# De-icing tests on a Westland Sycamore helicopter conducted during the season 1963-64

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LR-398

# DE-ICING TESTS ON A WESTLAND SYCAMORE HELICOPTER CONDUCTED DURING THE SEASON 1963-64

BY

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Subject: DE-ICING TESTS ON A WESTLAND SYCAMORE HELICOPTER CONDUCTED DURING THE SEASON 1963-64

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SUMMARY

The Westland Sycamore helicopter, equipped with an experimental fluid anti-icing system, gave satisfactory de-icing performance in the temperature range 0°C. to -15°C., the full range over which the helicopter was tested.

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# DE-ICING TESTS ON A WESTLAND SYCAMORE HELICOPTER CONDUCTED DURING THE SEASON 1963-64

## 1.0 INTRODUCTION

At the request of the British Ministry of Aviation, a Sycamore helicopter equipped with an experimental fluid anti-icing system (Fig. 1) was tested in the National Research Council's helicopter spray rig for the period January 17 to March 13, 1964.

The aircraft, pilot, maintenance and test personnel were supplied by the Ministry of Aviation. N.R.C. personnel were responsible for the operation of the spray rig and supervision of the icing trials.

## 2.0 PURPOSE

To assess the anti-icing effectiveness of the fluid system when using either a mixture of 90 percent alcohol and 10 percent glycerine or Kilfrost Fluid R328.

## 3.0 TEST EQUIPMENT

### 3.1 Aircraft

The aircraft was a Westland Sycamore (Fig. 2) (Registration No. XE308) powered by an Alvis Leonides 9-cylinder air-cooled radial engine of 550 b.h.p. driving a 3-bladed 48-ft. 11-in. diameter main rotor and a 3-bladed 14-ft. 7-in. diameter tail rotor. During the tests in the icing rig the main rotor speed was maintained at 250 r.p.m. with a corresponding speed of 1120 r.p.m. for the tail rotor.

### 3.2 Anti-Icing System

Basically the system consisted of the following:

(a) A fluid tank having a capacity of 21 Imperial gallons

(b) A fluid pump capable of a fluid flow of 90 gal./hr. to force the fluid up to the distributor at the rotor head

(c) A flow controller, which was a needle valve, was incorporated in a by-pass circuit. The relative resistances of the by-pass circuit and the main line circuit to the rotor head were changed by the opening of the needle valve, thereby varying the rate of fluid flow to the hub at the rotor head

(d) A solenoid valve situated in the main fluid line to the hub. This was actuated by a simple on-off switch which could be cycled manually or by an electronic timer

(e) An Electronic Timer. This unit was capable of controlling both the "on" time and the "off" time of the fluid flow by actuating the solenoid at the preset time interval. The maximum control range of the timer was 40 sec. on, 40 sec. off, calibrated in 1-sec. intervals

(f) A distributor which was a slinger ring of tre-foil plan form that collected the fluid sprayed from a six-way jet at the top of the control axle in the rotor head and distributed a third of the flow to each blade through flexible pipes

(g) Blade metering and distribution system. This was set in the leading edge of each blade (Fig. 3) and extended from root to tip in a rubber duct through which the fluid flowed under centrifugal action. The rubber duct was bonded to the leading edge of a standard metal rotor blade. In this duct, from a point near the blade root and extending to the tip, were meter-jet units spaced every three inches. The fluid flowed from the duct through the jet units and out onto the upper and lower blade surfaces. The metering orifice of the unit controlled the pressure and therefore the flow at the jets. By suitable re-arrangement of the metering orifice sizes along the blade, the spanwise pattern of the flow from the jets could be modified.

## 4.0 TEST PROCEDURE

On the first run of each day's testing, the helicopter was hovered in the icing cloud about 100 ft. downwind of the spray rig for a period of 5 minutes. The helicopter was then landed and ice thickness measurements and the spanwise extent of ice were noted. On some days it was not possible to remain airborne for the full 5 minutes because maximum power was required before the icing period was completed. The icing run was then terminated at the point of full power attainment.

Further tests, using the fluid system, were then conducted using the accretion run as a datum to measure its effectiveness in preventing the formation of ice, or alternatively the ability to remove ice that had already been formed. If the accretion run had been terminated because of the attainment of full power prior to the 5-minute period, subsequent tests using the fluid system were conducted, allowing the helicopter to reach full power prior to turning on the anti-icing system. If the helicopter could remain airborne, or a decrease in power resulted, the run was termed acceptable. If, however, the helicopter could not continue safe flight, then the run was unacceptable. When the system was being tested for its anti-icing effectiveness the helicopter was expected to maintain safe flight with only small increases of power permissible.

At the completion of each test run the helicopter was landed and the amount and thickness of ice remaining on the blade was measured.

## 5.0 TEST RESULTS AND DISCUSSION

The results of each of the test runs are shown in Table I.

The droplet size for all runs was held as close to 30 microns (median volume diameter) as was possible, and the cloud liquid water content was varied from 0.7 to 0.26 gm./m$^3$.

The fluid system worked satisfactorily from 0°C. to -15°C., the range of temperatures in which it was tested (Fig. 4). The system was not effective as an anti-icing system, but was effective as a de-icing system and in its conservation of fluid. As a de-icing system the minimum fluid consumption was 3.25 gal./hr. at -3.5°C. and the maximum was 10 gal./hr. at -14.5°C. An ice thickness of approximately 3/16 in. was required before shedding would occur, and at no time could ice be prevented from forming on the blades.

No provision was made to supply fluid to the tail rotor as it was expected that excess fluid from the main rotor would deposit on the tail rotor and so protect it sufficiently to prevent large accumulations of ice from forming on the blades. The first de-icing run indicated that the assumption of main rotor fluid protecting the tail rotor was erroneous. Severe vibrations resulted from tail rotor ice shedding asymmetrically. A 1-in. wide strip of polyethylene tape was applied symmetrically about the leading edge and for the full span of the tail rotor blade. This tape gave sufficient protection to the tail rotor so that no further problems arose from tail rotor icing.

Although the Sycamore was severely handicapped by limited engine power, this served to evaluate more precisely the effectiveness of the anti-icing system. A measure of the power required to operate for a period in the icing cloud was taken each first run of the day's operations, and provided the fluid system would allow a greater margin of power remaining at the end of each test run, the system operation was considered acceptable.

Each of the rubber gaiters supplied for use in the hub was found to be unserviceable on arrival in Canada. The rubber ring at the base of the gaiter was found to be partially or totally detached. A sample gaiter had the ring bonded by the Silicon adhesive R.T.V.3 in an endeavour to determine which adhesive would prove to be the best one to use; however, the R.T.V.3 proved successful and no further attempts were made to repair the remaining gaiters. The dispensing jets were found to be prone to blockage, and it is suggested that a very fine filter be provided in the system to alleviate this problem. Blockage could also occur by the continual removal and replacement of the dispensing jets; small pieces of rubber were sheared away from the supply tube each time a jet was replaced, making it difficult to maintain the system in a clean condition.

The use of 90 percent alcohol and 10 percent glycerine is acceptable as a de-icing fluid and was used over the full range of temperatures at which the helicopter was tested. The use of Kilfrost Fluid R328 is acceptable in the temperature range 0°C. to -7.5°C. Tests using this fluid were not conducted below the specified temperatures, and its effectiveness as a de-icing fluid at lower temperatures is uncertain.

## 6.0 CONCLUSIONS AND RECOMMENDATIONS

This system proved to be satisfactory for use in the Sycamore helicopter in icing conditions at temperatures not below -15°C. A requirement for use of the system below the designated temperature would need further testing.

The fluid economy of the system makes it desirable for use in the smaller type of helicopter when a de-icing system is a requirement.

Maintenance of the system was relatively high, and absolute cleanliness is necessary to maintain the system in a satisfactory operating condition.

This system should not be fitted to helicopters other than the Sycamore without prior testing.

/AM

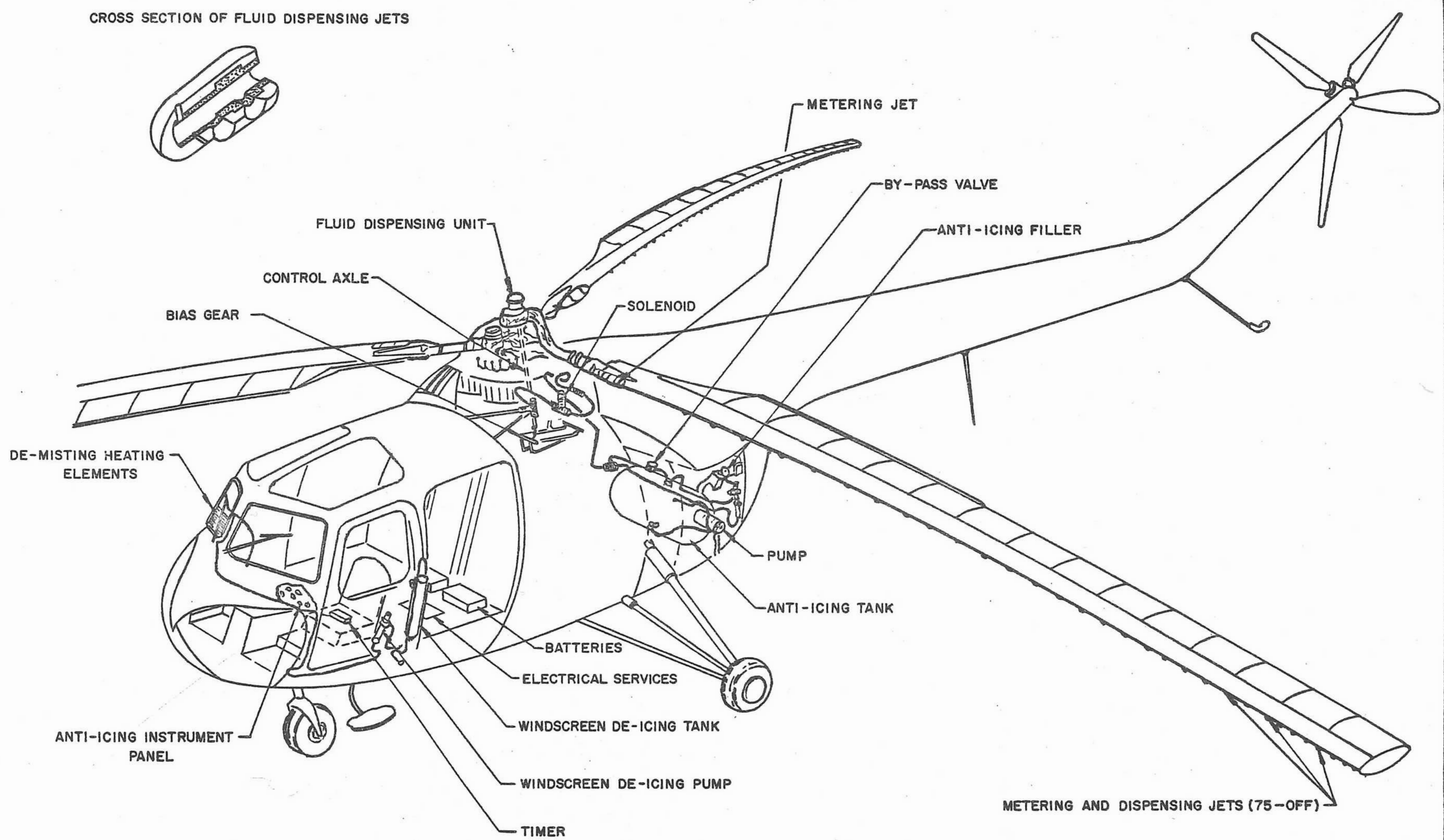
# TABLE I

## TABLE OF RESULTS - SYCAMORE

| Run No. | Temp. °C. | Flight Duration (min.) | Fluid type | Fluid flow gal./hr. | Fluid Cyclic time (sec.) on | off | Operation mode | Ice thickness M/R (in.) | Icing Extent % span | Max. boost in.Hg. | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 17/1/1 | -7.1 | 13 | - | - | - | | icing | 5/16 | 80 | - | Pilot familiarization - icing run only, poor cloud coverage. |
| 17/1/2 | -8.2 | 3 | AL/GL | 90 | cont. | | anti-icing | - | - | - | Discontinued run, excessive T/R vibration. |
| 27/1/1 | -6.1 | 5 | - | - | - | | icing | 1/4 | 60 | 44.0 | T/R vibration. |
| 27/1/2 | -6.1 | 2 | AL/GL | 90 | cont. | | anti-icing | - | - | - | Blades clean. |
| 28/1/1 | -12.8 | 3 | - | - | - | | icing | 3/16 | 98 | 44.0 | Accretion run. |
| 28/1/2 | -12.0 | 5 | AL/GL | 90 | cont. | | anti-icing | 3/32 | 60 | - | Poor system operation - excess ice remaining. |
| 28/1/3 | -11.3 | 4 | AL/GL | 90 | cont. | | anti-icing | - | - | - | Repeat of Run 2; fluid exhausted during run -- aborted run. |
| 28/1/4 | -10.6 | 5 | AL/GL | 28 | cont. | | anti-icing | 1/8 | 45 | - | Improved protection - acceptable run. |
| 28/1/5 | -10.6 | 11 | AL/GL | 28 | cont. | | anti-icing | 1/16 | 10 | - | Acceptable run - poorer cloud coverage than Run 4. |
| 29/1/1 | -7.2 | 6 | - | - | - | | icing | 1/8 | 70 | 44.0 | Poor cloud coverage. |
| 29/1/2 | -6.8 | - | - | - | - | | - | - | - | - | Timer malfunction after 1 min. in cloud. |
| 30/1/1 | -4.7 | 5 | - | - | - | | icing | 1/4 | 65 | - | Accretion run - some tail rotor vibrations |
| 30/1/2 | -4.1 | 16 | AL/GL | 28 | 2 | 2 | anti-icing | - | - | 43.0 | Small pieces of ice left at 40% span - acceptable run. |
| 30/1/3 | -4.0 | 16 | - | - | - | | icing | 3/4 | 50 | - | Determination of de-ice requirement at this temp.(yes). |
| 30/1/4 | -3.9 | 16 | AL/GL | 28 | 2 | 4 | anti-icing | 3/8 | 10 | | Acceptable run. |
| 30/1/5 | -4.3 | 17 | AL/GL | 28 | 2 | 6 | anti-icing | 1/4 | 30 | | Slightly worse than Run 4 but still acceptable. |
| 3/2/1 | -16.0 | 3 | - | - | - | | icing | 1/8 | 100 | 46.0 | Originally a 5-min. accretion; max. power reached at 3 min. |
| 3/2/2 | -15.0 | 3 | AL/GL | 28 | 2 | 2 | anti-icing | 1/8 | 30 | 42.0 | Acceptable; icing to 100% span. |
| 3/2/3 | -14.7 | 15 | AL/GL | 28 | 2 | 2 | anti-icing | 1/8 | 30 | 42.0 | Run 2 extended to 15 min.; acceptable. |
| 3/2/4 | -10.8 | 15 | AL/GL | 28 | 2 | 4 | anti-icing | 1/8 | 35 | - | Acceptable; little difference from Run 3. |
| 3/2/5 | -10.2 | 15 | AL/GL | 28 | 2 | 6 | anti-icing | 3/8 | 10 | - | Acceptable although ice thickness inboard is greater than Run 3. |
| 3/2/6 | -9.7 | 5 | AL/GL | 28 | cont. | | de-icing | - | - | - | Icing for 1 min. prior to system turn-on; acceptable run. |
| 6/2/1 | -6.5 | 5 | - | - | - | | icing | 1/4 | 45 | 42.0 | Accretion run. |
| 6/2/2 | -5.1 | 15 | AL/GL | 15 | 2 | 6 | anti-icing | 1/2 | 30 | 41.0 | Acceptable run; ice remaining is soft and mushy. |
| 6/2/3 | -3.5 | 15 | AL/GL | 7.5 | 2 | 2 | anti-icing | 3/16 | 40 | 38.0 | Acceptable run; small patches of ice remaining. |
| 12/2/1 | -5.9 | 5 | - | - | - | | - | 1/2 | 50 | 42.0 | Acceptable run. |
| 12/2/2 | -4.7 | 5 | AL/GL | 7.5 | cont. | | de-icing | - | - | - | 2 min. icing followed by 3 min. de-icing; marginal acceptable. |
| 12/2/3 | -4.3 | 5 | AL/GL | 7.5 | 2 | 2 | de-icing | - | - | - | As per Run 2. |
| 14/2/1 | -10.2 | 5 | - | - | - | | - | 3/16 | 60 | 42.0 | Accretion run. |
| 14/2/2 | -10.5 | 6 | AL/GL | 7.5 | 2 | 4 | anti-icing | 3/16 | 60 | 44.0 | Insufficient flow to maintain safe flight. |

# TABLE OF RESULTS - SYCAMORE

| Run No. | Temp. °C. | Flight Duration (min.) | Fluid type | Fluid flow gal./hr. | Fluid Cyclic time (sec.) on | off | Operation mode | Ice thickness M/R (in.) | Icing Extent % span | Max. boost in.Hg. | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 14/2/3 | -10.5 | 15 | AL/GL | 7.5 | cont. | | anti-icing | - | - | 42.0 | Marginal acceptable. |
| 17/2/1 | -13.7 | 5 | - | - | - | | icing | 1/32 | - | - | Due to low wind attempt at icing at 150' downwind not successful. |
| 17/2/2 | -12.4 | 5 | - | - | - | | icing | 3/16 | 90 | - | Accretion run. |
| 17/2/3 | -11.3 | 5 | AL/GL | 10 | cont. | | anti-icing | - | - | - | New jets fitted posn. 29-35, single hole spanwise - improved de-icing. |
| 17/2/4 | -10.7 | 15 | AL/GL | 10 | cont. | | de-icing | - | - | - | 2 min. icing prior to system on - satisfactory shedding. |
| 17/2/5 | -8.4 | 7 | AL/GL | 7.5 | cont. | | de-icing | - | - | - | Additional new jets fitted pos'n. 45-60; no improvement, marginal acceptable. |
| 17/2/6 | -8.6 | 6 | AL/GL | 7.5 | cont. | | de-icing | - | - | - | Jets rotated upwards 10°; no significant difference, marginal acceptable. |
| 17/2/7 | -8.5 | 5 | AL/GL | 7.5 | cont. | | anti-icing | - | - | - | Ice less patchy than Run 6 - acceptable run. |
| 18/2/1 | -9.7 | 5 | - | - | - | | icing | 1/16 | 80 | 43.0 | Accretion run. |
| 18/2/2 | -8.9 | 16 | AL/GL | 7.5 | cont. | | anti-icing | - | - | 45.0 | High power requirement during run makes this run unsuccessful. |
| 18/2/3 | -7.5 | 6 | AL/GL | 7.5 | cont. | | anti-icing | - | - | 42.5 | Repeat Run 2; slightly higher temp. made this run successful. |
| 22/2/1 | -16.9 | 5 | - | - | - | | icing | 5/16 | 100 | 47.0 | Accretion run; unable to maintain power due to high drag. |
| 22/2/2 | -15.9 | 10 | AL/GL | 28 | cont. | | de-icing | - | - | 46.0 | Icing until full power attained, then de-ice; acceptable. |
| 22/2/3 | -14.5 | 6 | AL/GL | 28 | 2 | 6 | anti-icing | - | - | 44.0 | Small pieces of ice on blades - acceptable. |
| 22/2/4 | -12.7 | 7 | AL/GL | 28 | 2 | 6 | anti-icing | - | - | 42.0 | Repeat of Run 3 - results same as Run 3; acceptable. |
| 22/2/5 | -11.9 | 6 | AL/GL | 28 | cont. | | anti-icing | - | - | 42.0 | No improvement over Run 4. |
| 24/2/1 | -13.4 | 5 | - | - | - | | - | 3/16 | 100 | 44.0 | Accretion run. |
| 24/2/2 | -13.4 | 5 | AL/GL | - | 2 | 6 | de-icing | - | - | 45.0 | 5 min. icing followed by 3 min. de-icing in forward flight; acceptable. |
| 24/2/3 | -13.4 | 5 | AL/GL | 28 | 2 | 6 | de-icing | - | - | 45.0 | 5 min. icing followed by 3 min. de-ice in hover; acceptable. |
| 24/2/4 | -13.4 | 5 | AL/GL | 28 | 2 | 6 | de-icing | - | - | 45.0 | 5 min. icing followed by 3 min. de-ice in flat pitch - marginal acceptable. |
| 24/2/5 | -13.6 | 9 | AL/GL | 28 | 2 | 6 | de-icing | - | - | 46.0 | 5 min. icing followed by 3 min. de-ice in cloud; acceptable. |
| 25/2/1 | -16.4 | 5 | - | - | - | | icing | 5/16 | 100 | 44.0 | Accretion run. |
| 25/2/2 | -16.3 | 3 | AL/GL | 28 | 2 | 6 | de-icing | - | - | - | De-ice Run 1; failure; error in interchanging jets. |
| 27/2/1 | -15.4 | 5 | - | - | - | | icing | 5/16 | 100 | 44.0 | Accretion run. |
| 27/2/2 | -13.9 | 7 | AL/GL | 28 | cont. | | de-icing | - | - | - | De-ice Run 1; marginal acceptable. |
| 27/2/3 | -13.0 | 5 | AL/GL | 28 | cont. | | de-icing | - | - | - | 5 min. icing followed by 3 min. de-ice; marginal acceptable. |
| 27/2/4 | -10.4 | 5 | AL/GL | 28 | cont. | | de-icing | - | - | - | Repeat Run 3; marginal acceptable. |




SYCAMORE HELICOPTER
FLUID ANTI-ICING SYSTEM LAYOUT

FIG. I
LR-398

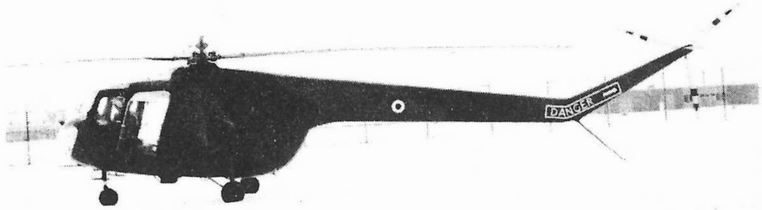



FIG. 2 WESTLAND SYCAMORE HELICOPTER

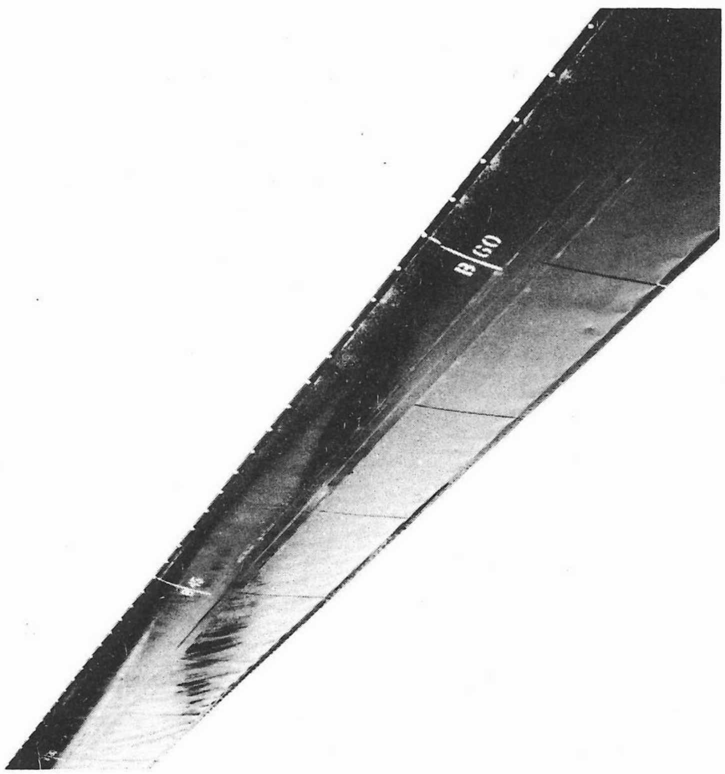
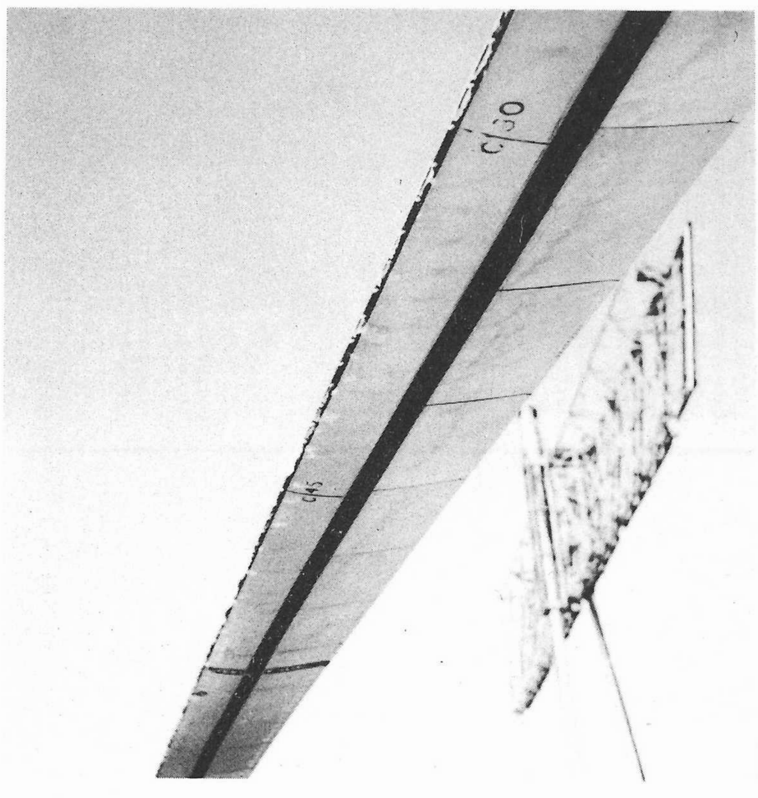



FIG.3 FLUID JETS AT LEADING EDGE OF MAIN ROTOR BLADE




MAIN ROTOR BLADE AFTER DE-ICING CYCLE

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R.D. Price. May 1964. 8 pp. + 4 figs.

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LIMITED

1. Helicopter rotors - Icing
2. Anti-icing and de-icing systems - Test results
3. Helicopters (Westland Sycamore

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