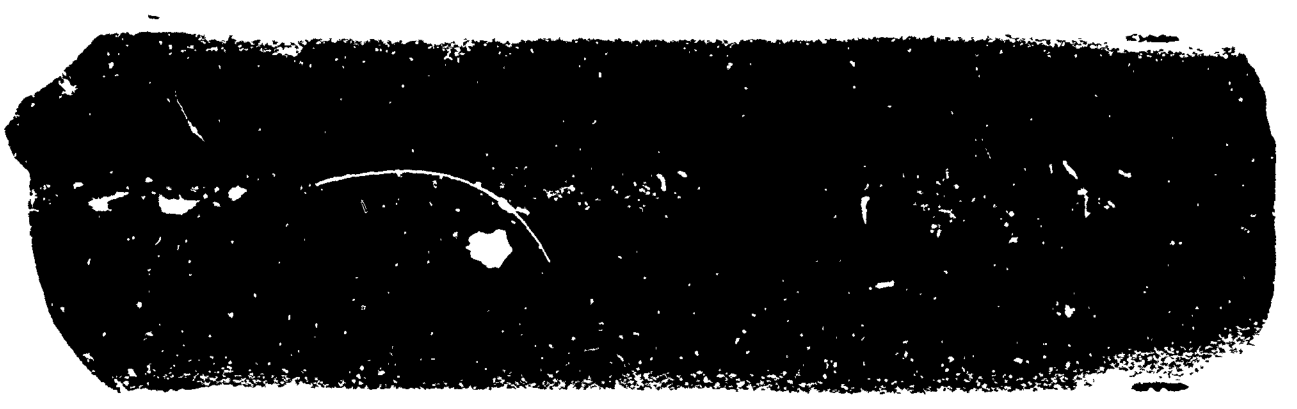


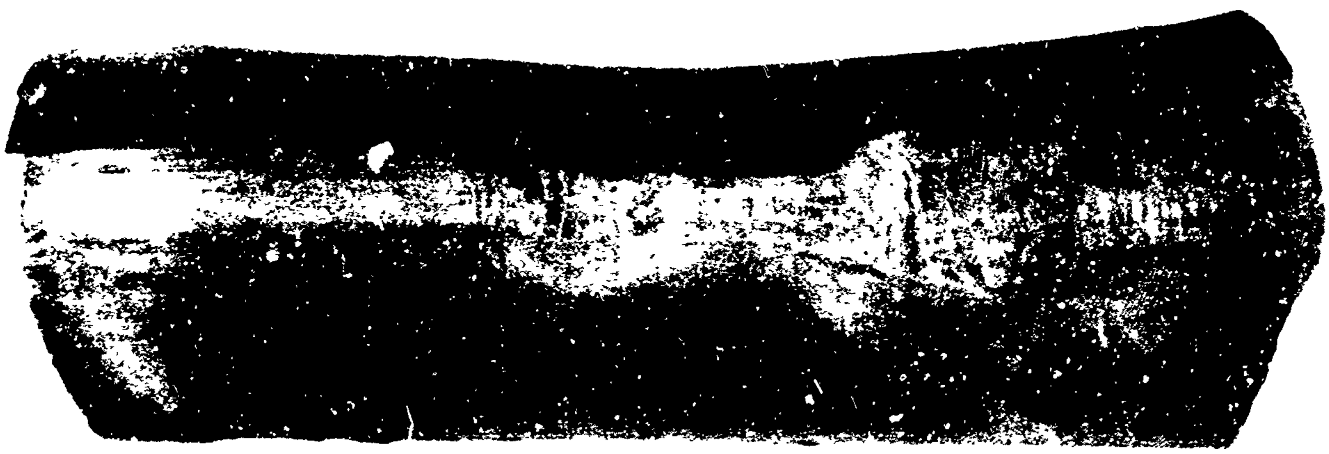
Figure 11. Comparison of Neoprene Samples -101 and -103 Tested at High Speed (500 mph)

a. Sample - 105, No. 6 - - Test Time 6 min. 44 sec.

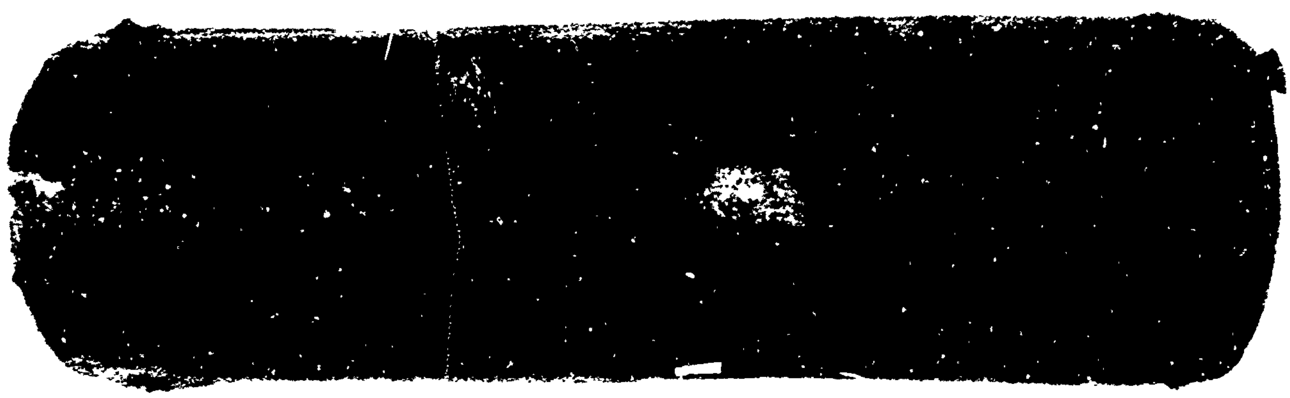


b. Sample - 105 No. 3 - - Test Time 7 min. 25 sec.

Figure 12. Advanced State of Failure of Sample -105 Stainless Steel Tested at High Speed (500 mph)



Sample - 109



Sample - 111

Test Time: 6 minutes 48 seconds

Figure 13. Comparison of Sampie -109 Neoprene Sheet and Sampie -111 Precured Urethane Sheet Tested at High Speed (500 mph)

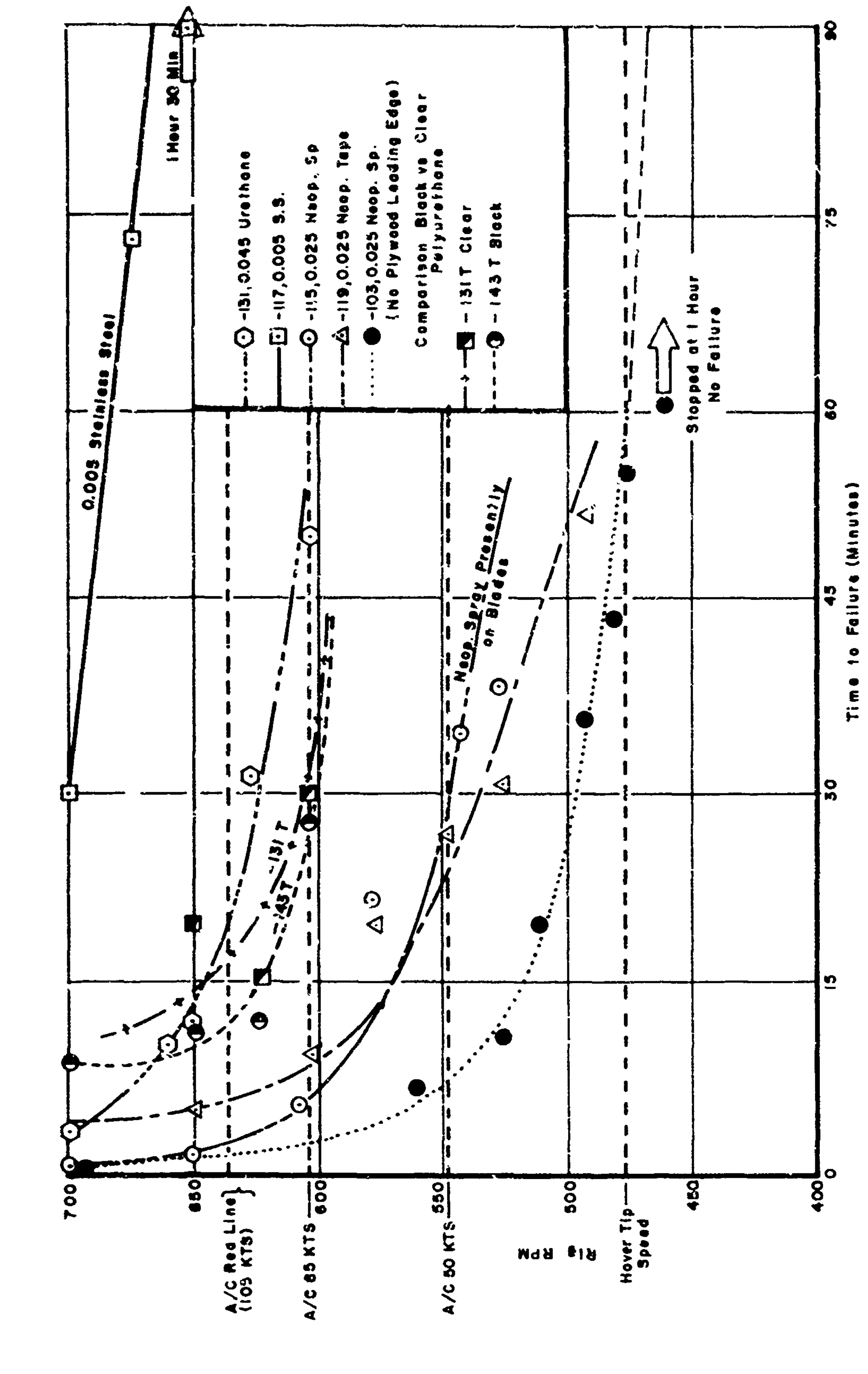


Figure 14. Time-to-Failure for Samples Tested at Varying Speeds

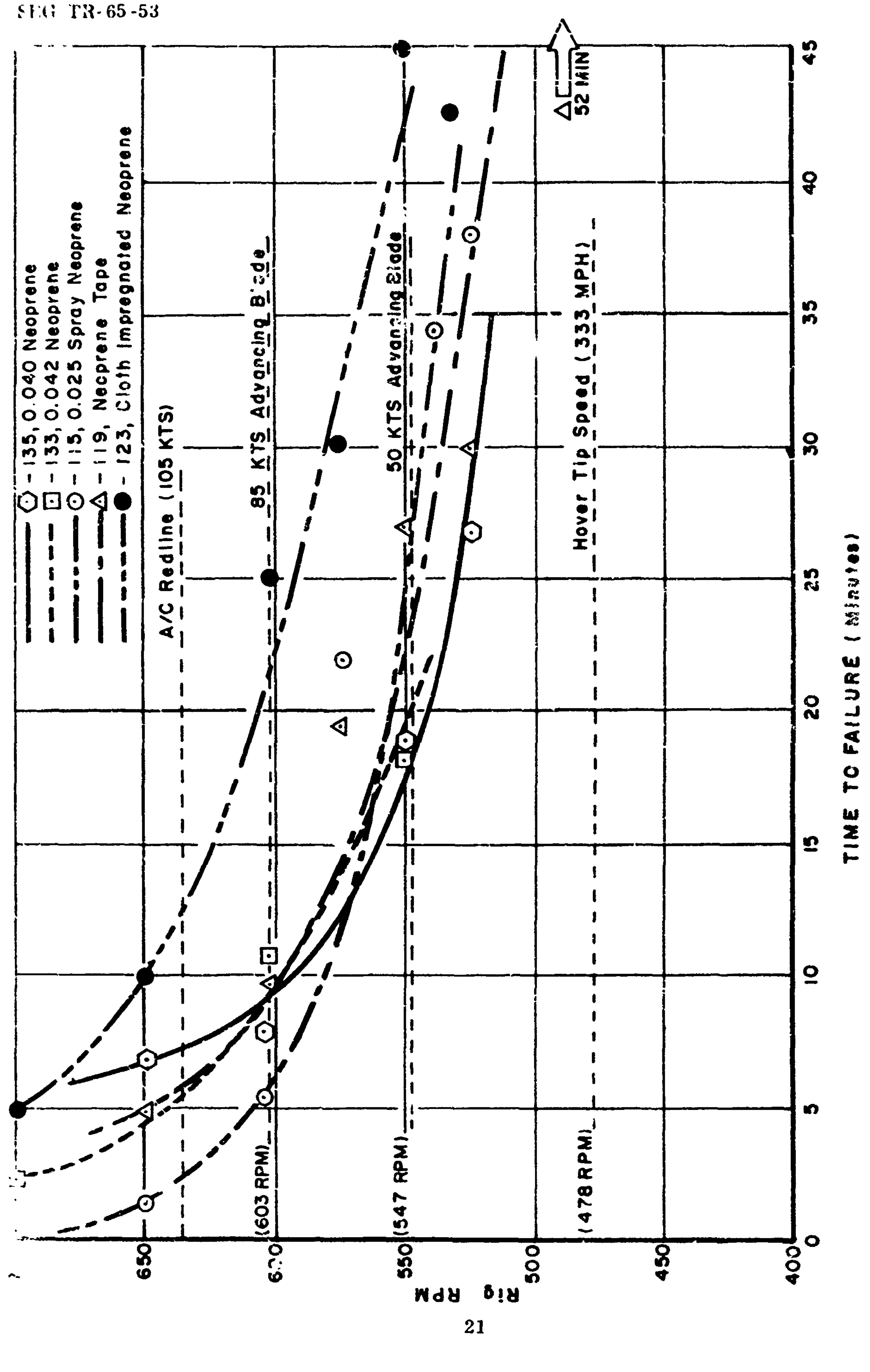


Figure 15. Comparison of Neoprene Samples Tested to Failure

were run at speeds below hover tip speed and these were on Samples -103 and -129.

The significance of varying the test speed is clearly shown in Figures 14 and 15. The curve of a material which shifts to the right with increasing time-to-failure, and upward with increasing speed indicates a material which provides greater resistance to rain erosion. Results shown in Figure 15 indicate good correlation of the various neoprene samples with the exception of sample -123. Sample -123 was a composite construction of cloth impregnated with neoprene, and cannot truly be compared to pure neoprene tapes or sheets.

A significant point is that (excluding the -129 material) no material tested at hover tip speed failed after one hour of testing. Examination of Figures 14 and 15 reveals that for most of the curves a definite boundary or area exists, above which failures occur rapidly and below which the time-to-failure increases or may never fail if the speed is low enough. This might be considered analogous to the alternating load endurance limit and "run out" for metals. The failure curves are shaped very similar to classical S-N curves. Thus, use of these materials on an actual aircraft at hover flap speeds should not result in failures in a reasonable period of time. As the speed of operation increases, the time-to-failure decreases proportional to the damage done. A study of Figures 14, 15 and 21 emphasize this point very well.

The fact that some materials provide better protection at high speeds while others are better at low speeds is illustrated by Figure 15. Allowing for obvious scatter, there is a strong trend for certain materials such as the -115 material to be better at higher speeds, although the curve crosses all the others and is the worst at low speeds.

A comparison of Figures 2 and 16 shows the similarity and degree of duplication of the test sample failures to actual service encountered failures of the -115 material. The mode of failure for both was for water to enter initially formed pin holes in the material and then for the material to separate and peel from the nylon rip-stop-cloth.

The mode of failure of the precured neoprene sheet -119 was such that the leading edge would erode away evenly. If the erosion were allowed to continue to total failure, the neoprene would completely erode along the center and peel from the wood into two parts.

The time-to-failure for the -123 material was the best for all the neoprene types tested; however, its mode of failure was such that it would create a severe airflow disturbance if it were to fail in flight. Figure 19 illustrates this type of failure for a multilayer cloth-neoprene impregnated material.

Sample -129 (Figure 20) was the poorest material tested, with failures occuring below the hover flap speed as shown by Figure 21. The material was very brittle and portions of it would chip and crack off after only short periods of exposure to water.

Figure 21 shows the extremes of protection offered by the various materials tested. Depending on the speed of operation required, a choice of several materials is available. For an impact velocity of 300 mph, a neoprene material would be sufficient, for an intermediate speed of 400 mph one would select a polyurethane material and for extended operation around 500 mph, Stainless Steel would be required.

Although Stainless Steel -117 (shown in Figure 17) was the best material tested, it was not recommended for this application because of its known susceptibility to sand abrasion when applied in very thin sheets (0.005 in.). Figure 14 shows that the third Stainless sample had not failed when the test was stopped after 1 hour 30 minutes.

Polyurethane -131 was second only to stainless steel in providing resistance to rain erosion. Figure 14 shows the

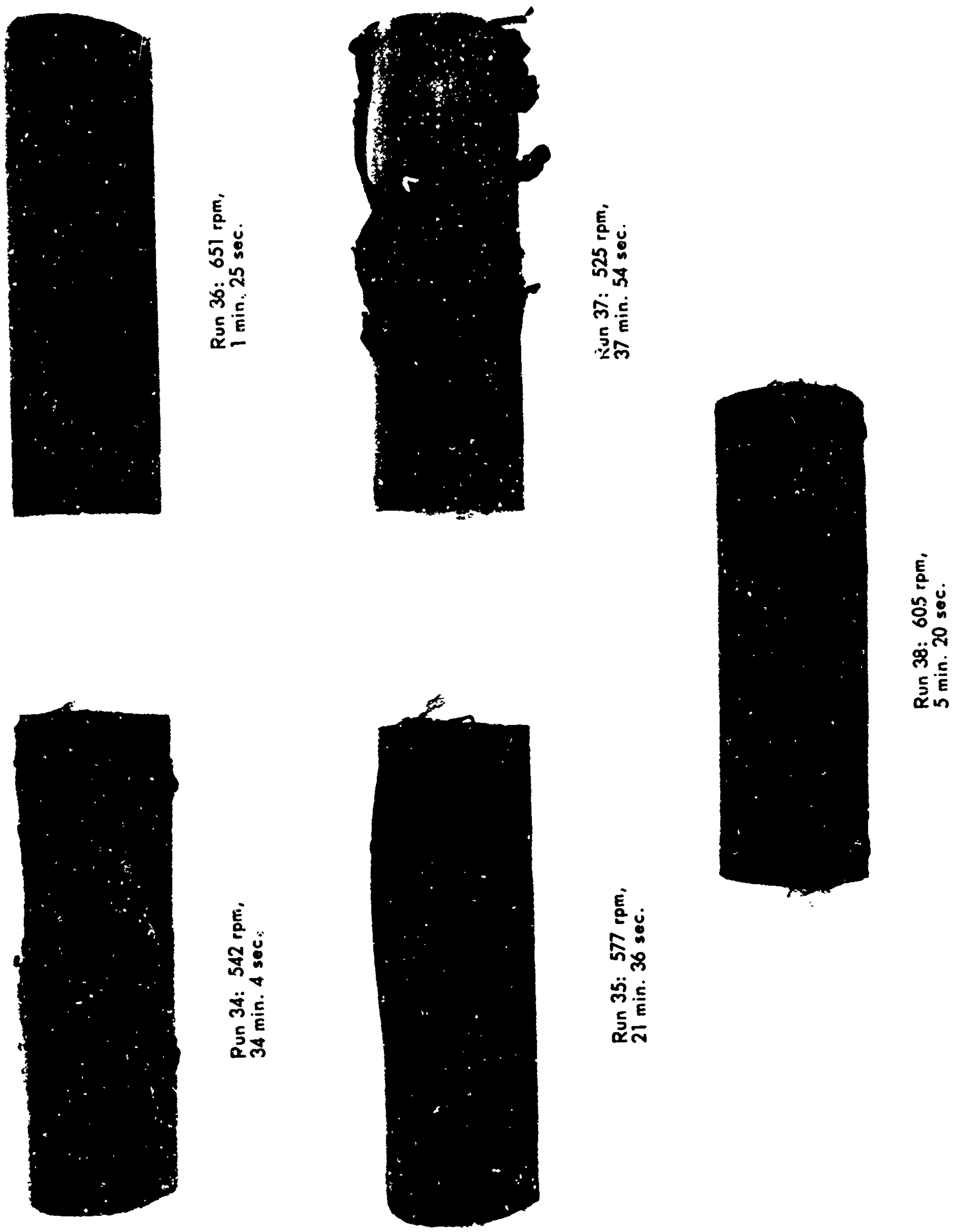


Figure 16. Sprayed Neoprene Sample -115 Tested at Various RPM

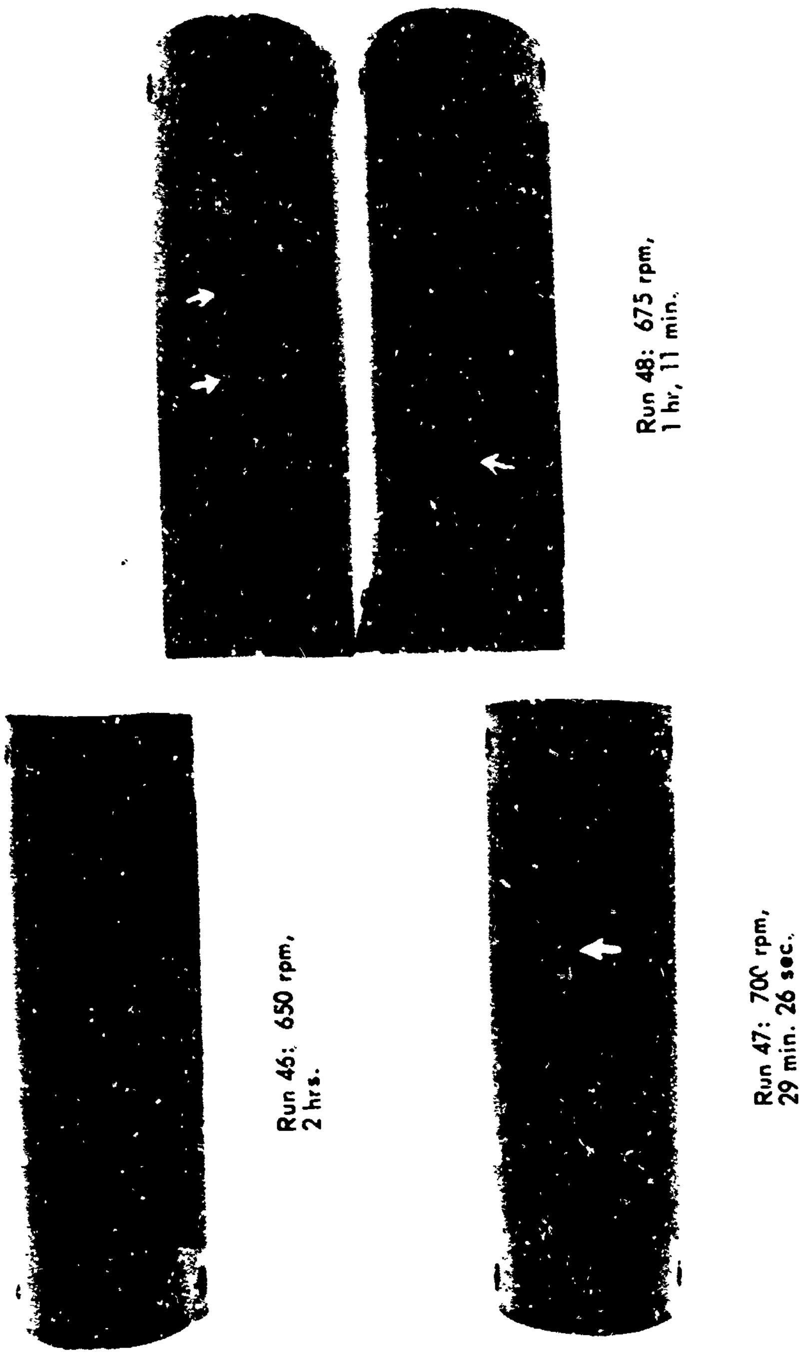
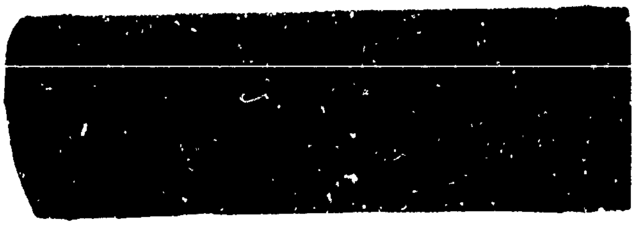
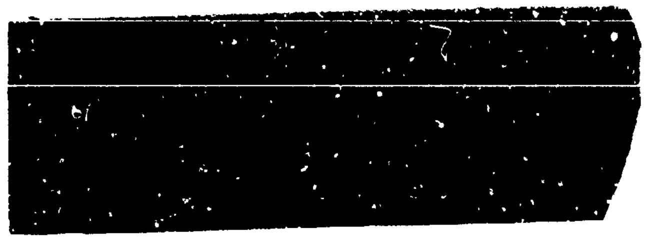


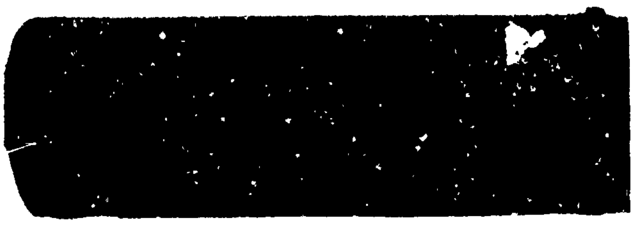
Figure 17. Stainless Steel With Plywood Backing, Sample -117, Tested at Various RPM



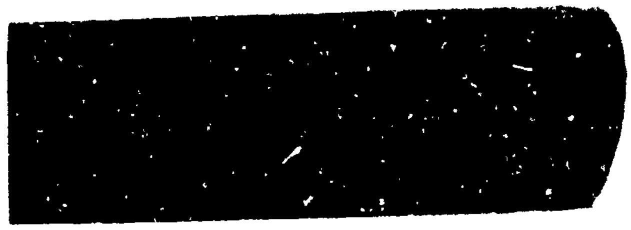
Run 39: 650 rpm,
5 min. 16 sec.



Run 43: 550 rpm,
26 min. 58 sec.



Run 40: 603 rpm,
9 min. 19 sec.



Run 44: 525 rpm,
30 min. 35 sec.

Run 42: 575 rpm,
19 min. 26 sec.

Run 45: 490 rpm,
51 min. 30 sec.

Figure 18. Precured Neoprene Sheet With Plywood Backing, Sample -119, Tested at Various RPM

Run 57: 550 rpm,
47 min, 23 sec.

Run 54: 650 rpm,
10 min, 5 sec.

Run 55: 575 rpm,
30 min. 18 sec.

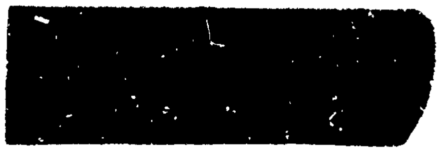
Run 58: 535 rpm,
42 min. 29 sec.

Run 56: 700 rpm,
5 min. 13 sec.

Run 59: 605 rpm,
12 min. 43 sec.

Figure 19. Cloth Impregnated with Neoprene, Hard Backing, Sample -123, Tested at Various RPM

Run 63: 604 rpm,
2 min. 49 sec.



Run 75: 465 rpm,
40 min. 10 sec.

Run 69: 550 rpm,
1 min. 39 sec.

Run 76: 525 rpm,
3 min 8 sec.

Run 70: 500 rpm,
12 min. 58 sec.

Run 77: 575 rpm,
1 min. 0 sec.

Figure 20. Tradename Material on Plywood Backing, Sample -129, Tested at Various RPM

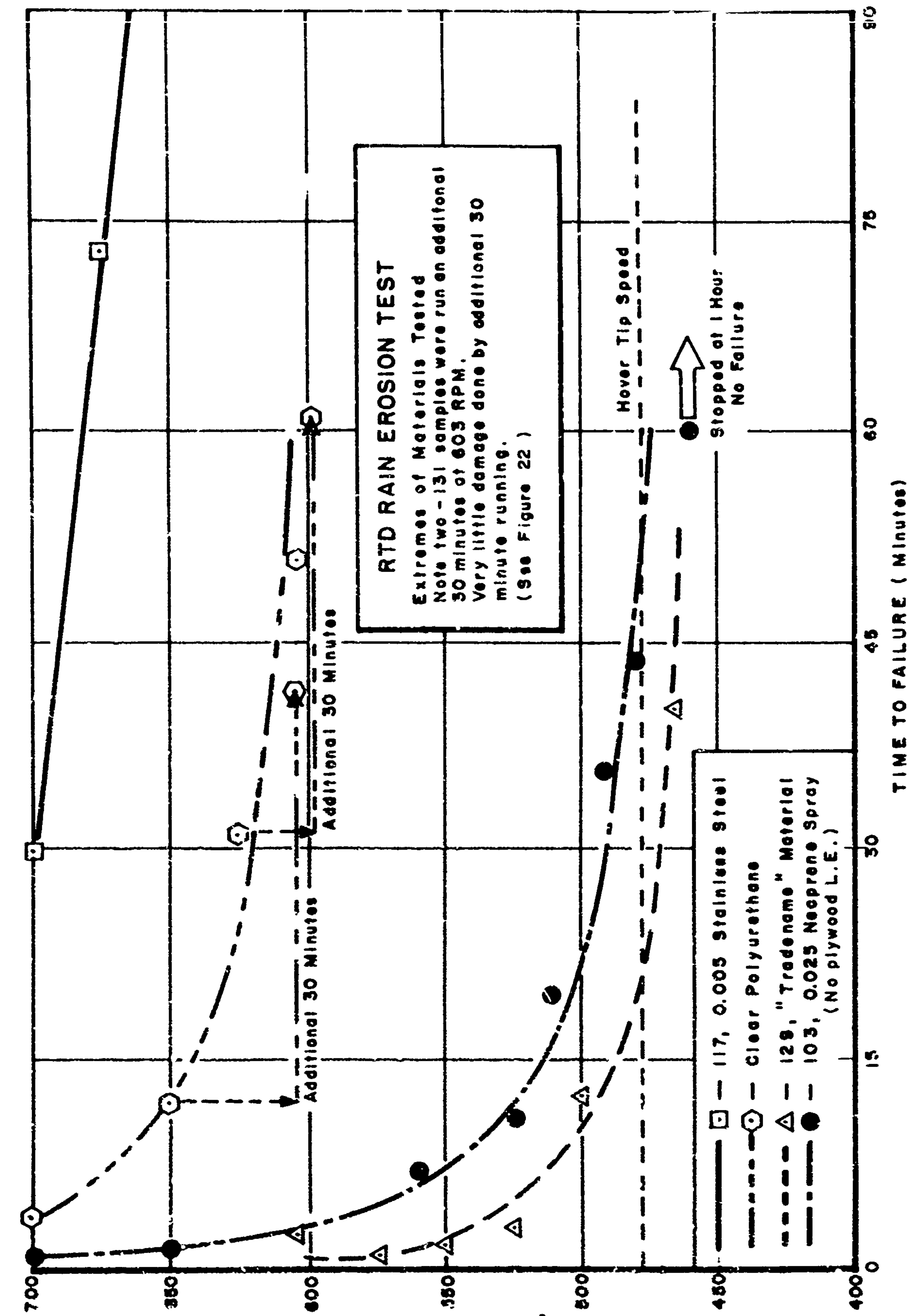
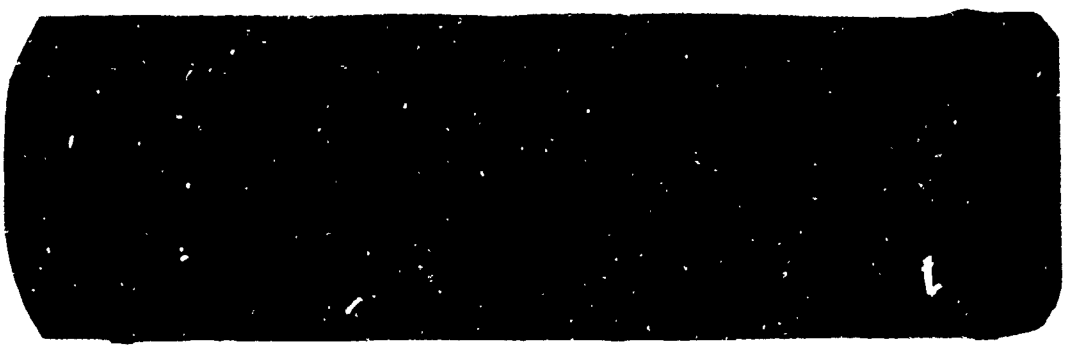


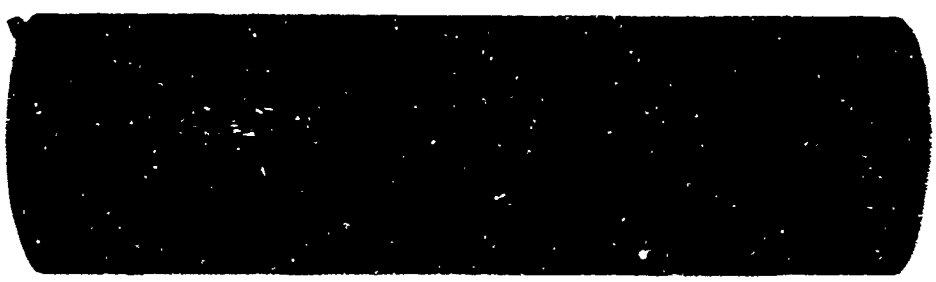
Figure 21. Extreme Values for Specific Materials Tested

a. Initial Failure
625 Rpm, 31 min. 10 sec.

b. Failure After Additional
Run of 30 Minutes at 603 rpm

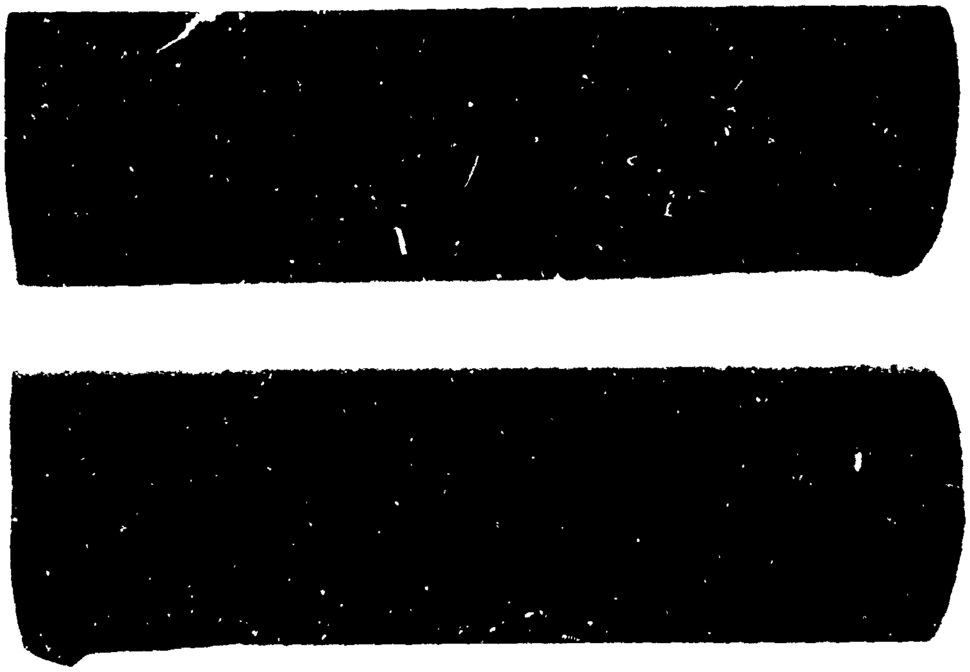


c. Initial Failure
650 rpm, 11 min. 49 sec.



d. Failure After Additional
Run of 30 Minutes at 603 rpm

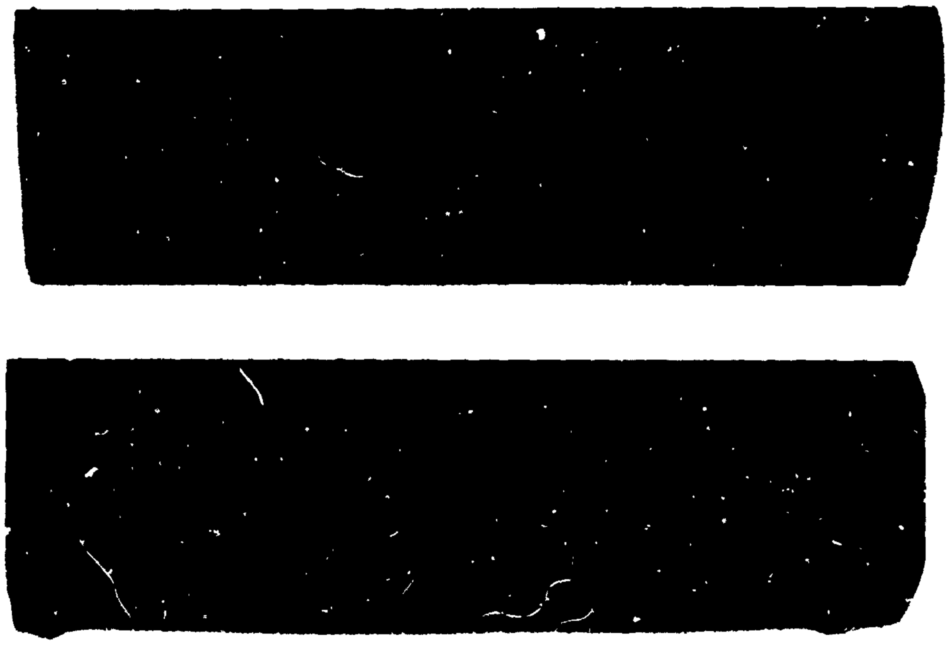
Figure 22. Test of Polyurethane Sheet Material, Sample -131, After Initial Failure



-143T

-131T

a. Run 78: 650 rpm. Sample -131T failed after 19 min. 32 sec, and Sample -143T after 11 min. 49 sec.



-143T

-131T

b. Run 80: 625 rpm. Sample -131T failed after 15 min 39 sec, and Sample -143T after 12 min. 45 sec.

Figure 23. Comparison of Clear and Impregnated Polyurethane, Samples -131T and -143T

results for the -131 material, and Figure 21 indicates the results for two -131 samples run an additional 30 minutes at 603 rpm. Previously these samples were considered failed after exposure at 650 and 635 rpm. Thus, it can be seen that continued exposure of the material after it has initially failed does not cause rapid deterioration of the coating. Comparison photographs of these samples are shown in Figure 22. The outstanding resistance of this material warranted further study and testing and a series of comparison tests of various polyurethane materials was begun.

3. COMPARISON TESTS

The manufacturer believed that the clear polyurethane -131 might age rapidly when exposed to ultraviolet radiation (sunlight) as no experience was available for this formulation. Impregnating the polyurethane with carbon would reduce the possibility of this deterioration from sunlight but would also degrade its resistance to rain erosion. Two additional sample configurations were fabricated, both of which were optimized for weight by being tapered (suffix T for tapered) from leading edge to trailing edge. One of these samples was clear polyurethane -131T and the other was carbon impregnated polyurethane -143T. The maximum leading edge thickness was reduced from the original -131 thickness (0.045 inch) to 0.038 inch.

The difference in the results for the two samples when comparison tested (one sample on each tip of the same test club) is shown by the curves of Figure 14. Figure 23 shows the physical deterioration to both samples after equal exposure times and various tip speeds. The amount of deterioration was slight for both samples, although the damage to the carbon impregnated -143T material was noticeably greater. (Actual deterioration of the -131T samples is not apparent in the photographs because of the transparency of the clear polyurethane). Both materials, however, exhibited outstanding resistance to rain erosion under these test conditions.

Two additional samples were fabricated to evaluate the effect of rip-stop cloth on the material bond strength. Tests on carbon impregnated polyurethane -125 samples bonded over rip-stop cloth and carbon impregnated polyurethane -127 samples bonded directly to the birch plywood were not conducted at the time the equipment was destroyed.

As a result of the comparison tests of the -131T and -143T polyurethane, protective strips of -143T material shaped as shown in Figure 24 were recommended for installation on the leading edges of all HH-43B/F helicopter servo flaps.

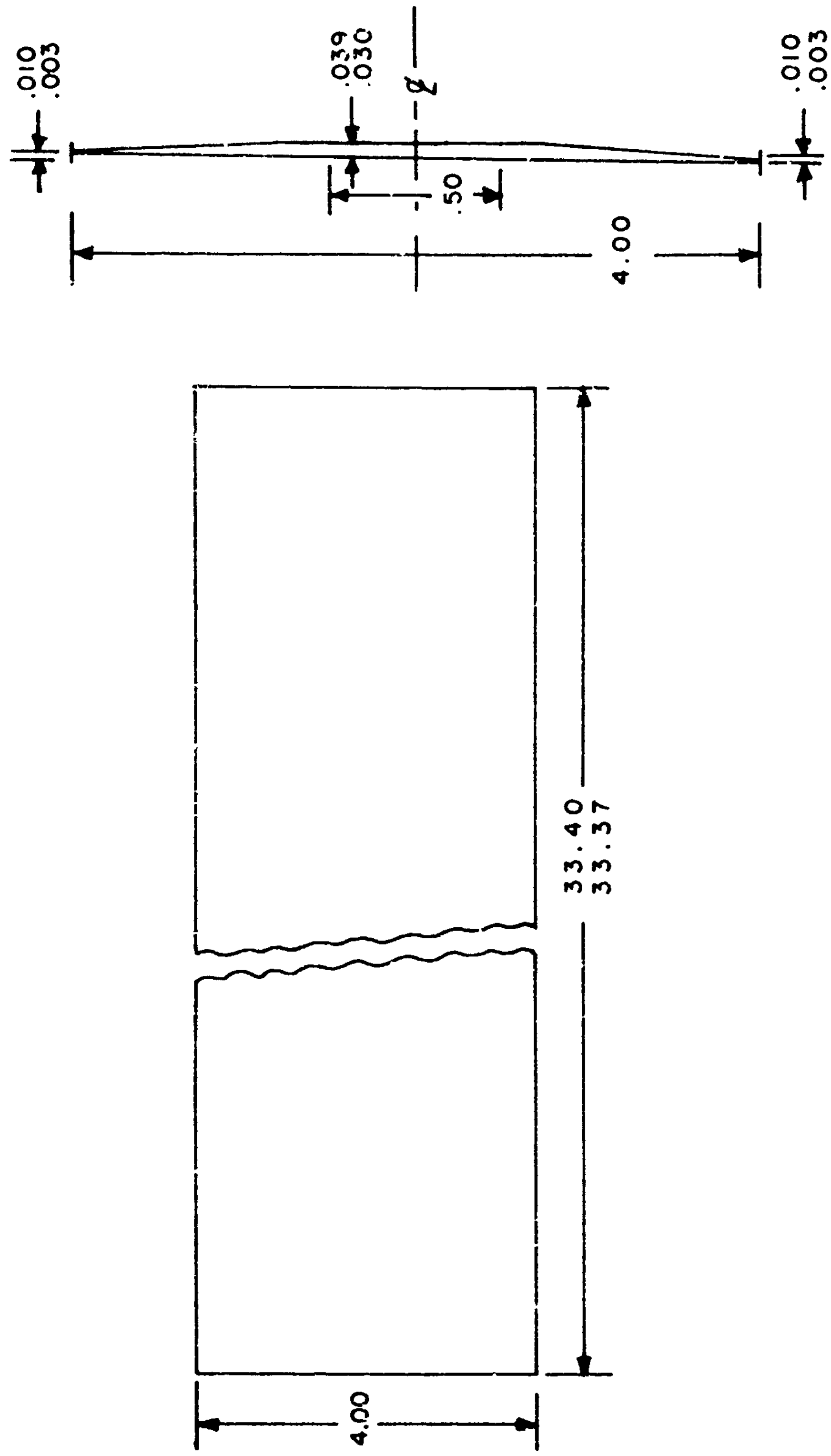


Figure 24. Detail Diagram of Recommended Protective Strip of -143T Material

SECTION IV

CONCLUSIONS

1. TEST RESULTS

a. The Sample -131 polyurethane material was the best one for the specific application of those tested.

b. Due to the little degradation in resistance caused by carbon impregnation and the unknown effect of ultraviolet radiation (sun light), the Sample -143T material tapered from leading to trailing edge was recommended.

c. The Sample -101 material is not adequate and the Sample -103 (sprayed neoprene presently used on servo flaps) is at best marginal. Had the Sample -103 been applied to the bare wood instead of over nylon rip-stop cloth, a better bond probably would have been achieved and the tendency for the material to peel away after it was initially damaged would have been reduced. The resistance of the various neoprenes (whether tape or spray) was very nearly the same at lower speeds. Several neoprenes appeared to be better than the others at the higher speeds. The scatter band, as shown by Figure 15, points out the generally good correlation of the test results.

d. The resistance of a material to rain erosion is a function of the hardness of the backup material. A given material applied over a soft structure will fail faster than the same material applied over a hard structure.

e. Testing a material at an off-design speed in no way determines the adequacy of that material at another speed; some of these materials were tested at speeds of 500 mph but were to be used at speeds considerably lower than this (in the range of 400 mph). The curves may cross as the test speed is lowered, such as occurs for Samples -115 and -135, and -115 and -119, as shown by Figure 15 at 12-1/2 minutes and 20 minutes, respectively. Thus, a material entirely adequate when used at one speed may be unsatisfactory when used at a different speed. For example, in a high speed application of approximately 460 mph, Sample -135 would be superior and Sample -115 would not be competitive; at 350 mph, however, both materials would provide essentially the same protection and the selection could be based on economics.

2. FUTURE TESTS

a. The water flow rate for these tests was excessive but the results are valid on a comparative basis. There is no way at present to correlate these times-to-failure with those encountered on the aircraft in actual service. A method to correlate test time and service time to failure would be very useful for future tests.

b. The spray rig should be moved at least 15 feet from the plane of the test club and the water pressure should be maintained at 35-40 psi. This will increase the area of coverage for each needle and will provide a more even distribution of water droplets.

SECTION V

RECOMMENDATIONS

As a result of these tests, recommendations were made to the HH-43B/F System Program Office to utilize the -143T material (a fabric-backed carbon-impregnated polyurethane sheet tapered from 0.038 inch leading edge to 0.003 inch trailing edge) as a servo-flap leading-edge protective material.

APPENDIX

DESCRIPTION OF TEST SAMPLES

The critical condition for these tests was total weight of the protective material, since the weight of the material applied to the flaps must be limited to avoid aerodynamic instability. Therefore, the weight of the various samples was held essentially constant by varying the thickness. This accounts for the range in thicknesses from 0.005 inch for stainless steel to 0.050 for the polyurethanes. The maximum weight of leading edge material for which the aircraft manufacturer had substantiating flight test data was 0.2 pounds for the 33.4-inch flap.

The materials tested in this test program were as follows:

Code No.	Material
-101	Sprayed neoprene, 0.005-0.010 thick over spruce core covered with nylon rip-stop cloth, spec MIL-C-7070, Type I
-103	Sprayed neoprene, 0.025-0.030 thick over spruce core covered with nylon rip-stop cloth, spec MIL-C-7070, Type I
-105	Stainless steel, 1/4-hard 0.005 thick over spruce core covered with nylon rip-stop cloth, spec MIL-C-7070, Type I
-107	Brush-on urethane 0.020-0.030 thick over spruce core covered with nylon rip-stop cloth, spec MIL-C-7070, Type I
-109	Precured neoprene sheet 0.025-0.030 thick at leading edge, tapering to 0.003-0.010 at edges, over spruce core covered with nylon rip-stop cloth, spec MIL-C-7070, Type I
-111	Precured urethane sheet 1/32 thick over spruce core covered with nylon rip-stop cloth, spec MIL-C-7070, Type I
-113	Polyethlene tape over spruce core covered with nylon rip-stop cloth, spec MIL-C-7070, Type I
-115	Same as -103 except basic block is spruce faced with 1/32 in. thick 3-ply birch plywood covered with nylon rip-stop cloth, spec MIL-C-7070, Type I
-117	Same as -105 except basic block is spruce faced with 1/32 in. thick 3-ply birch plywood over layer of No. 120 glass fabric
-119	Same as -109 except basic block is spruce faced with 1/32 in. thick, 3-ply birch plywood covered with nylon rip-stop cloth, spec MIL-C-7070, Type I
-121	Same as -111 except basic block is spruce faced with 1/32 in. thick, 3-ply birch plywood covered with nylon rip-stop cloth, spec MIL-C-7070, Type I
-123	Neoprene-coated fabric to a thickness of 0.040 ±0.005 inch at leading edge, and tapering to 0.003 - 0.010 at edges (Neoprene impregnated 0.005 Dacron fabric built up in layers) over spruce block faced with 1/32 in thick, 3-ply birch plywood covered with nylon rip-stop cloth, spec MIL-C-7070, Type I
-125*	Polyurethane boot (0.030 in.) over spruce core faced with 1/32 in. thick, 3-ply birch plywood, over nylon rip-stop cloth, spec MIL-C-7070, Type I
-127*	Polyrethane boot (0.030 in.) over spruce core faced with 1/32 in. thick, 3-ply birch plywood (without rip-stop cloth - bonded to bare wood)
-129	"Tradename" material, 0.008 ±0.002 in. thick, brushed on over spruce block faced with 1/32 in. thick, 3-ply birch plywood
-131	Polyurethane sheet, 0.045 - 0.050 in. thick, fabric backed over spruce block faced with 1/32 in. 3-ply birch plywood
-131T	Same as -131 but tapered from 0.038 in. at leading edge to 0.003 in. at trailing edge

*Note - samples not yet tested due to destruction of test equipment.

-133 Neoprene sheet, 0.040 - 0.043 in. thick, over spruce block faced with 1/32 in. 3-ply birch plywood.

-135 Neoprene sheet, 0.038 - 0.040 in. thick, fabric-backed, over spruce block faced with 1/32 in. 3-ply birch plywood

-137 Stainless steel, 0.013 in. thick over wood block coated with 1/32 in. fiberglass

-139 Neoprene sheet, 0.035 in. thick over wood block coated with 1/32 in. fiberglass

-141 Brush-on urethane over wood block coated with 1/32 in. fiberglass

-143T Same as sample -131T polyurethane except carbon impregnated

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UNCLASSIFIED
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DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) Systems Engineering Group Wright-Patterson Air Force Base, Ohio	2a REPORT SECURITY CLASSIFICATION Unclassified 2b GROUP

3 REPORT TITLE

EVALUATION OF RAIN-EROSION-RESISTANT MATERIALS TO PROTECT THE HH-43B/F HELICOPTER ROTOR

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

5 AUTHOR(S) (Last name, first name, initial)

Chopin, Matthew W.

6 REPORT DATE	7a TOTAL NO OF PAGES	7b NO OF REFS
August 1966	45	5

8a CONTRACT OR GRANT NO	9a ORIGINATOR'S REPORT NUMBER(S)
b PROJECT NO 976Z	SEG-TR-65-53
c	9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d	

10 AVAILABILITY/LIMITATION NOTICES

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11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY
	Systems Engineering Group Wright-Patterson Air Force Base, Ohio

13 ABSTRACT

This report describes the tests of various materials to determine a suitable protective covering for the HH-43B/F helicopter servo-flap leading edge when operating in rain.

Nineteen materials were tested and compared on a rain erosion spray rig in the electric motor whirl stand facility at WPAFB Ohio. Impact velocity varied from 330 to 750 ft per second.

A description of the facility, test procedures, results and recommendations is presented. Photographs of the spray rig and test specimens are also included.

DD FORM 1 JAN 64 1473

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14 KEY WORDS	LINK A		LINK B		LINK C	
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Rain Erosion Tests						
HH-43b Helicopter						
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