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DOCUMENTATION OF ICE SHAPES ON THE MAIN ROTOR OF A UH-1H HELICOPTER IN HOVER

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John D. Lee

The Ohio State University
Columbus, Ohio

and

Rorry Harding

Hovey and Associates Ltd.
Ottawa, Canada

and

Richard L. Palko

Calspan Field Services, Inc.
Tullahoma, Tennessee

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John D. Lee

Aeronautical and Astronautical Research Laboratory
The Ohio State University
Columbus, OH 43220

Rorry Harding

Hovey and Associates (1979) LTD.
Ottawa, Canada

Richard L. Palko

Calspan Field Services, Inc.
AEDC
Tullahoma, TN

SUMMARY

A helicopter icing flight test program in the hover mode was conducted in the period January through March 1983, by the NASA (Lewis Research Center) and the Army (AVRAD COM) with a UH-1H aircraft at the Canadian National Research Council spray rig at Ottawa, Canada. The ice formations were documented after landing by means of silicone rubber molds, stereo photography and outline tracings for later use in aerodynamic analyses. The documentation techniques are described and the results presented for a typical flight.

1.0 INTRODUCTION

During the winter of 1982-83, the NASA (Lewis Research Center) and the Army (AVRADCOM) conducted a Helicopter Icing Flight Test (HIFT) program with a UH1H aircraft at the Canadian National Research Council spray rig at Uplands Airport, Ottawa, Canada. The Ohio State University Aeronautical and Astronautical Research Laboratory (OSU/AARL) was given the responsibility for fabricating and/or acquiring all hardware and providing the manpower to document the ice formations on the main rotor using molding techniques, stereo photography and section tracing together with general photographic coverage to support the other methods.

With assistance and support of personnel from NASA-Lewis and the Air Force/Arnold Engineering Development Center (AEDC) the necessary equipment was designed, fabricated and tested at OSU/AARL. After an evaluation of the requirements on-site, a subcontract was awarded to Hovey and Associates, Ottawa, to set up a documentation station, to assemble the equipment and materials, and to perform the ice documentation. In application, a number of modifications were made on-site by Hovey engineers.

The UH-1H Helicopter used in the program is shown diagrammatically in Figure 1; Figure 2 is a photo of it hovering in the cloud. Immediately after landing, one of the blades was enclosed in a van (Figure 3) where the temperature and lighting could be controlled for the documentation.

An unusually warm winter prevented as extensive a test program as planned; however, there were enough opportunities to acquire data to show the feasibility of all of the techniques attempted, and some degree of documentation was successful on five flights (see Table I). Of these, one (Flight E) had sufficient ice documentation to be useful for comparison of the techniques and for applications to a minimal wind-tunnel test program. Data from such a program will be used for input to a performance program and for comparison with the measured degradation on-site; these data will be reported when that phase of the program is completed. Further details of the documentation program follow.

2.0 PROCEDURES

2.1 Molding Technique

After a review of some of the techniques used previously (refs. 1, 2) and those in development at NASA-Lewis (ref. 3), one of the latter was selected. This technique used a Dow-Corning silicone rubber compound with a hardening catalyst which can be used at sub-freezing temperatures to set up in 2 to 4 hours, thus having the potential of minimizing damage to the ice formation. The basic compound was diluted with Dow-Corning 200 fluid to a suitably low viscosity. The catalyzed mixture was degassed to remove disolved air and bubbles induced by the mixing. In order to handle the relatively large quantities of the compound needed to cover the anticipated ice accretions, a set of 4 degassing units was assembled, each using a vacuum pump connected to a one-foot deep chamber, having a removeable top with a window for observing the degassing progress and valves for controlling the rate. The details of the procedure and the proportions of the chemicals are given in the appendix.

Ten plywood mold-containers were fabricated (see Figure 4) in two parts for attachment around the rotor blade. Each "box" isolated a segment of the blade about ten inches wide (spanwise) and permitted molding of ice form two inches ahead of the leading edge to six inches aft.

In practice the silicone rubber compound was mixed and degassed while the stereo photos were being taken and, upon attachment of the mold-boxes, the mixture was poured into the cavities around the ice accretions, all items being maintained at temperatures below freezing in order to prevent damage to or loss of any ice. After a period of about two hours the temperature was increased, the mold-boxes were removed with the ice still in the molds, and the blade cleaned. The ice was allowed to melt of the molds while the compound continued to harden.

2.2 Stereo Photography

The stereo photography technique was an application of that developed at AEDC (ref. 4) whose personnel provided the design layout of the cameras and reference system. Two Hasselblad cameras were provided by NASA-Lewis. These were assembled onto a rigid support frame together with a grid projector and a set of flash guns. The support frame was adjustable vertically at any station along the blade so that 2 or 3 stereo pairs could be taken from different elevations in order to view all of the ice accretion at that station. The analysis of a given stereo pair of photographs requires the reference to several control points within the field of view, preferably surrounding the region being measured. To supply a set of such points, a rig was fabricated consisting of two plane surface at (about) $\pm 45^{\circ}$ to the blade chord and designed to be readily mountable to the blade from the rear (trailing edge). Control points were also available from markers on the surface of the rotor blade. Figure 5 shows the rig and the camera system as used; the layout, as specified by AEDC personnel, is given in Figure 6.

In practice, ice is a very difficult subject to photograph and some means is generally required to enhance the surface. Various methods of applying (spraying/dusting) talcum powders were attempted, with limited success.

The films were developed locally and then forwarded to AEDC for analysis with the stereo photogrammetic analysis system.

2.3 Section Tracing

An electrically-heated wire, mounted between two electrodes and powered by a.c. current through a rheostat, was used to make thin cuts through the ice in chordwise planes. Posterboard, cut to fit the basic rotor profile by using an aluminum template, was inserted into the cuts. The contour of the ice adjacent to the posterboard was then traced onto its surface. Such tracings were taken between the mold-boxes after they had been installed.

2.4 Test Site Preparations

Hovey and Associates of Ottawa, Canada, performed the on-site documentation using the equipment described above. An enclosed shelter was assumed necessary in order to control the temperature for the molding process and the lighting for the photography. A "scissors-lift van" was rented from Air Canada and the interior was modified for the test program (see Figures 3, 4, 5).

Initially, the molding material was to be mixed and degassed in the van but this preparation was moved to a nearby building made available by the NRC.

3.0 DISCUSSION OF RESULTS

3.1 Silicone Rubber Molds

Views of typical molds are shown in Figure 7; except for visual inspection of the ice formations and the resulting molds, it is difficult to appreciate the reproduction of detail which is attainable in a controlled situation such as this. Figure 8 shows a set of photo-reproductions (in full-scale) of the ends of the molds from Flight E, superimposed on a grid with a profile of the rotor airfoil. In constructing these projections, it was noted that there was enough of the bare blade (uniced) molded that the ice formation could be oriented with the grid and profile with an error of less than one degree. Such a set of results as Figure 8, is only from one "slice" out of each mold; a more representative average could be obtained by taking several slices.

3.2 Stereo Photogrammetry Results

A detailed description of the stereo photogrammetry procedures and results is in publication by AEDC (ref. 5). Typically, a photo set is shown in Figure 9 and the results from the data analysis are plotted in Figure 10.

The other data for Flight E from the photogrammetric analysis were rearranged to obtain Figure 11 (in the same format as Figure 8). In doing this, the upper and lower contours were shifted from their plotted orientation to match the blade profile.

3.3 Section Cut Results

Projections of the hand-sketched contours on the paper templates as oriented onto a reference grid are reproduced in Figure 12.

4.0 CONCLUSIONS

Ice shapes as documented by the three methods may be compared by superimposing the results of Figures 8, 11 and 12. The formation varies slowly enough that the stated stations are sufficiently close for such a comparison. The deviations appear to be no more than those which appear from comparing successive "slices" by any one method, since the ice formation contains considerable three-dimensional detail, as illustrated by Figure 13. The depth of the ice, as measured from the results of the three methods is plotted in Figure 14. The section sketches appear to lack the definition of the contour, which is probably an important feature in determining the aerodynamics.

The long-range goal in describing ice formations should be a mean (two-dimensional) shape plus a superimposed grain roughness. The section sketches may give the mean shape; the stereo photogrammetry has the potential for better definitions including the detailed irregularities. The molding technique offers the potential for a nearly exact reproduction (in full size) of all of the details and hence for the best definition of the shape and the apparent roughness. Such an accurate reproduction is necessary in order to obtain the correct aerodynamic data for the ice formations.

APPENDIX

Procedures For Use Of Molding Chemicals

Materials: Base Dow-Corning 3110 RTV
Catalyst Dow-Corning 4
Thinner Dow-Corning 200, 20 cc

(1) Store the materials at outside temperatures or at least below freezing. Prior to mixing and degassing, cool down the proparation room to sub-freezing temperatures also.

(2) Pour 555 gms. of thinner on top of 5000 gms of base in a container. This is sufficient to do 3 mold frames if wooden filler pieces are used. Do not mix the thinner with the base.

(3) Using a syringe add 33 gms (25 cc) catalyst to the thinner (floating on top of the base, unmixed). Mix thoroughly using a 1" x 3" paddle on an rod in an electric drill for 8 minutes. For temperatures of -20°C, 26 cc of catalyst can be used, which changes the ratio to 1.142 (from 1/150) by weight. This could probably be bumped further but has not yet been tried.

(4) De-aerate for 12-14 minutes. The mix never stops bubbling in the vacuum chamber but the molds resulting from this do not seem to have any air bubbles or inclusions.

(5) Do not use the last 1 inch of material at the bottom of the pail (not properly mixed).

REFERENCES

1. Stallabrass, J. R. and Lozowski, E. P., (NRC Low Temperature Lab), "Ice Shapes on Cylinders and Rotor Blades", NATO Panel X Symposium on Helicopter Icing, 1978.

2. Aircraft Icing, A Workshop held at Lewis Research Center, Cleveland, Ohio, July 19-21, 1978.

3. Richter, G. P., Private Communication.

4. Palko, Richard L. and Cassady, Patrick L., "Photogrammetric Development and Application at AEDC". Paper No. 82-0610, AIAA 12th Aerodynamic Testing Conference, Williamsburg, VA, March 21-24, 1983.

5. Palko, R. L. and Cassady, P. L., "Photogrammetric Analysis of the Buildup on a U.S. Army UH-1H Helicopter Main Rotor in Hover Flight", AEDC-TR-83-43, September 1983.

TABLE I

FLIGHT RECORD

Flight No.	NRC RIG DATA Wind mph	Flow lbs/hr	LWC gm/m3	Temp °C	Time in Cloud minutes	Extent of Ice	Comments
2	5 M	2800	.4	-12.5	6+	–	Not Retained
3	8 M	3200	.4	-10.0	8-3/4	–	Not Retained
3	8 M	3200	.4	- 9.5	12	Small section at 65%	
4,A	10 M	4400	.4	-12.0	4-1/4	to 75%	--
5	11 M	6200	.4	- 9.5	7-3/4	–	Shed at 6 min.
5	11 M	6200	.4	- 8.5	5	–	Shed at 5 min.
5,B	11 M	6200	.4	- 8.5	4-1/4	to 65%	--
6,C	7 M	4000	.4	-17.5	4	to 85%	--
7,D	5 L	2600	.4	-21.5	6	to 92%	--
8,E	10 L	6200	.7	-19.0	3	to 92%	ΔP Inlet Limit

TABLE II

HIFT DOCUMENTATION RECORDS

Date: Feb 11/83
Flight#: E (8)

1.	Weather Type	Clear sunny
	Air Temp °C	-18.9 °C
	Wind Velocity	10 mph
	Wind Direction	Out of E
2.	Liquid Water Content	.7 gm/m^3
3.	Helicopter	
	Time into Cloud	
	Time Left Cloud	
	Performance Time	2:54

4. Began Ice Documentation:

Mold Boxes
11:45 - 12:15 boxes on +2¼ hrs. drying time

5.	Photos Z	18 to L.E.
	Y_t	12 in.
	Y_b	12 in.

6. Comments:

- In Cloud 95% of time
- ½ of copter in cloud
- Cameras all o.k.
- 26 cc catalyst used (instead of 25)
- 8 min. mix.
- 13 min.
- 19°F in van @ 12:00
- First run of day

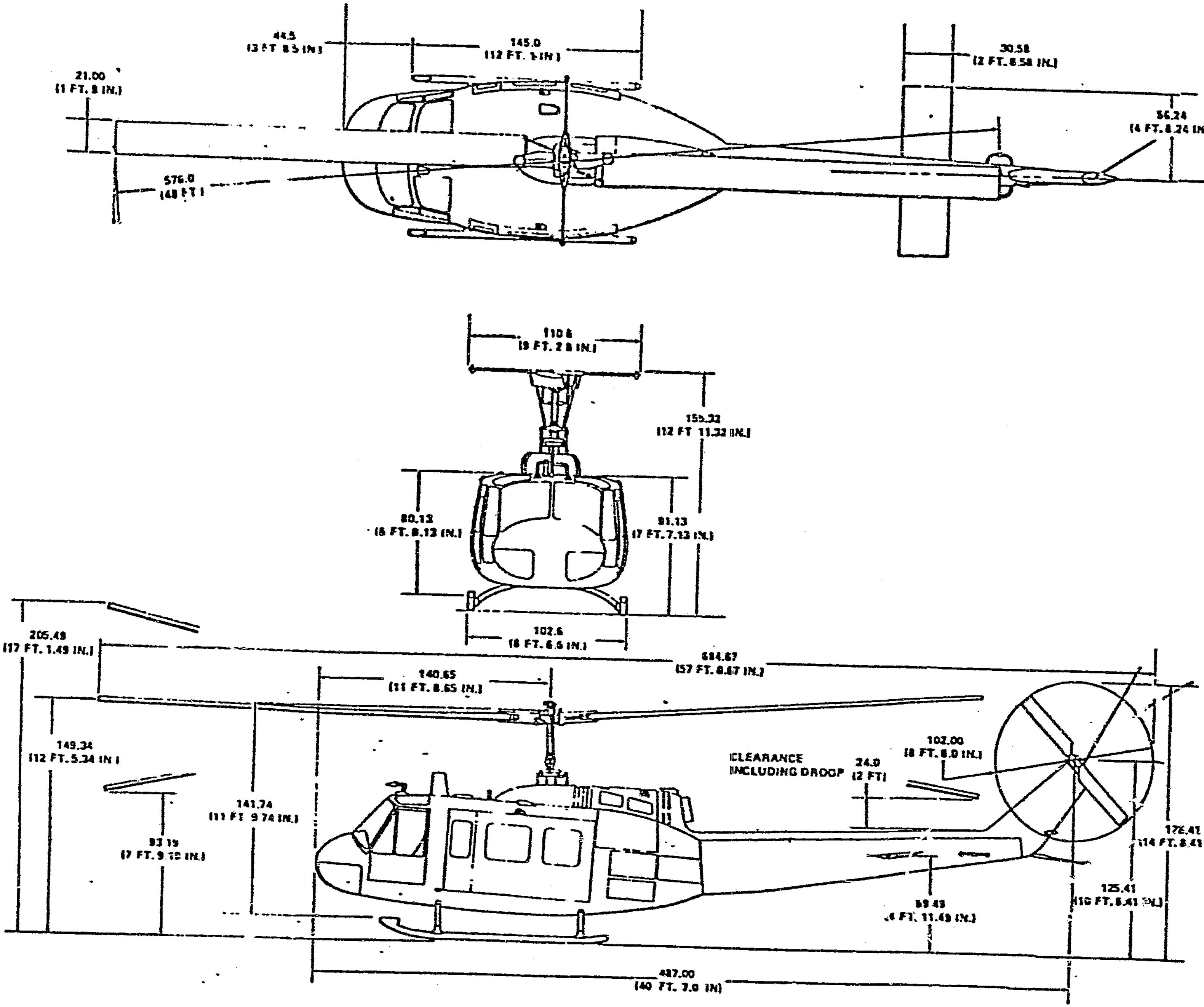

FIGURE 1. Outline of Army UH-1H Helicopter Used in Icing Program.

FIGURE 2. Photos of the Army UH1H Hovering in the NRC Icing Cloud.

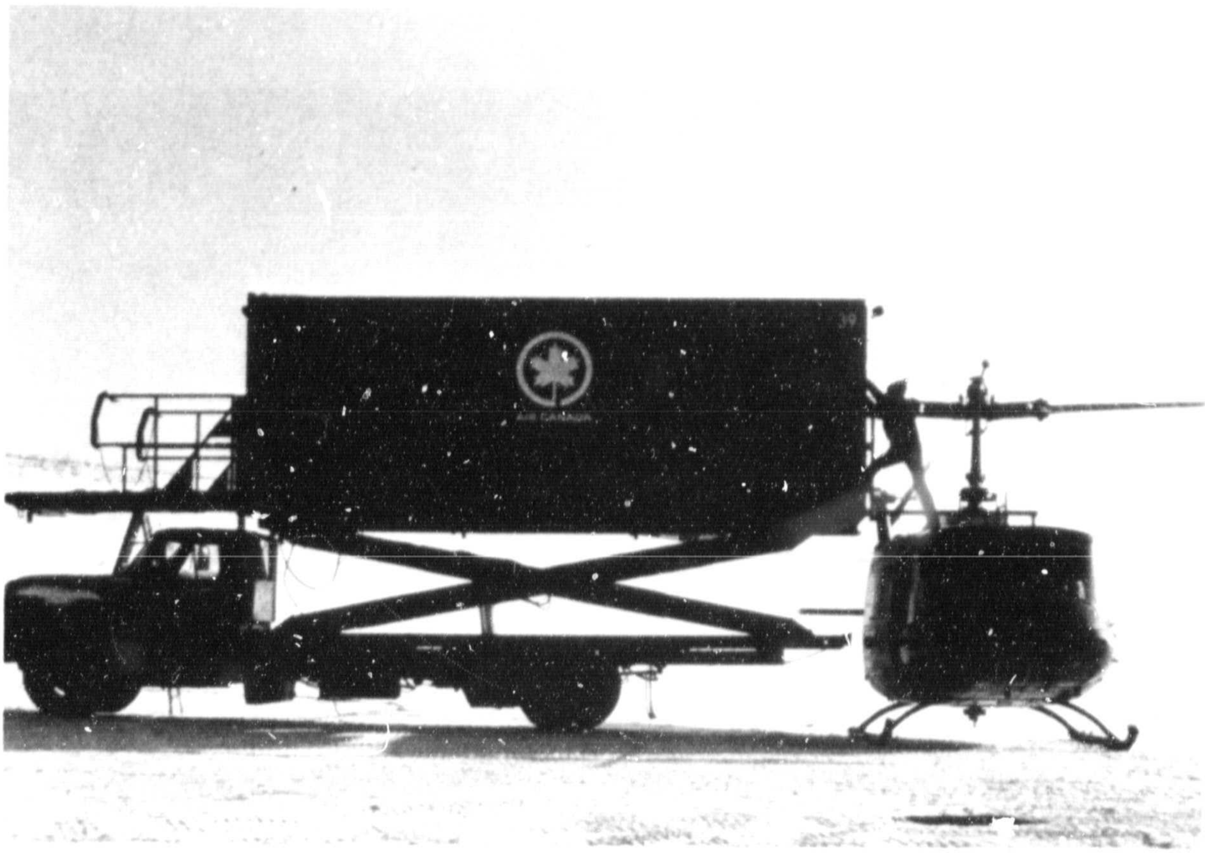

FIGURE 3. Helicopter with the Van Used as the Documentation Station.

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FIGURE 4. Interior of Van Showing Rubber-Mold Boxes Attached to the Rotor Blade.

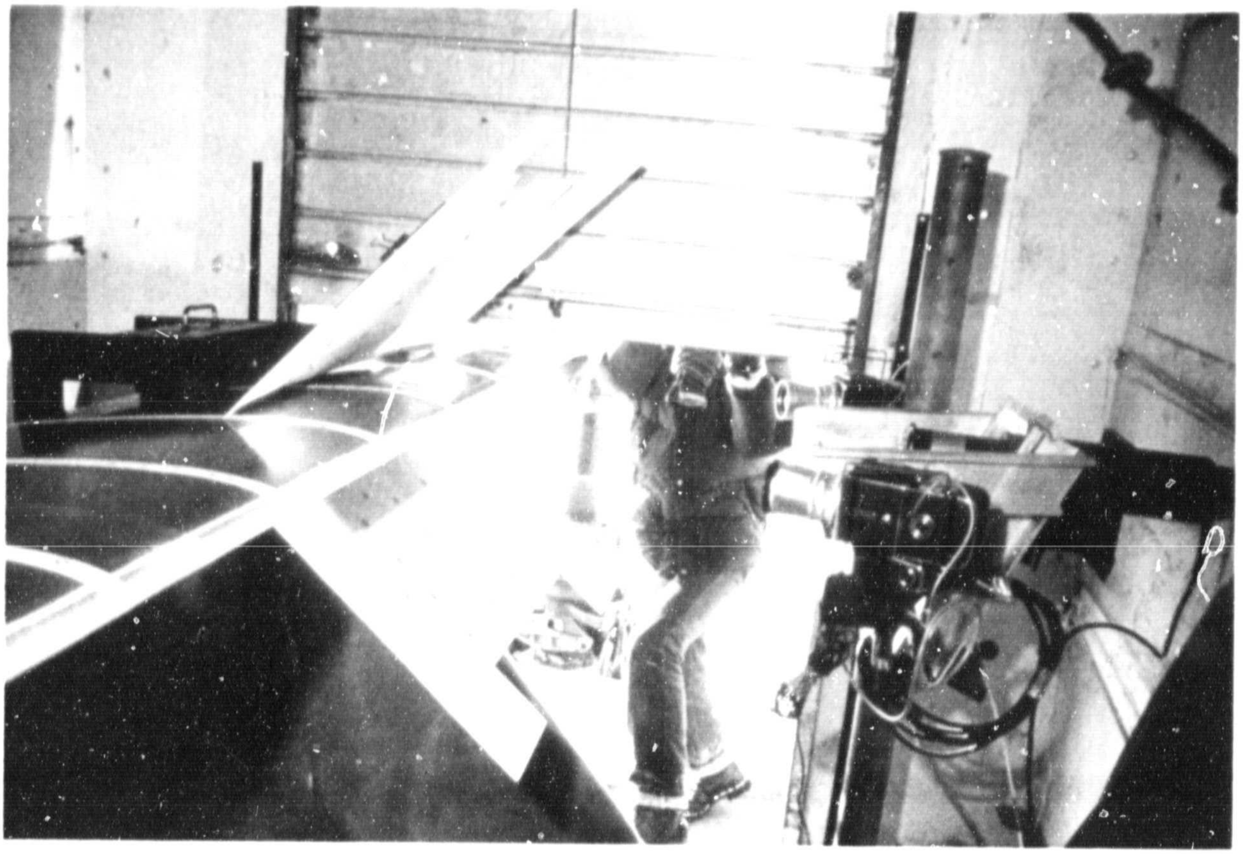

FIGURE 5. Interior of Van Showing Stereo Photography Set Up.

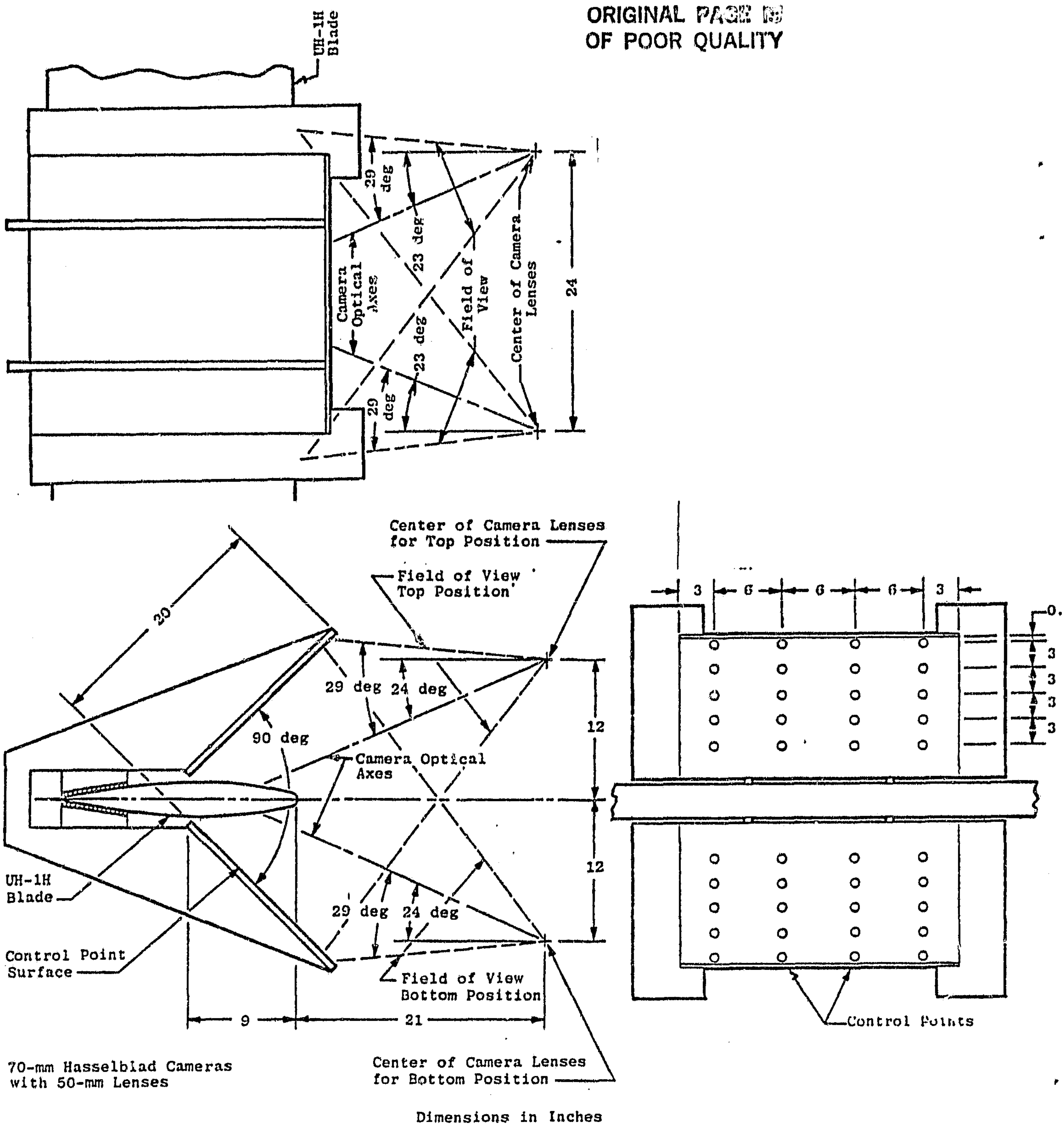

FIGURE 6. Layout of Stereo Photography Cameras and Control-Point Target.

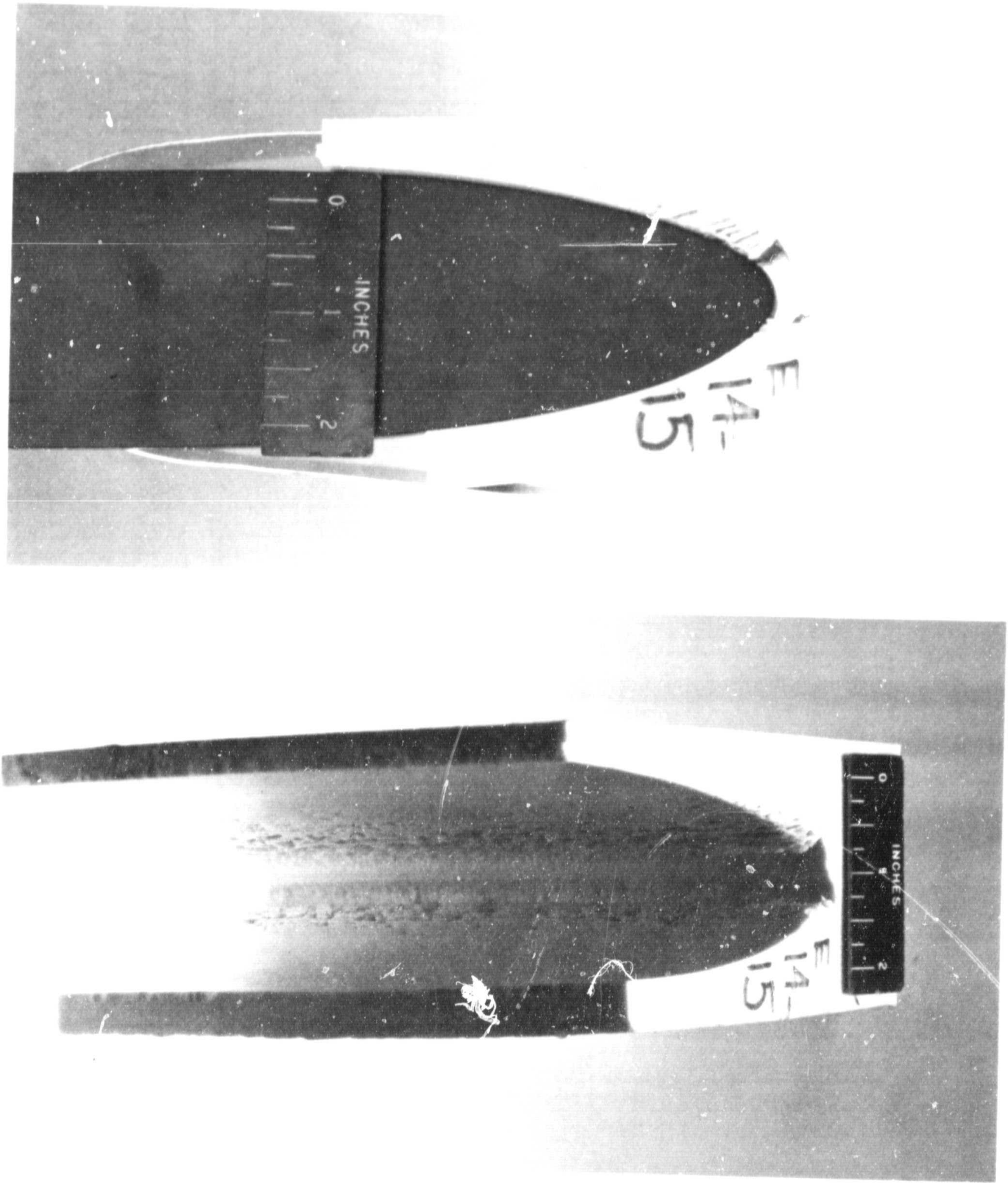

FIGURE 7. Typical Molds Obtained of Ice Formations.

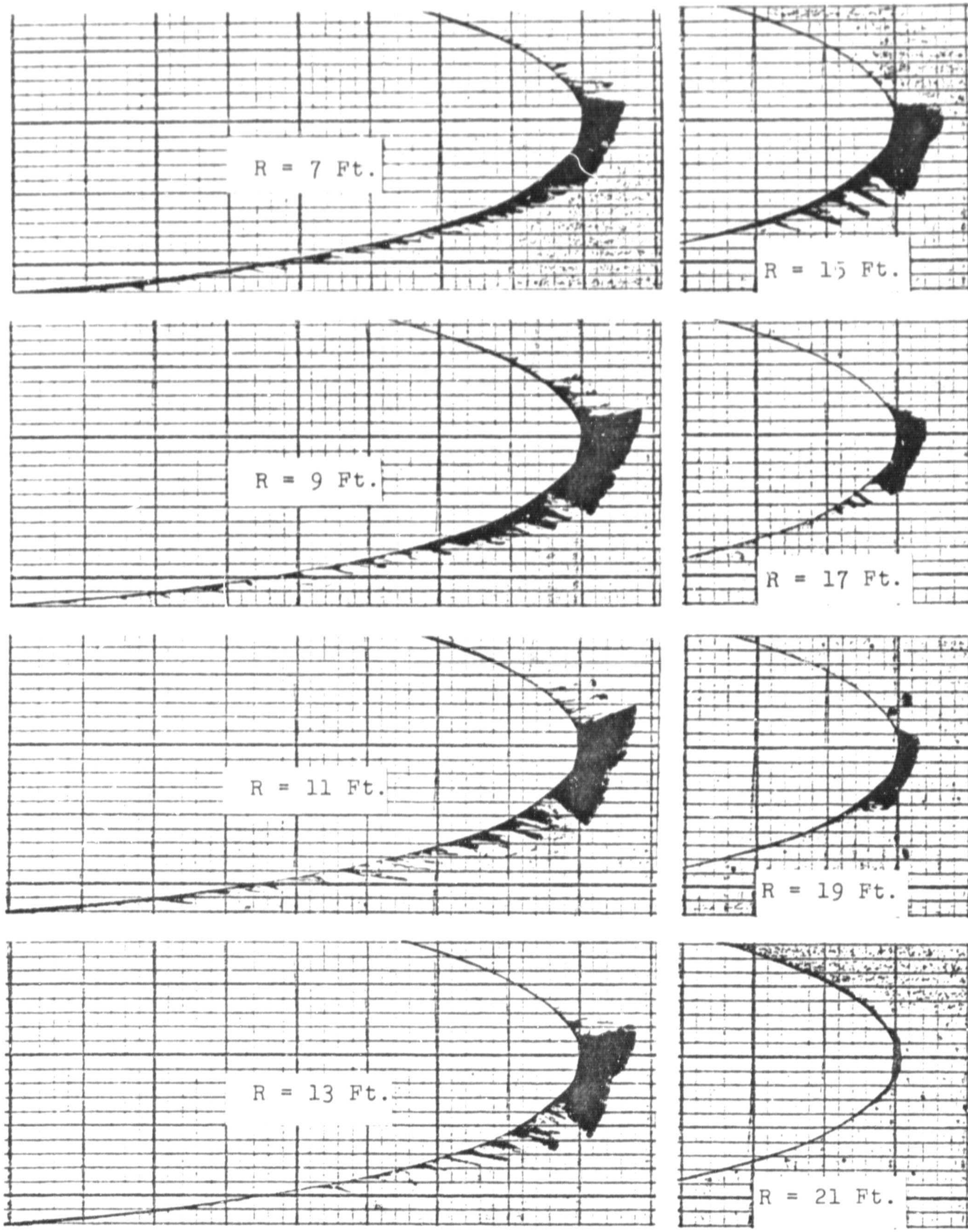

FIGURE 8. Projections of the Molds Obtained From Flight E.

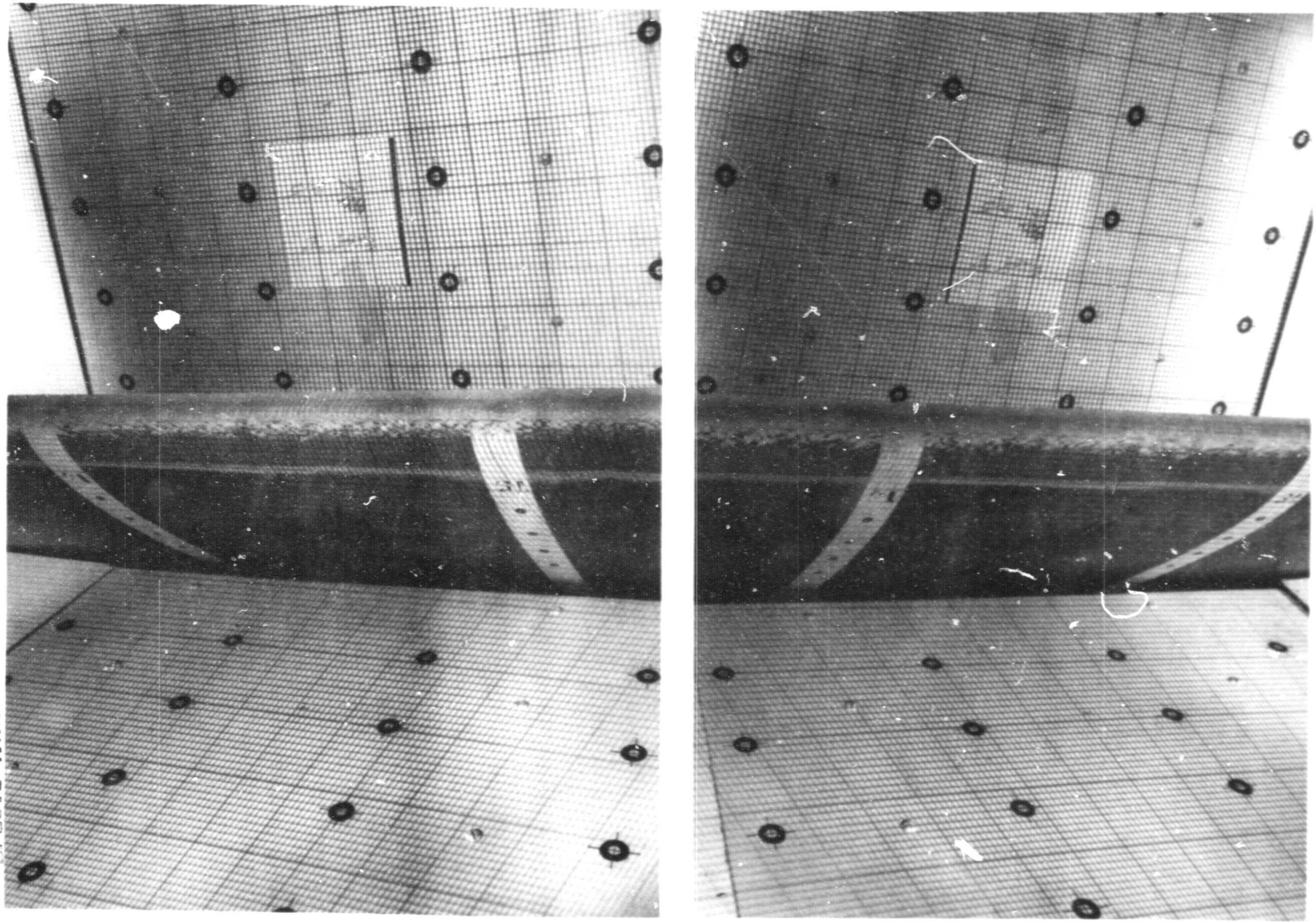

FIGURE 9. Typical Stereo Camera Photo; One of Set of 4 Used in Photogrammetric Analysis: Flight E, R = 8 Ft.

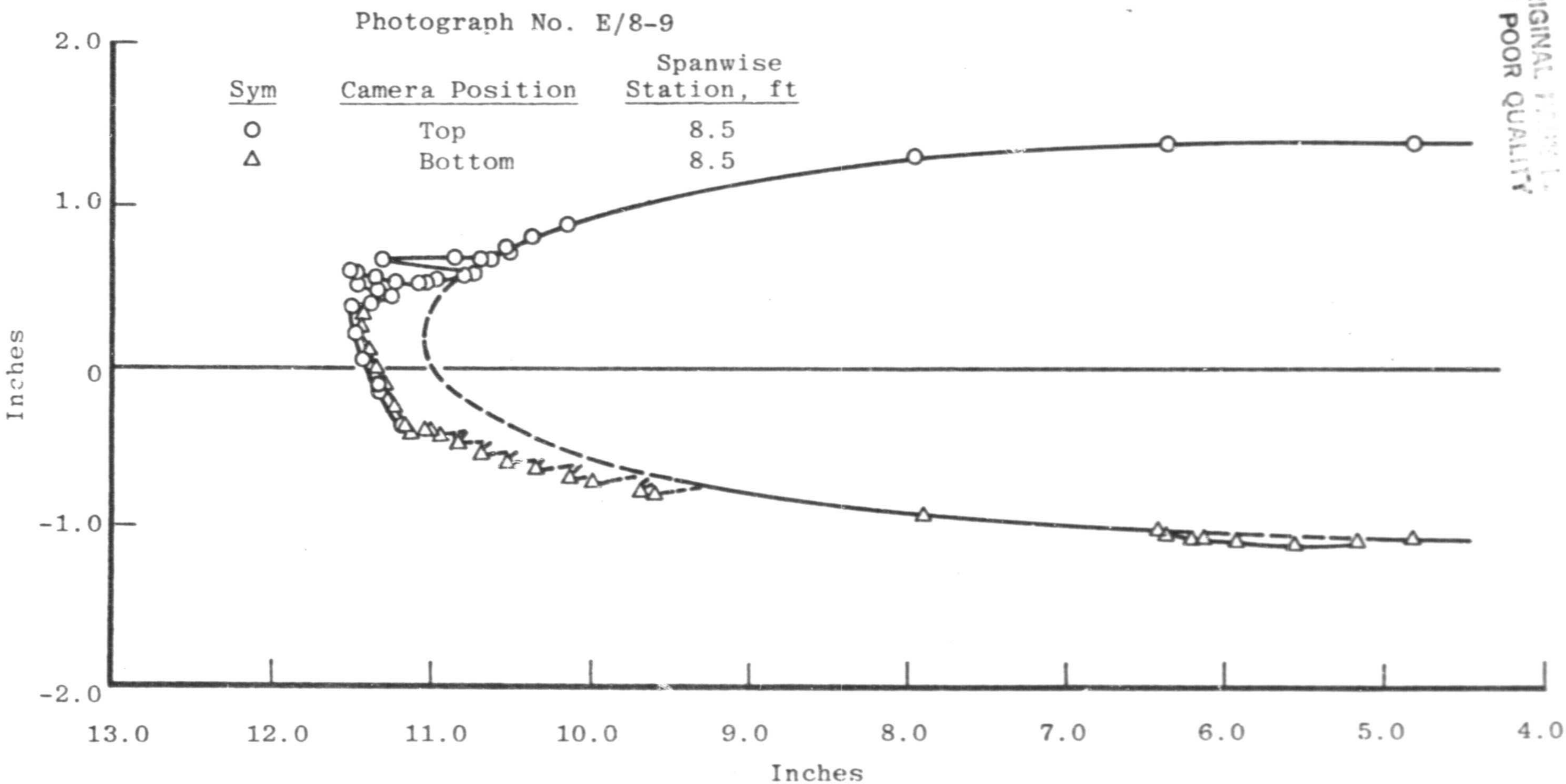

FIGURE 10. Typical Results From the Photogrammetric Analysis of Reference 5.

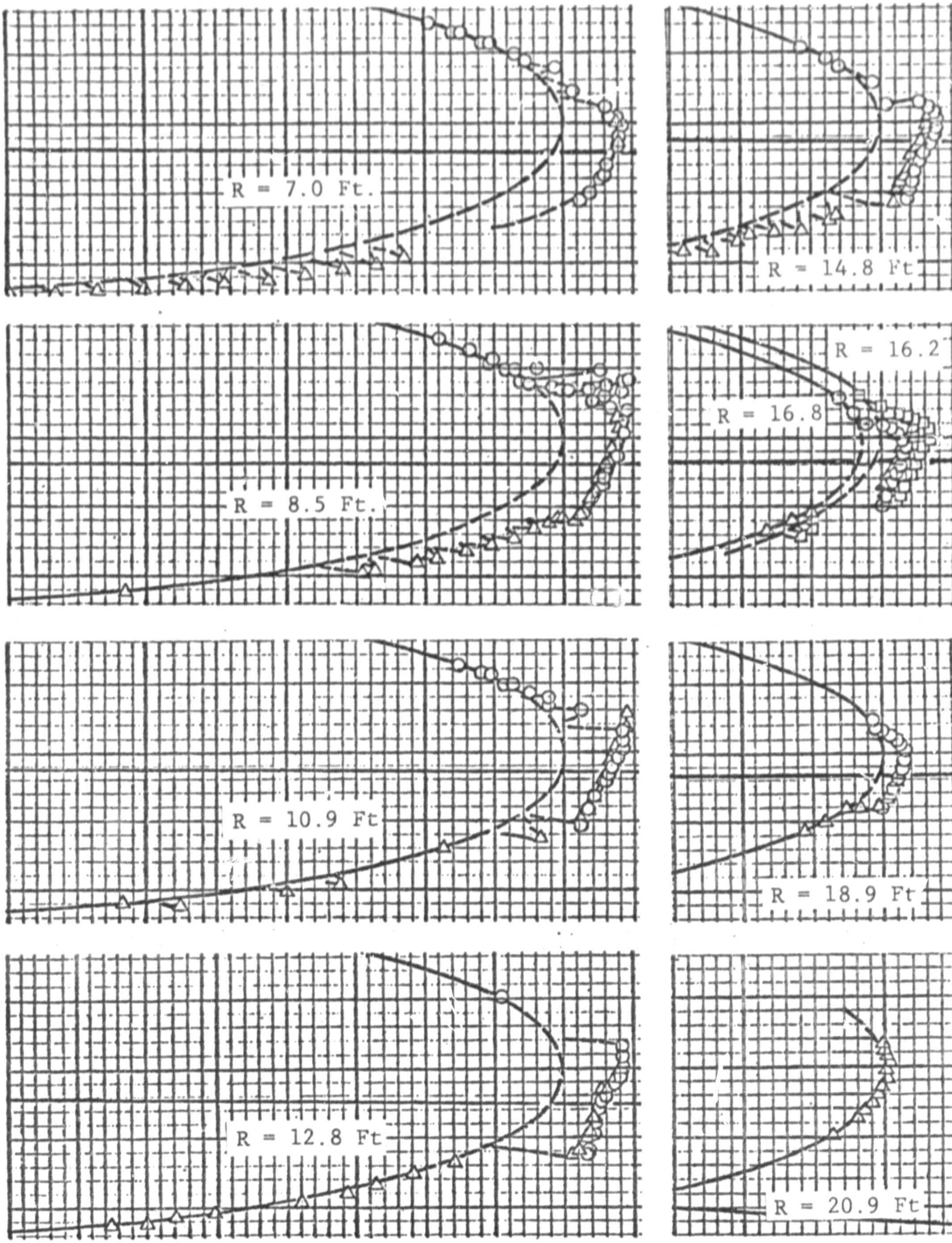

FIGURE 11. Results From Photogrammetric Analysis for Flight E.

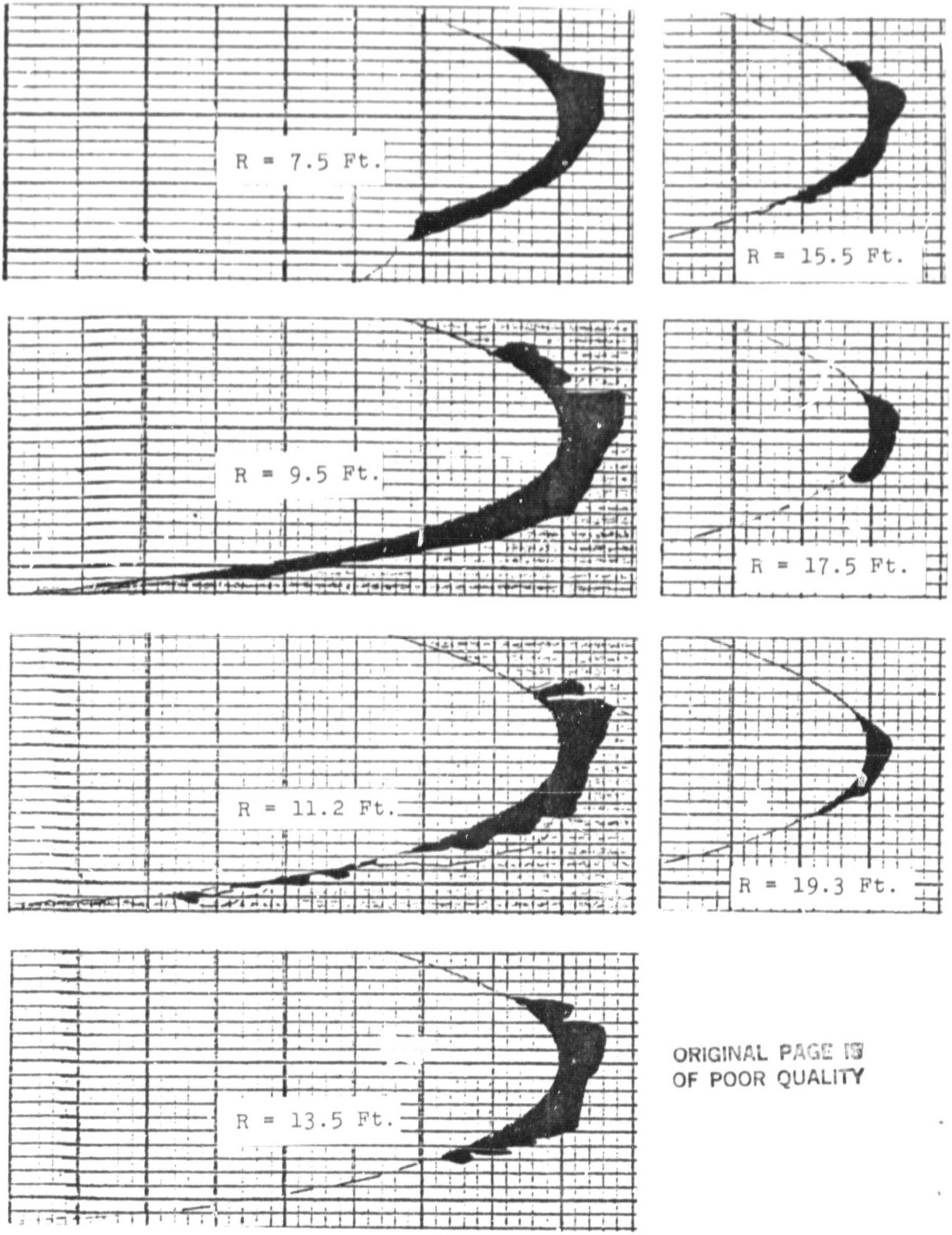

FIGURE 12. Results From Section Cuts on Ice, Flight E.

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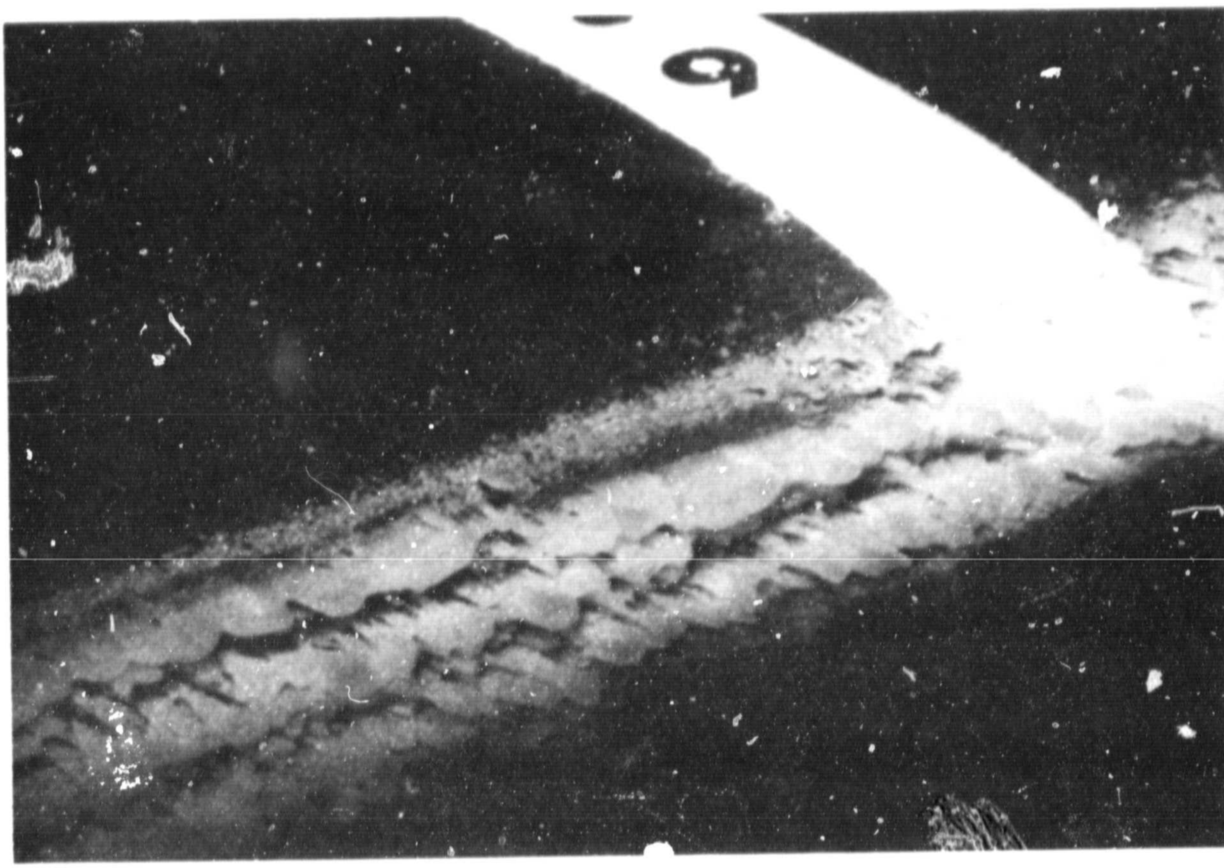

FIGURE: 13. Photo of Typical Ice Formation on Rotor Blade. (The White Stripe is 1 in. Wide)

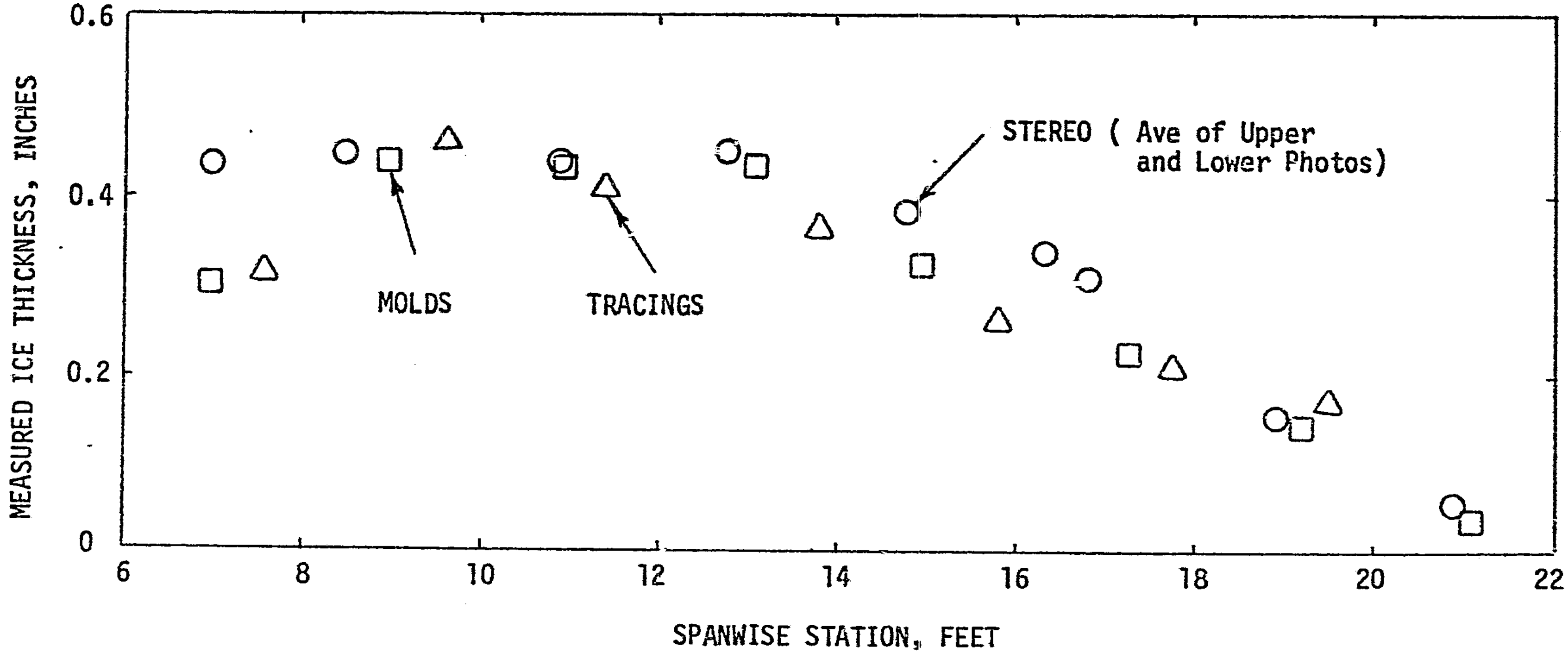

FIGURE 14. Extent of Ice Accretion on Rotor for Flight E; Comparison of Different Methods of Documentation.

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