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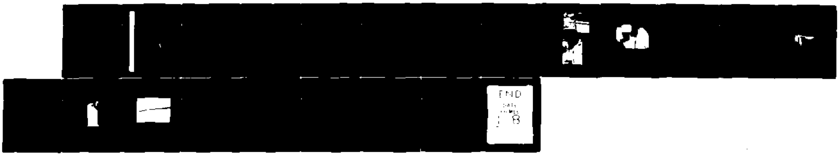

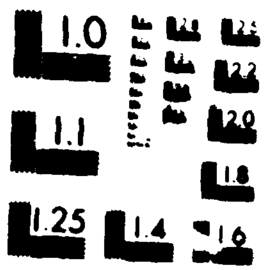
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MELBOURNE, VICTORIA

Aero Propulsion Technical Memorandum 442

CALIBRATION OF THE ARL RAIN AND ICING FACILITY (U)

by

P.N. Doogood

Approved for Public release

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CALIBRATION OF THE ARL RAIN AND ICING FACILITY

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SUMMARY

Modifications have been made to the water injection system of the ARL Icing Facility to improve rain and ice distribution over the working area. Air velocity and water content measurements have indicated the effectiveness of the development and the facility is now considered to be ready for use.

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CONTENTS

1. INTRODUCTION

An important phase in the development of much Defence hardware is testing in extreme climatic environments.

It was known that the ARL Icing Facility (Ref 1) was capable of producing low temperatures and consequent icing and freezing rain conditions to meet the low end of the required environmental test specification. It was not known if the air velocity across the outlet nozzle was uniform or what effect any peaks or troughs in this would have on rain and ice distribution on the target.

This report describes the methods used to analyse the characteristics of the icing facility and the action taken to refine its performance so that it could meet the required cold climate specifications.

2. THE ARL RAIN & ICING FACILITY

The Facility makes use of an energy saving feature of the Aero Propulsion Division's 1500 kW Brown Boveri Compressor in which air at a pressure of up to 1000 kPa is expanded through a recuperative turbine to ambient pressure producing a temperature drop of approximately 20°C. Because the compressor is isothermal the resultant temperature can be as low as -15°C in certain conditions.

By varying the compressor driving pressure over the range of 70 to 700 kPa an equivalent range of velocities and temperatures can be achieved at the working section for short periods (Fig 1). Because the sensing probe used was not de-iced, velocity measurements were not carried out above 45 m/s.

The cold air is piped into a 310 mm diameter duct which is 12 metres long. The test model is mounted about one metre from the exit of the duct (Fig 2). A pneumatically operated diversion valve at the commencement of the duct permits work to be done on the test model whilst the facility is running and provides an accurate model exposure timing system (Fig 3). Three metres upstream of the nozzle end of the duct a water injector is located. This is comprised of an ARL designed air blast water atomiser mounted in a fairing through which air is pumped via an electric heater. The heat flow is controlled to prevent icing of the fairing and exhausts to atmosphere.

The elements of the atomiser can be changed so that different water droplet sizes can be produced to match differing requirements for heavy rain, glaze ice and rime ice, and further tuning is enabled by variation of atomiser driving air pressure. Water flow to the atomiser is measured by a standard ball type flowmeter.

An aircraft type heated temperature probe is mounted one metre upstream of the nozzle. This is de-iced by 24 volt power from the nearby control room. Velocity of the airstream is measured by a simple pitot/static tube which is mounted at the nozzle face and may be swung into the stream as required.

3. TEST METHOD

A mounting rack to hold the model had been set up one metre downstream from the nozzle and a representative airspeed of about 40 metres per second could be obtained at this location from a compressor driving pressure of 350 kPa. A preliminary test in freezing rain at a rate of 100 mm per hour was carried out for a duration of 5 minutes. Air temperature was -9°C and model skin temperature -4°C. The technique used for reducing model skin temperature prior to the run was to wrap the test area of the model in aluminium cooking foil and run the rig for long enough to reach the desired temperature using a thermocouple attached to the model skin. A considerable amount of ice was built up on the model during this chill phase but this was readily removed along with the foil.

The result of this test (Fig 4) indicated that the freezing rain was not evenly distributed in the duct. A velocity traverse was carried out both horizontally and vertically at 25 mm intervals in the plane of the test model. Because the Pitot/Static instrument used for these calibrations was not heated they were done at reduced airspeeds. Figs 5 & 6 drawn from these results indicate a large variation of velocity across the working section, with the values in general increasing continuously towards the centre.

Another problem was that it could not be assumed that the rain deposition rate on the target was equal to the water input to the atomiser. Although the driving compressor is designed to remove moisture content from the air between compression stages, a small quantity (approx 3% of ambient moisture content) passes through the recuperative turbine.

4. WATER SAMPLING

To determine the total water content of the stream a sampling technique was devised which used an iso-kinetic probe (Fig 7). This was made by the author and driven by a vacuum pump which was controlled so that the static pressure inside the 12 mm diameter probe throat was the same as that outside in the main air stream. The air/water mixture from the sampling probe was drawn by the vacuum pump through a tube packed with a dessicant with a very high water absorption capability. Although provision was made for de-icing the probe it was decided to traverse the duct sampling moisture content at the same air speed as for the velocity calibration.

Figure 8 shows the distribution of rain across the working section at an equivalent rain rate of 170 millimeters per hour. Eleven samples were taken with run times of 5 minutes for each. The dessicant tubes were accurately weighed before and after sampling to determine the actual water content. As expected the measured distribution of water content across the duct showed a marked similarity to the velocity profiles discussed earlier.

The sample at the centre of the duct was repeated with the added water turned off. Over the 5 minute sampling period 0.97 grams of water was collected, the equivalent to 40 millimeters of rain per hour. The difference between the mean rain rate over the duct (220 mm) and the flow rate for added water (equivalent to 170 mm) is due to this natural water content of the air in the stream.

5. WATER ATOMISER MODIFICATION

To reduce the peaks of velocity and water concentration in the centre of the working section it was decided to mount a small conical baffle of 60 mm diameter on the heated atomiser fairing immediately upstream of the atomiser itself (Fig 9). This was designed to create a small recirculation zone downstream of the atomiser and thus improve the mixing of water droplets and air and even out the velocities across the working section. Another water content sampling traverse was carried out and the plot from this indicated that the baffle was effective. The mean rain rate over the centre 150 mm (the size of the test model) was 152 millimetres per hour which was a significant improvement over the previous result (Fig 10).

The increased recirculation generated by the baffle also increased the amount of water lost from the stream due to droplet impingement on the duct walls and subsequent aglomeration. This water fell from the stream at the nozzle exit and was therefore not sampled. This explains the apparent discrepancy in water flow rates.

To further test the effectiveness of this modification, several calibration runs were carried out on a 25 mm diameter copper tube mounted in the working section in accordance with MIL SPEC 810-D. Again a thermocouple was attached to the model and again the foil chilling technique was used. A two minute run using the previous conditions of 100 mm per hour rain rate and -9°C air temperature produced a uniform build up of glaze ice about 5 mm thick at the leading edge across the relevant section of the working section. This result was considered to be satisfactory (Fig 11).

CONCLUSION

The ARL Rain and Icing Facility is now at a stage of development where it can be used to carry out environmental tests on military hardware. The potential for further refinement still exists but with the limited resources available and the priority of other tasks it is not considered to be essential for efficient use of the facility.

ACKNOWLEDGEMENT

The author gratefully acknowledges the guidance and assistance given to him by Mr P.B. Atkins of ARL in the experimental program and testing techniques described in this report.

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1. Experimental Investigations of Aircraft Intake Icing. ARL Report to be published. By P.B. Atkins

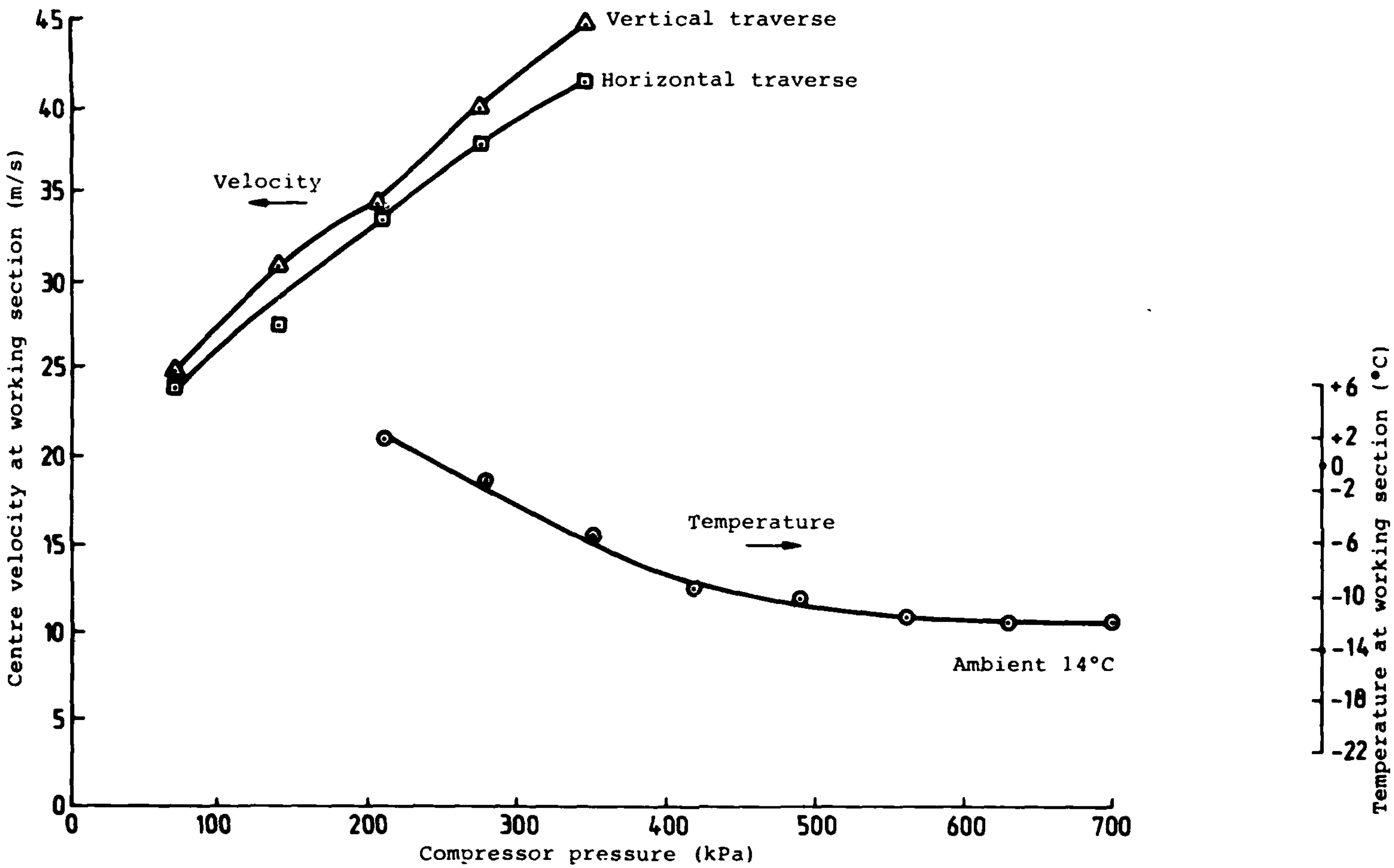

FIG. 1 TYPICAL PERFORMANCE OF ICING FACILITY

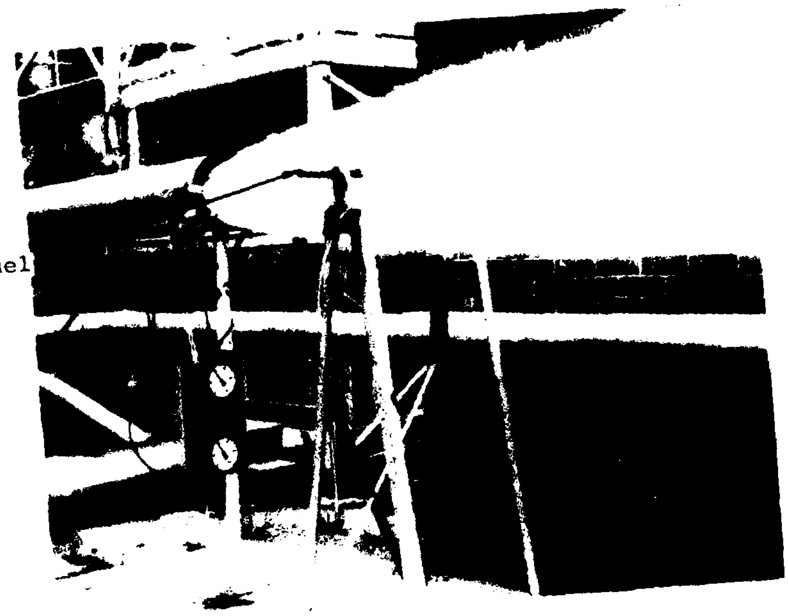

FIG. 2 ICING FACILITY IN OPERATION

FIG. 3 DIVERSION IN OPERATION

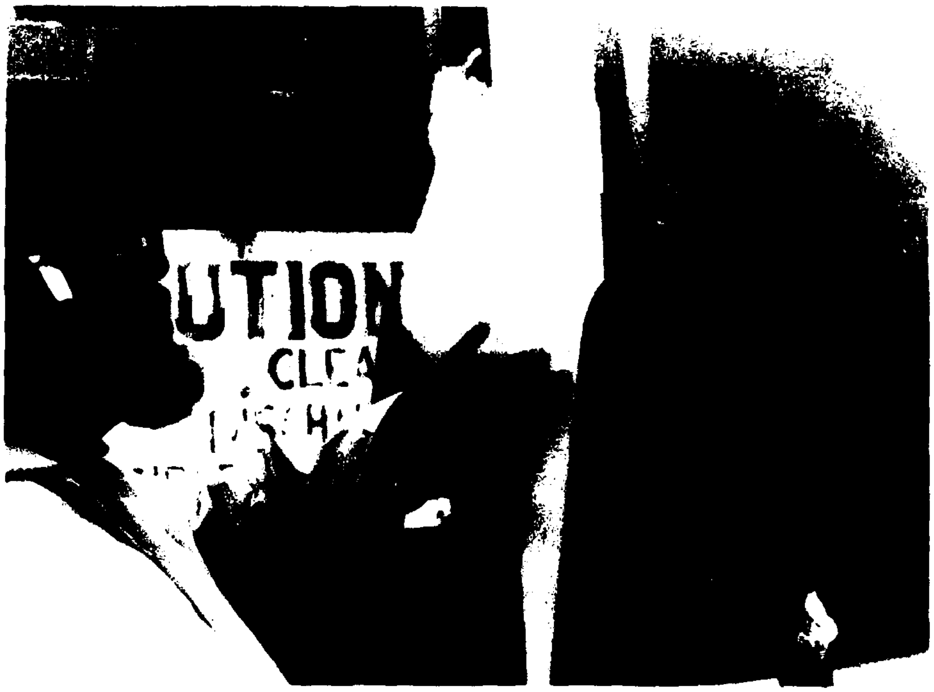

FIG. 4   ICE DISTRIBUTION BEFORE ATOMISER MOD

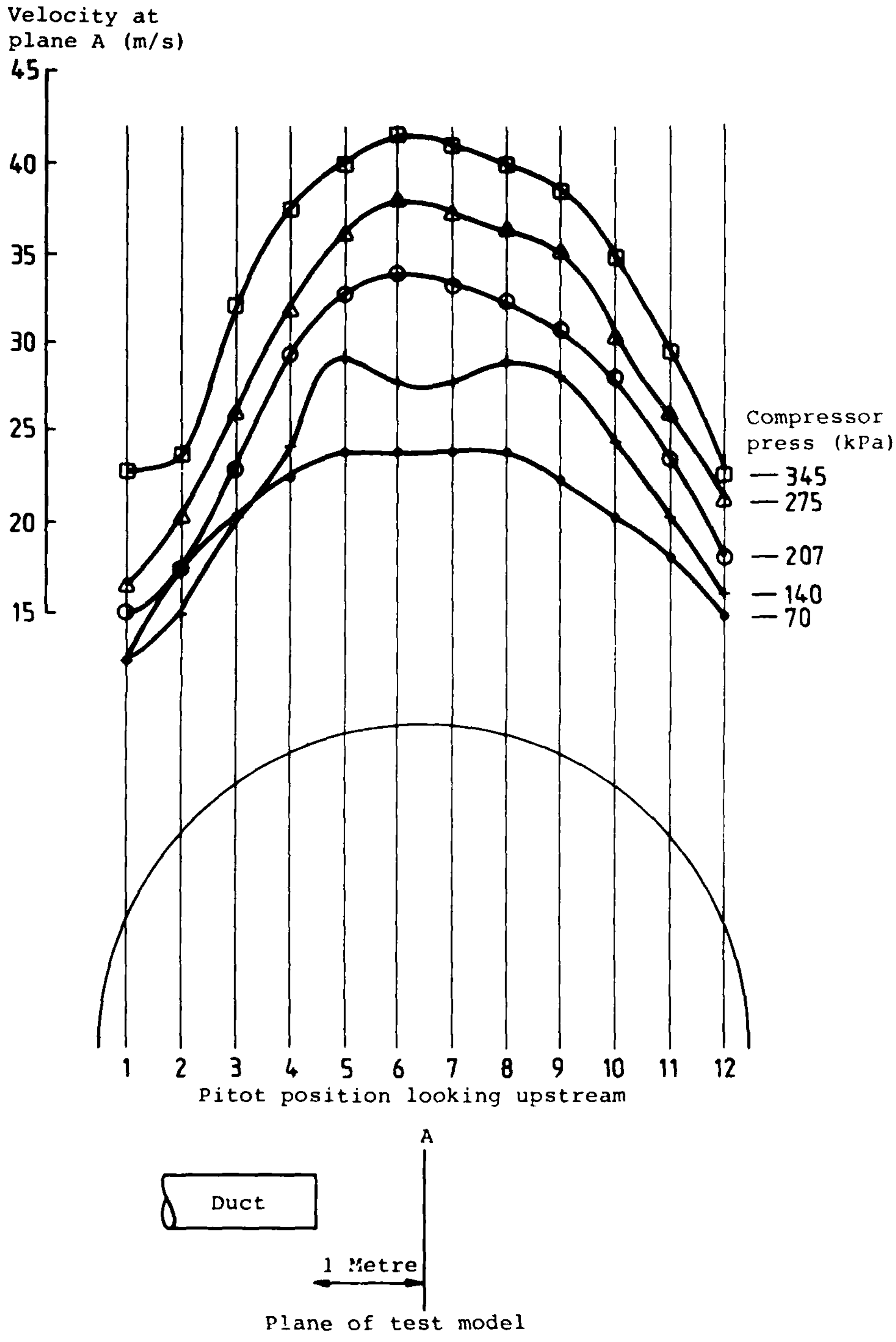

FIG. 5 HORIZONTAL VELOCITY TRAVERSE OF TEST SECTION

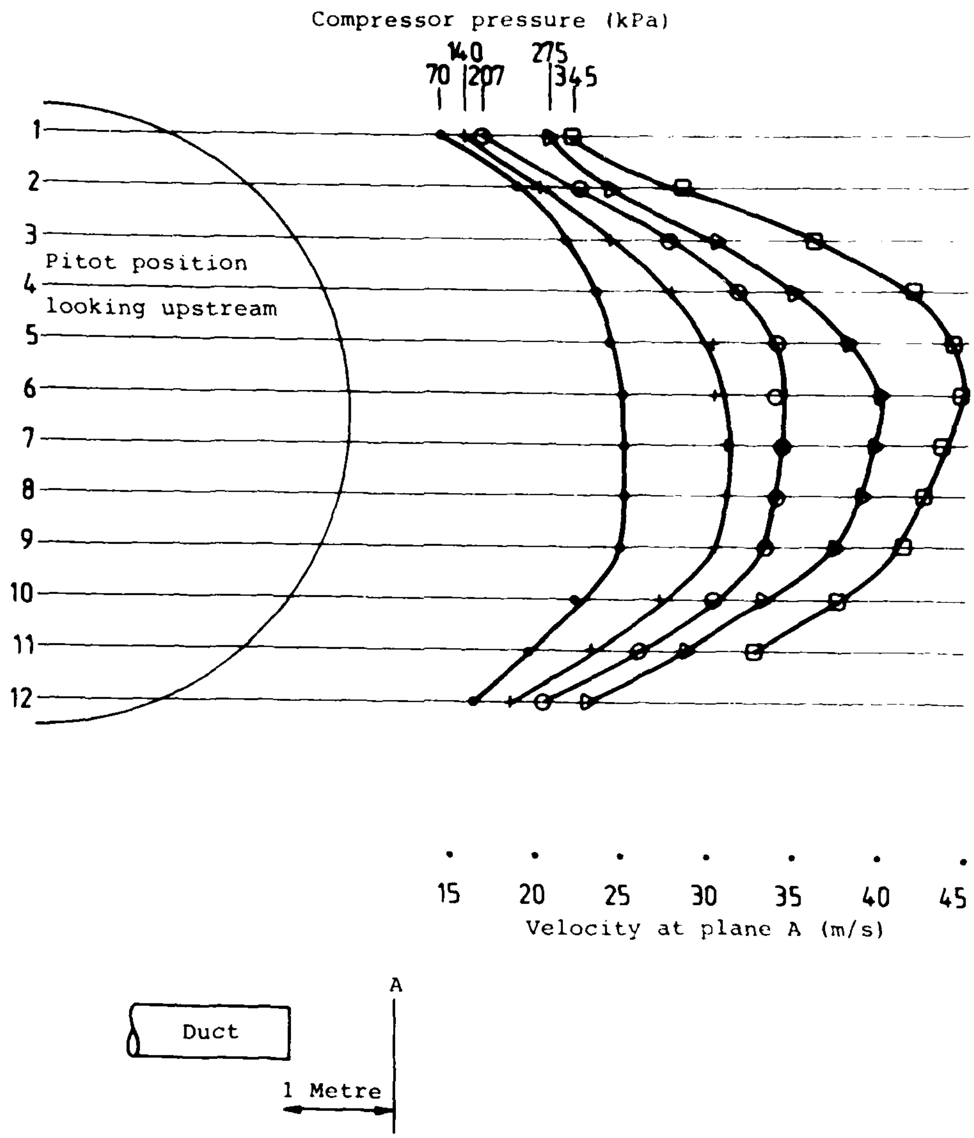

FIG 6. VERTICAL VELOCITY TRAVERSE OF TEST SECTION

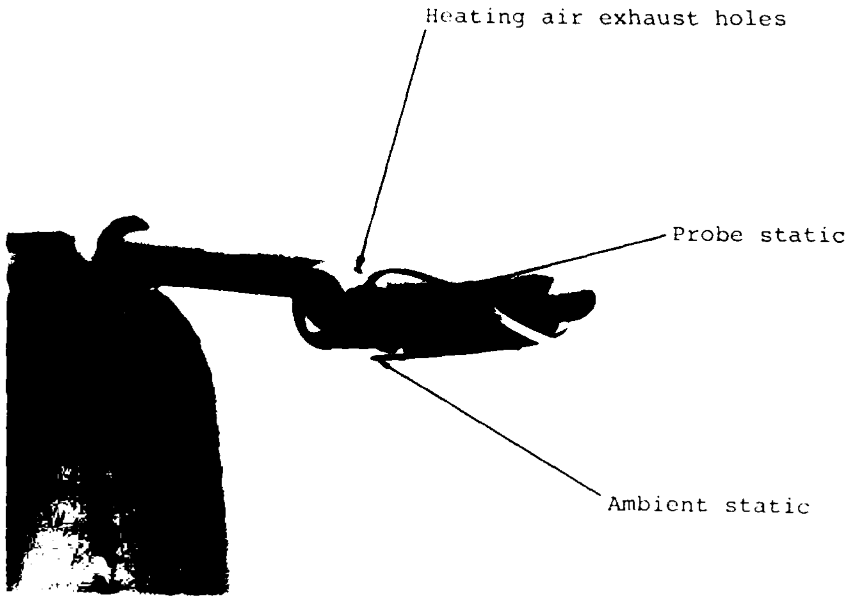

FIG 7. ISO-KINETIC PROBE

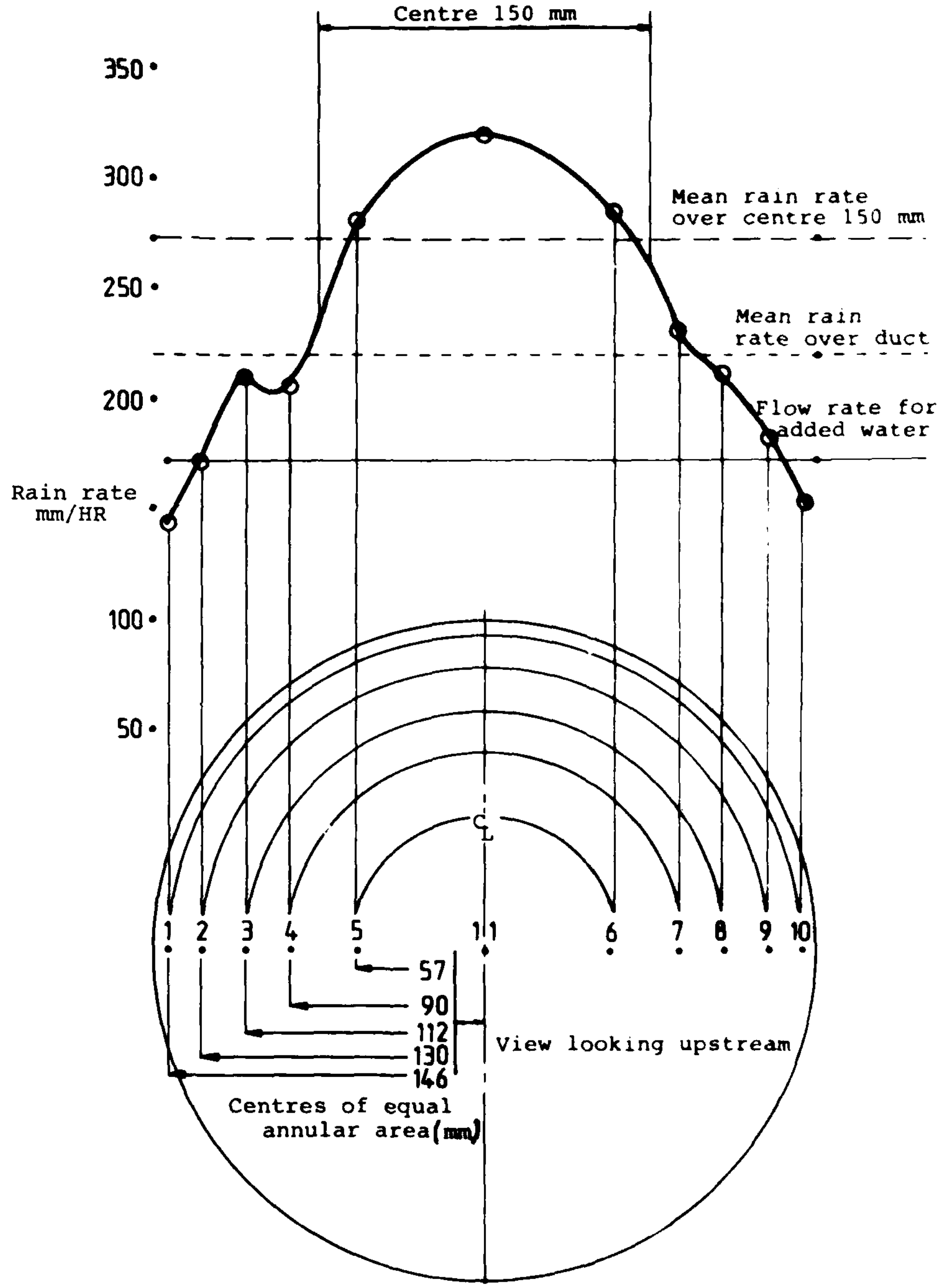

FIG 8. RAIN DISTRIBUTION BEFORE ATOMISER MOD

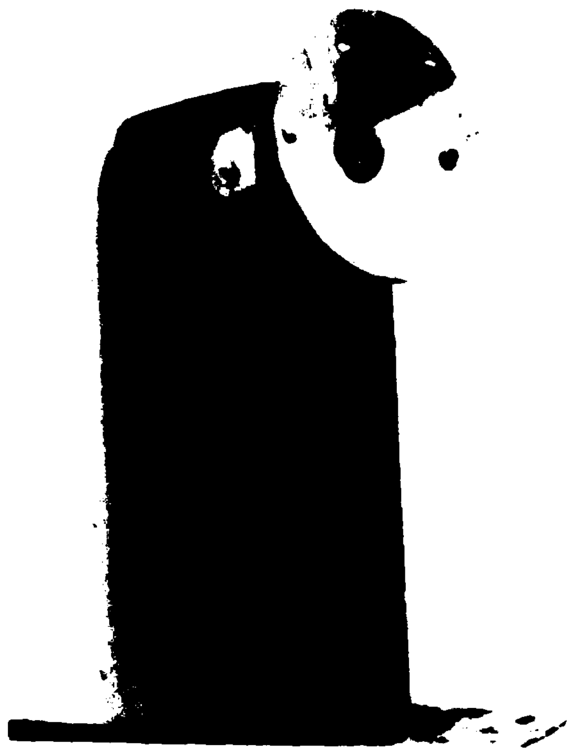

FIG. 9 AIR HEATED WATER ATOMISER WITH BAFFLE MODIFICATION

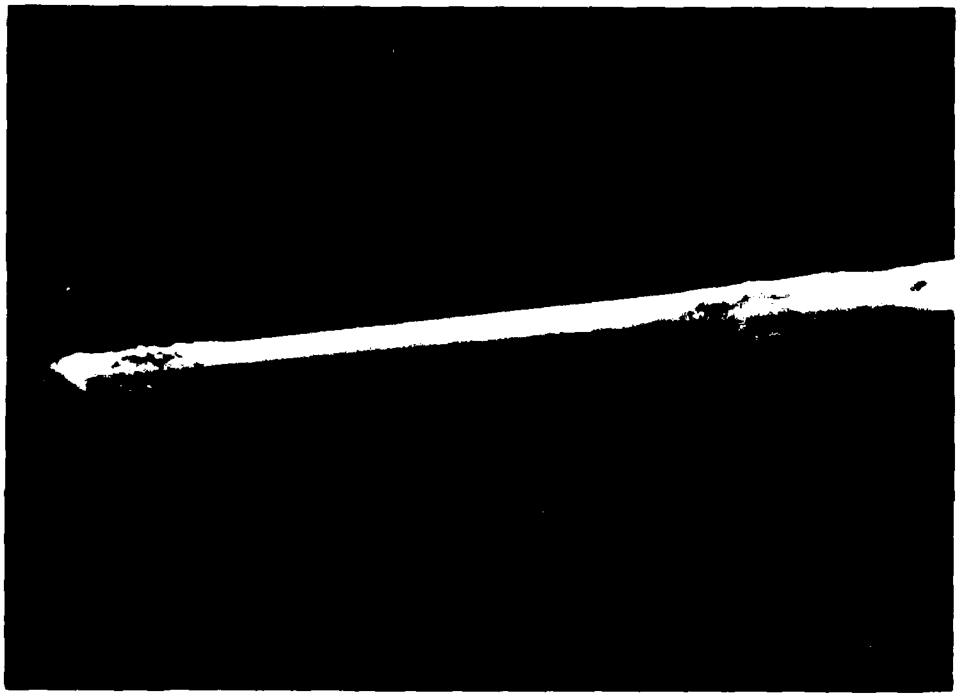

FIG. 11 UNIFORM GLAZE ICE BUILD UP. 2 MINUTES AT AT -9°C & 100 mm/HR RAIN RATE

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Test facilities Cold weather tests Ice formation Artificial precipitation	0055F 0043F

16. Abstract

A rain and icing facility was set up at ARL in the early seventies to test anti icing systems for aircraft engine air intakes. This report describes mo[illegible]ations made to the facility to meet a specific test requirement and analyses the e[illegible]t that these have ~~been~~ made on its performance.

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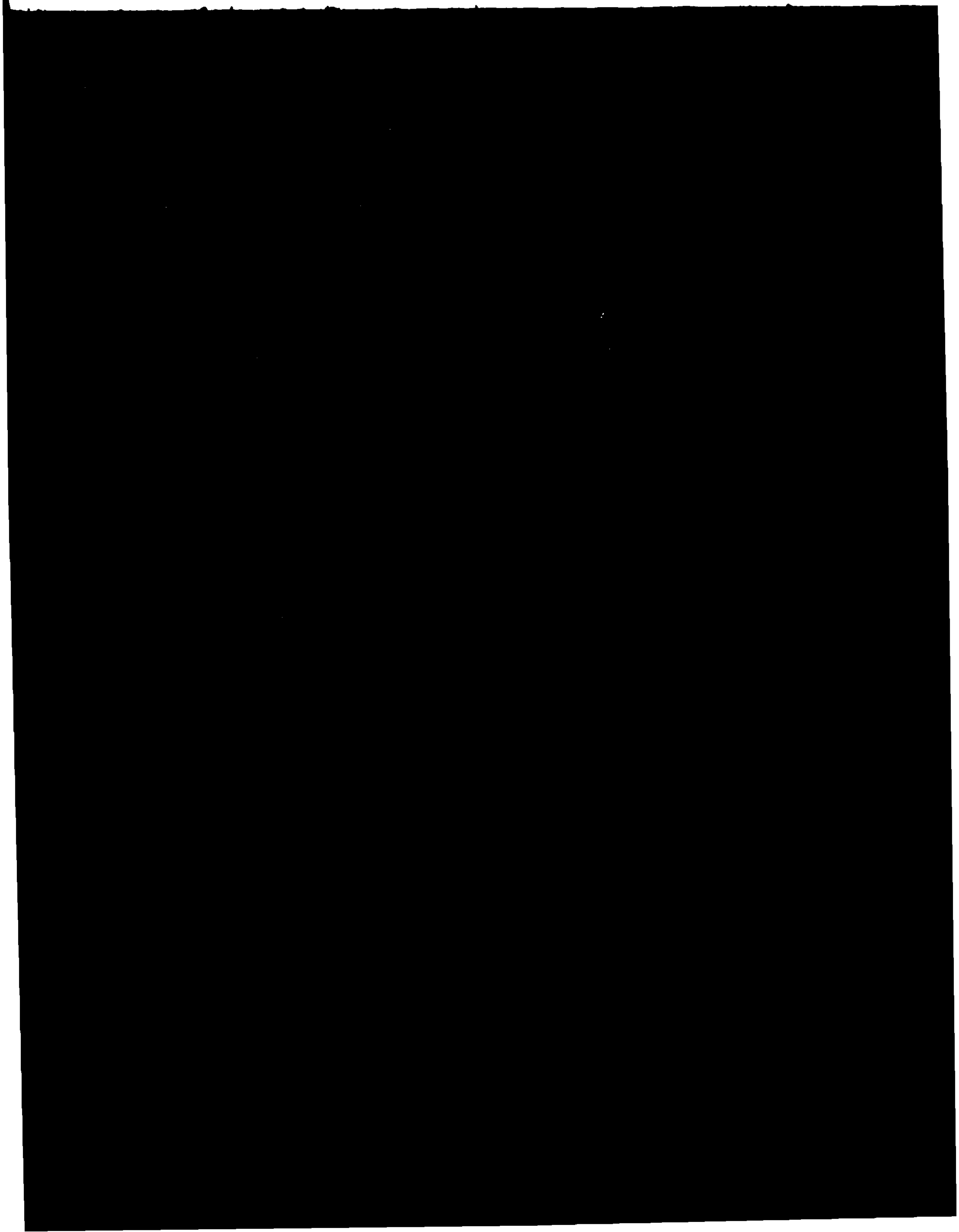
FIG. 4 ICE DISTRIBUTION BEFORE ATOMISER MOD



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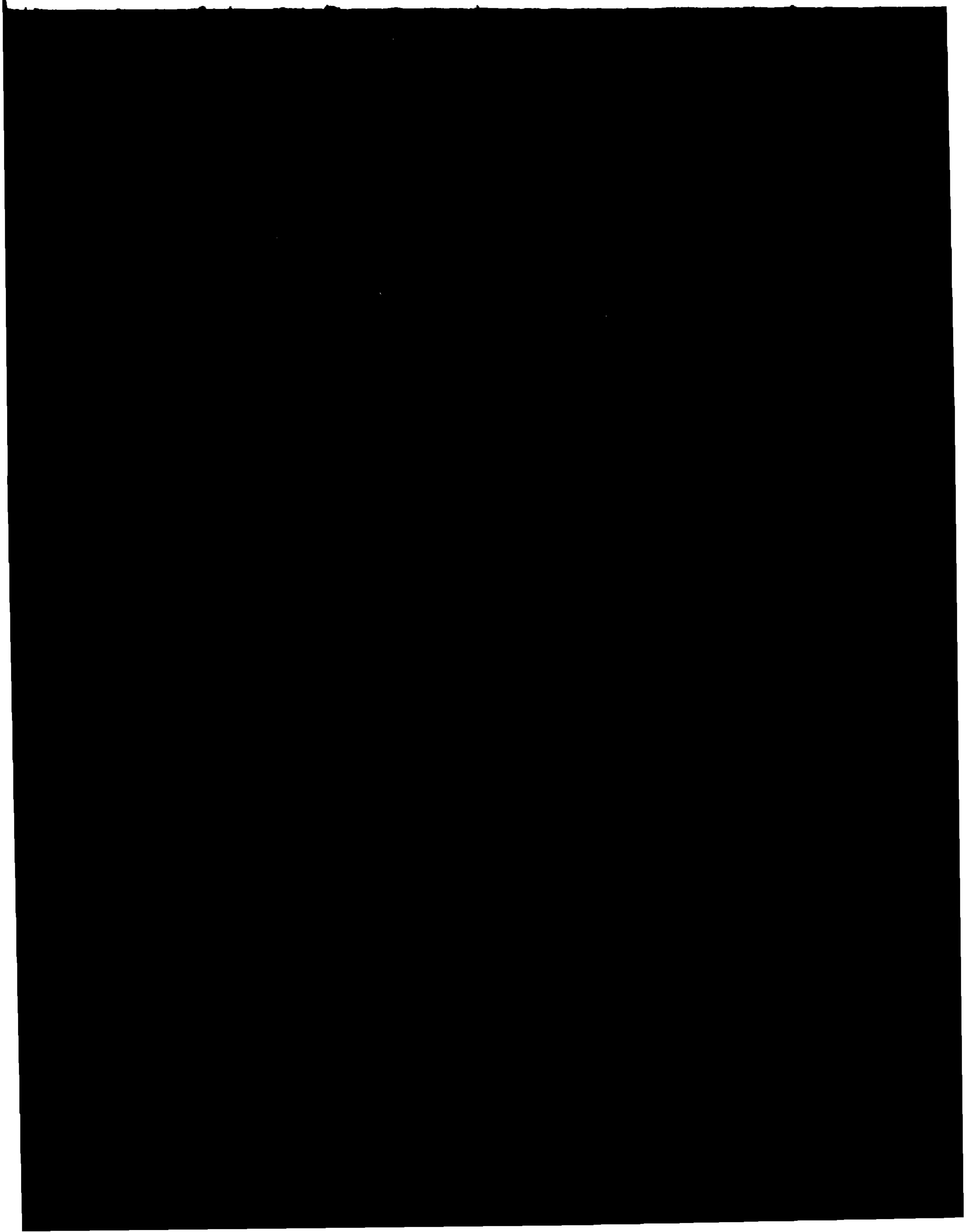

FIG 6. VERTICAL VELOCITY TRAVERSE OF TEST SECTION

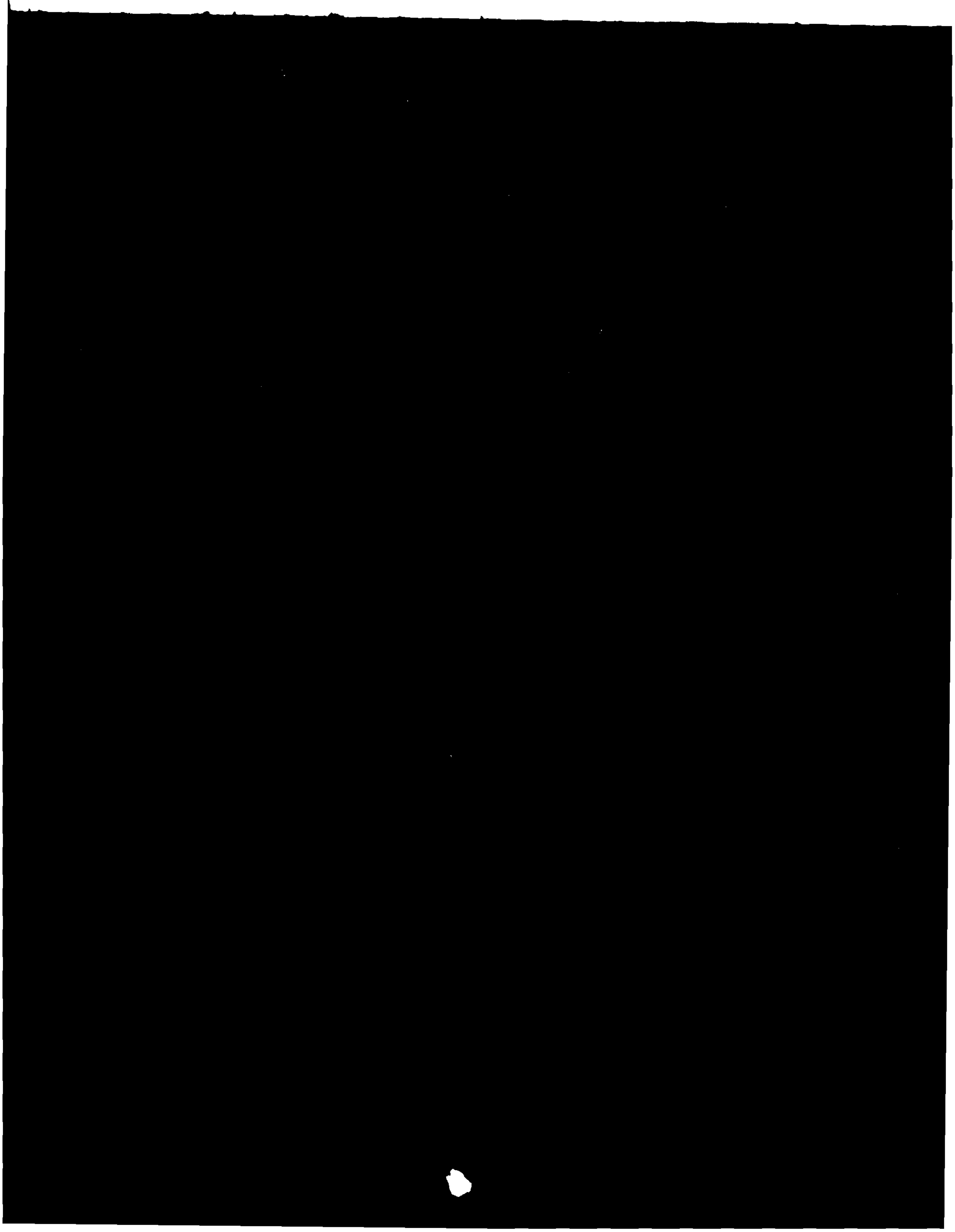

FIG 7. ISO-KINETIC PROBE