WADC TECHNICAL REPORT 55-55

LIGHT TRANSMISSION AND HAZE REQUIREMENTS FOR ENTS FOR TRANSPARENT ENCLOSURES

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PROJECT No. 7157

WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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FOREWORD

This report by Harold C. Glover, the Project Engineer, covers work conducted in the Aero Medical Laboratory, Directorate of Research, Wright Air Development Center. This investigation was performed in support of Project No. 7157, "Improving Visual Efficiency of Flying."

This report has been reviewed by Lt Colonel George O. Emerson, USAF (MC), Chief, Vision Section.

ABSTRACT

An analysis is made of the effects upon visibility induced by various transparencies through which aircrew members must perform the visual tasks of flying. Ranges of light transmission and haze values are established to define limits which are highly desirable, values acceptable if other factors take precedence, and minimum light transmission and maximum haze values which can be tolerated. The further reduction in light transmission induced by the angle of incidence of sloping windshields and its effect upon night visibility is evaluated.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

INTRODUCTION

The increased usage of electrical conductive coatings on aircraft windshields and canopies for the purpose of defogging, defrosting, or the removal of static charges imposes reductions in the light transmission and increases the haze values. In addition, the present trend among aircraft designers to slope windshields at progressively steeper angles for aerodynamic reasons reduces further the amount of light transmitted. The increased altitude capability of present and future aircraft requires the use of pressurized helmets with visors which further reduce the amount of useful light for vision out of the aircraft. The purpose of this investigation is to establish limits of light transmission and haze values for aircraft transparencies and visors based upon the visibility requirements for aircraft pilotage. These values should be useful as a guide in the development of canopies, windshields and visors with adequate light transmission and sufficiently low haze values, to meet operational visual requirements.

LIGHT TRANSMISSION AND HAZE REQUIREMENTS FOR TRANSPARENT ENCLOSURES

Approach

Transparency samples having various transmission and haze values were utilized to evaluate the effect of light transmission and haze upon visibility. Tests were conducted under a range of illumination conditions corresponding to the range from daylight to the darkest night conditions. Two types of test methods were employed. The first was to evaluate the visibility through the transparency samples using the Luckiesh-Moss, Low-Contrast test charts developed by the Lighting Research Laboratory, General Electric Company, Cleveland, Ohio. The second method evaluated visibility through the various transparency samples while viewing a laboratory developed Maximum-Contrast, Variable-Size Test Target.

The Luckiesh-Moss Low-Contrast test chart as used has test numerals ranging from 3.9% to 37.0% contrast with the white background. This test chart was viewed at a distance of five feet under controlled illumination conditions to simulate the various natural light conditions listed above. Visual contrast threshold values were measured through transparency samples having various light transmission and haze values. These were compared with values obtained with unobstructed vision.

The Maximum-Contrast, Variable-Size Test Target consists of a thin target which by rotation could present an apparent variable size from zero to three inches in diameter. This target is painted a dull black against a white background. The target is 24 inches in length and was viewed at a distance of 10 feet under varying light conditions. The standard practice of off center fixation was followed during this

testing to provide maximum visibility under the low level of illumination conditions employed.

In addition, and as a check on the results from the testing program, computations were made to compare percentage changes in night sky brightness which would effectively be produced by transmission losses due to the transparencies. This analysis established limits of transmission and haze values based upon the visibility requirements for aircraft pilotage.

Discussion

Laboratory tests revealed that any loss in light transmission affects visibility adversely during nighttime conditions. Many military operations are carried out under the very poorest visibility conditions, where even a small loss in light transmission may cause barely visible objects to become undetectable. Under these circumstances it is very important that the aircraft transparencies have high light transmission values. It is equally important for both day and nighttime visibility that the transparencies possess low haze values.

The low light transmission value of windshields, which is caused by the large number of laminated layers and great thickness, is further accentuated by the high angle of incidence prevalent in new aircraft designs. Several designs call for a windshield angle of incidence of 65 degrees. This angle of incidence is responsible for reducing the light transmission to 80% of that as measured normal (90 degrees) to the surface (Ref. 1). Thus a windshield with a transmission value of 83%, as measured normally, has an effective transmission of 66.4% when installed at an angle of 65 degrees, while a windshield with a transmission value of 75% has an effective transmission of 60% when installed at 65 degrees inclination. This loss in light

transmission alters the visibility conditions considerably, and effectively reduces the apparent brightness of moonlight night sky conditions to moonless night sky conditions. The moonless night sky conditions are very near the lower visibility limits. With this amount of transmission loss, the pilot will be unable to see unlighted aircraft through the windshield unless a bright moonlit night condition prevails.

Since any reduction in visibility induced by transmission and haze losses in the visor are superimposed upon those due to the aircraft transparencies, the visor must have the very highest obtainable transmission values and the very lowest haze values.

The following range of values has been established with consideration given to the initial optical properties of transparent materials, windshield angle of incidence, and the visibility requirements for night flying conditions. In each instance the lower permissible limit is given for light transmission and the higher permissible limit for haze values.

TABLE 1

LIGHT TRANSMISSION AND HAZE VALUES

		WINDSHIELDS				CANOPIES	VISORS
		INCIDENCE ANGLE					
		55°	60°	65°	70°		
HIGHLY DESIRABLE VALUES	Transmission	71%	74%	83%	99%	89%	90%
	Haze	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
ACCEPTABLE IF OTHER FACTORS TAKE PRECEDENCE	Transmission	66%	69%	78%	93%	83%	86%
	Haze	1%	1%	1%	1%	1%	1%
MINIMUM VALUE	Transmission	64%	67%	75%	89%	77%	79%
MAXIMUM VALUE	Haze	2%	2%	2%	2%	2%	2%

CONCLUSIONS:

1. That the very highest light transmission and the very lowest haze values obtainable for windshields, canopies and helmet visors are required to meet operational visual requirements.

2. That the light transmission requirements for windshields be based upon the light transmitted at the angle of windshield slope, in addition to that value as measured normal to its surface.

REFERENCES

1. Visual Factors in the Design of Military Aircraft, Major E. A. Pinson and Captain A. Chapanis, The Journal of Aviation Medicine, Volume 17, Number 2, April 1946