REPORT NO. H-1324

DATE 26 October 1936

SUBJECT

FR-1324

Report on

Airplane Camouflage. Tests of October 1, 1936 on Reduction of Daytime Visibility of Airplane by Artificial Illumination.

by

E. O. Hulburt

NAVAL RESEARCH LABORATORY

WASHINGTON 25, D. C.

[redacted]

26 October 1936

NRL Report No. H-1324

FR-1324

NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report on

Airplane Camouflage. Tests of October 1, 1936, on Reduction of Daytime Visibility of Airplane by Artificial Illumination.

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON DC

Number of Pages: Text - 5 Plates - 7

Authorization: Bu.Aero.Conf.ltr.Aer-E-252-RL, F39-5, of 24 July 1936.

Prepared by: _____
E.O. Hulburt, Physicist, Superintendent,
Physical Optics Division.

Approved by: _____
H.M. Cooley, Captain, USN, Director.

Distribution:
Bu.Aero. (5)
Bu.Eng. (2)

ts

TABLE OF CONTENTS

Appendices

A B S T R A C T

Twelve 420 watt lamps were mounted under the lower surface of the fuselage of an airplane. During three daytime flights of the plane observers on the ground concluded that at distances up to about 2 miles the lights illuminated from one-fourth to one-half of the under surface of the fuselage to a brightness slightly less than that of a cloudy background and somewhat greater than that of a blue sky background. At distances from about 3 to 6 miles, when viewed with the unaided eye, neither the lights nor any effect of their illumination were perceptible.

CHAPTER 1.

INTRODUCTION

AUTHORIZATION

1. The present tests were authorized by reference (a). Other correspondence pertinent to this problem are listed as references (b) to (d).

Reference:
(a) Bu.Aero.Conf.ltr.Aer-E-252-RL, F39-5 of 24 July 1936.
(b) OpNav ltr. Op-22-B(SC) A21 Serial 1467 of 9 November 1935.
(c) Bu.Aero.ltr. Aer-E-252-RL (F39-5) of 23 November 1935.
(d) NRL Report No. H-1230, 20 January 1936, "Airplane Camouflage, Preliminary Report on Reduction of Visibility by Artificial Illumination".

HISTORICAL

2. A proposal originally made during the World War was restated in references (b) and (c) to the effect that the visibility of an airplane in the daytime viewed against a sky background might be reduced by illuminating with lights on the plane those surfaces which are in shadow and hence darker than the sky background. A laboratory investigation, reference (d), bearing on the proposal was carried out which indicated that an adequate illumination, if provided by electric lights, would require not less than 100 watts electrical energy for each square foot of illuminated surface.

SCOPE OF THE PRESENT REPORT

3. As described in the following paragraphs, the proposal has been given a limited experimental test. The restrictions imposed on the test were that the cost of the illuminating equipment be not greater than $500.00 and that the plane be not incapacitated. A 5000 watt illumination was installed on the under surface of the fuselage of a plane of area 40 square feet. During tests in flight it was observed that the illumination had no appreciable effect on the visibility of the plane at distances beyond 3 miles.

CHAPTER 2.

SUMMARY OF TESTS AND CONCLUSIONS

CONDITIONS OF TESTS

4. Twelve 420 watt tungsten lamps spaced about two feet apart were mounted on the under surface of the fuselage of airplane Type XFF-1. The surface was polished aluminum. The plane was tested at the Naval Air Station, Anacostia, D.C., on October 1, 1936, between 10 A.M. and 3 P.M. in three flights according to the following program: In each flight the plane mounted to an altitude of about 5000 feet above the Air Station and flew at this altitude to a distance of about 6 miles in a direction roughly away from the sun alternately turning the lights on and off for 30 second intervals. The weather was clear, no haze. During the single morning flight the sky was covered with thinnish white clouds; during the two afternoon flights mostly blue sky appeared with few clouds.

5. The flights were observed from the ground by representatives from the Bureau of Aeronautics, the Naval Air Station and the Naval Research Laboratory.

CONCLUSIONS

6. It was concluded:

(a) That at distances up to about 2 miles, when viewed with the unaided eye, the lights illuminated roughly from one-fourth to one-half of the under surface of the fuselage to a brightness slightly less than that of a cloudy background and somewhat greater than that of a blue sky background for angles to the sun greater than 30°.

(b) That at distances from about 3 to 6 miles, when viewed with the unaided eye, neither the lights nor any effect of their illumination was perceptible, the plane appearing as a dark speck against the sky background no matter whether the lights were on or off. This was due to the fact that the artificial illumination covered only a small portion, from 1/5 to 1/10, of the total surface of the plane visible to the observer, the remaining 4/5 to 9/10, which was not illuminated, being the controlling factor in the appearance of the plane.

(c) That in order to produce perceptible effects on the plane as a whole there would be required an artificial illumination perhaps 10 times more extensive than that used and well spread over the wings, vertical surfaces and engine of the plane. Such an illumination, in the case of electric lights, would require upward of 50,000 watts power supply and would probably necessitate rebuilding the entire plane for a correct installation. Whether a correct installation within practical limits could be designed is not certain.

(d) That the proposal to reduce visibility by added illumination is based on the hypothesis that the unilluminated plane be darker than the background. The hypothesis is often true, but not always true, for sunlighted surfaces of a Navy gray or aluminum painted plane often appear brighter than the background, and in such case added illumination would increase the visibility of the plane.

CHAPTER 3.

DETAILS OF TESTS

Details of Installation

7. A plane Type XFF-1 was used, the fuselage being of polished aluminum. Twelve landing lights were mounted about 8 inches below the lower surface of the fuselage in two rows 25 inches apart, with six lights in a row spaced 25 inches apart. They illuminated about 40 square feet. Photographs of the installation are shown in Plates 1 and 2. The lights required 12 volts and 35 amperes or 420 watts each, a total of about 5000 watts for the twelve lamps. Therefore on 40 square feet there was provided an illumination energy of 5000 watts, or 120 watts per square foot. About 10 to 20 percent of the light was wasted due to obstructions of the lamp mountings and to the fact that the reflectivity of the polished aluminum was about 75 percent. Hence illumination energy from about 100 watts emerged from each square foot of the illuminated area.

8. The battery capacity was sufficient for supplying power to the lights for about 20 minutes. A photograph of the battery installation is shown in Plate 3. A list of the parts of the installation with weights is given in Table 1.

TABLE 1.

Function	Apparatus	Weight
Power Supply	4 65 Amp.Hr. Batteries	280 lbs.
	34 ft. cables ALP 11	15
	2 relays	5
	2 switches, Type A and bracket	0.5
Illumination	12 Mogul lamps, 25 V, 35 A	1.5
	12 Mogul sockets	6
Supports	Tubing and clamps	40
	Total	348 lbs.

Tests in Flight

9. Observations of the plane were made from the ground during three flights at the Naval Air Station, Anacostia, D.C., on October 1, 1936, between 10 A.M. and 3 P.M. In each flight the plane mounted to an altitude of about 5000 feet above the Air Station and flew at this altitude to a distance of about 6 miles in a direction roughly away from the sun alternately turning the lights off and on for 30 second intervals. The weather was clear with no haze and good visibility.

10. First flight, 10 A.M. Sky covered with thinnish white clouds, the day being moderately bright. At distances up to about 1 mile the individual lights could be seen with the unaided eye. Beyond about 1.5 miles the individ-

ual lights fused together and a portion of the fuselage, 1/4 to 1/2, appeared to be illuminated to a brightness a little less than, or perhaps equal to, the brightness of the cloud background. The wings and empennage areas, which were greater than that of the fuselage, remained dark. Photographs are shown in Plates 4 and 5 of the plane with and without lights at distances of 1.3, 1.6, 2.3 and 2.6 miles. They were taken in rapid succession as the plane moved away. They give a fairly truthful representation of the way the plane appeared to the eye. The enlargements on each plate offer no further information; they are merely to aid the reader in looking at the original pictures and to save him the trouble of using a magnifying glass. When the plane moved to distances beyond 3 miles, the illumination could not be seen, the plane appearing always as a dark speck against the clouds no matter whether the lights were on or off.

11. Second flight, 2:30 P.M. Sunny, blue sky with few clouds. Against the blue sky at distances up to 2 miles the unilluminated plane appeared somewhere near the same brightness as the blue sky, except that during circling at the initial part of the flight a bright sun reflection occurred at times. The lights appeared somewhat brighter than the sky. Photographs are shown in Plates 6 and 7 of the plane with and without lights at distances 0.7, 0.9, 1.3 and 1.6 miles. Pictures (a) of Plates 6 and 7 do not agree exactly with the impression of the observers; they indicate a fairly great contrast in brightness between the lights and the blue sky, whereas the observers' impression was that the lights undoubtedly appeared brighter than the sky, but not considerably brighter. The accentuated photographic contrast of the lights and the sky is due to the relative sensitivity of the panchromatic film used in the camera to blue and to yellow-white light. At distances beyond 3 miles, neither the lights nor any effect of their illumination could be seen, the plane appearing always as a speck slightly darker than the blue sky.

12. Third flight, 2:45 P.M. The third flight was an immediate repetition of the second flight with identical results.

13. The orientation of the plane during the flights was such that always more than half of the lights and of the illuminated area was actually exposed to the observers. The fact that at distances beyond 3 miles neither the lights nor any effect of their illumination were perceptible to the observers was due to the relative smallness, about 1/5 to 1/10, of the illuminated areas as compared to that of the unilluminated areas. The latter remained dark against the background and were the controlling factor in causing the plane as a whole to appear as a dark speck.

14. In each case upon landing after the first and third flights two lamps on the port side were broken. From the appearance of the shattered bulbs the damage was believed to have been caused by pebbles thrown back by the air stream from the propeller.

Discussion

15. The foregoing tests have brought out clearly that illuminating a small portion of a plane to a brightness comparable with that of the sky background had no perceptible effect on the visibility of the plane as a whole. The tests have neither proved nor disproved the original proposal that an illumination sufficient to brighten the entire plane to match the sky would reduce the visibility of the plane; from theory, i.e. common sense, the essen-

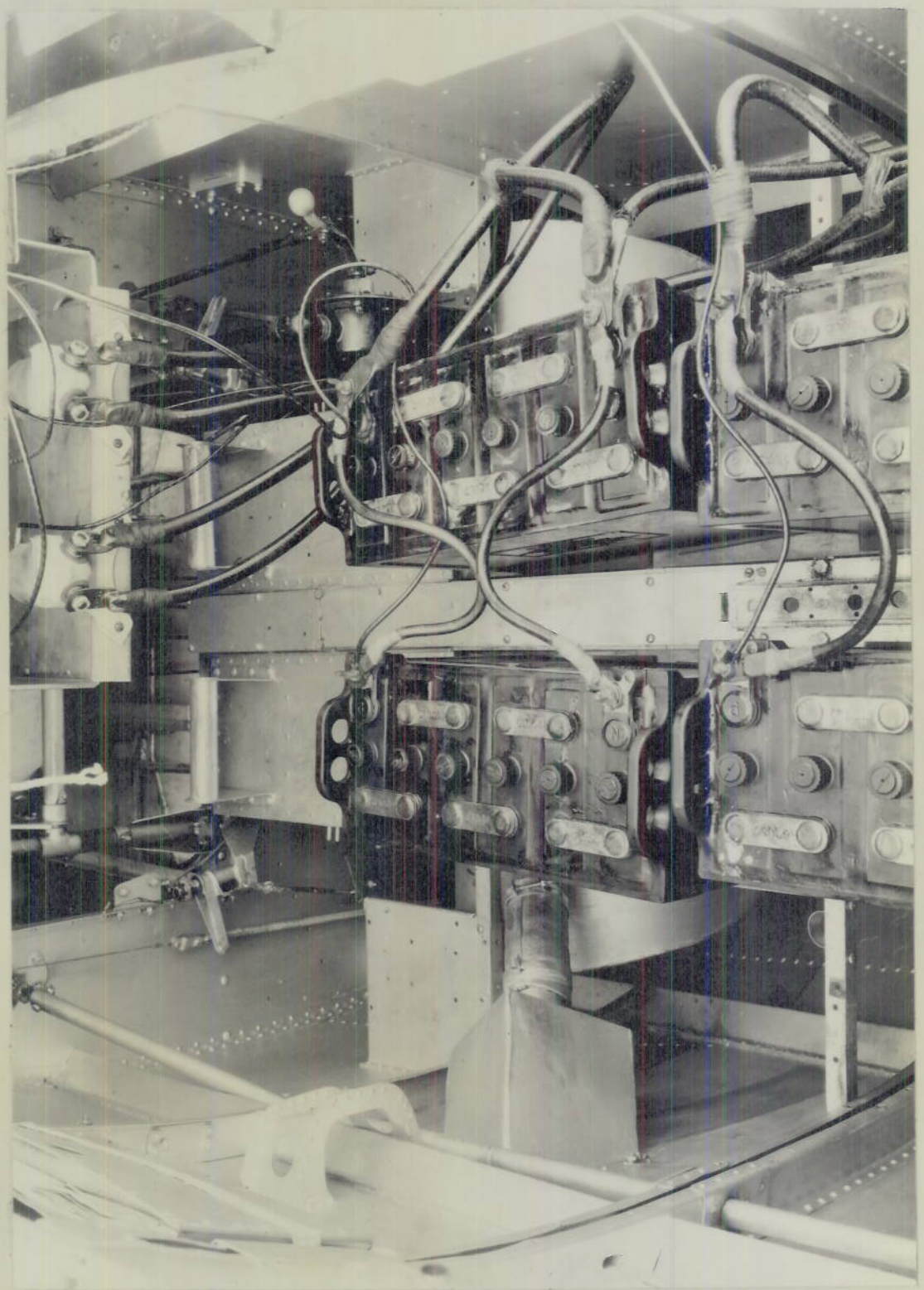
tial correctness of the proposal is not questioned. The tests have demonstrated that practical difficulties in installing and providing power for such a complete installation will be great. In the event that a more complete installation were envisaged, the tests offer no information on questions of its effectiveness and control against a background of such variable and changing brightness and color as the sky.

Illumination installation

Plate 1

Illumination installation

Plate 2



Power supply for the illumination.

Plate 3

(a) Lights on, distance 1.3 miles, against clouds.

(a) Enlarged 13 times

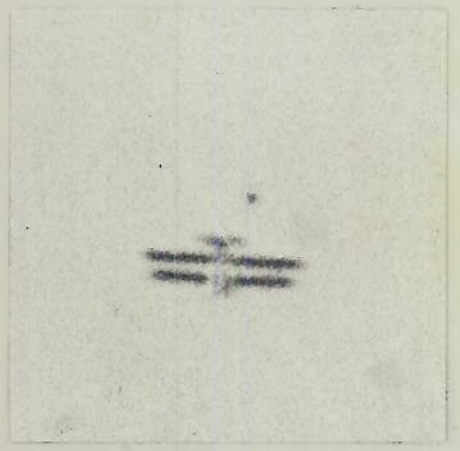
(b) Lights off, distance 1.6 miles, against clouds.

(b) Enlarged 13 times.

Plane against clouds.

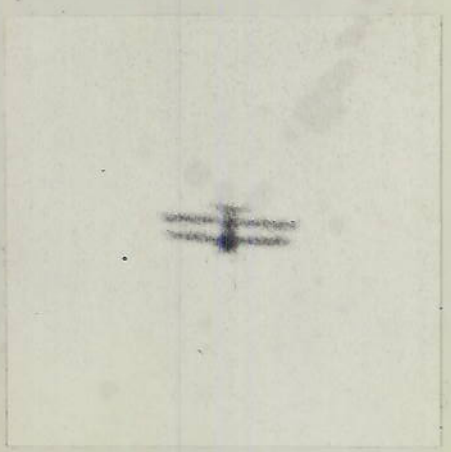
Plate 4

(a) Lights on, distance 2.3 miles against clouds



(a) Enlarged 13 times.

(b) Lights off, distance 2.6 miles, against clouds.

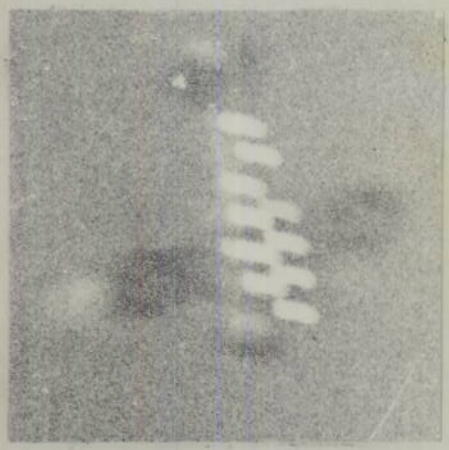


(b) Enlarged 13 times

Plane against clouds.

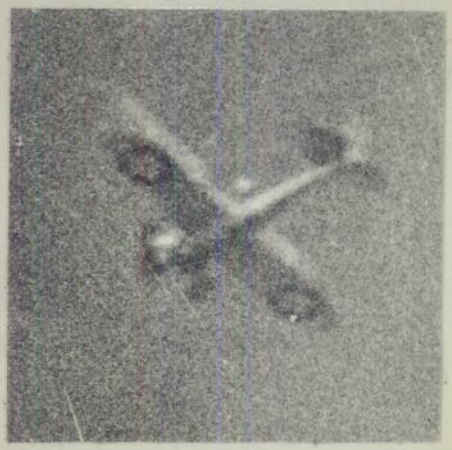
Plate 5

(a) Lights on, distance 0.7 miles, against blue sky.



(a) Enlarged 13 times.

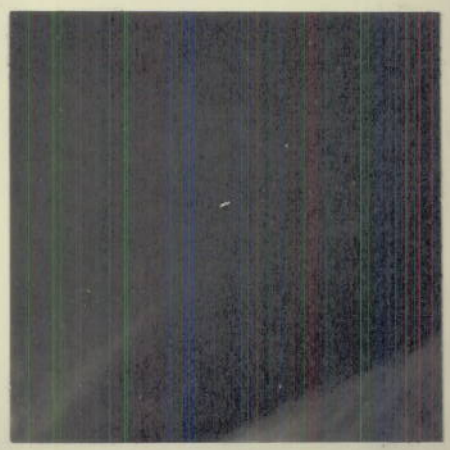
(b), Lights off, distance 0.9 miles, against blue sky.



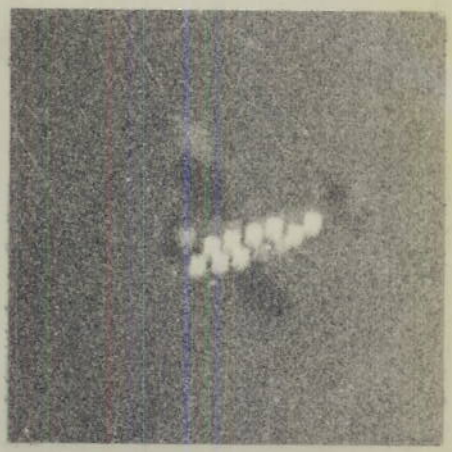
(b) Enlarged 13 times.

Plane against blue sky

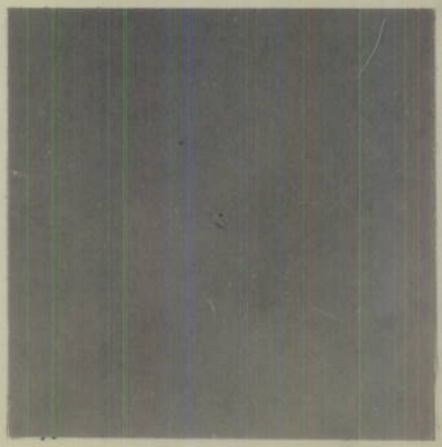
Plate 6



(a) Lights on, distance 1.3 miles, against blue sky blue sky.



(a) Enlarged 13 times.



(b) Lights off, distance 1.6 miles, against b lue sky.

(b) Enlarged 13 times.

Plane against blue sky.

Plate 7