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REFRACTION ERRORS IN AERIAL PHOTOGRAPHY AT HIGH FLIGHT SPEEDS

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OBJECT

The object of this investigation is to determine the effect of high-speed flight on optical resolution in aerial photography.

SUMMARY

During the period, January 31, 1955 to April 30, 1955, the curve for the deviation of a light ray passing through a boundary layer has been constructed as a function of the wall-to-free-stream temperature ratio. It is found that the deviation is independent of the Mach number of flight when the wall-to-free-stream temperature ratio is used as a parameter.

INTRODUCTION

Present-day, aerial photographic-reconnaissance operations must keep pace with the flight speeds of supersonic fighter aircraft. Such high speeds impose new problems on the photographic system. The designer encounters structural problems concerned with the photographic windows due to ram pressure loading and to the thermal stresses induced at high flight speeds. In addition to the structural problems, boundary layers existing in high-speed flight create an optical problem not ordinarily encountered. The boundary layer forms, in effect, an optical wedge of air over the photographic windows. Refraction of the light rays occurs as they pass through the boundary layer; this is due to the temperature difference existing between the window surface and the free stream. This problem has been discussed briefly in the progress report for the period ending January 31, and preliminary results were discussed briefly (3,4,5). Further calculations have been performed during the period from January 31 to April 30 and are discussed below.

RESULTS AND DISCUSSION

In Fig. 1, the gross deviation of a light ray passing through a laminar boundary layer* is plotted as a function of the wall-to-free-stream temperature ratio. The deviation is plotted as the nondimensional variable, $\delta/\tan\theta_i$, which reduces the data to a single curve. By using the dimensionless temperature (wall-to-free-stream temperature ratio) as the independent variable, the Mach number is eliminated as a parameter. Thus the curve shown in Fig. 1 is valid for any Mach number up to Mach 8.0 and for rays entering the boundary layer at any angle of incidence. The curve is constructed for an altitude of 50,000 feet.

The deviations calculated are significant at the higher wall-to-free-stream temperature ratios and become especially important at large angles of incidence. Further calculations are being performed for the case of cooled surfaces.

*References 1 and 2 are concerned with the loss of resolution caused by turbulence in the boundary layer, whereas this analysis is concerned with the distortion produced by the bending of the light rays.

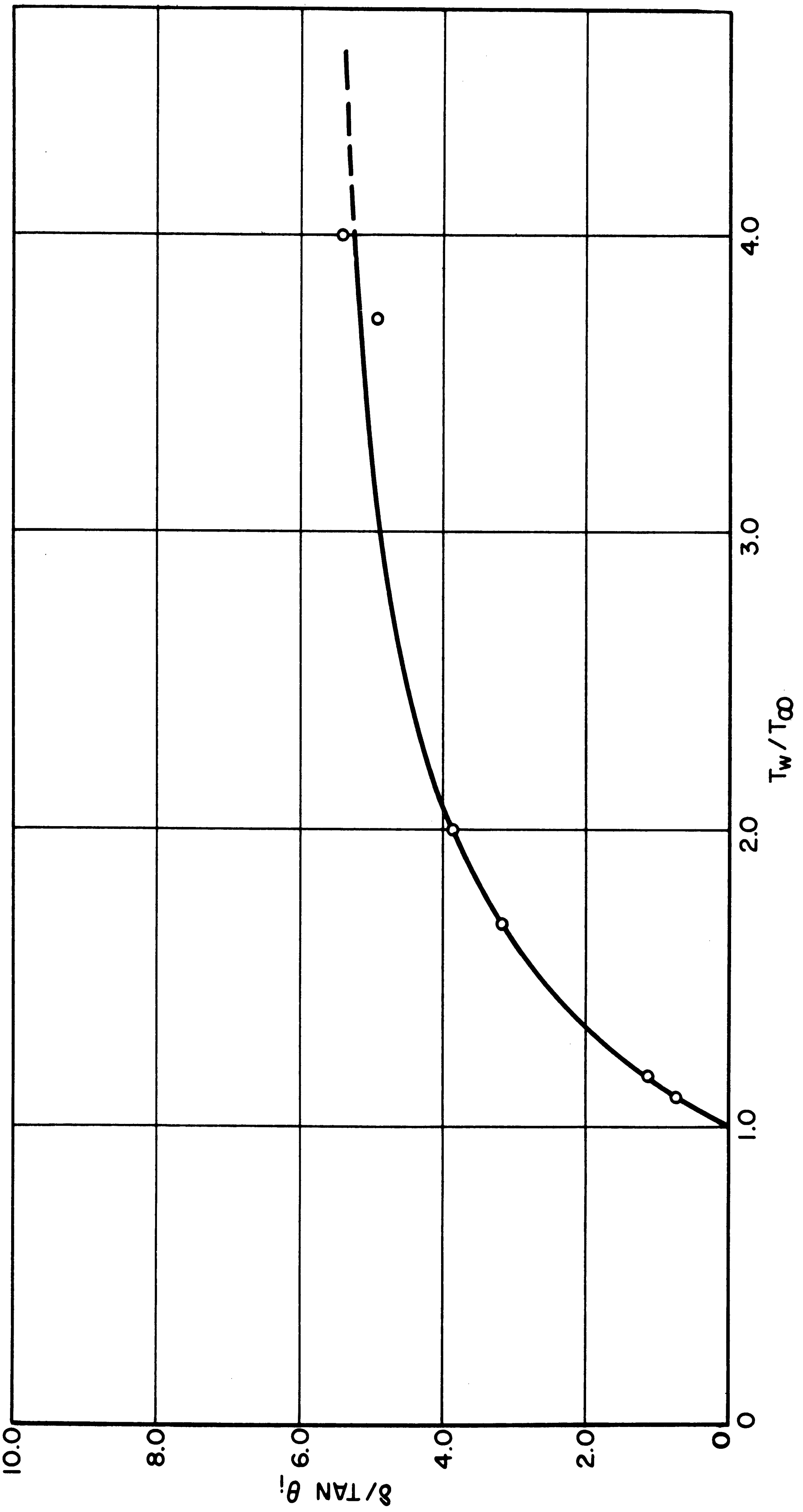

Fig. 1. Deviation of a light ray passing through a boundary layer as a function of the wall-to-free-stream temperature ratio.

PLANS FOR THE NEXT PERIOD

Further calculations are contemplated on the deviation of a light ray passing through a boundary layer. However, the emphasis during the next period will be shifted to the structural problem encountered in the forward oblique window of the RF-101. The durability of the forward oblique window as originally specified has been questioned. A meeting between personnel from Wright-Patterson Air Force Base; Libbey-Owens-Ford, Toledo, Ohio; Liberty-Mirror Division, Brackenridge, Pennsylvania; and the University of Michigan was held at the Libbey-Owens-Ford plant in Toledo on April 29, 1955, to discuss the problem.* It was concluded at the meeting that the real problem was to manufacture a glass configuration in the RF-101 that had sufficiently high mechanical- and thermal-strength properties so that it could be guaranteed not to break under any anticipated condition; breakage of the forward oblique window during flight would undoubtedly cause loss of the aircraft.

Preliminary calculations, performed to determine the thickness required for the forward oblique window, indicate that the thickness of the forward oblique window as originally specified is not sufficient to withstand the stagnation pressure at sea level if full power is applied to the aircraft; it is realized that full stagnation pressure will not be realized, however.

In order to insure that the initial flight tests on the RF-101 will proceed as scheduled, University personnel recommended that a metal plate or a laminated window be substituted for the forward oblique photographic window until the problem is further resolved.

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*During the tests performed on a 3/4-inch window coated with the 81E conductive coating, a crack developed because of local hot spots. Air Force personnel initiated tests to determine the thermal endurance of this new type of window when the electrically conductive coating failed. It was found that specimens having artificially damaged coatings failed at temperature differences along the surface as low as 40 to 50°F. (Some uncertainty exists in these tests, however, as to the amount of damage done to the glass itself in simulating coating failure.)

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