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EVALUATION FIELD TESTS
OF
SEARCHLIGHTS AND REFLECTIVE MATERIALS
IN
SEARCH AND RESCUE OPERATIONS

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1. INTRODUCTION

The only two visual aids presently available to an aviator forced down at sea during the hours of darkness are a small, single-celled, flashlight, and a flare. The flare, of course, is expended after only one use, and the flashlight is visible for only a few hundred yards, even when its battery is fresh and the atmosphere is clear. Then too, both of these aids require that the man be alive and able to operate them. To be effective at all times a visual aid must function independently of any cooperation from the downed airman. There are a number of possible approaches to the solution of these problems, such as improved pyrotechnics or a better light for the pilot. Improvements such as these would be helpful, but would still fall far short of providing effective visual aid in the variety of situations in which search and rescue operations must be carried out. A more complete solution to the problem has been proposed, involving the use of a light-weight searchlight on the rescue helicopter together with effective reflectorization of the pilot's clothing, life raft, and life vest. This report describes an investigation into this proposal in which several searchlights and reflectorized targets were tested at a site where the search and rescue operations could be simulated under controlled conditions.

2. PRELIMINARY INVESTIGATIONS

Preliminary investigations were made from the Potomac River Bridge at Ludlow, Maryland. The searchlights were mounted on the roof of a truck which furnished power to operate the lights. The truck was then positioned on the bridge in such a way that the lights could be directed over the water from a point approximately 150 feet above the water surface. This site was found unsatisfactory because of excessive bridge traffic and because of difficulty in controlling the location of targets in the river. The test site was then transferred to the Chesapeake Bay Annex of the Naval Research Laboratory at Chesapeake Beach, Maryland. This location proved to be much more satisfactory, and was used for all subsequent tests.

Many different types and sizes of light sources are available for use in an airborne helicopter searchlight. For the purposes of this test, the choice was narrowed to three representative types: a 3000-watt incandescent lamp,

a 1250-watt carbon arc lamp, and a 1000-watt mercury capillary arc lamp. All three were mounted in AN/AVQ-2A searchlights from which the carbon arc mechanism had been removed. For comparison, an AN/AVQ-2A searchlight with its regular 8400-watt carbon arc lamp was included in the test.

It became apparent early in the investigations that treatment of the target surfaces with retroreflective materials resulted in a considerable increase in detectability. Retroreflectors have the property of returning a substantial portion of the light incident upon them in a narrow beam aimed toward the source of light. The reflected light is narrowly confined in this manner even when the orientation of the retroreflector itself varies within wide limits. Thus with an observer located close to a searchlight, as is the case in the searching helicopter, retroreflectors appear much brighter in the searchlight beam than do painted surfaces. Two commercially available types were chosen for this test. The first, "Stimsonite", is of the trihedron mosaic plaque type. Both red and white reflectors were tested. The second, "Scotchlite", is made of glass beads, imbedded in plastic sheets. Red, white, and yellow samples were tested. The gain in brightness of a target covered with "Scotchlite" compared with the same target covered with a good paint, is of the order of 500 times. The gain when the target is covered with "Stimsonite" is of the order of 5000 times. These comparisons presuppose that the areas covered are equal in size and that the colors are the same.

3. TEST SITE AND FACILITIES

The Chesapeake Bay Annex of the Naval Research Laboratory is located just south of Chesapeake Beach, Maryland. Fig. 1 is a general view of the area. The equipment was located on the edge of a 100-foot high cliff, overlooking the Bay. The target area was a radial sector 40° wide and 2500 yards in radius, extending outward from the shore with the searchlights at its apex. The searchlights were mounted in cradles on top of the power truck which contains generating and auxiliary equipment for operating the searchlights. The lights were placed on the edge of the truck so that their beams could be directed out over the cliff. The hand control units were mounted on a board which was clamped to a stand about 25 feet to the rear of the truck. A plotting chart consisting of a map of the area and a sighting device was used to ascertain angles of azimuth. An optical range

finder was used to measure the distance to the targets in the test area. Placement and anchoring of the targets in the area were carried out from a Navy launch with which radio communication was maintained from the observation site. The arrangement of the test equipment is shown in Figs. 2 and 3.

4. SEARCHLIGHTS

The incandescent lamp, shown mounted in a searchlight in Fig. 4, is a 28-volt, 3-kw searchlight lamp with a mogul bipost base, a C-6 filament and a T-24 bulb. It has a rated life of 10 hours. The filament coil is about 1-1/2 inches long and 1/4 inch in diameter. The lamp is 11-1/2 inches long. It was mounted with the axis of its filament coil horizontal, and perpendicular to the axis of the reflector. The lamp produces a beam 11.3° by 3.6° with a peak intensity of about 6,000,000 candles.

The L-9 arc mechanism, shown in Fig. 5, is a standard motion picture projection lamp adapted for use in an early experimental airborne searchlight. It is rated at 45 amperes at 26.5 volts and operates continuously for 20 minutes on one trim of carbons. The lamp mechanism is 24-1/2 inches long. The beam produced has a peak intensity of 45,000,000 candles, and a beam width of 3°

The BH-6 air-cooled mercury arc lamp, shown mounted in a searchlight in Fig. 6, is approximately 3-1/4 inches in length and is constructed of quartz tubing with tungsten electrodes sealed into each end, extending through mercury pools into the lamp. The light source is approximately 1.5 by 25.0 millimeters and has an output of 60,000 lumens. The lamp requires 17 amperes at 115 volts, 60 cycles. The air-cooling system for this lamp requires a volume equivalent to about 7 cubic feet of free air per minute at room temperature. This flow must be maintained at a pressure of 20 p.s.i. at the nozzles of the mount. A 3/4 horsepower compressor is required to supply the necessary air. With the lamp mounted perpendicular to the axis of the reflector (Fig. 6) the searchlight beam has a width of 8.1° and a vertical spread of 2.3°. The peak intensity is about 22,000,000 candles.

The AN/AVQ-2A searchlight is the standard airborne searchlight now in use by the Navy for anti-submarine warfare. The source is a high intensity carbon arc. The power

requirements are 120 amperes at 70 volts, dc, and 8.5 amperes at 28 volts, dc. With the 19-inch reflector this searchlight produces a 3.75° beam with a peak intensity of about 85,000,000 candles. The mirror is back-silvered glass, having a focal length of 6 inches. A remote hand control mounted in the cockpit of the aircraft directs the light beam in azimuth 26.5° right or left and in elevation from 5° up to 45° down. Table I summarizes the characteristics of all four searchlights. Fig. 7 gives the candle-power distributions of the searchlights.

5. TARGETS

The "Scotchlite" retroreflective sheeting used to cover the targets in the test is a "wide-angle, flat-top" design manufactured by the Minnesota Mining and Manufacturing Company. It consists of a plastic sheet in which minute glass beads are imbedded. The beads in turn are covered over with a plastic film so that the upper surface is smooth. This material can be wet by rain or spray without appreciable impairment of the retroreflective properties. It will act as a retroreflector when illuminated by a beam of light incident on the surface at an angle as great as 80 to 85 degrees, although with a very much reduced efficiency. The sheeting used in this test was about .005 inch thick and can be applied readily to irregular surfaces.

The "Stimsonite" tetrahedron mosaic plaques used in the test were manufactured by the American Gas Accumulator Company. Two sizes of plaques were used. One was 1-13/16 inches in diameter and about 5/16 inch in diameter (1.6 square inches). The other was 1-5/16 inches in diameter and about 1/16 inch thick, with an effective surface about 1-3/16 inches in diameter (1.1 square inches). The plaques are made of a transparent plastic with the tetrahedron mosaic molded into the rear surface. The rear mosaic surfaces were protected by a plastic backing in the large plaques and by a thin metal sheet in the smaller plaques.

The mosaic plaques have a narrower angle of divergence (angular width of reflected beam) than the glass bead sheeting and a correspondingly higher efficiency. Since the divergence angle required in the search and rescue operation is very small, well within the effective range of "Stimsonite", a given area of "Stimsonite" will appear much brighter than the same area of "Scotchlite", except at high angles of in-

cidence on the surface, when the wide-angle feature of "Scotchlite" yields higher brightnesses. Since the target surfaces are very irregular, it is difficult to predict overall performance accurately. The estimates given earlier in this report (500 times the brightness of good paint for "Scotchlite" and 5000 times for "Stimsonite") were based on a consideration of the known properties of these retroreflectors together with a very approximate estimate of the weighting of the angles of incidence on the various parts of the targets.

The targets used were as follows:

a. Four two-man life rafts: one each was covered with red, yellow, and white "Scotchlite" and one was left plain. A "Scotchlite" covered raft is shown in Fig. 8.

b. Four "Mae West" life vests: one was left plain and the others were covered with red, yellow, or white "Scotchlite" as shown in Fig. 9.

c. Seventeen helmets: These were mounted on metal plates which were strapped to innertubes. The method of mounting is shown in Fig. 10. Thirteen of the helmets were covered with red or white "Scotchlite". "Stimsonite" buttons were affixed to the remaining four. Fig. 13 shows the manner in which the retroreflective materials were placed on helmets and their bright appearance when illuminated by a light source placed close to the line of sight.

The targets were anchored in a 40° radial sector at ranges from 750 to 2500 yards. The arrangement of the various targets and reflective materials was changed from time to time to determine the visibility of the reflectors under different conditions and at different ranges. A typical target layout is shown in Fig. 11.

To demonstrate the proposed use of searchlights and retroreflectorized targets, an incandescent searchlight was mounted and flown on an H04S helicopter. This searchlight was similar to the incandescent unit previously described. The light was mounted on a Mark 50 bomb rack on the port side of the helicopter, just forward of the rear landing gear strut.

In order to provide general illumination as the helicopter approaches the scene of the rescue three 450-watt floodlights were mounted on the helicopter aimed forward and downward to illuminate the surface of the water just ahead of the aircraft. A fourth floodlight was mounted on the starboard rear wheel strut, illuminating the surface below the aircraft to facilitate the rescue. Once the target has been located, these four lights enable the pilot to fly contact on the target while the rescue is being performed. Fig. 12 shows the helicopter installation of the searchlight and floodlights.

6. RESULTS

There was considerable variation in the ranges at which the targets were detectable, depending on the amount of haze present in the atmosphere. On clear nights all of the retroreflectorized targets were visible with any of the lights at ranges up to 2500 yards. On hazy nights, however, there were marked differences in detectability of different targets with various lights. Except on moderately hazy nights all of the retroreflectorized targets were visible using the L-9 searchlight. On these same nights the incandescent searchlight provided adequate illumination to approximately 1250 yards, beyond which the targets were too dim for positive recognition.

The H6 mercury capillary lamp illuminated the white and yellow targets better than did the incandescent light, but because of the spectral distribution of the light emitted by the mercury source the red targets did not appear as bright as with the incandescent source which has only one-third the intensity.

The AVQ-2A searchlight, while providing the highest peak candlepower, sometimes failed to illuminate the targets as well as did a light of less candlepower because of the large amounts of back-scattered illumination.

Upon completion of the test work a demonstration sponsored by the Bureau of Aeronautics, was conducted for interested military personnel and civilians. The demonstration set-up can be seen in Figs. 1,2, and 3.

The chart on the side of the small building in the photographs shows a proposed flight pattern for search. The demonstration included an examination of the incandescent searchlight and floodlight installation on the HO4S helicopter, a static demonstration of the four searchlights mounted on the truck and a simulated helicopter rescue, showing a proposed technique for search, hovering and the actual pickup.

7. DISCUSSION

The arrangement used in this test to simulate a helicopter searching for a downed aviator in open sea differs from the actual situation in several important respects. While fixing the location of the searchlights and the targets in a carefully measured test area provides accurate information in many respects, it eliminates the uncertainty as to the location of the targets. This difference might well affect the decision as to preferred equipment, particularly as to the searchlight selected. In this test, the L-9 carbon arc searchlight with a narrow beam performed very well. In an actual search operation the narrow beam might increase the chance of overlooking a target that is in range of the light. For this reason, and because it is the simplest and lightest of the lights tried, will operate for long periods without attention, and will operate from a 28-volt dc power system, the incandescent searchlight is considered preferable for helicopter installation.

Treating targets with retroreflective material is highly advantageous. The white retroreflectors were more efficient than red or yellow. In the test situation, the water surface was relatively calm. In actual rescue operations, whitecaps might be present and might easily be confused with a white target as the searchlight sweeps the area looking for survivors. To avoid this possible confusion, the use of red retroreflective materials is recommended.

Both types of retroreflectors were found very useful. "Stimsonite" is much more efficient than "Scotchlite" for the same area, but the ease of application of "Scotchlite" may be decisively advantageous. It may also be that larger areas could be covered practically with "Scotchlite" than with "Stimsonite" and this might reduce the advantage in efficiency of the "Stimsonite".

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TABLE I

SEARCHLIGHT UNIT	POWER REQUIREMENTS	PEAK CANDLEPOWER	BEAM WIDTH	TOTAL WEIGHT***
AN/AVQ-2A	120 Amps at 70 Volts, dc 13.45 Amps at 28 Volts, dc 1.3 Amps at 115 Volts, 400 Cycles	85,000,000	3.75°	145 lb.
AN/AVQ-2A with 3-KW incandescent lamp	100 Amps at 28 Volts, dc 1.3 Amps at 115 Volts, 400 Cycles	6,000,000	11.3°H X 3.6°V	120 lb.
AN/AVQ-2A with B-H6 mercury capillary lamp	1000 Watts at 115 Volts, 400 Cycles* 6.2 Amps at 28 Volts, dc 1-KW**	22,000,000	8.1°H X 2.3°V	240 lb.
AN/AVQ-2A with L-9 carbon arc mechanism	50 Amps at 28 Volts, dc 1.3 Amps at 115 Volts, 400 Cycles	45,000,000	3°	150 lb.

* A 60-cycle power supply was used for this test.

** Approximately this amount of power is required for an air compressor to provide the necessary cooling for this lamp.

*** Estimated for helicopter installation including control unit, amplifier, and necessary lamp auxiliaries, exclusive of power generating equipment.