# ASSESSMENT OF DISTORTION OF WINDSHIELDS

*By*

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A method to measure distortion of Aircraft windshield is described. The assessment criteria are based on distortion produced by a certain specific area corresponding to the area covered in form perception by the human eye. Since visual acuity is maximum in the fovea, the permitted deviation of objects is minimum at the centre of the area. The maximum deviation permissible for different angular distances from the centre are worked out on the basis of changes in visual acuity for different angles from the fovea.

Use of visibility of fringes formed by double gratings for localised distortion is also described.

## Introduction

Distortion in the aircraft transparencies can be expected to cause pilot errors and fatigue to the pilot during flight. Optical imperfections such as bull's eyes, embedded foreign material, could be mistaken as other objects. Distortions interfere with visual target detection and reduce the ability to estimate the size, form and distance of sighted objects causing annoying undulations in the contours of the sighted objects. Sometimes the object could be seen as double.

The extent to which parallel plane panels will cause apparent changes in, direction, size, shape and distance of an observed object as well as the change in the angle of parallax for two objects at different distances have been computed by Cibis and Haber[1] The permitted inherent deviation error for good panel material have been laid down as 3' of arc[2]. Studies by Luczek[3] have qualified the loss of visual range due to inclination and material of the windshield e. g., Perspex could produce a loss of visual range as much as 38% at an angle of 80°.

## Test Proecdures Followed

While distortion is a recognised evil in transparencies, however, it is difficult to detect and evaluate because distortion is most disturbing during movement of the eyes or movement of the object. Such movements are hard to incorporate into objective tests.

The test procedure commonly followed is to determine the deviation produced by the material for normally incident rays. The optical arrangement is as shown in

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Fig. 1. The screen has grid pattern drawn on it such that when the projected image of the grid falls on the screen, the two grid patterns merge together. The grid lines may deviate by the introduction of the test object depending on the distortion in the object. The recommended maximum deviation is 3 minute of arc.

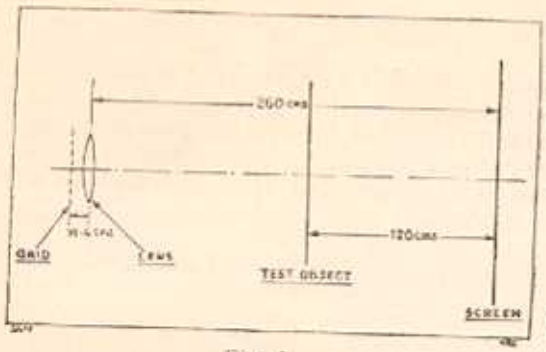



Fig. 1

Another practical method to test for distortion is to view or to photograph the objects through the completed windshield. In one such test Brown[4] used a Binocular camera to simulate pilot's vision. A grid was placed behind the windshield. The photograph showed grid lines wavy or curved and angle between lines different from 90°.

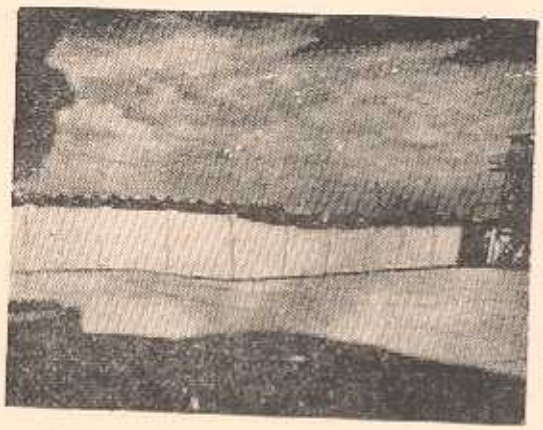
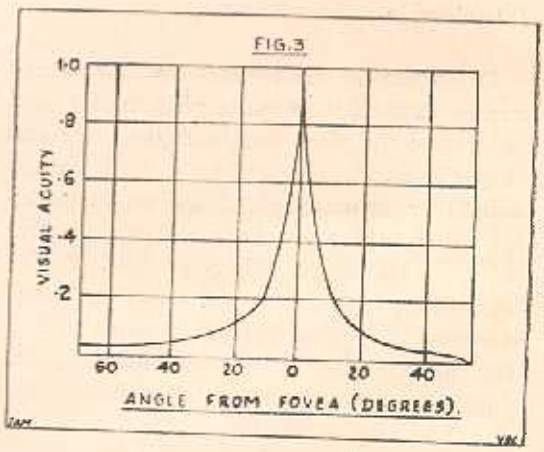


Fig. 2

Fig. 2 is a photograph taken through a windshield which is cleared by the criteria based on the deviation of the grid lines. But based on photographic technique the same windshield shows unacceptable degree of distortion. This difference between the two assessment techniques has arisen because the grid deviation is based on point to point scanning while the photographic technique takes the windshield as a whole. Human visual scanning and perception, however, do correspond to neither of the above techniques.

### Visual Acuity and Angular Distances from the Fovea

When the pilot looks out through the windshield his vision covers a certain area of the windshield, the perception of details depending on the visual acuity,




However the visual acuity diminishes with the increase in angle away from the fovea. Fig. 3 gives the values of visual acuity for different angles, from the fovea.

An experiment was conducted with three subjects to determine the deviations for different angular distances from the fovea within which two point objects are seen as one. Double lines with increasing

distance between them were presented at the fovea and at various angles from the fovea. The distance between the lines when they were just seen as separate were recorded. The average values of the maximum seperation permissible for various angles from the fovea for the three subjects is given in Table I.

From the foregoing it can be concluded that in the assessment of distortion of the windshield, instead of point to point scanning, a definite area of the windshield should be examined at a time. The windshield should then be shifted to bring the adjacent area normal to the rays. In a similar fashion this specific area should be examined for distortion. The process should be continued to cover the total windshield. The specific area recommended for this purpose is an angular area of 15°, as form perception is possible within this angle. The recommended maximum deviation of the projected grid from the grid lines on the screen are given in Table II.

TABLE I

Minimum Angular Separation And Angle From Fovea

| Subject | Angle from fovea | Average minimum angular separation for seeing double |
|---|---|---|
| A | 1.5° | 4′ |
| | 3° | 7.5′ |
| | 4° | 9.5′ |
| | 5° | 11′ |
| B | 1.5° | 3′ |
| | 3° | 6′ |
| | 4° | 9′ |
| | 5° | 14′ |
| C | 1.5° | 3′ |
| | 3° | 6.5′ |
| | 4° | 10′ |
| | 5° | 13′ |

TABLE II

Maximum Permissible Angular Separation

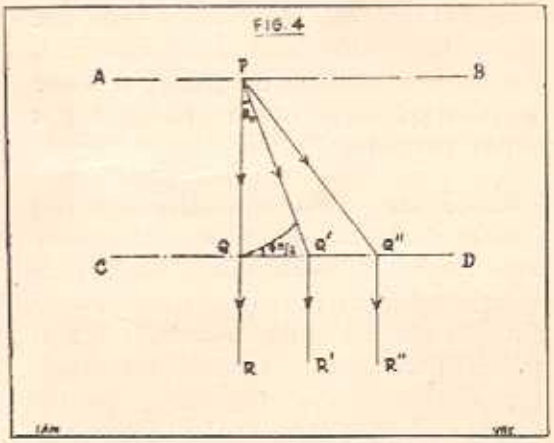
| Angle From Fovea | Maximum Permissible Deviation |
|---|---|
| 1° 30′ | 3′ |
| 3° | 6′ |
| 6° | 12′ |
| 10° | 18′ |

## Fringes Formed By Double Gratings

In studying the distortion produced which are more of a localised nature, accurate methods to measure deviation of light rays are necessary.

The fringes formed by two gratings when they are kept parallel to each other

FIG. 4




could be used for this purpose[5]. Let A B and C D (Fig. 4) be two similar gratings with grating element '△' placed at a distance D apart and let a plane wave front of monochromatic light be incident on A B. Let P and Q be two exactly identical points on the two gratings on the normal and so be P' and Q'. Let PP' = Q Q' = $n\triangle$ where $n$ is an integer.

Consider the directions Q R and Q' R' normal to the gratings. Two rays are diffracted in these directions, the first follow the path P Q and the second P Q'. If the path difference Q's is equal to $2m \frac{\lambda}{2}$, the rays will reinforce at the focus of a telescope objective. When Q's = $(2m+1) \frac{\lambda}{2}$ the rays will destructively interfere. If Q' PQ = $\theta n$ then Q Q' = D $\theta n$.

$$\theta n = \frac{n\triangle}{D}$$

$$Q's = Q\,Q' \frac{\theta n}{2} = n \triangle \frac{\theta n}{2}$$

$$= \frac{n^2 \triangle^2}{2D}$$

Thus is $\frac{n^2 \triangle^2}{2D} = m\lambda$, the rays will reinforce. Since the rays originate from the point P, the image of the point P is formed at the focal plane of the telescope objective. Similar pencils of rays start from every element of the grating A B and therefore an image of the grating A B is formed in the focal plane.

Where the plane wavefront passes through localised distortions, the wave front becomes corrugated. Since each band is formed from the contributions of different sections of the wavefront, corrugation of the wavefront affects the visibility of the bands. Depending on the degree of distortion the band system will get deteriorated. Band system will vanish whenever there is appreciable degree of distortion in the area covering the gratings.

**Recommended procedure For Measurement of Distortion**

a) Determine the area on the wind shield which subtends 15° at pilot's eye. This will depend on the distance of the pilot's eye from the windshield. For practical purpose five representative values may be chosen as follows :

i) Centre of the control panel
ii) Left end of the control panel
iii) Right end of the control panel
iv) Left side panel
v) Right side panel.

In measuring distortion of a particular area, use the corresponding values of 15° area.

b) Mount the windshield on a platform which can be moved transversely as well as up and down. (Fig. 5)

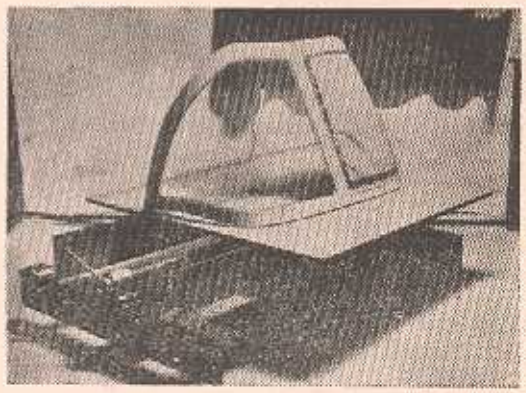


Fig. 5

c) Use the optical arrangement similar to that described in (Fig. 1)

d) Starting from left hand side edge of panel, present an area of 15° with its centre normal to the rays.

e) Observe the deviation of the projected grid lines from the lines drawn on the screen.

f) Similarly check other areas scanning the windshield from left to right and from top to bottom.

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