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AN INVESTIGATION OF THE CHARACTERISTICS OF A PROPELLER ALCOHOL FEED RING

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RESTRICTED BULLETIN

AN INVESTIGATION OF THE CHARACTERISTICS OF A PROPELLER ALCOHOL FEED RING

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SUMMARY

An investigation has been conducted to compare the discharge characteristics of an alcohol feed ring and of a standard alcohol discharge nozzle when utilized to supply anti-icing alcohol to the propeller-blade feed shoes on a Curtiss-Wright C-46 cargo airplane. The investigation was conducted at the Materiel Command Ice Research Base at Minneapolis, Minn., by the National Advisory Committee for Aeronautics. Flight tests were made in dry air to determine the alcohol-flow pattern produced by each device along the propeller-blade leading edges, as well as flight tests in natural icing conditions to determine the degree of ice protection afforded by the alcohol system incorporating only the feed ring. The investigation indicated that the use of feed rings resulted in an improved distribution of alcohol over the propeller-blade leading edge and in a more efficient use of alcohol. The feed rings tested proved to be serviceable, requiring no maintenance during 100 hours of flight service.

INTRODUCTION

Alcohol as a means of protection against ice formation on propeller blades is widely used by commercial air lines on transport airplanes. The usual propeller alcohol anti-icing system consists of nozzles fixed to the propeller hub which discharge alcohol onto feed shoes mounted on the propeller blades. Delivery of alcohol through the discharge nozzles normally used often results in inadequate protection, since any one location of the discharge nozzle will not provide optimum distribution for all possible propeller-blade angles.

The present investigation was undertaken to determine if improved protection at various blade angles could be obtained through the use of a propeller alcohol feed ring developed by the B. F. Goodrich Rubber Company. Comparative alcohol-distribution tests of one propeller fitted with discharge nozzles and the other propeller fitted with alcohol feed rings were made on a Curtiss-Wright C-46 cargo airplane during flights in clear air. Tests also were made of the effectiveness of the system incorporating feed rings in preventing ice formation during flights in natural icing conditions at the Materiel Command Ice Research Base, Minneapolis, Minn.

Appreciation is extended to the B. F. Goodrich Rubber Company for contributing the propeller alcohol feed rings and feed shoes.

DESCRIPTION OF EQUIPMENT

All tests of the propeller alcohol system were conducted on the C-46 airplane, which was equipped with thermal ice-prevention equipment on the wings, empennage, and windshield, and therefore was capable of operating for extended periods in natural icing conditions.

The propellers on which the tests were conducted were Hamilton Standard hydromatic three-blade propellers, design number 6194A-0, hub number 23E50-473, 15 feet 0 inch in diameter. Anti-icing feed shoes 52 inches in length were cemented to the leading edges of the propeller blades. Figure 1 shows the shape of the C-46 airplane cowl and its relation to the propeller, which are believed to influence the distribution of alcohol on the propeller blades. The photograph (fig. 1) was taken prior to the installation of the ice-prevention equipment on the test airplane.

The standard propeller alcohol system with the discharge nozzle consists of a small metal tube mounted on the propeller hub at the root of each blade. The nozzle is adjusted to discharge fluid into the grooves of the propeller anti-icing feed shoe. Alcohol is supplied from a slinger-ring assembly to the discharge nozzles. A discharge-nozzle arrangement, similar to the one tested on the C-46 airplane, is shown in figure 2.

The alcohol feed ring, Goodrich number 453642F, consisted of a molded neoprene ring provided with a hollow metal stem and was cemented, in accordance with the manufacturer's instructions, to the propeller-blade shank as shown in figure 3. The neoprene ring was internally cored in such a manner as to permit flow of alcohol from the metal stem to a discharge slot which extended over the anti-icing feed-shoe grooves at the hub end of the propeller blade. The metal stem of the feed ring was connected to the slinger ring with a flexible U.S.A. 20-28 natural-rubber tube. The feed-ring installation, therefore, provided for the flow of alcohol from the slinger ring to the hub end of the blade anti-icing feed shoe at all blade angles without loss of fluid. The connecting rubber tubes were secured to the feed-ring stems and the slinger-ring outlets by safety-wire wrappings at each end. The total weight of the rings and connecting tubes for one propeller was 10 ounces.

Isopropyl alcohol was used for all tests of the propeller alcohol equipment. To obtain the desired flow rate, a needle valve, installed in the alcohol line downstream from the pump, was used in conjunction with the propeller alcohol rheostat control, which is located in the pilots' compartment.

A stroboscope, synchronized with the right engine, was used to observe ice formation on the propeller during icing flights.

TESTS AND RESULTS

The feed rings were attached to the left propeller only, for the comparative alcohol-distribution tests, and the standard discharge-nozzle installation was employed for the right propeller. For the purpose of determining the flow patterns. Bon Ami was applied to the camber and thrust faces of both propellers before each test.

The alcohol-flow rate was regulated by the rheostat controlling the alcohol pump. The needle valve in the alcohol line was adjusted to limit the minimum flow at approximately 3 gallons per hour to each propeller. It was found that a maximum flow rate of approximately 5 gallons per hour per propeller was obtainable.

The comparative distribution tests were made at two propeller speeds during level flight at cruising engine power, and at one propeller speed during climb and descent. The flow pattern also was observed on the right and left propellers with feed rings mounted on both propellers during level flight at a cruising-power condition. For the tests in level flight and climb, an alcohol-flow rate of approximately 3 gallons per hour per propeller was maintained for a period of 5 minutes, after which the flow was stopped and the flow patterns were observed. The flow pattern for the descent condition of flight was obtained after maintaining a flow rate of approximately 5 gallons per hour per propeller for 4 minutes and then a flow rate of approximately 3 gallons per hour per propeller for 3 minutes.

Representative sketches of the flow patterns obtained on the camber face of the propeller blades during these tests are shown in figure 4. There was very little flow over the thrust face of the blades. A flow of alcohol to the end of the propeller feed shoes was obtained with both the feed-ring and discharge-nozzle installations as shown in figure 4, except in test 1 when the alcohol reached the feed-shoe tip only on one blade of the standard nozzle-equipped propeller. The alcohol-flow patterns were partially obliterated during tests 2 and 3 when the coating was removed by unexpected agencies. However, faint traces in the cleared zones and reference to the flow lines outside the cleared areas permitted extension of the flow lines with reasonable accuracy.

The tests of the ice protection afforded by the feed-ring installation were made in conjunction with tests of the thermal ice-prevention equipment installed on the C-46 airplane. The alcohol feed rings were installed on both propellers and the airplane was flown in a wide variety of natural icing conditions. During all icing tests alcohol flow to the propellers was started before entering icing conditions. Protection against loss of airplane performance was obtained in all flights except one without increasing the propeller speed above 950 rpm, which corresponds to 1900 rpm engine speed. The alcohol-flow rate was maintained at approximately 5 gallons per hour per propeller during all the icing flights. Observations with the stroboscope indicated that the formation of ice was not entirely prevented, but that periodic accumulations of ice were satisfactorily removed by the flow of alcohol along the blade leading edges.

During one flight in icing conditions at 13,500 feet pressure altitude, propeller ice protection was not adequate at the cruising propeller speed. Ice formed on the blade leading edges, as evidenced by decreased airspeed and rate of climb. Normal rate of climb and airspeed were restored by increasing the propeller speed to 1200 rpm, which is the ice-emergency propeller-operating speed for the C-46 airplane.

After 100 hours of flight service, visual inspection of the feed rings showed no evidence of failure and no maintenance was required.

DISCUSSION

The comparative alcohol-distribution tests indicated that better blade leading-edge coverage was obtained at all propeller speeds and flight conditions investigated with the feed rings than was possible with the standard alcohol-discharge nozzles. Figure 4 shows that a more efficient use of alcohol was obtained with the alcohol feed-ring installation for all conditions tested. The distribution tests also indicated that alcohol was satisfactorily provided to the blade leading edges at the ice-emergency propeller speed only by the use of the feed rings.

Protection against loss of airplane performance was effected at normal cruising propeller speed in light-to-moderate icing conditions with the feed-ring installation. When more severe icing conditions were encountered, protection was obtained only by operating the propellers at the ice-emergency speed. Therefore, since the distribution of alcohol was satisfactory at the ice-emergency propeller speed only by utilizing the feed rings, it may be concluded that propeller ice protection in severe icing conditions for the C-46 airplane can be realized only with the alcohol feed-ring equipment used in conjunction with the ice-emergency propeller speed.

Although the tests in icing conditions indicate that an effort must be made to develop a method of propeller ice protection superior to the alcohol system, the use of feed rings in lieu of the standard discharge nozzle resulted in a definite improvement of the propeller alcohol system. It should be noted that good alcohol distribution and coverage of the propeller-blade leading edge are very difficult to obtain with as large a diameter propeller as were used in the tests and therefore the alcohol system could not have been expected to remove ice accumulations under all conditions, even though an improvement in the system had been made.

CONCLUSIONS

1. The use of the propeller alcohol feed ring resulted in a more satisfactory distribution of alcohol along the leading edge of the propeller blade than did the standard alcohol-discharge nozzles, indicating a greater degree of ice protection and a more efficient use of alcohol.

2. The alcohol feed-ring equipment required no maintenance in 100 hours of flight service.

3. The manufacturer's recommendations for installation of the feed rings were satisfactory.

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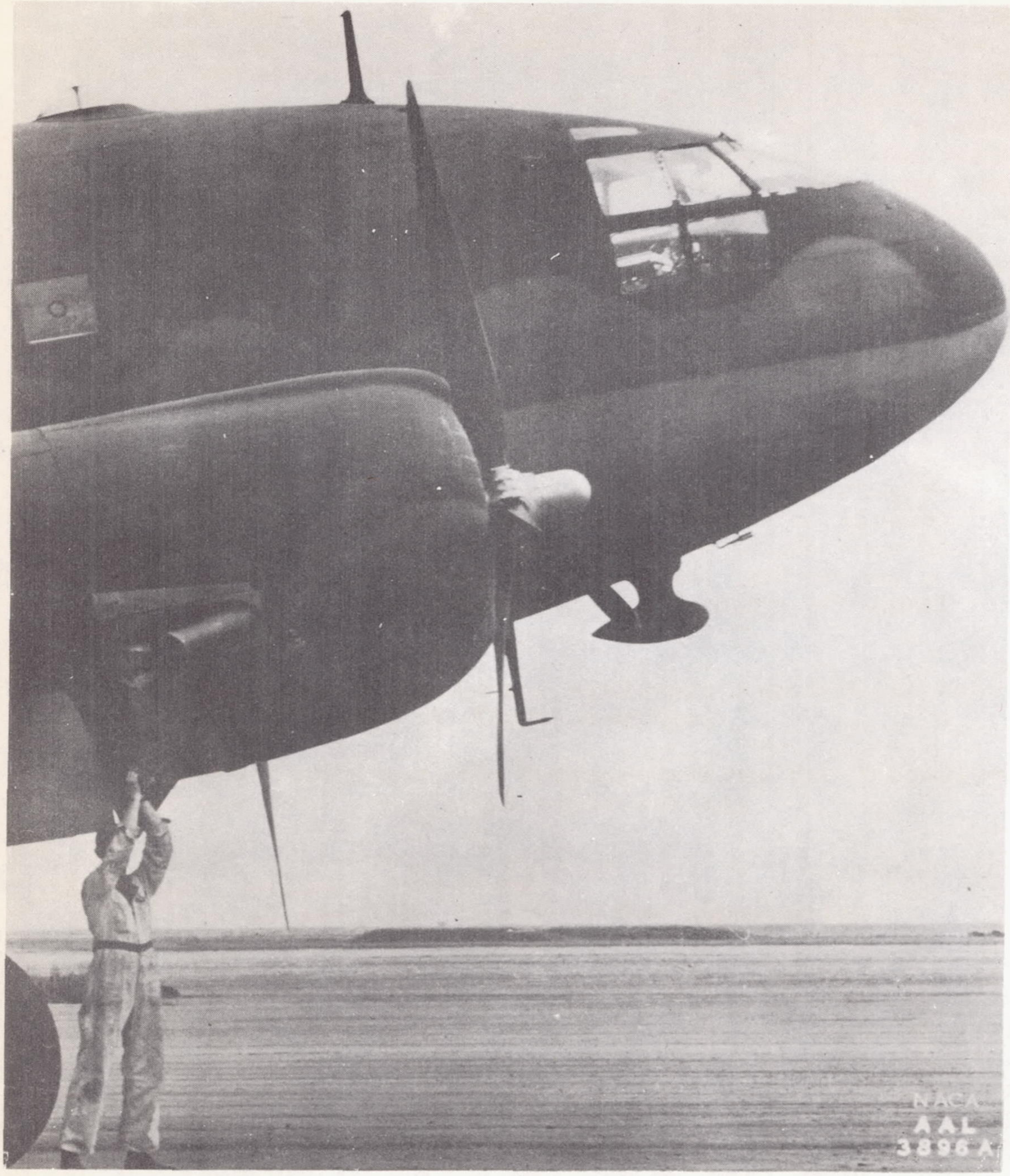


Figure 1.- The right propeller and engine cowl of the C-46 airplane on which the tests of the alcohol feed rings were made.

Figure 2.- A typical propeller alcohol-discharge-nozzle installation.

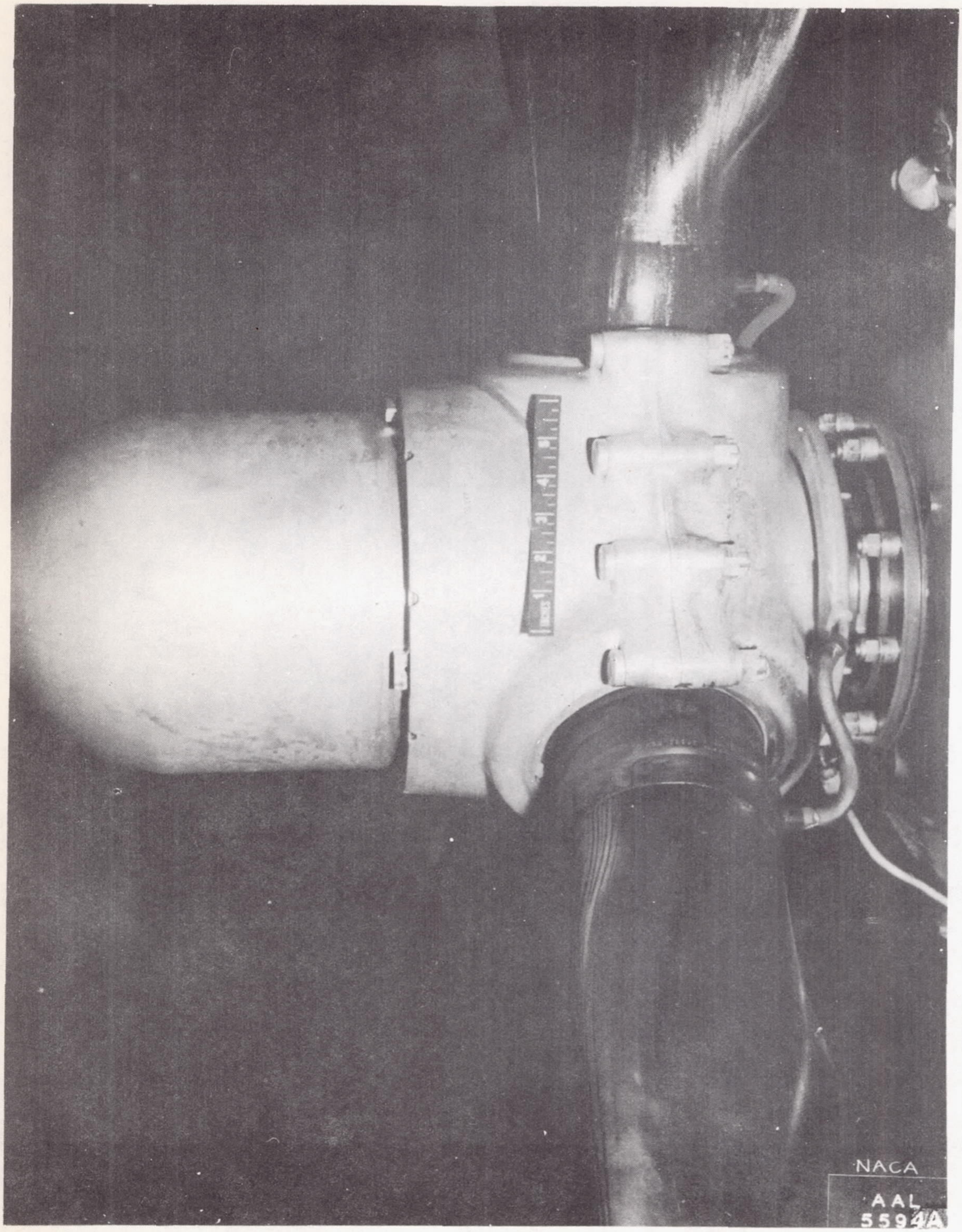
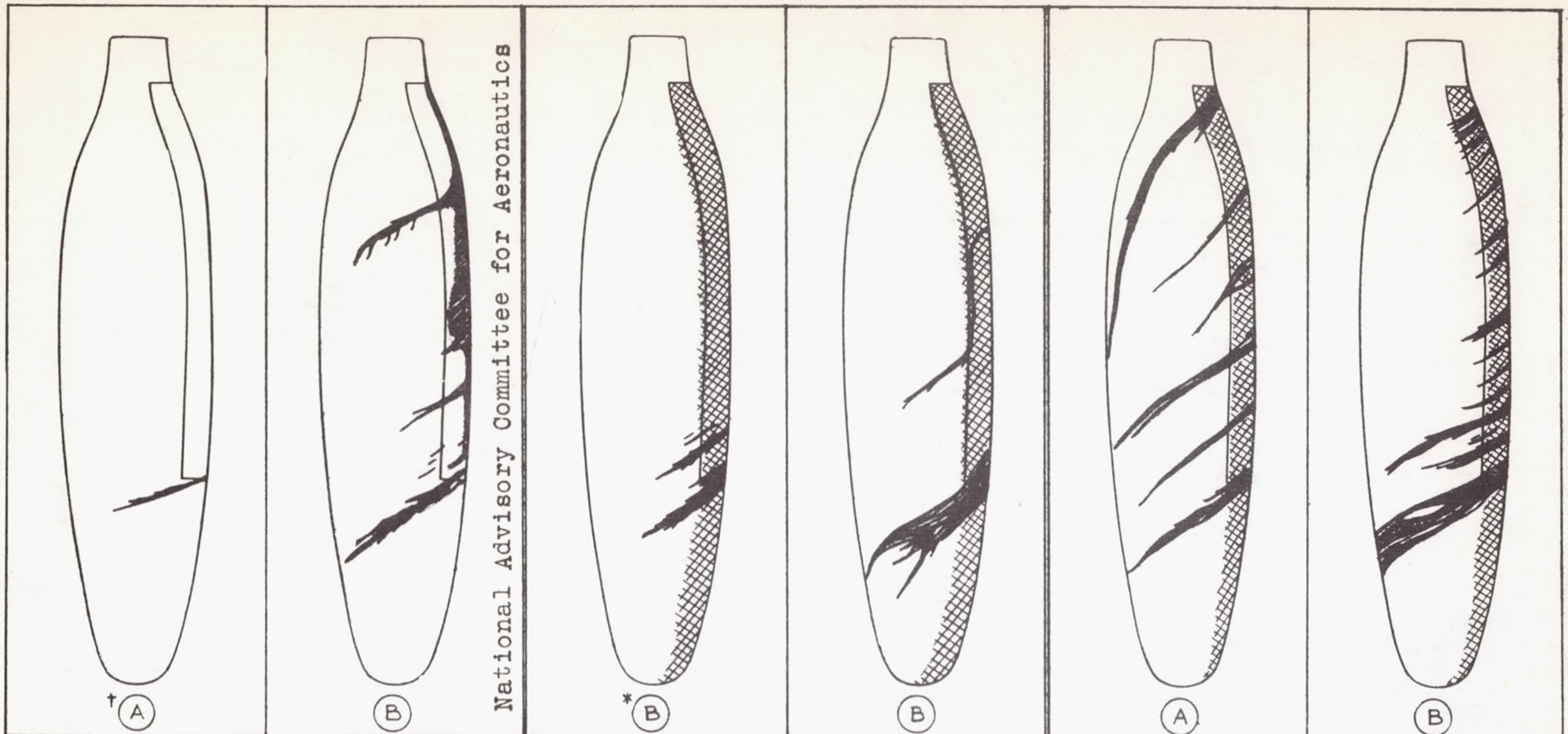


Figure 3.– The B. F. Goodrich Co. propeller alcohol feed rings installed on the propeller blades of the C-46 airplane.

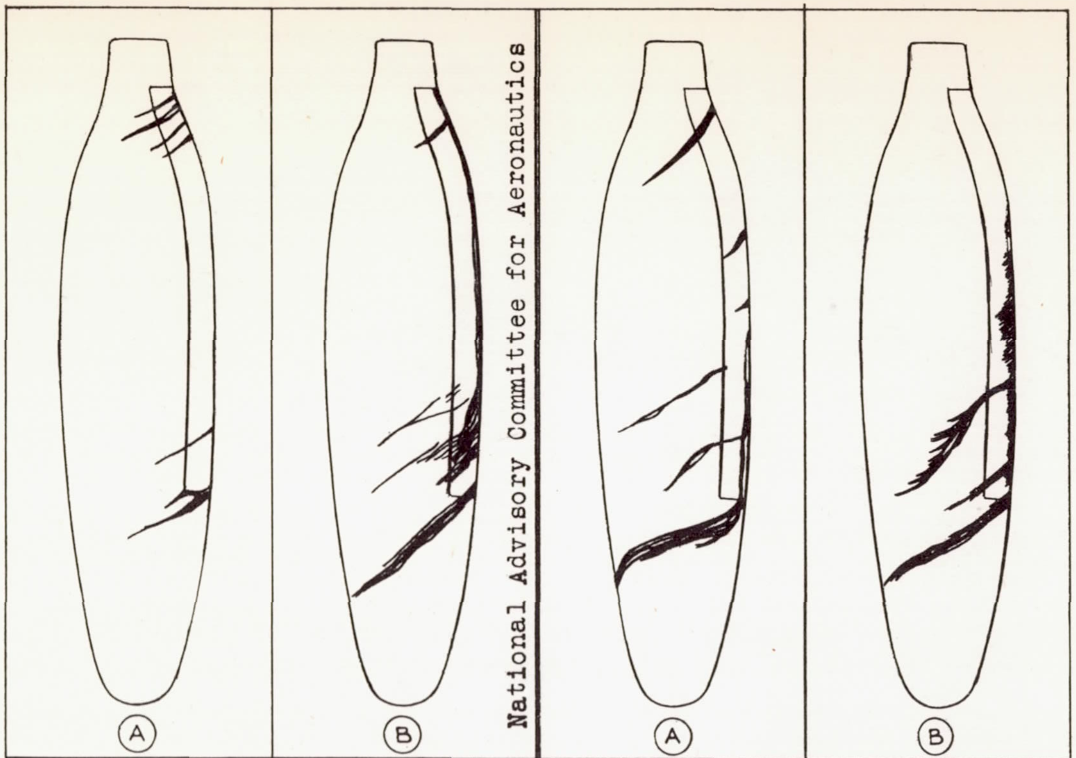


TEST 1	TEST 2	TEST 3
1200 RPM[1] 154 MPH[2] 4000 FEET[3]	1025 RPM 177 MPH 3000 FEET	950 RPM 187 MPH 4000 FEET
1- PROPELLER SPEED 2- CORRECT INDICATED AIRSPEED 3- PRESSURE ALTITUDE (APPLY THROUGHOUT TABLE)	CROSS-HATCHED AREA INDICATES WHERE BON AMI WAS REMOVED BY ABRASION FROM DUST DURING ENGINE RUN-UP.	CROSS-HATCHED AREA INDICATES WHERE BON AMI WAS REMOVED WHEN AIRPLANE ENCOUNTERED CLOUDS OF HIGH WATER CONTENT.

ALCOHOL FLOW RATE APPROXIMATELY 3 GALLONS PER HOUR PER PROPELLER FOR 5 MINUTES.
(A) - STANDARD ALCOHOL DISCHARGE NOZZLE INSTALLED. (B) - B. F. GOODRICH ALCOHOL FEED RING INSTALLED.

†FLOW OBTAINED TO END OF FEED SHOE ON ONE BLADE ONLY. *FEED RINGS INSTALLED ON BOTH PROPELLERS FOR TEST 2.

FIGURE 4 - COMPARISON OF ALCOHOL FLOW DISTRIBUTION ON CAMBER FACE OF PROPELLERS OF C-46 AIRPLANE EQUIPPED WITH B. F. GOODRICH ALCOHOL FEED RINGS ON LEFT PROPELLER AND STANDARD ALCOHOL DISCHARGE NOZZLES ON RIGHT PROPELLER DURING LEVEL FLIGHT.
(a)



TEST 4	TEST 5
1025 RPM 132 MPH 3500-7400 FEET CLIMB ALCOHOL FLOW RATE APPROXIMATELY 3 GALLONS PER HOUR PER PROPELLER FOR 5 MINUTES.	1025 RPM 195 MPH 5000-3000 FEET DESCENT ALCOHOL FLOW RATE APPROXIMATELY 5 GALLONS PER HOUR PER PROPELLER FOR 4 MINUTES, THEN APPROXIMATELY 3 GALLONS PER HOUR PER PROPELLER FOR 3 MINUTES.

(A) - STANDARD ALCOHOL DISCHARGE NOZZLE INSTALLED.
(B) - B. F. GOODRICH ALCOHOL FEED RING INSTALLED.

FIGURE 4 (CONCLUDED) - COMPARISON OF ALCOHOL FLOW DISTRIBUTION DURING CLIMB AND DESCENT CONDITIONS
(b)