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TECHNICAL NOTE

D-346

THE SHOCK-WAVE PATTERNS ON A CRANKED-WING CONFIGURATION

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

The shock-wave patterns of a complex configuration with cranked cruciform wings and a cone-cylinder body were examined to determine the interaction of the body bow wave with the flow field about the wing. Also of interest, was the interaction of the forward (76° sweptback) wing leading-edge wave with the rear (60° sweptback) wing leading-edge wave. The shadowgraph pictures of the model in free flight at a Mach number of 4.9, although not definitive, appear to indicate that the body bow wave crosses the outer wing panel after first being refracted either by the leading-edge wave of the 60° sweptback wing or by pressure fields in the flow crossing the wing.

INTRODUCTION

Supersonic and hypersonic vehicles consisting of wings, bodies, and stabilizers in combination are subject to thermodynamic and aerodynamic problems associated with the impingement of shock waves from one component onto another. However, in some cases, for example, when the wing leading edge and the fuselage shock-wave run nearly parallel and meet at a very small angle, it is difficult to anticipate whether the body shock wave will cross the wing or simply combine with the wing shock wave in a single wave envelope around the entire configuration. The shock-wave behavior for such a case, a cruciform wing-body configuration with cranked wings, and a cone-cylinder body was determined from tests in the Ames pressurized ballistic range at a Mach number of approximately 4.9. Shadowgraph pictures obtained from the tests were analyzed and the results are presented herein.

MODEL AND TEST

Model

The model tested consisted of a cone-cylinder body with cranked cruciform wings. A sketch of the projected model plan form showing the basic model dimensions is presented in figure 1. The cone-cylinder body had a hemispherical nose and, in addition, the corner where the conical forebody meets the cylindrical afterbody was rounded slightly. The wing plan form was a double delta with the forward portion swept back 76° and the afterportion swept back 60°. The airfoil section, taken perpendicular to the wing leading edge, consisted of a 6° included angle wedge with a blunted (hemicylindrical) leading edge.

Test

The model was tested in free flight at a Mach number of 4.9 and at sea-level atmospheric pressure. The model was launched from the 37-mm shock-heated helium gun described in reference 1. The gun was composed
of a 37-mm launch tube and a 90-mm pump tube. Shadowgraph pictures, A
triggered by the model, were obtained in 2 orthogonal planes at 24 prede- 4
termined observation stations, for a ballistic flight of 203 feet. Typical 3
shadowgraph pictures at roll orientations of approximately 0° and 45°, 3
respectively, are presented in figures 2(a) and (b).

The model was launched by means of an aluminum-faced four piece ethocel sabot at zero angle of attack and at an initial muzzle velocity of approximately 6000 feet per second, higher speeds being precluded by difficulties associated with launching the model without breakup or large pitching disturbances.

REDUCTION OF DATA

The basic data were the shadowgraph pictures and the time of model flight between stations. Shock-wave positions with respect to the model at several longitudinal model stations and for various angles of roll were determined from the shadowgraphs. The magnification factor (due to the use of a conical light optical system) was determined for each picture by comparing the known (measured) body length to the apparent body length. The roll angle of the model was determined from the shadowgraph pictures by comparing the projected wing span to the actual wing span or, equivalently, by measuring the projected included angle of the swept wing and comparing it to the reference angle of 60°. Since both of these methods lose their sensitivity as the roll angle approaches zero, the actual roll angles used to determine the data presented in figure 3 were taken from a faired curve of the measured roll angle versus time, with the roll rate assumed to be constant.

RESULTS AND DISCUSSION

The primary interaction anticipated in the present test was that of the bow wave generated by the body on the 60° part of the swept wing. However, another interaction was also considered -- that between the 76°

sweptback leading-edge bow wave and the 60° part of the swept wing. Although the 76° leading edge operates in the wake of the body bow wave, it can be readily estimated from the body bow wave slope that the flow Mach number approaching the wing leading edge is supersonic, approximately 4.4. Therefore, the 76° sweptback wing leading edge will have a weak bow wave (as a result of the large amount of sweep) which will interact with the 60° leading-edge bow wave.

Although a large number of shadowgraph pictures were examined during this investigation, the data presented herein will be discussed with the aid of only two typical pictures. The shadowgraph picture presented in figure 2(a) shows two shock waves visible immediately behind the model base, near the center of the wing semispan, which apparently are extensions of the body bow wave and the 76° sweptback wing leading-edge wave. It should be noted that these two waves appear in both the upper and lower halves of figure 2(a), although those in the lower half of the picture appear to be somewhat masked by other disturbances in the flow. Coalition of these waves farther downstream to form the strongest shock wave in the system indicates that these waves must originate from a strong disturbance, such as the nose of the body or the leading edge of the 76° sweptback wing. Since there are no sources to originate such strong shock waves other than those just mentioned, it is convincingly evident that these two shock waves are extensions of the body bow wave and the 76° leading-edge wave. However, it is not certain from the data whether these two waves crossing the outer wing panel actually impinge on the wing as shock waves or instead occur as a distributed pressure rise on the wing surface.

A further study of figure 2(a) shows that the body bow wave is refracted in crossing the wing as is evident from the lack of an exact straight line agreement between the portions of the wave upstream and downstream of the wing. This refraction of the body bow wave is further evidence of the interaction of the body bow wave with the flow field about the wing and is due either to the leading edge wave of the 60° sweptback wing or to local pressure fields in the flow.

The shadowgraph picture presented in figure 2(b) shows the body bow wave ahead of the wing leading edge and a complex of waves aft of the wing trailing edge consisting of two leading-edge waves from the 60° sweptback wing and one body bow wave for each side. In this particular picture, the body bow wave aft of the wing trailing edge and one wing wave appear to be coincident. However, since there is no evidence of interaction between the body bow wave and the flow field about the wing in this view, the body bow wave position aft of the wing trailing edge can be easily ascertained with the aid of a straight edge. The leading-edge shock waves from the 76° sweptback wing are not readily apparent in this view. There are, however, some fine waves just inside the bow wave far downstream that appear to be in approximately the right location.

Presented in figures 3(a), (b), and (c) are polar plots of the locus of the body bow wave and the 76° leading-edge wave with respect to the model longitudinal center line, for three longitudinal stations. Since the model is symmetrical about the body axis and the indicated angles of pitch and yaw were small (less than 2°), the data presented in figure 3 are typical of all four quadrants for each longitudinal station. It should be pointed out that there are no data presented in figure 3(a) for the 76° leading-edge wave since its position could not be ascertained. The locus of the body bow wave at this particular location, however, appears to be circular in shape with no evidence that the 76° leading edge wave had any effect on it. In figures 3(b) and (c), the locus of the body bow wave aft of the model is seen to diverge from this circular shape (conical wave, fig. 3(a)) to one more nearly square in shape. This divergence of the locus of the bow shock is believed to be due to the refraction of the bow wave in the vicinity of the wing, as previously mentioned.

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In figures 3(b) and (c), the data presented for the 76° sweptback wing leading-edge shock wave are limited to polar angles less than 25°. At polar angles greater than 25°, the model was rolled with respect to the viewing plane in such a manner that it was impossible to distinguish the 76° leading-edge wave with any degree of certainty. It is also felt that the apparent agreement between these data and that for the body bow wave at an angular position of 45° is purely fortuitous.

In addition to the wave configurations already discussed, it may be of interest to the reader to note several other interesting wave configurations. Figure 2(a) shows the leading-edge bow wave from the 60° sweptback wing in the plane 90° to the page, the recompression waves associated with the base flow and the finely detailed wake of the entire configuration. In figure 2(b), although the 76° leading-edge waves cannot be easily distinguished, the recompression wave due to the body base is easier to pick out than in the other view and there is a decided change in the wake pattern due to the model roll.

CONCLUDING REMARKS

Data have been presented showing the shock-wave patterns obtained in free flight at a Mach number of 4.9 for a cruciform wing-body configuration with cranked wings and a cone-cylinder body. While the results obtained from the available data are not definitive, there is evidence to indicate that both the body bow wave and the 76° wing leading-edge wave cross the wing after first being refracted either by interaction with the leading-edge wave of the 60° sweptback wing or with pressure fields in the flow.

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif., Aug. 22, 1960

REFERENCE

1. Seiff, Alvin: The Use of Gun-Launched Models for Experimental Research at Supersonic Speeds. AGARD Rep. 138, July 1957.

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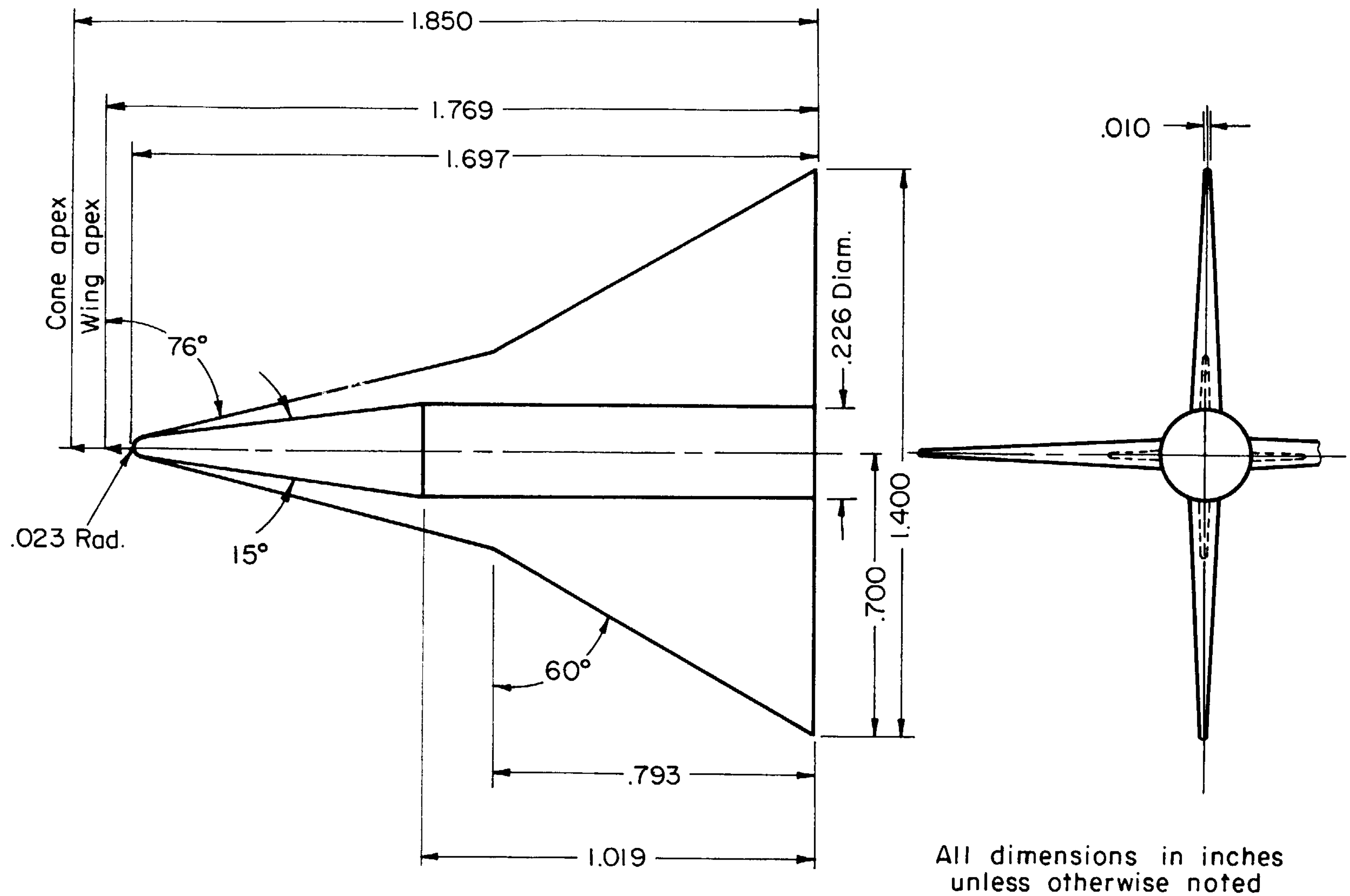
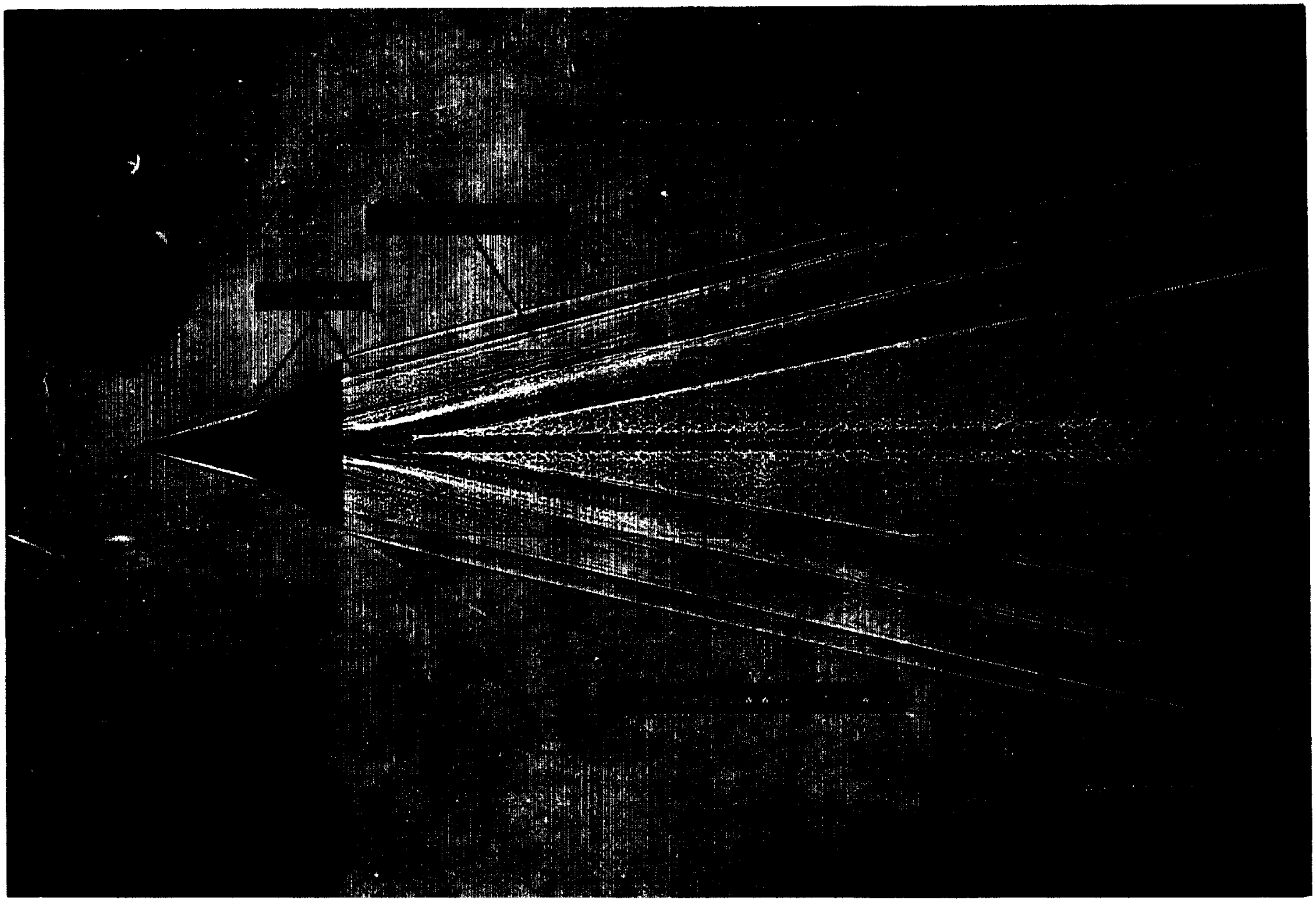


Figure 1.- Model arrangement.



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(a) $\varphi \cong 0^{\circ}$.

Figure 2.- Typical shadowgraph; M = 4.9.

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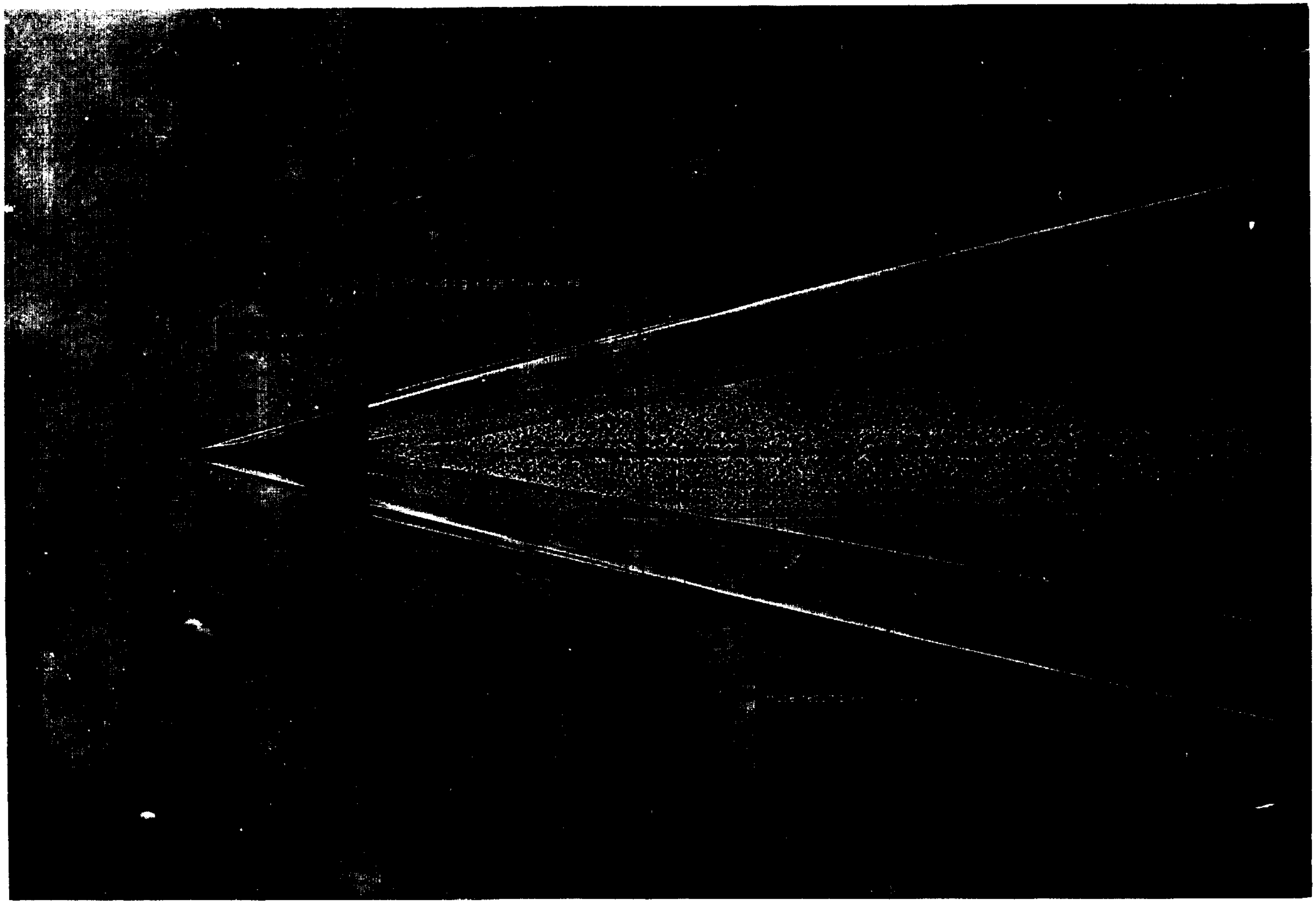

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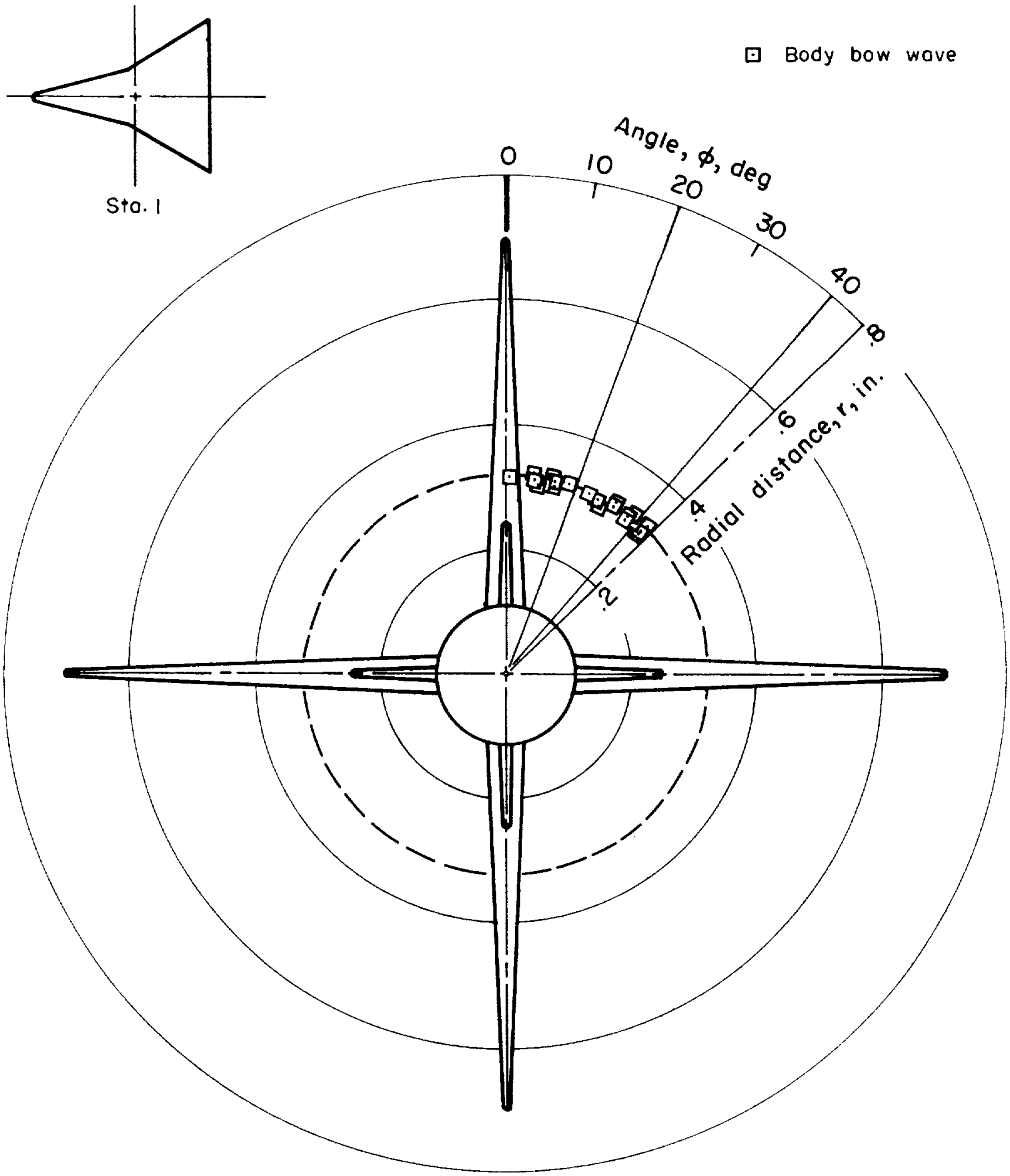
(b) $\varphi \cong 45^\circ$.

Figure 2.- Concluded.



(a) Ahead of 60° sweptback wing leading edge, station 1.

Figure 3.- Cross section of shock wave envelope.

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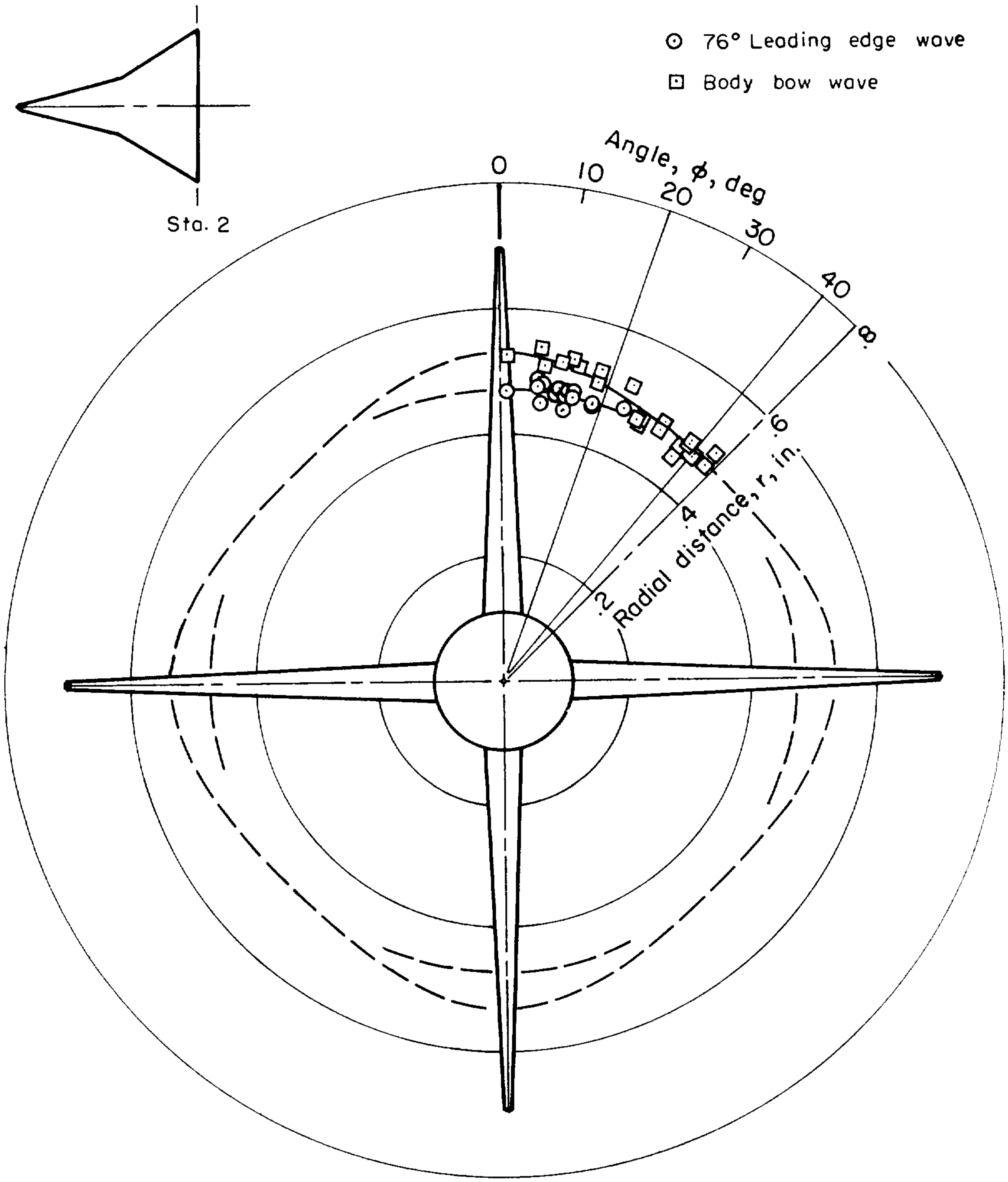
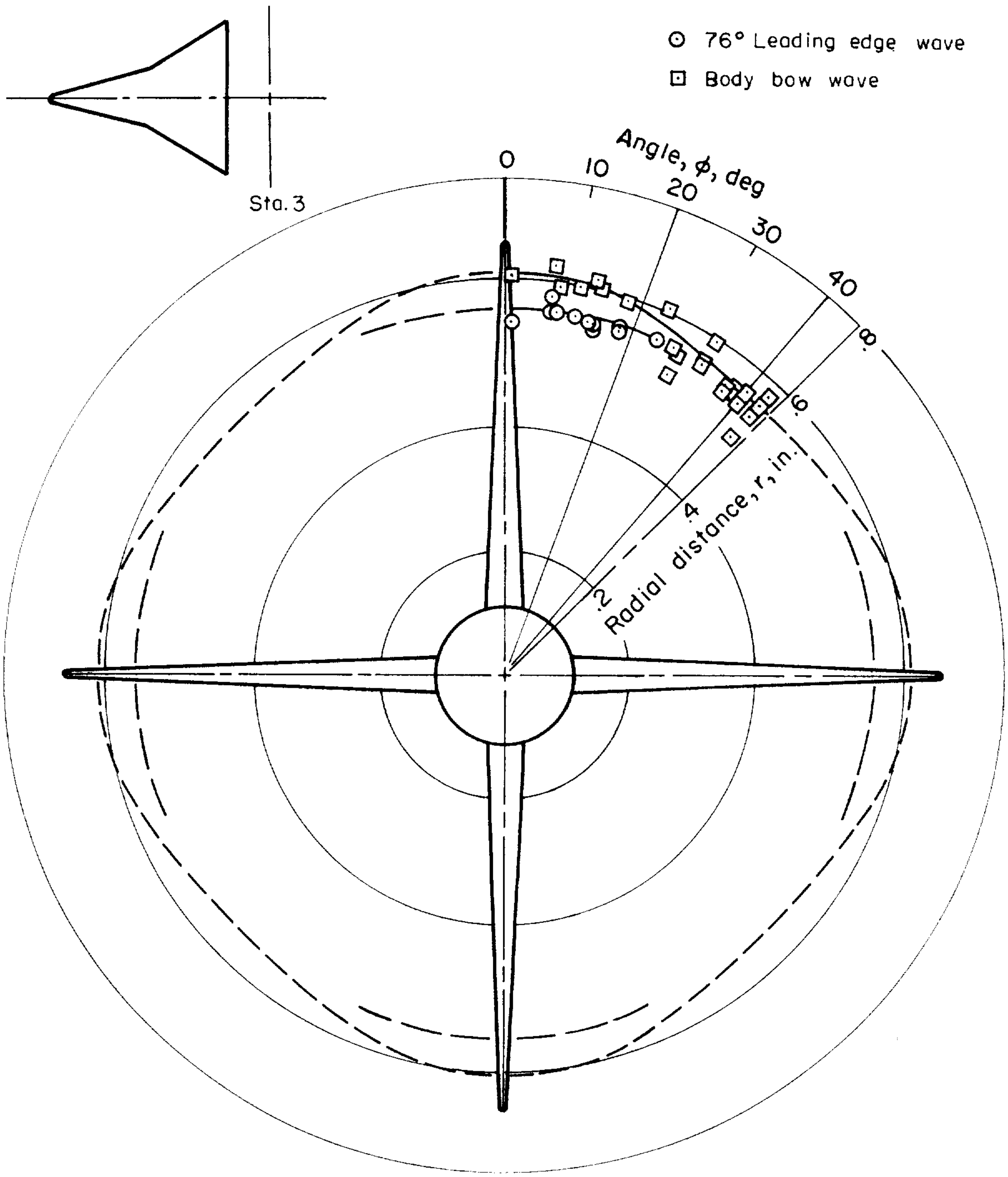


(b) At trailing edge of wing, station 2.

Figure 3.- Continued.



(c) 1/4 body length behind wing trailing edge.

Figure 3.- Concluded.

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THE SHOCK-WAVE PATTERNS ON A CRANKED-WING CONFIGURATION. Robert I. Sammonds. November 1960. 12p. OTS price, $0.50. (NASA TECHNICAL NOTE D-346)

A cruciform wing-body configuration with cranked wings and a cone-cylinder body was tested in the Ames pressurized ballistic range at a Mach number of 4.9. Shadowgraph pictures were examined to determine the interaction of the body bow wave with the flow field about the wing. The results, although not definitive, appear to indicate that the body bow wave crosses the outer wing panel after first being refracted by interaction with the flow field about the wing.

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