WADC TECHNICAL REPORT 54-505

A METHOD FOR SIMULATED NIGHT FLYING DURING DAYLIGHT HOURS

RICHARD E. HORN

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RDO No. 696-67

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 Dr. Richard E. Horn, the project engineer, was prepared under RDO No. 696-67, "Aircraft Visual Requirements." Work was performed under the auspices of the Aero Medical Laboratory, Directorate of Research, Wright Air Development Center, Wright-Patterson Air Force Base. Research was started on 23 September 1952 and completed on 21 July 1954. The manuscript of the report was completed on 24 September 1954.

The equipment described in this report was developed at the request of Air Research and Development Command. The need for such equipment was set forth in a formal requirement by Headquarters, Air Resupply and Communications Service, Military Air Transport Service, and concurred in by the Director of Research and Development, USAF. On 1 January 1954, the Air Resupply and Communications Service (MATS) was discontinued, and the various units were transferred to the operational jurisdition of theatre commanders or other major command headquarters. Although the initial comprehensive training of Air Resupply and Communications Service crew has been completed and the units deployed, this equipment will be very useful in maintaining proficiency in the field, and in the training of replacement crews.

ABSTRACT

A method of simulating night flying conditions during daylight hours is described. This work was undertaken to satisfy a requirement set up by the Air Resupply and Communications Service for a method of pilot indoctrination in low level, night flying which would have a high safety factor. The pilot undergoing training wears lenses of very low light transmission which are mounted in a special goggle that excludes all stray light. Supplemental lighting is provided for the essential instruments. The complete absence of ground lights simulates the actual conditions of the combat zone.

PUBLICATION REVIEW

This report has been reviewed and is approved.

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

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

INTRODUCTION

The Air Resupply and Communications Service (formerly under Military Air Transport Service) had as one of its missions during the recent Korean conflict, the supplying of troops, by air. Air supply was necessary, since the units were often cut off from their main supply routes and the terrain was such that land supply was difficult. A typical resupply run consisted of flying at approximately 500 feet over a designated troop area and dropping supplies by parachute. This activity was carried out at night, when possible.

Training for these missions consisted only of night flights at the higher altitude of 5,000 feet, because even training flights were hazardous. When actual missions were flown, especially in rugged terrain, the aircraft loss rate was high. It was considered that the loss rate could be greatly reduced by realistic, but safe, training in low altitude night flying. This report describes the work carried on at the Aero Medical Laboratory in developing a training device which would permit pilot indoctrination in very low level, night flying during daylight hours.

LABORATORY WORK AND EXPERIMENTATION

Selecting the System

The Air Resupply and Communications Service set up a requirement for a training device which would permit pilot indoctrination in very low level, night flying, during daylight hours. Visibility of the safety pilot would be maximal. This would be advantageous, since it would permit greater concentrations of aircraft within a given area, over varied terrain contours, with maximum safety. The device would simulate two or more of the conditions encountered on actual missions. These are: full moon, clear night; half moon, clear night; no moon, clear night; overcast night.

A device to accomplish the needed simulation could take one of two forms, either a double- or single-stage system. The double stage system would be similar to the mutually exclusive color filter combination used in the present two color view limiter system of instrument flight training. The pilot undergoing training wears a goggle, which contains a filter lens of one color, while the aircraft transparencies are covered by a filter of another color. Each filter has a transmission such that the combination of the two cuts out all view outside the aircraft. However, with either filter alone, vision is fairly good except for some color distortion. The student pilot can see only his instruments, but the instructor pilot has good vision outside the aircraft. This system cannot be adapted successfully to fulfill the Air Resupply and Communications Service requirement. It is difficult to control the saturation of the goggle filter and the transparency filter so that the transmission is satisfactory. Here, instead of elimination of light transmission, as in instrument flying training, it is necessary to control precisely the total amount and color quality of the light transmitted.

The use of double polaroids was next investigated. One set could be worn by the student pilot, with the other set affixed to the transparencies with the planes of polarization at right angles to each other. The safety pilot maintains adequate vision outside the aircraft, while the illumination transmitted to the eye of the student pilot is reduced. However, upon a slight tilt of the head (less than 10°), the degree of occlusion is reduced approximately 75% for the student. This would allow too much vision outside the aircraft for the student pilot, and was therefore not acceptable.

The use of circular polaroids was also investigated. They would allow normal head movements without lessening the degree of occlusion. However, the state of the art in the development of circular polarization was not yet far enough advanced to allow its use.

The single stage system can take two possible forms. The first is a filter over the transparencies. This allows ease in seeing instruments, but is obviously not satisfactory, since the safety pilot has no better vision outside the aircraft than the student. The second form consists of a goggle with the required density lenses worn only by the student pilot. High intensity illumination is necessary for the essential instruments. The safety pilot has normal vision inside and outside the aircraft. This latter form was adjudged to be the one most likely to fulfill the requirements for a training device, all the double stage systems having been found deficient.

Lens Requirements

The consideration of the lens material to be employed involves many aspects. No commercially available glass is of a sufficiently low transmission. Therefore, a development program for a new type of glass, with a desirable transmission curve, would have to be initiated. Also, no definite knowledge could be gained that it would be possible to produce a satisfactory glass even after a long development program. Experimental melts and small production runs lead to large expenditures of money and resultant high costs for any glass produced. Glass has the additional disadvantage of being heavy.

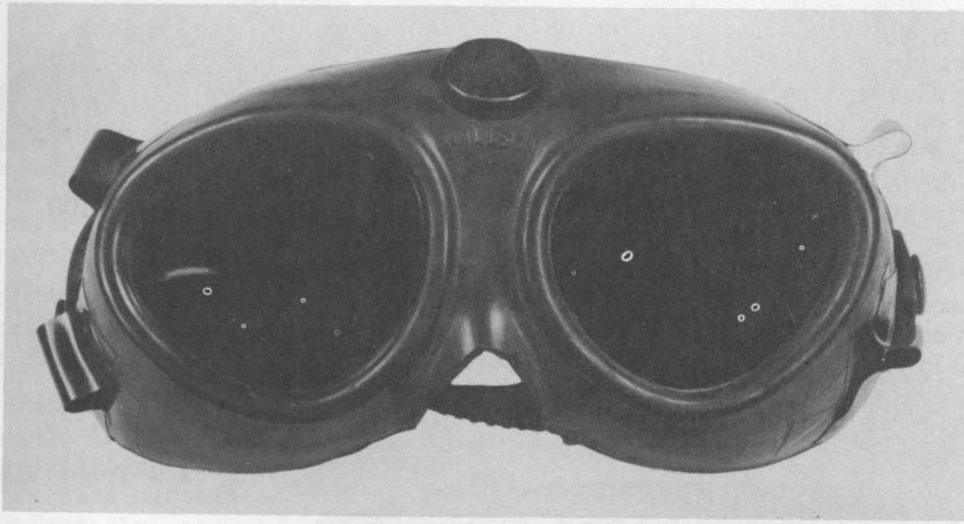
Wratten neutral density filters provide a ready means of obtaining the desired transmission characteristics. However, the filters are sheets of gelatine material, and to have any practical use must be bound in glass. This again introduces a weight factor. Also, the expense involved for one pair of lenses is considerable.

The only material left for consideration is plastic. Commercial products were investigated and tested, but none could be found with the desired transmission, or anything close to it. All the known manufacturers of ophthalmic quality plastic sheet were solicited to see if a desirable product could be made. Only two companies were found that were still making ophthalmic quality sheet plastic and considered it possible to produce plastic sheet of the required density. One company was able to make laboratory sample sheets 7 x 12 x .03 inches in two density ranges. In production, the thickness must be strictly controlled, since only a slight change in thickness results in a considerable change in transmission. Also, a thickness of .06 inches would be more satisfactory for a production lens. The material used is cellulose acetate, which is subject to scratching. However, the small cost of replacement lenses, and the low weight of the plastic more than offset this factor.

The four night illumination conditions which the Air Resupply and Communications Service would like to have simulated have been mentioned previously in this report. Using available illumination data, wratten filters were mocked-up, in combinations, as lenses in an experimental goggle. The range needed on a bright clear day is from density 5.2 to density 5.8 or a transmission of from 1/158,490 to 1/630,060. Since Air Resupply and Communications Service missions normally would be flown in all types of weather, the training should be under all weather conditions. Lenses of density 5.4 could simulate all night weather conditions when training in corresponding day weather conditions. On a bright clear day, the lens will simulate full moonlight. On an overcast day the lens will simulate a dark overcast night. By using one density for the lens, the goggle can be of simple design. Also, lens stocking problems could be reduced.

Goggle Requirements

In studying the design necessary for a goggle to hold the lenses, certain factors must be considered. Since the lens is very dense, the person wearing the goggle will be in a dark adapted state. Any light leaking into the goggle, around the edge, or at the ventilating ports, destroys to some degree the wearer's dark adaptation. In addition, the light is extremely annoying. Since the goggle must be light tight, only a ventilating port with a built in light trap is satisfactory. Figure 1 shows an early experimental port arrangement. The principal of light traveling in a straight line is employed here to provide a light trap. The inside tube and outside shield are at right angles to each other, and thus effectively trap most of the light. Any stray light that might come through the tube is directed toward the goggle surface which is fairly matte in finish. This design was not successful, however, because air stagnated in the tubes and the lenses soon fogged.



A - FRONT VIEW

B - REAR VIEW

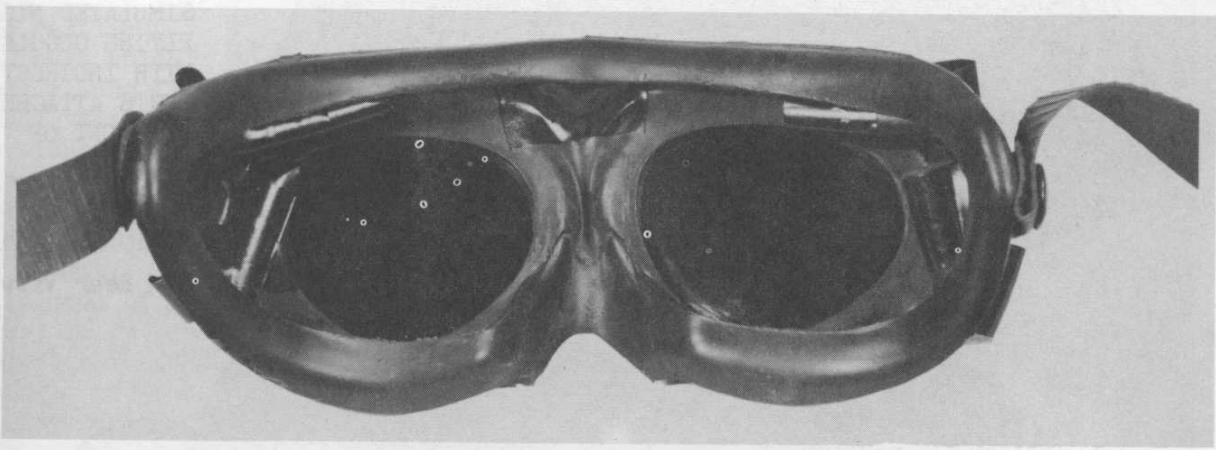


Figure 1. SIMULATED NIGHT FLYING GOGGLE WITH TUBE LIGHT TRAP

A port which fulfills the requirements successfully is shown in Figure 2. This port is normally used on welding goggles to prevent the bright light of the welding torch from entering the eyes, or on acid goggles where splashing liquids could injure the eye. Again, the principle of light travelling in a straight line is employed to provide a light trap. The air openings are spaced on the front and rear surfaces, so as to have a space approximately 3/16 inch wide, which is open on neither side. In addition, the portion of the opening which is not curved has a lip which extends inward approximately 1/16 inch from each surface. The inner surfaces are painted matte black to reduce reflections to a minimum. The screening is to prevent the entry of foreign objects.

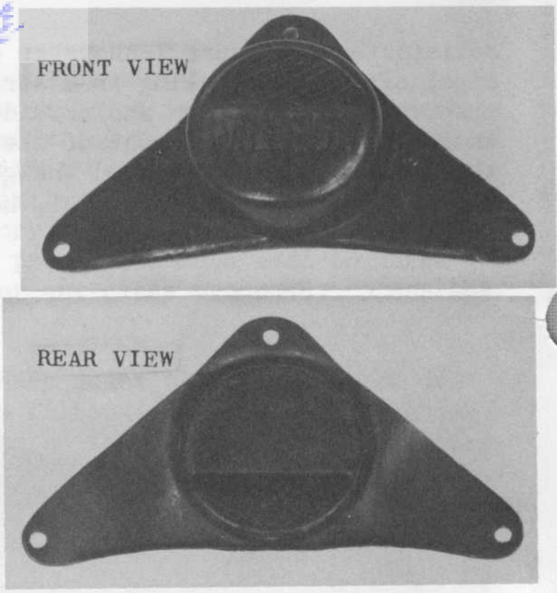
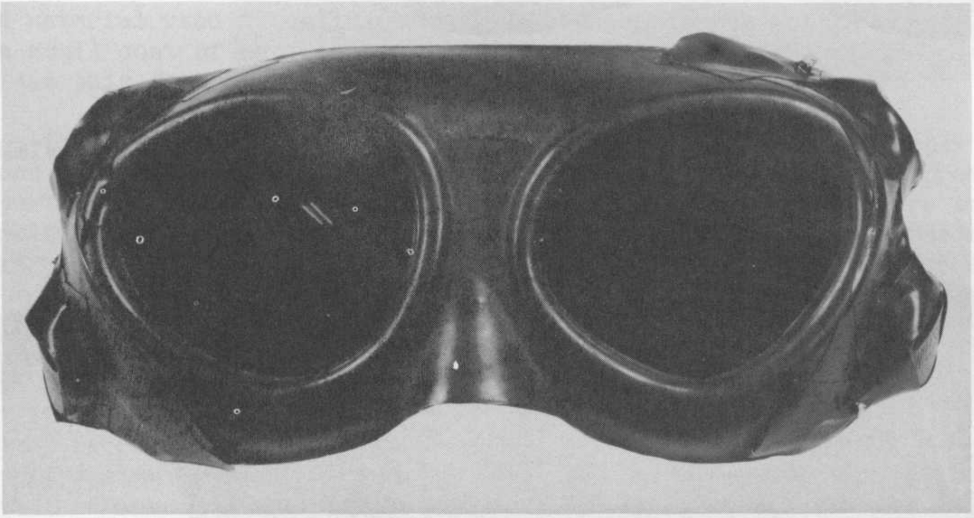


Figure 2. INDIRECT VENTILATION PORTS

The first model with indirect ports is shown below in Figure 3. The ports are attached by screws to the front surface of the goggle. Since the port flanges do not fit tightly to the goggle, the whole port is sealed to the goggle with black plastic tape.

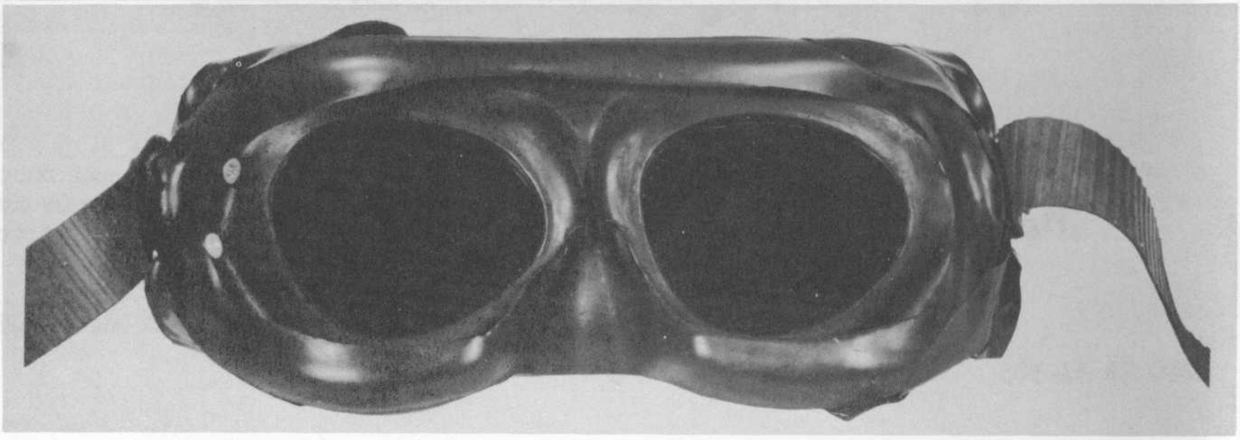


A - Front View

Figure 3.

EARLY MODEL SIMULATED NIGHT FLYING GOGGLE WITH INDIRECT PORTS ATTACHED TO FRONT OF GOGGLE

B - Rear View



A later model is shown in Figure 4. Here, the port flanges are considerably reduced, and a different method of attachment is used. The ports are fitted through small openings in the goggle about 3/4 their size. The rubber frame of the goggle is elastic and seals itself around the port making a light tight seal. This method of attachment functions well. If a more permanent bond is desired, rubber-metal cement can be used as a sealant.

The goggle frame was selected from the many styles of cover goggles available for industrial use. It was especially necessary that the goggle edges fit closely to the face, and thus provide a seal against light. The goggle selected is a rubber mask style available for workers in the chemical process industries in operations where there is exposure to splashes of corrosive liquids. The goggle is made of oil resistant rubber, fits the face closely and comfortably, and can be worn over correction glasses if necessary. A special feature of the goggle is the resilient rolled edge which assures a snug fit of most all facial contours without pressure. It also acts as a shock absorber if the goggles should be subject to heavy impact. The head band is made of 3/4 inch molded rubber with an adjustable buckle and hook arrangement to allow for variations in head size.

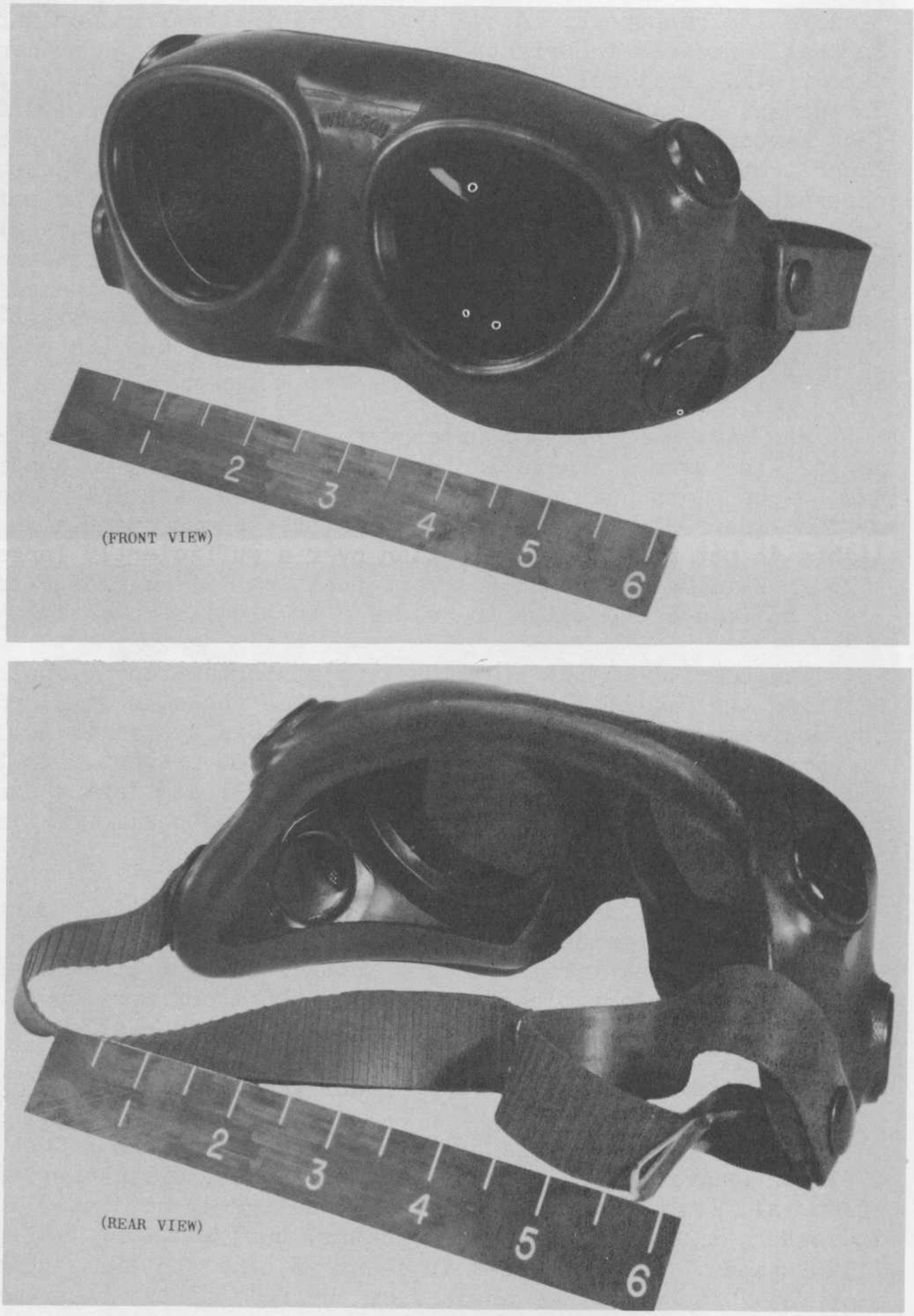


Figure 4. GOGGLE USED IN SIMULATED NIGHT FLYING

Instrument Lighting Requirements

There is only one requirement for the instrument lighting system - the pilot must be able to read the instruments with sufficient accuracy to control the aircraft. Spragg and Rock (1,2) in a series of studies on dial reading performance, found that there is a critical brightness level between 0.02 and 0.05 foot lamberts, below which there is greater frequency and magnitude of errors, and relatively slow responses. Above this level the task suddenly becomes much easier. Further increases in brightness, however, produce no further increments of performance. This critical region has been confirmed by Rock (3), and more recently by Spragg and Kanwisher (4). Cole, McIntosh, and Grether (5) found that this (0.02 foot lamberts) is the level at which a group of pilots tended to set their red floodlighting system for normal night flying. The same group, however, set their rheostats at 0.003 foot lamberts when vision for objects outside the aircraft was of prime concern. This was considered to be the minimum brightness setting at which safe flight could be maintained. Since vision outside the aircraft is of prime concern in Air Resupply and Communications Service missions, 0.003 foot lamberts was taken as the proper effective instrument lighting requirement (this is not the total brightness of the instruments, but the brightness as seen through the goggle lens).

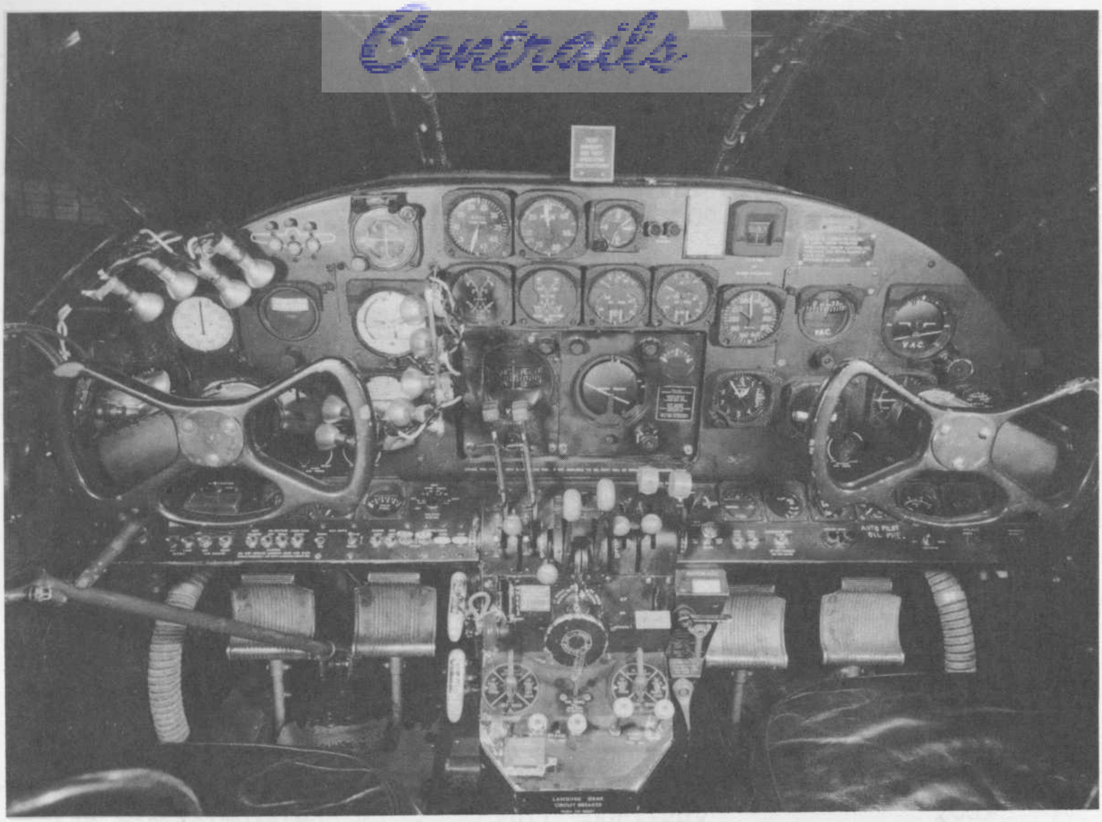
Many types of light sources were investigated for illuminating the instruments. Photoflood and reflector spotlights provide adequate illumination, but have certain disadvantages. Photoflood bulbs last only a relatively short period of time (four-six hours), and produce tremendous quantities of heat. The spotlights do not provide illumination over a sufficiently large area, and heat production is still a problem. One very practical disadvantage is the lack of a good place to locate the bulbs in relation to the instruments.

The possibility of lighting each instrument individually was also investigated. By using two small spotlight bulbs mounted three to six inches from each instrument the minimum requirements are met. Since this system is to be used in daylight, there will be additional natural illumination present. On those days when the natural illumination is reduced, the goggles will simulate a dark night. On such a night, instrument lighting would be a minimum to allow maximum vision outside the aircraft.

In an effort to increase the contrast of the instrument dials and thus increase visibility, two standard aircraft instruments were compared with two which had previously been repainted for use on another project (the faces were white with the numbers and pointers black). Using a laboratory mock-up of the lighting system for illumination, the latter were found to be more readable.

FLIGHT TESTING

Flight testing of the system was carried out in a C-45 aircraft between October 1953 and January 1954. Figures 5 and 6 show the lighting installation. Only the essential flight instruments (directional gyro, air speed indicator, rate of climb indicator, altimeter, flight indicator, bank and turn indicator) were repainted and illuminated. As can be seen in Figure 5, the spotlight bulbs in most instances are positioned at an extreme angle from the face of the instruments they illuminate. This reduces the illumination on the instruments, from the potential available, by a factor equal to the cosine of the angle between a perpendicular to the face of the instrument and a line parallel to the long axis of the bulb. This is shown in



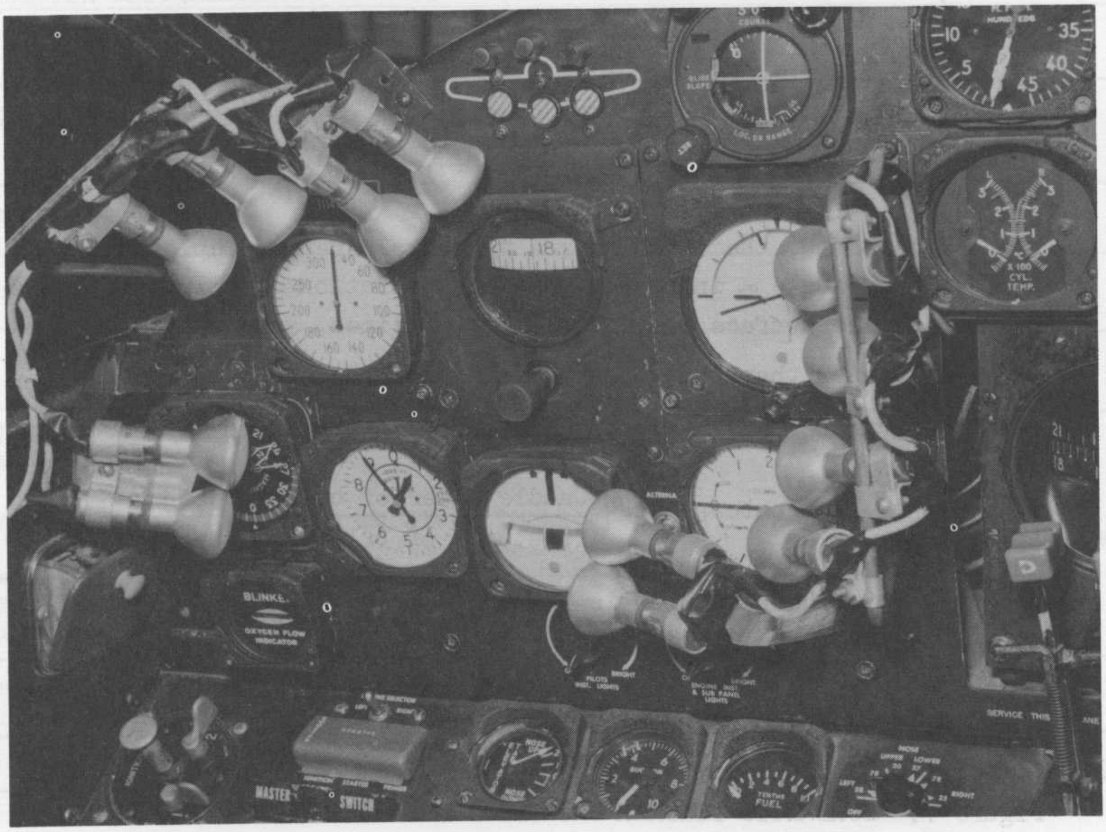
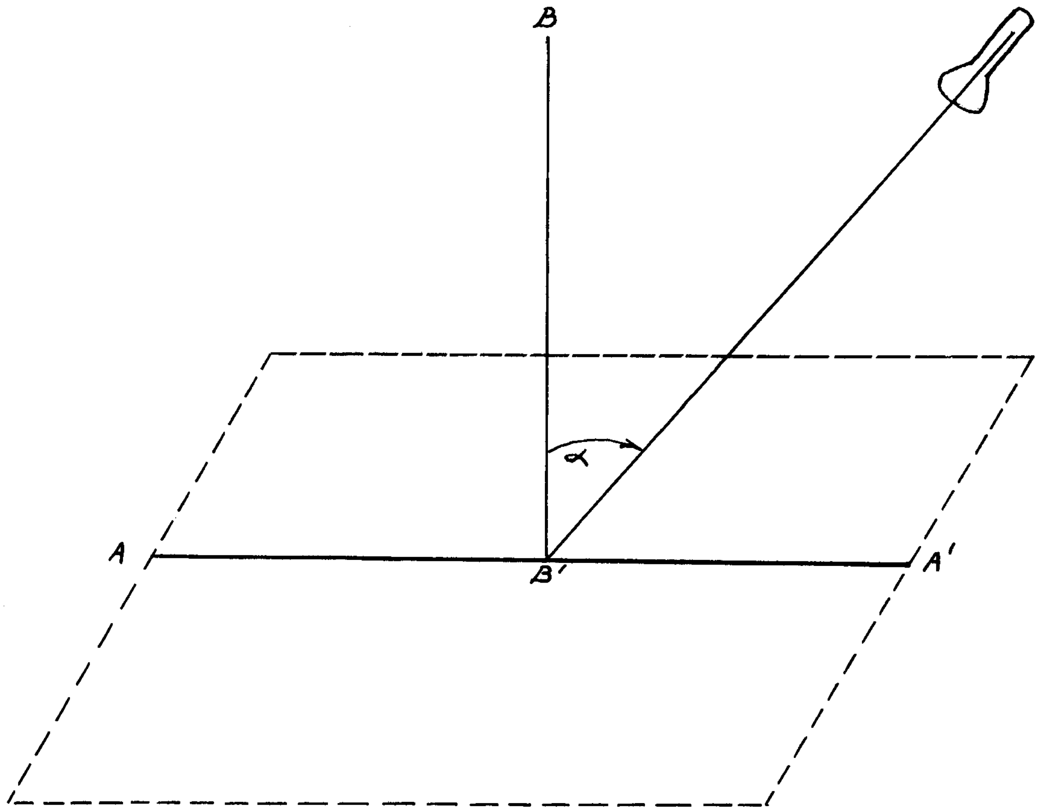


Figure 5. SHOWS SPECIAL INSTRUMENTS AND LIGHTS INSTALLED IN COCKPIT OF C-45
Figure 6. CLOSEUP OF LIGHT INSTALLATION AND SPECIAL INSTRUMENTS



When angle α = 0, the light source is normal (perpendicular) to the surface. As angle α increases, the concentration of illumination is reduced on the surface outlined in dotted lines, and is spread over an area greater than that shown. The illumination on the dotted parallelogram for any angle of the bulb is computed by the formula:

$$\text{Footcandles} = \frac{\text{Candle power of bulb x cosine } \alpha}{(\text{distance of bulb from surface})^2}$$

When α = 30°, the reduction is 14%.

When α = 60°, the reduction is 50%.

Figure 7. SCHEMATIC DIAGRAM SHOWING REDUCTION OF EFFECTIVE LIGHTING

Figure 7. The installation in this instance was governed by a flight safety requirement peculiar to the C-45 aircraft used. It is not expected that such an extreme angle of incidence would be encountered on most aircraft in which this system would be installed permanently. The recommended installation is at a distance of from three to six inches from the face of the instruments, with the bulbs making an angle of not more than 30° with the instrument face.

The appendix contains instructions and a copy of the questionnaire given to the pilots employed in the simulated night flying test program. A small airport with a lake beside it was used as the target area. The altitude flown in the vicinity of the target area was 300 to 500 feet at an airspeed of 110 to 130 knots. Tables 1-6 are a compilation of the answers given on the questionnaires.

TABLE 1

BRIGHT CLEAR DAY

Condition Best Simulated	Full Moonlight	100%
Able to Identify Ground Target	Easily With Difficulty	60% 40%
Goggle Comfortable to Wear	Good Fair Poor	40% 40% 20%
Light Leaks in Goggle	Yes No	20% 80%
Light Leaks Around Edge	Yes No	40% 60%
Lenses Fog	Yes No	80% 20%
Illumination on Instruments Adequate (NOTE: One person reported directional gyro couldn't be seen further than 15 inches)	Yes No	60% 40% (100% could read with difficulty)
Instruments Easier to See Than Those Normally Used	Yes	100%
Adequate System for Indoctrination of Resupply Pilots	Yes	100%

TABLE 2

BRIGHT HAZY DAY

Condition Best Simulated	Full Moonlight Half Moonlight Overcast Night	66.67% 16.67% 16.67%
Able to Identify Ground Target	Easily With Difficulty	50.00% 50.00%
Goggle Comfortable to Wear	Good Fair	33.33% 66.67%
Light Leaks in Goggle	Yes No	50.00% 50.00%
Light Leaks Around Edge	Yes No	50.00% 50.00%
Lenses Fog	Yes No	16.67% 83.33%
Illumination on Instruments Adequate	Yes No	16.67% 83.33% (40% could read with difficulty) (60% seen, but not read)
Instruments Easier to See Than Those Normally Used	Yes	100.00%
Adequate System for Indoctrination of Resupply Pilots	Yes Didn't Know	83.33% 16.67%

TABLE 3

CLOUDY OVERCAST DAY

Condition Best Simulated	Full Moonlight Half Moonlight No Moon Overcast Night	27.2% 45.5% 9.1% 18.2%
Able to Identify Ground Target	Easily With Difficulty	72.7% 27.3%
Goggle Comfortable to Wear	Good Fair	54.5% 45.5%

TABLE 3 (Continued)

CLOUDY OVERCAST DAY

Light Leaks in Goggle	Yes No	27.3% 72.7%
Light Leaks Around Edge	Yes No	45.5% 54.5%
Lenses Fog	Yes No	72.7% 27.3%
Illumination on Instruments Adequate	Yes No	72.7% 27.3% (75% could read with difficulty) (25% seen, but not read)
Instruments Easier to See Than Those Normally Used	Yes	100.00%
Adequate System for Indoctrination of Resupply Pilots	Yes	100.00%

TABLE 4

ALL CONDITIONS

(Summary Tables 1-3)

Condition Best Simulated	Full Moonlight Half Moonlight No Moon Overcast Night	54.5% 27.4% 4.5% 13.6%
Able to Identify Ground Target	Easily With Difficulty	63.6% 36.4%
Goggle Comfortable to Wear	Good Fair Poor	45.5% 50.0% 4.5%
Light Leaks in Goggle	Yes No	31.8% 68.2%
Light Leaks Around Edge	Yes No	45.5% 54.5%
Lenses Fog	Yes No	77.3% 22.7%
Illumination on Instruments Adequate	Yes No	59.1% 40.9%

TABLE 5

CRITICISMS NOT OTHERWISE COVERED

1. Directional gyro not as visible as other instruments
2. No forward vision, therefore not realistic
3. Goggle lenses should be larger
4. Fogging serious enough to totally obscure vision; had to close eyes and wipe goggles
5. More substantial lighting system
6. Good simulation of night flying; simulates actual combat conditions

TABLE 6

SUGGESTIONS FOR IMPROVEMENT

1. Darker lenses
2. Need two mile visibility with goggles on
3. Better instrument lighting
4. Larger field of vision
5. Compare white and regular instruments with same lighting
6. Use a lot of small air vents instead of present arrangement
7. Heavier numbers on directional gyro as on altimeter
8. Use open fields for targets instead of runways
9. Add clock so that timed patterns can be flown

DISCUSSION AND CONCLUSIONS

The results of the flight test program show the system to be workable - the pilot can fly his aircraft and identify a ground target under simulated night conditions. Modifications have been made in the goggle to prevent fogging. A suction tube has been added to pull air over the lenses and thus prevent the accumulation of moisture. The tube can run either to the outside of the aircraft through the side windows, or be connected to the suction system of the aircraft instruments. A variable "C" clamp attached to the hose is used to regulate the amount of air flow. This will allow adequate ventilation, but will not cause discomfort due to drying of the eyes. Figure 8 shows this modification.

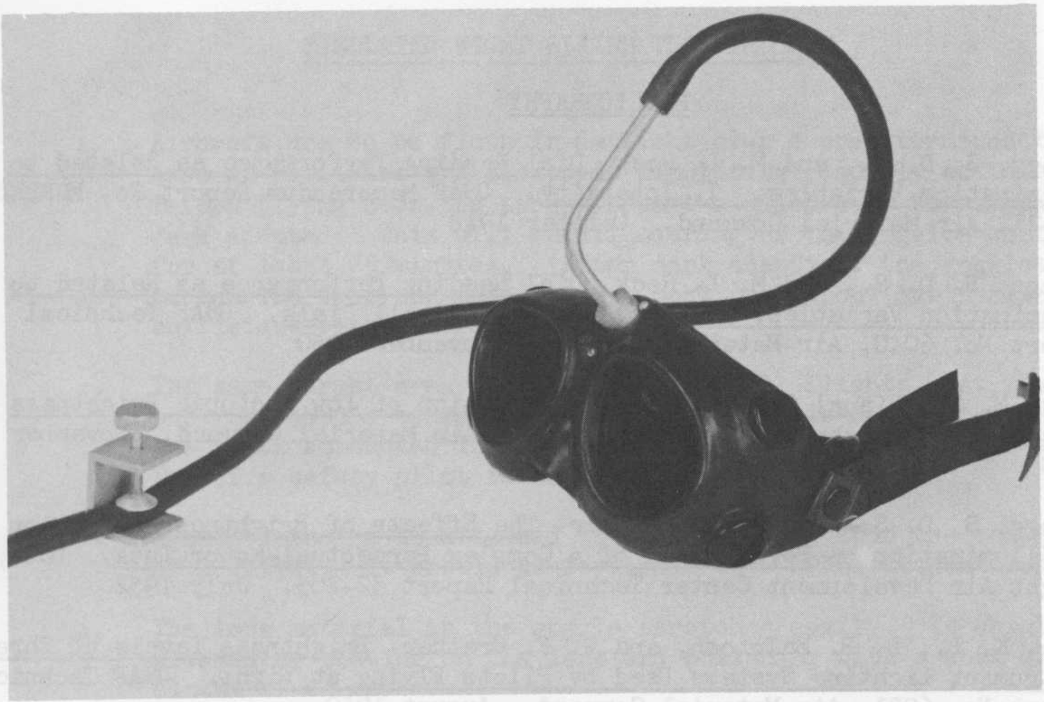


Figure 8. SIMULATED NIGHT FLYING GOGGLE WITH SUCTION HOSE ATTACHMENT

The rolled edges of the goggle should be extended and reinforced at some points. This will provide a more comfortable fit for various facial contours, as well as making a better seal for the elimination of light leakage.

The lighting system is adequate if installed properly. The elimination of lens fogging will also increase the instrument readability.

Later studies on instrument dials have indicated that a black background face with high reflectivity white numbers and pointers would make a slightly more readable presentation. The type V-7 compass indicator should be substituted for the directional gyro on those aircraft where it is not already installed as the directional indicator. It is standard on many of the newer aircraft, and since it possesses both a pointer and instrument dial, headings are much easier to determine than with the rotating card presentation of the directional gyro.

Probably the most important factor disclosed by the flight test is the true night simulation produced by the system. All the houses, buildings, and vehicles gave the impression of being blacked out. This is the condition encountered in night combat situations. In ordinary night training, light clutter from the ground is always present.

While the system was developed for a particular training procedure (resupply activity), it should also be equally useful in many varied training procedures which are now of necessity carried on at night. By training in the daytime, greater concentrations of aircraft are possible within a given area, with a higher safety factor than ever found at night, and with a true simulation of night combat illumination conditions.

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APPENDIX

INSTRUCTIONS AND QUESTIONNAIRE FOR SIMULATED NIGHT FLYING TEST PROGRAM

SIMULATED NIGHT FLYING TEST PROGRAM

1. Aircraft are to be flown in daylight over a predetermined target area at altitudes and airspeeds simulating resupply activities. Before flying over the target area the pilot must be completely dark adapted. This will entail wearing of the goggles continuously for at least 25 minutes. (After dark adaption, the goggles cannot be removed from the face and put back on without again allowing sufficient time for readaption.)

2. The same target area should be used in all flights. At least two runs should be made over the area. It is desirable to have the tests conducted in a variety of weather conditions if possible. Use of a safety pilot is mandatory.

3. A questionnaire is attached to be filled out upon the completion of a flight. It should be forwarded to WCRDF-4 without delay.

4. The lens material in the goggle scratches easily. It should be cleaned by blowing on the lens and polishing with a soft clean cloth.

Questionnaire (Return to WCRDF-4 upon completion)

1. Name ______________________ Rank ____________ Date ________

2. Altitude flown ______________ 3. Airspeed __________

4. Weather conditions: ___ bright clear day; ___ cloudy overcast day;

   ___ rainy day; ___ other (explain)

5. Which condition was best simulated

   ___ full moonlight ___ half moonlight, clear night

   ___ no moon, clear night ___ overcast night ___ other (explain)

6. Was the ground target identified ___ easily ___ with difficulty

   ___could not be identified ___ other (explain)

7. Is goggle comfortable to wear? ___ good ___ fair ___ poor

8. Are there any leaks in the goggle? ___ no ___ yes; location

9. Are there any light leaks around the edge of the goggle? ___ no

   ___ yes; location

10. Did the goggle lenses fog up? ___ no ___ yes After how long a time?

11. Is the illumination on the flight instruments adequate? ___ yes; ___ no

    If NO, _____ Dials could be read with difficulty; _____ Dials could be seen but not read; _____ Dials could not be seen

12. Are the white instrument faces easier to see than those normally used?

    ___ yes; ___ no

13. Do you think this is an adequate system for resupply pilots to be indoctrinated in the initial impact of LOW-LEVEL night flying?

    ___ yes; ___ no

14. Give any criticism not covered by this questionnaire.

15. Give any suggestions you may have for improvements.