NATIONAL BUREAU OF STANDARDS REPORT

9437

THE CHARACTERISTICS OF A LIGHTING AND VISUAL SIGNALING SYSTEM FOR ANTI-SUBMARINE WARFARE HELICOPTERS

By

William F. Mullis

and

Edward L. Walters

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards is a principal focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. Its responsibilities include development and maintenance of the national standards of measurement, and the provisions of means for making measurements consistent with those standards; determination of physical constants and properties of materials; development of methods for testing materials, mechanisms, and structures, and making such tests as may be necessary, particularly for government agencies; cooperation in the establishment of standard practices for incorporation in codes and specifications; advisory service to government agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; assistance to industry, business, and consumers in the development and acceptance of commercial standards and simplified trade practice recommendations; administration of programs in cooperation with United States business groups and standards organizations for the development of international standards of practice; and maintenance of a clearinghouse for the collection and dissemination of scientific, technical, and engineering information. The scope of the Bureau's activities is suggested in the following listing of its three Institutes and their organizational units.

Institute for Basic Standards. Applied Mathematics. Electricity. Metrology. Mechanics. Heat. Atomic Physics. Physical Chemistry. Laboratory Astrophysics.* Radiation Physics. Radio Standards Laboratory:* Radio Standards Physics; Radio Standards Engineering. Office of Standard Reference Data.

Institute for Materials Research. Analytical Chemistry. Polymers. Metallurgy. Inorganic Materials. Reactor Radiations. Cryogenics.* Materials Evaluation Laboratory. Office of Standard Reference Materials.

Institute for Applied Technology. Building Research. Information Technology. Performance Test Development. Electronic Instrumentation. Textile and Apparel Technology Center. Technical Analysis. Office of Weights and Measures. Office of Engineering Standards. Office of Invention and Innovation. Office of Technical Resources. Clearinghouse for Federal Scientific and Technical Information.**

---

*Located at Boulder, Colorado, 80301.
**Located at 5285 Port Royal Road, Springfield, Virginia, 22171.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
2120410	October 18, 1966	9437

THE CHARACTERISTICS OF A LIGHTING AND VISUAL SIGNALING SYSTEM

FOR

ANTI-SUBMARINE WARFARE HELICOPTERS

By

William F. Mullis

and

Edward L. Walters

Aircraft Illuminating Engineering Group
Photometry Section
Metrology Division

Prepared

for

Lighting Section AIR 53353
Naval Air Systems Command
Department of the Navy
Washington, D. C.

NBS

U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

THE CHARACTERISTICS OF A LIGHTING AND VISUAL SIGNALING SYSTEM FOR ANTI-SUBMARINE WARFARE HELICOPTERS

By

William F. Mullis

and

Edward L. Walters

ABSTRACT

The characteristics of a lighting and visual signaling system for use on anti-submarine warfare helicopters is presented together with flight evaluation results of prototype equipment. The system employs the use of main rotor-blade tip lights, and a tri-colored, target-bearing light. The lights effectively (1) reduce the amount of voice communication required between participating aircraft, (2) differentiate between rotary-wing and fixed-wing aircraft, and (3) maintain visual security from enemy-surface, and sub-surface vessels until target contact has been established. The system installation is described and suggested improvements over the prototype equipment are evaluated. The equipment was designed and constructed by the Aircraft Illuminating Engineering Group of the National Bureau of Standards, and the flight tests were conducted under Project No. 023-AE53-36 at the Naval Air Test Center, Patuxent River, Maryland.

the helicopters. When "contact" with a potential target is made the tip lights would be immediately switched to the flashing mode and simultaneously the target-bearing light would be switched on. This action would not only indicate the "hot" helicopter, but also would give the bearing of the target to the higher flying, fixed-wing aircraft. Upon seeing this signal, the fixed-wing aircraft would commence to orbit the hot "helo" until the white beam (which automatically has assumed its position 180° away from the target) was intercepted. The aircraft would then bank toward, and fly down the white beam and over the helicopter to obtain the target bearing.

3. DESIGN OF PROTOTYPE EQUIPMENT

The following described equipment was designed, constructed, and flight tested to determine the practicality of the system concept. The system was installed on an SH-3A model helicopter, and was powered from the aircraft's electrical system. The blade lights were powered from the 115-volt, 400Hz system while the bearing light was powered from the 28-volt dc bus. Power was transmitted to the blade lights through the de-ice slip rings and special wiring was installed along the top surface of each blade. Provisions were made for presenting more signals than the system concept demanded in order to determine if additional signals would be helpful in executing the ASW mission. That is, the system was made redundant in that the blade-tip lights could provide either red or white signals. The electrical and lighting characteristics of the equipment were as described below.

3.1 Blade-Tip Lights

Each blade-tip light consisted of two Type 600, 6.2-volt,26-watt, reflector-type incandescent lamps positioned to illuminate a diffusing plexiglass window installed in the upper surface of the blade. Provision was made for operating the lamps separately, and a red lens was placed over one of them in order to obtain either the red, or the white luminous ring. Provision was also made for dimming and flashing each lamp, for changing the flash frequency and on-to-off ratio, as well as for steady-burning operation. The intensity distributions of the blade lights were as shown in Figure 1. Figure 2 is a photograph of one of the tips with the lamps installed and with the plexiglass cover removed.

1. INTRODUCTION

Present anti-submarine warfare (ASW) missions are conducted from carriers by fixed-wing aircraft, and sonar-dipping helicopters operating in the same general areas. The lighting system of these aircraft are similar, and it is difficult to distinguish one type of aircraft from the other in hours of darkness. Aside from causing confusion, this difficulty creates a hazardous situation. Further, the lights are visible from surface vessels, and during the initial deployment of the aircraft they may furnish clues concerning the direction of the ship from which the aircraft are operating. Present operational procedures also require considerable voice communication in identifying the "hot" helicopter (the aircraft making the initial contact with an enemy submarine), and in directing other aircraft to the target area. The Air Systems Command requested that the National Bureau of Standards seek a method for correcting, or alleviating, as much as practical, these undesirable conditions.

It was decided that the most practical approach would be the development of a lighting and visual signaling system for night-operating helicopters which would effectively (1) reduce the amount of voice communication required between participating aircraft, (2) differentiate between rotary-wing and fixed-wing aircraft, and (3) maintain visual security from enemy-surface and sub-surface vessels until "contact" is made with the unfriendly target.

2. SYSTEM CONCEPT

The system concept was to provide blade-tip lights on helicopters for identification and for signaling, and a tri-colored bearing light for indicating the direction of an enemy target. As conceived, the tip lights would be visible from the upper hemisphere only, and provisions would be made for selective flashing, or steady-burning operation. The bearing light would be designed to present a tri-colored signal, consisting of a red, a green, and a white beam, filling adjacent sectors. The azimuthal direction of the signals would be positioned automatically by the sonar-detection equipment.

In use, the light system would be employed as follows: During initial deployment of the aircraft, and during the hunting (sonar-dipping) phase of the mission, the helicopters would operate with only the blade-tip lights burning. These lights would be operated in the steady-burning mode, and the ring of light thus created by the rotating blades would unmistakably distinguish all the "helos" from the fixed-wing aircraft. At the same time, visual security would be maintained from surface vessels since the lights would be visible only from above

the helicopters. When "contact" with a potential target is made the tip lights would be immediately switched to the flashing mode and simultaneously the target-bearing light would be switched on. This action would not only indicate the "hot" helicopter, but also would give the bearing of the target to the higher flying, fixed-wing aircraft. Upon seeing this signal, the fixed-wing aircraft would commence to orbit the hot "helo" until the white beam (which automatically has assumed its position 180° away from the target) was intercepted. The aircraft would then bank toward, and fly down the white beam and over the helicopter to obtain the target bearing.

3. DESIGN OF PROTOTYPE EQUIPMENT

The following described equipment was designed, constructed, and flight tested to determine the practicality of the system concept. The system was installed on an SH-3A model helicopter, and was powered from the aircraft's electrical system. The blade lights were powered from the 115-volt, 400Hz system while the bearing light was powered from the 28-volt dc bus. Power was transmitted to the blade lights through the de-ice slip rings and special wiring was installed along the top surface of each blade. Provisions were made for presenting more signals than the system concept demanded in order to determine if additional signals would be helpful in executing the ASW mission. That is, the system was made redundant in that the blade-tip lights could provide either red or white signals. The electrical and lighting characteristics of the equipment were as described below.

3.1 Blade-Tip Lights

Each blade-tip light consisted of two Type 600, 6.2-volt,26-watt, reflector-type incandescent lamps positioned to illuminate a diffusing plexiglass window installed in the upper surface of the blade. Provision was made for operating the lamps separately, and a red lens was placed over one of them in order to obtain either the red, or the white luminous ring. Provision was also made for dimming and flashing each lamp, for changing the flash frequency and on-to-off ratio, as well as for steady-burning operation. The intensity distributions of the blade lights were as shown in Figure 1. Figure 2 is a photograph of one of the tips with the lamps installed and with the plexiglass cover removed.

3.2 Target-Bearing Light

The target-bearing light consisted of a 28-volt, 80-watt, single-ended, quartz-iodine lamp encircled by a red- and a green-colored filter except for a 12° angle. The circle, other than the 12° sector, was equally divided between the red and the green. The beacon presented, therefore, a tri-colored signal consisting of a 174° sector of red light, and an equal sector of green light, plus the 12° sector of white light. A pictorial diagram of the light assembly and its flux distribution is shown in Figures 3 and 4. The colored-lens system was mounted on a horizontally rotating mechanism whose azimuthal position was remotely controlled by a dc-reversing motor. For the flight test, its direction or azimuth was set manually. In actual service, its bearing would be positioned automatically by the sonar-detection equipment. A compass with a synchro following system was provided to indicate the setting of the light to the operator. The light was housed in a slightly altered type 8400 anti-collision light housing and was installed on the tail pylon of the helicopter. In this position, the light could be seen 360 degrees around the helicopter except for a small angle forward of the aircraft which was blocked by the main rotor hub.

3.3 Electrical Wiring

The circuit for controlling the blade-tip lights is shown in Figure 5. Flashing and varying the on-to-off ratio, as well as for changing the flash frequency of the lamps, was controlled by a variable speed motor, cam and relay arrangement. Dimming of the lamps was accomplished by a variable output (0-10 volts) transformer, Type 5-1338, manufactured by the Superior Electric Company, Bristol, Connecticut. The color of the signal was determined by whether the lamps with, or those without the red filters were switched on. Power to the lamps was transmitted through the de-ice slip rings, Nos. 1, 2, and 3, as shown in Figure 6. The blade wiring consisted of installing a flat cable bonded along the upper exterior surface of each blade. The cable was designated as P/N SS-1022-105B, and manufactured by the Spectra-Strip Wire and Cable Corp., Garden Grove, California. Two #22 stranded wires were used in parallel to each lamp in order to obtain adequate current capacity and to decrease the IR drop in the leads. The resistance of the wiring was such that with the transformer adjusted for a maximum output (10 volts), the voltage across the lamp load was approximately 6.0 volts. The cable was bonded to the blade surface with a structural epoxy adhesive and designated as EC-2216A and EC-2216B, and manufactured by the Minnesota Mining & Manufacturing Company. The cable was secured at both the

tip cap and the root-end of the blade by conventional cable clamps. Figure 7 is a schematic diagram for the blade lights, and Figures 8 and 9 show the blade wiring during the process of installation. No special wiring was required for the bearing light. Its lamp and drive motor were powered from the 28-volt dc system, while the synchro direction indicating arrangement was powered from the 115-volt, 400-Hz system. The circuit of the bearing light is given in Figure 10.

4. SYSTEM EVALUATION AND RESULTS

The lighting and signaling system was evaluated during a series of flight tests by pilots of the Service Test Division of the Naval Air Test Center, Patuxent River, Md. Results of the flight test program will be fully covered in a report from that activity. The system is considered to be desirable, feasible and practical, but certain improvements are required with respect to the lighting distribution requirements and with respect to final engineering of individual components. The test installation was intended primarily as a means of determining the practicality of the system. No attempt was made to optimize the design of individual components and, unfortunately, the flight tests were terminated before the light fixtures could be modified to give the desired intensity distribution patterns. The test helicopter was transferred to the Naval Air Station, Jacksonville, Florida, for a complete overhaul, and the equipment was removed before this work could be completed. The tests progressed far enough, however, to show that the system concept is sound and that no particular problems exist that cannot be remedied. The results of the tests and the needed changes indicated by the test for improving the system are described below.

a. Blade Lights.

The blade lights as constructed were not satisfactory in that the bulk of the luminous flux from the fixtures was directed upward instead of near, or slightly above, the horizontal as required. It was found that with the present operational procedure, the fixed-wing aircraft is in the range of 1-4 degrees above the hovering helicopter when the lateral separation is on the order of 1-2 miles. At greater lateral distances, the elevation angle is even less. This them, (1-4 degrees above the horizontal) is the region where the maximum intensity is required. Each tip light of the units evaluated produced only about 1-5 candelas over this region under static conditions. When the blades were rotating, the apparent intensity of the luminous ring over this region becomes even less. On the other hand, the intensity near the zenith of a fixture under static conditions was on the order of 45 candelas. It is apparent, therefore, that the intensity distribution of these lights should be inverted, even though useful ranges

(1-3 miles) were obtained with the present design. With the greater intensity near the horizontal, threshold viewing ranges would be increased considerably and the illumination available at practical working distances would be substantially increased. The desired distribution could easily be obtained with a fixture such as that sketched in Figure 11. This design requires only a slight modification to the fixtures tested; i.e., the addition of a V-type reflector to the plexiglass window to redirect a portion of the light in the desired direction. Indeed, fixtures of this type were installed on the test helicopter, but time was not available for evaluation before the aircraft was transferred. The fixtures were flown from the Naval Air Test Center, Patuxent River, Md., to Jacksonville, Fla., however, and apparently presented no particular aerodynamic problems. It appears that such a fixture, or the equivalent, having an intensity distribution as presented in Figure 12, would prove satisfactory, particularly when the helicopter is hovering. The question arises, however, whether any tip-lighting fixture can satisfy the lighting requirements under all flight conditions and still maintain visual security from surface vessels. A sharp "cutoff" of the underside of the beam appropriate for hovering would not necessarily be the same for other flight modes. For example, in forward flight, the leading portion of the rotor is tilted downward. Under this condition, portions of the light ring would also be directed downward and would be visible at lower angles than during hovering. This would also be true during banking and turning. Under such conditions, visual security from surface vessels would be sacrificed. Visual security could be maintained most of the time, however, and would certainly be an improvement over the present lighting system.

No particular advantage, or requirement, could be seen for use of other than the white lights. Indeed, the lower intensity of the colored lights makes them less desirable. To make the red lights of an intensity equal to that of the white lights of a given wattage rating would require larger-sized wire and controls, and more power. Further, no advantage could be found for having both red and white lights. Flashing of the lights was found satisfactory, as was the dimming arrangement. The tests indicated that a flash rate of 60-80 per minute with a 1:1 on-to-off ratio was satisfactory. Dimming control was found to be necessary, particularly if the lights are to be used for both the ASW and the formation-flying missions.

Mechanically, the blade lights appeared satisfactory in that no problems were experienced during the series of tests. There was a filament failure in one of the 10 lamps. However, a post examination showed no unusual distortion, or damage to the filaments of the other lamps. It is thought that the one failure should be attributed to a manufacturing defect rather than to its use in the blade-tip light.

b. Bearing Light.

The test pilots reported that the color separation, and the intensity of the bearing light appeared satisfactory. Also, the ability to fly on a given bearing was reported as being within 5 degrees of the exact direction even though no particular care was taken in "bore-sighting," or aligning the light with respect to the aircraft's compass. Concern was expressed, however, about the need to modify the signals presented. As explained earlier, the procedure for obtaining the target bearing was for the higher-flying aircraft to orbit the "hot" helicopter until it intercepted the white beam of the beacon, then to fly down the beam over the helicopter and proceed to the target area. This procedure was reported to have worked well except for the maneuver of banking, or turning down the beam. As reported, with relatively close-orbiting separations, a critical maneuver was required to prevent overshooting the narrow 12° white beam. As the orbiting range increased, the turning maneuver was less severe and the system worked satisfactorily. It appears, however, that rather than change the normal operating range between aircraft, some method is needed to pre-warn the pilot that he is approaching the white beam. The width of the beam should not be increased, or bearing accuracy would be sacrificed. Several methods of accomplishing the pre-warning have been suggested. One possible method is to incorporate additional small colored filters adjacent to the white beam so that the pilots could see a color change prior to interception of the white beam. This might be possible if sufficiently distinctive colors could be found to give adequate color separation. It is believed, however, that the use of additional colors might result in color-merging and probably would aggravate rather than help in this situation.

A more promising method may be to retain the three basic colors as used in the test light, but with angular sectors designed as shown in Figure 13. In this arrangement, the red color would cover the entire circle except that of the narrow white beam, and a green sector adjacent to, and clockwise of, the white beam. With this arrangement, all fixed-wing aircraft would orbit counterclockwise and hence, the green sector would be seen immediately before entering the white beam. Orbiting aircraft would then start their turn upon seeing the green signal, and would complete the turn upon entering the white beam. This procedure would not only give forewarning, but would also be safer in that all aircraft would be circling in the same direction. With the bearing light designed as tested, the initial concept was that the planes would orbit the helicopter in the direction closest to the white beam; i.e., the proper orbit was clockwise if the light was red when detected, and the orbit was counterclockwise if the light was green when detected.

Another point was raised concerning the location of the beacon. As installed on the tail pylon, a small sector forward of the aircraft was blocked from view by the main-rotor hub. This is undesirable even though the tip lights are visible in this region and will give notice when a contact is made. Even so, it is possible at times for the target bearing to be obscured because of the blocked-white beam. This would probably be an infrequent occurrence. However, to circumvent this possibility two choices come to mind. The first is to mount the light on top of the main rotor-hub assembly. In this position no substantial blockage can occur. A small angle would still be shielded by the tail-pylon assembly, but this angle would be of little significance. The other choice would be to use two synchronized lights. Both lights would be designed to present the same signal, and one would be mounted on the tail pylon, while the other would be mounted on the bottom of the aircraft fuselage. With this arrangement, all required angles would be covered. The preferred choice would be the single light mounted on the main rotor hub, if it is practical to do so. Failing this, the question to be resolved is whether the risk of missing the target bearing from a single unit mounted on the tail is sufficient to justify installation of a second light and its complex synchronizing circuits.

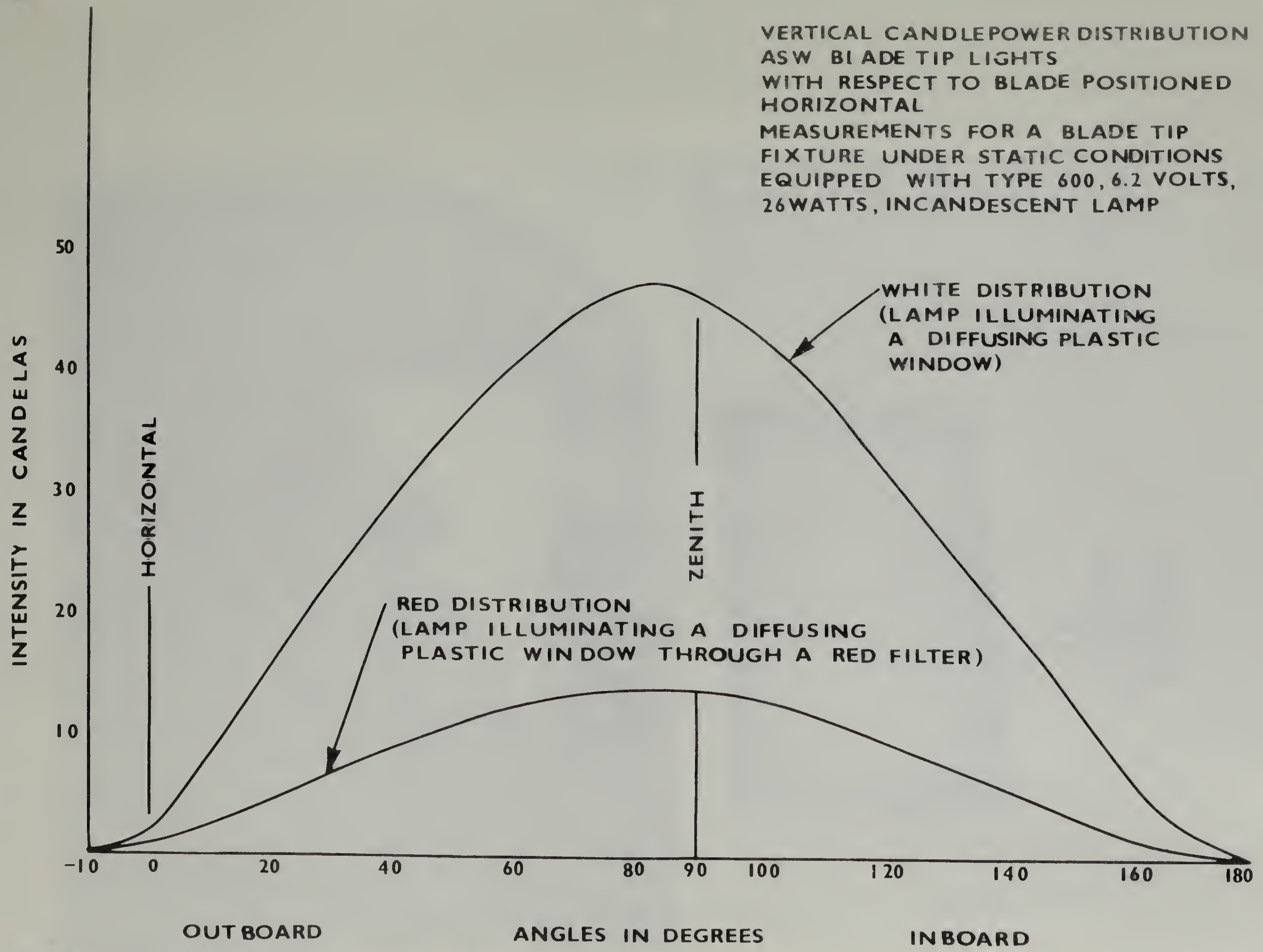
c. Blade Wiring.

The performance of the blade wiring was considered excellent during the series of flight tests. No trouble was encountered, nor were there any signs of material deterioration at the end of the tests. The blade wiring was subjected to more than 180 hours of flight, although the visual evaluation portion of the tests consumed only some 15-20 hours. The blade wiring had been installed about a year before the lighting tests began, and had been subjected to earlier flights in which a new type of aircraft engine was being investigated. The duration of the installation, as well as the severity of the flights, suggest that the use of readily available commercial materials for bonding the wiring to the exterior blade surface is practical. Further, the installation procedure is well adaptable to a retrofit program on a local level.

5. OTHER CONSIDERATIONS

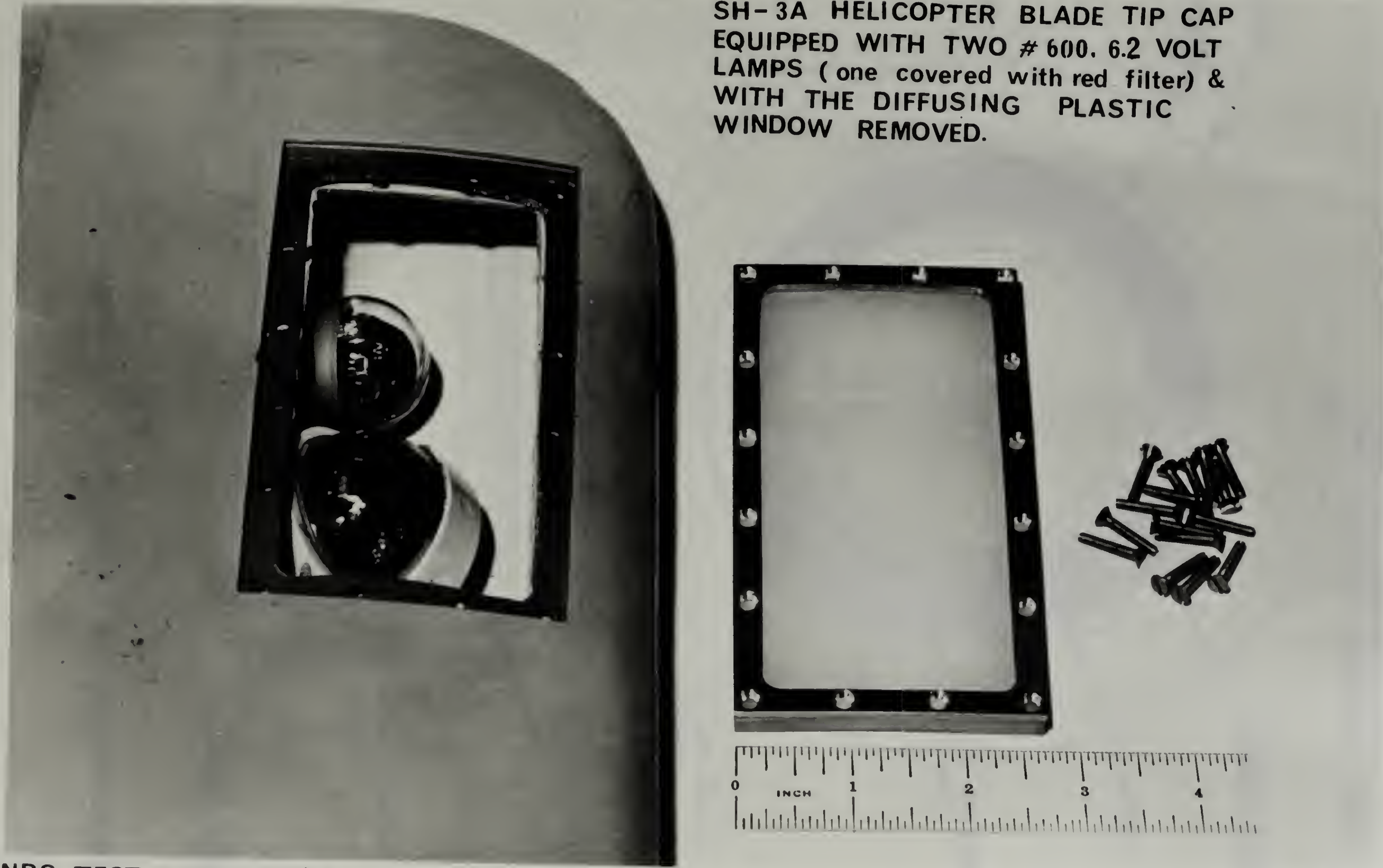
Although the lighting system described herein was developed primarily for use on ASW helicopters, the bearing light might be used equally well aboard ships taking part in ASW missions. A light of this type aboard a destroyer could serve the same purpose of indicating the direction of an enemy target to the fixed-wing aircraft without the need for radio communications. When used in conjunction with other lights to indicate the "hot" ship, its use would be identical to that in the air.

Based upon these tests, the system appears both practical and feasible. No problems are evident that cannot be readily solved. It is our judgment that the system merits further investigation, and it is recommended that properly designed equipment be developed by industry in sufficient quantity for fleet evaluations.



NBS TEST 212.11N-12/66

FIG. 1

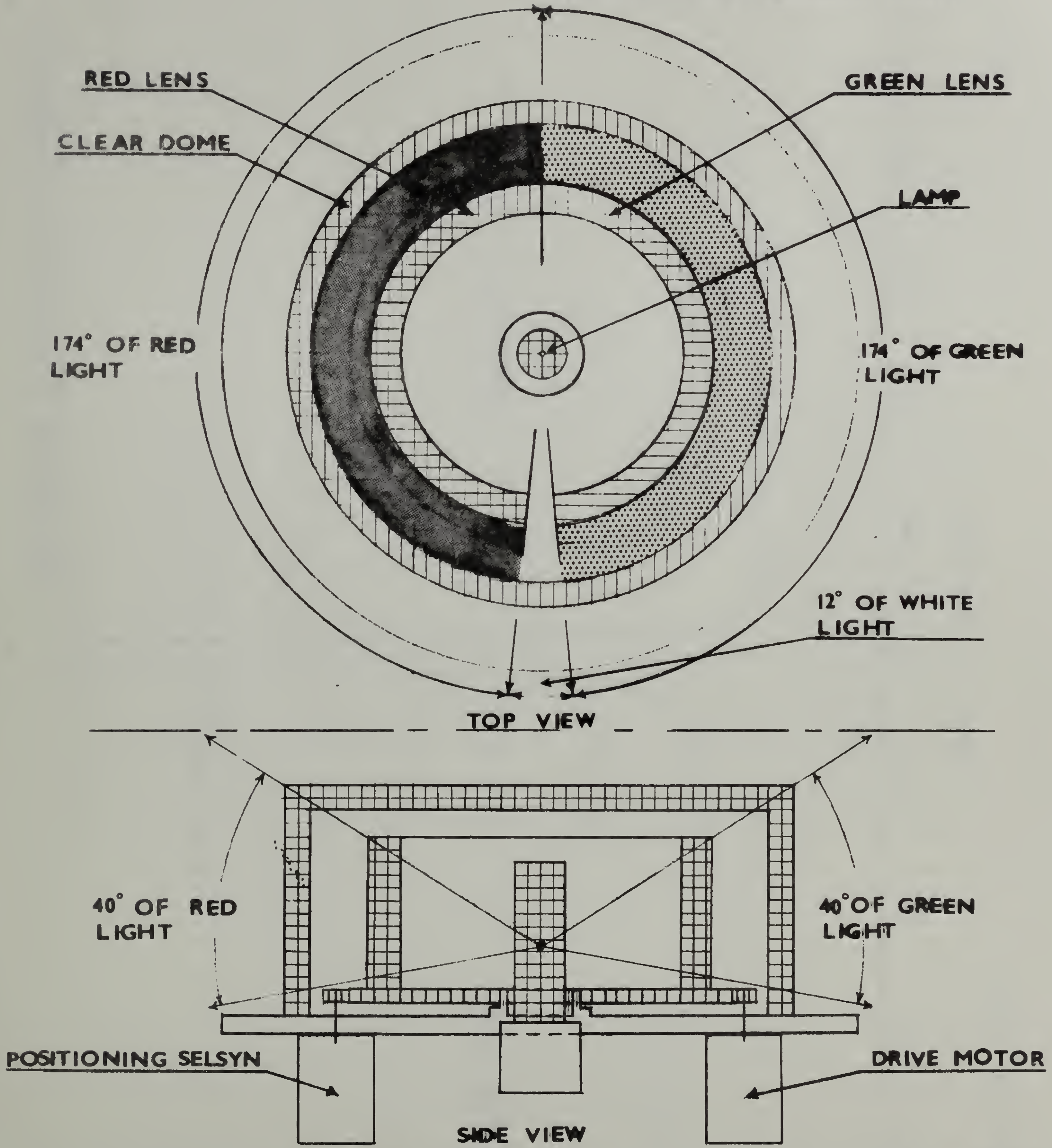


SH-3A HELICOPTER BLADE TIP CAP EQUIPPED WITH TWO # 600. 6.2 VOLT LAMPS (one covered with red filter) & WITH THE DIFFUSING PLASTIC WINDOW REMOVED.

NBS TEST 212.11N-12/66

FIG. 2

PICTORIAL DIAGRAM OF
ASW TRI-COLOR BEARING LIGHT

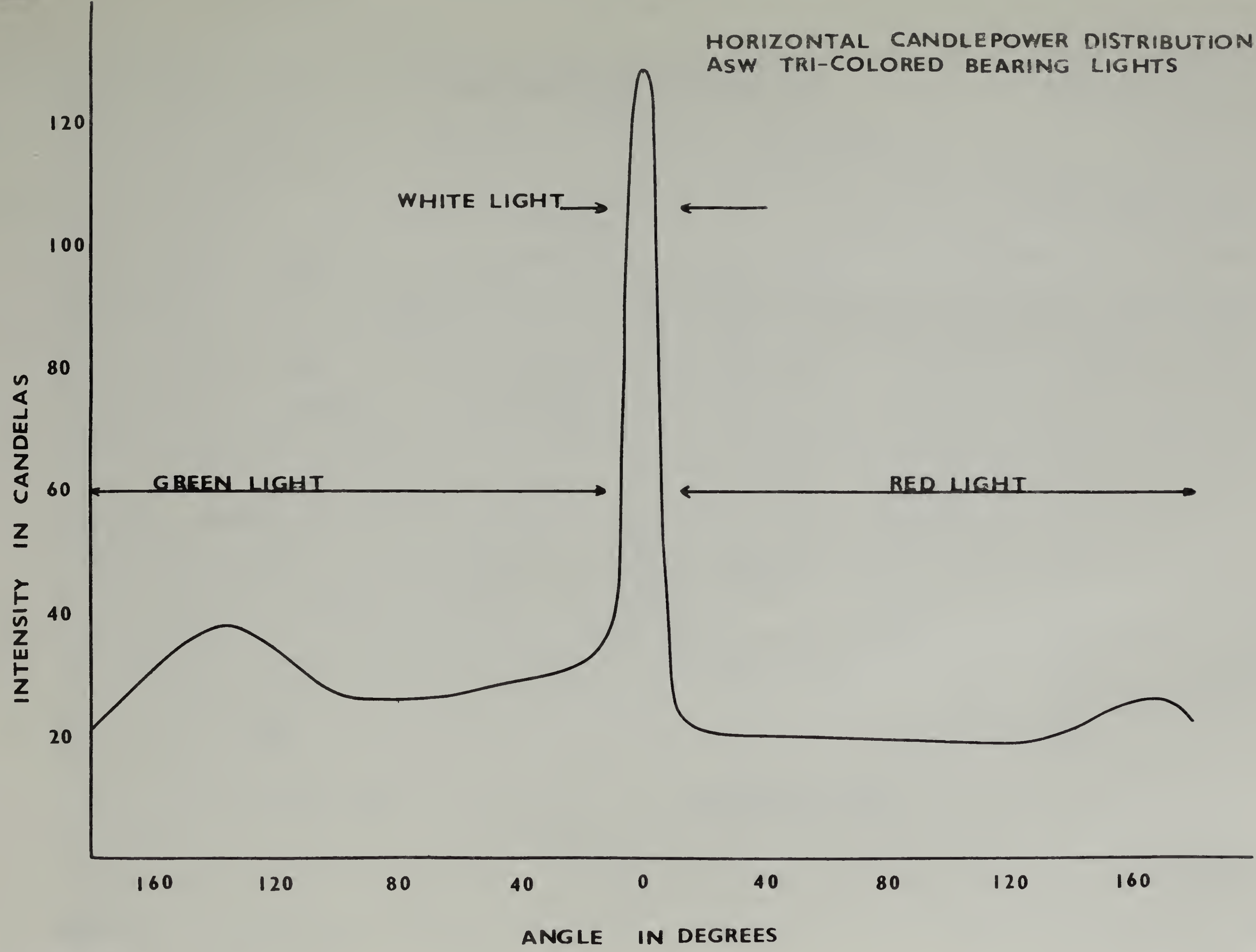


(LENS SYSTEM TO BE AUTOMATICALLY POSITIONED BY SONAR EQUIPMENT)

NBS TEST 212.11N-12/66

FIG. 3

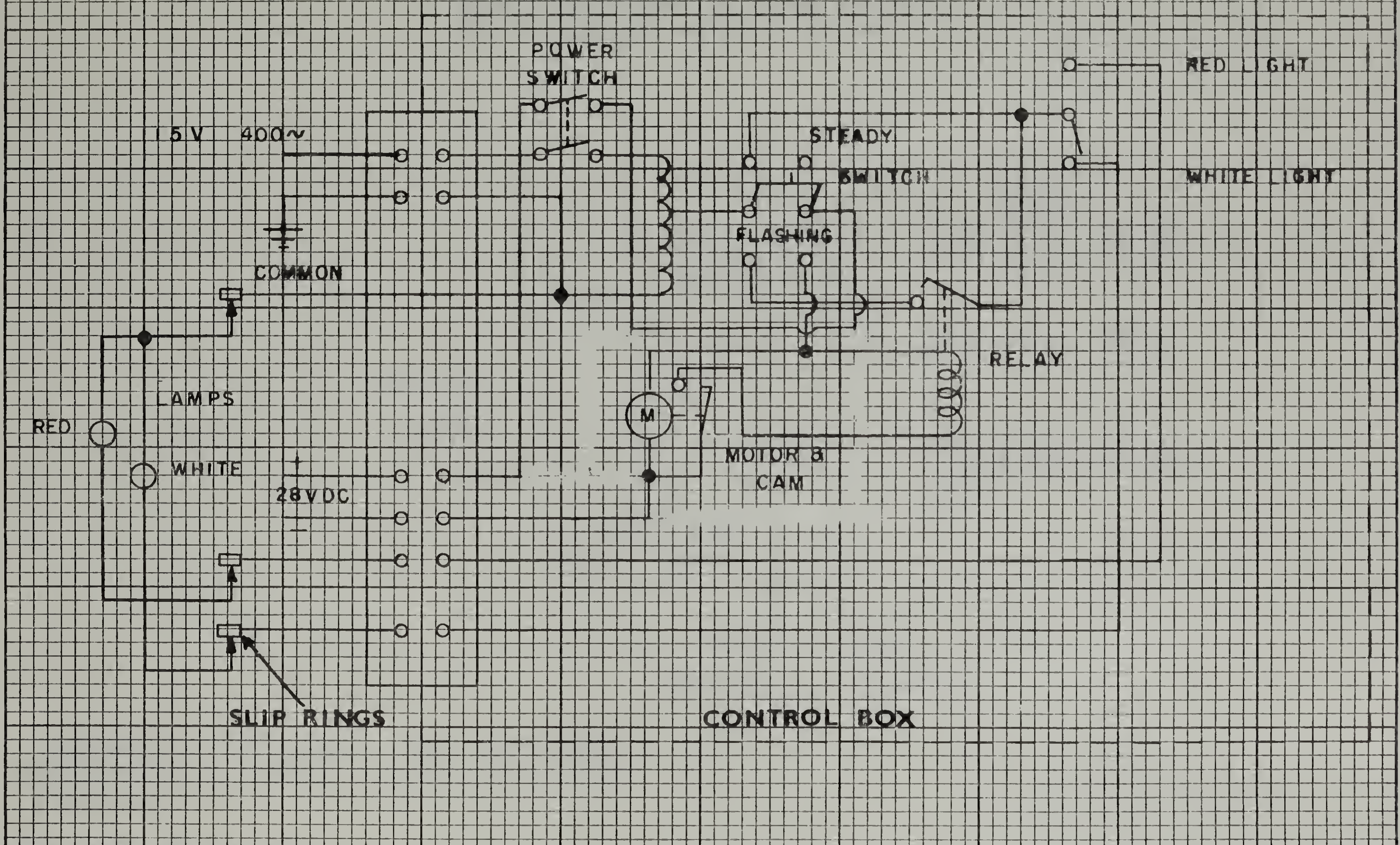
HORIZONTAL CANDLEPOWER DISTRIBUTION
ASW TRI-COLORED BEARING LIGHTS



NBS TEST 212.11N-12/66

FIG. 4

SIMPLIFIED WIRING DIAGRAM FOR CONTROLLING BLADE TIP LIGHTS

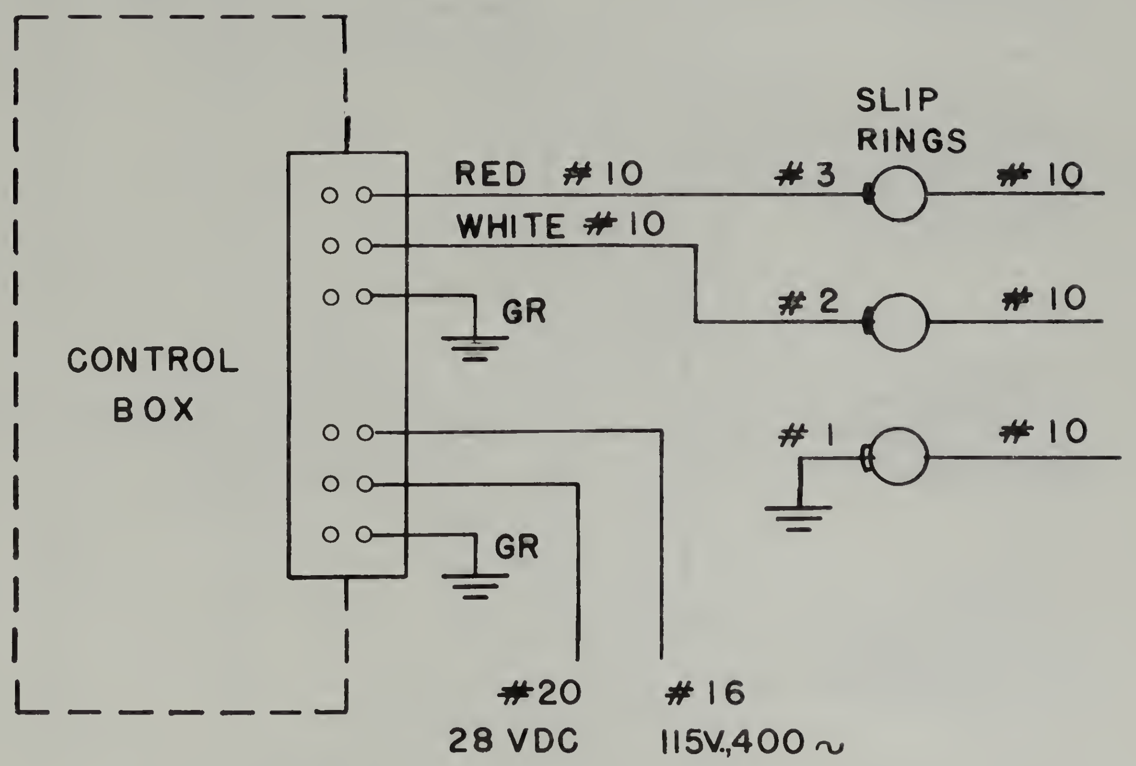


NBS TEST 212 IIN-12/66

FIG 5

WIRING DIAGRAM

MAIN ROTOR BLADE LIGHTS
SH-3A HELICOPTER



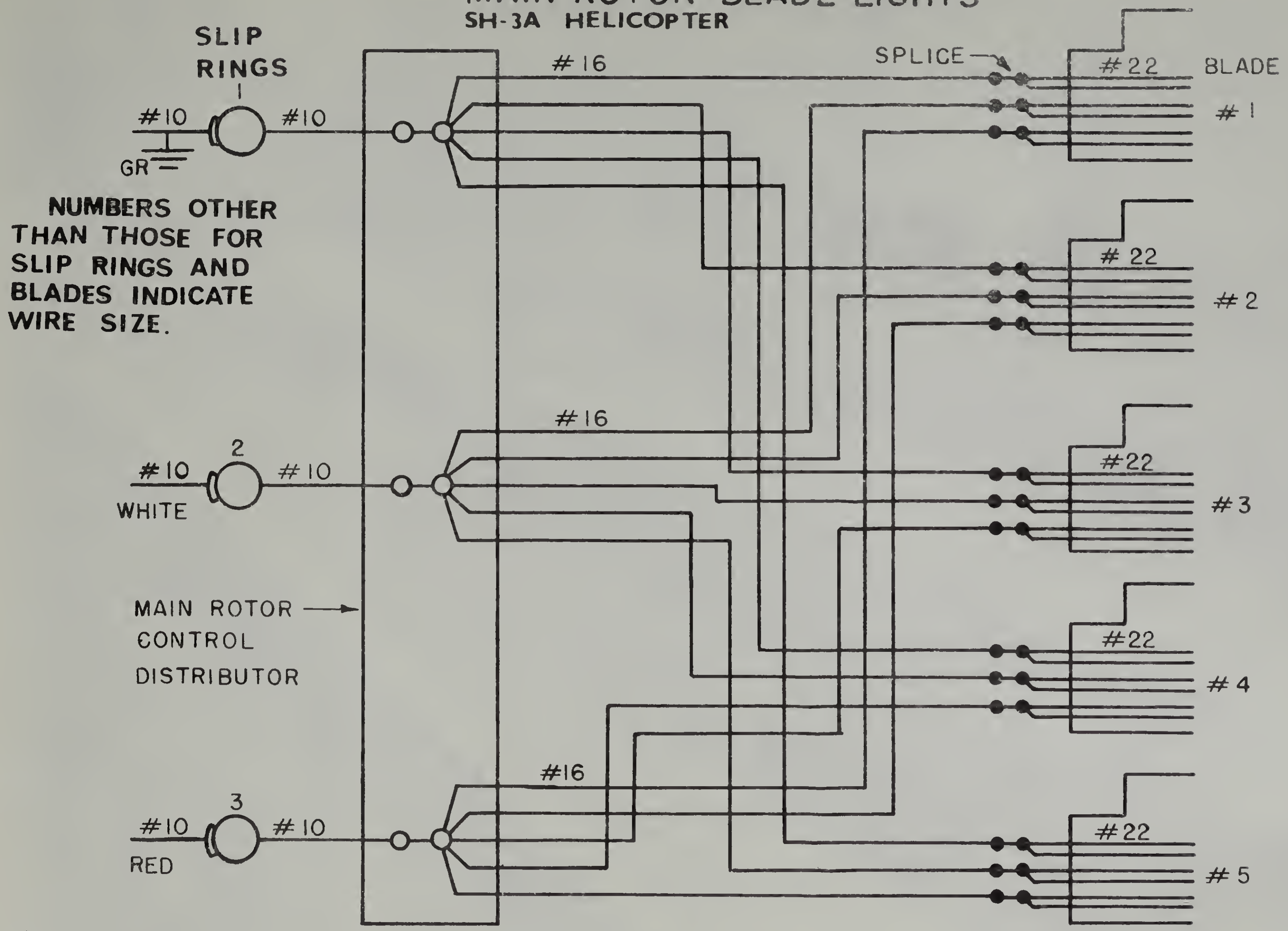
NUMBERS 1 THROUGH 3 ARE SLIP-RING DESIGNATIONS OTHER NUMBER DESIGNATE WIRE SIZE.

NBS TEST 212.11N-12/66

FIG.6

WIRING DIAGRAM

MAIN ROTOR BLADE LIGHTS
SH-3A HELICOPTER

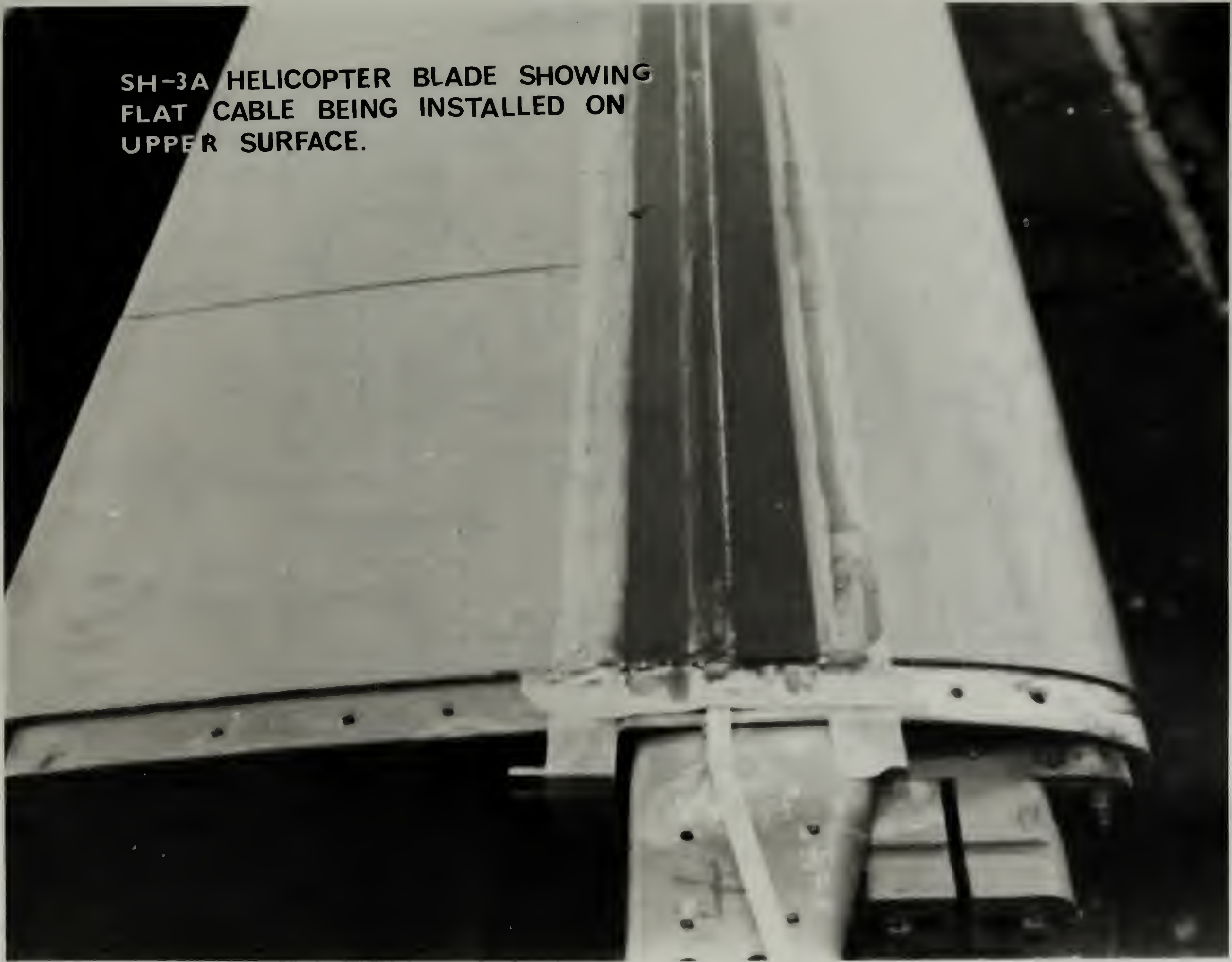


NBS TEST 212.11N–12/66

FIG. 7

NBS TEST 212.11N-12/66

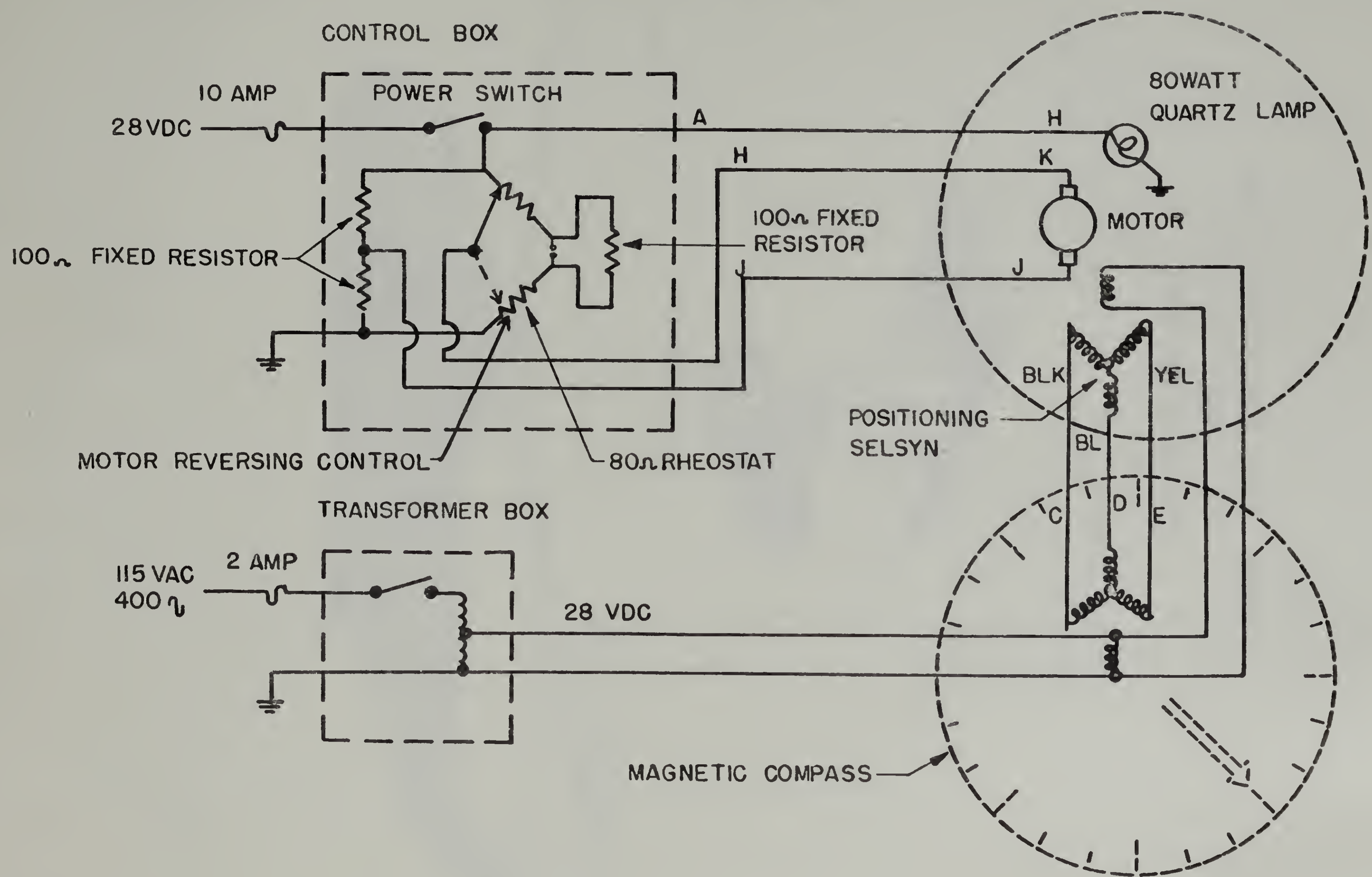
FIG. 8



NBS TEST 212.11N-12/66

FIG. 9

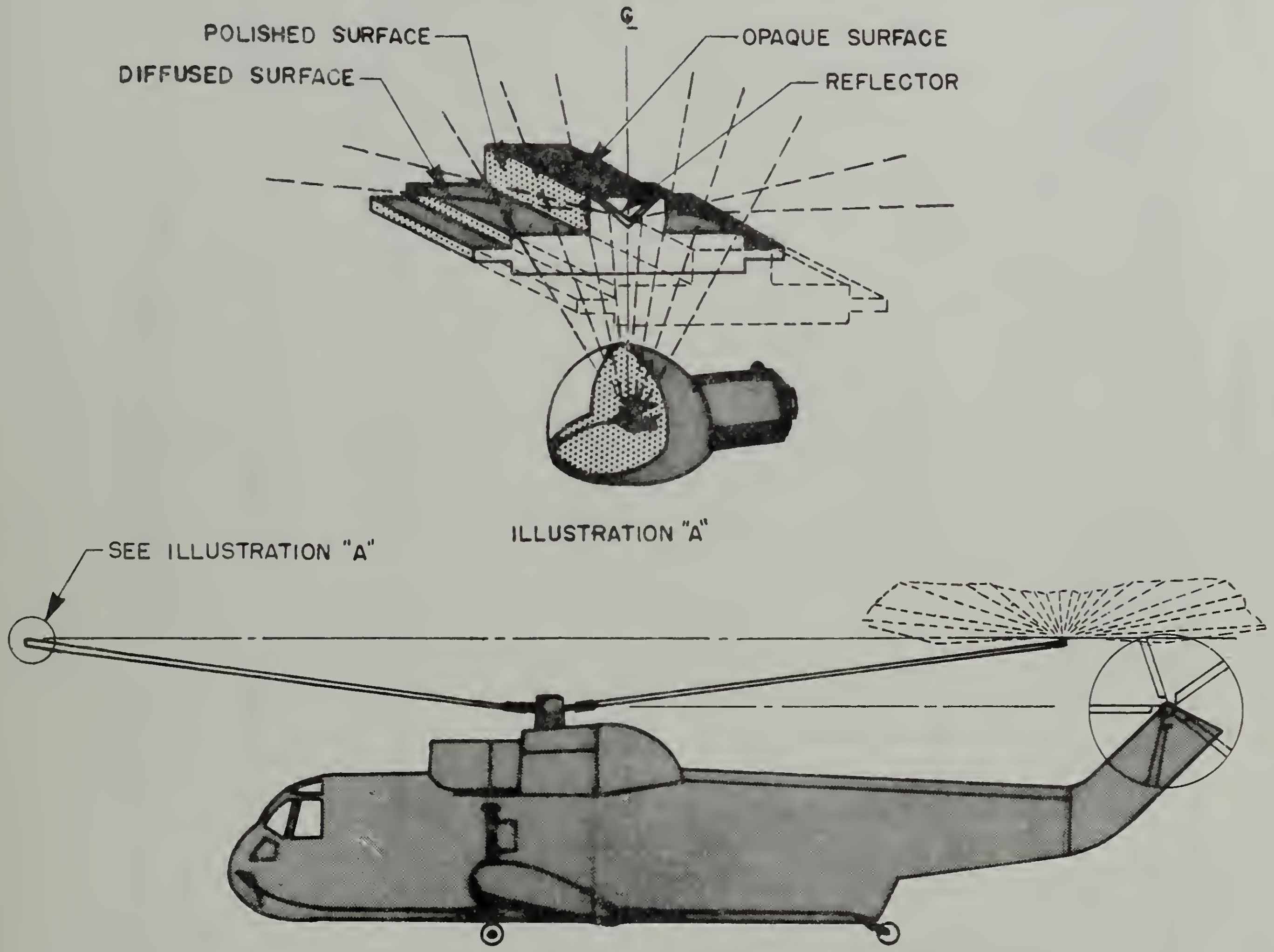
ASW VECTOR LIGHT CONTROL SYSTEM
SH-3A HELICOPTER
PATUXENT RIVER, MD.



NBS TEST 212.11N-12/66

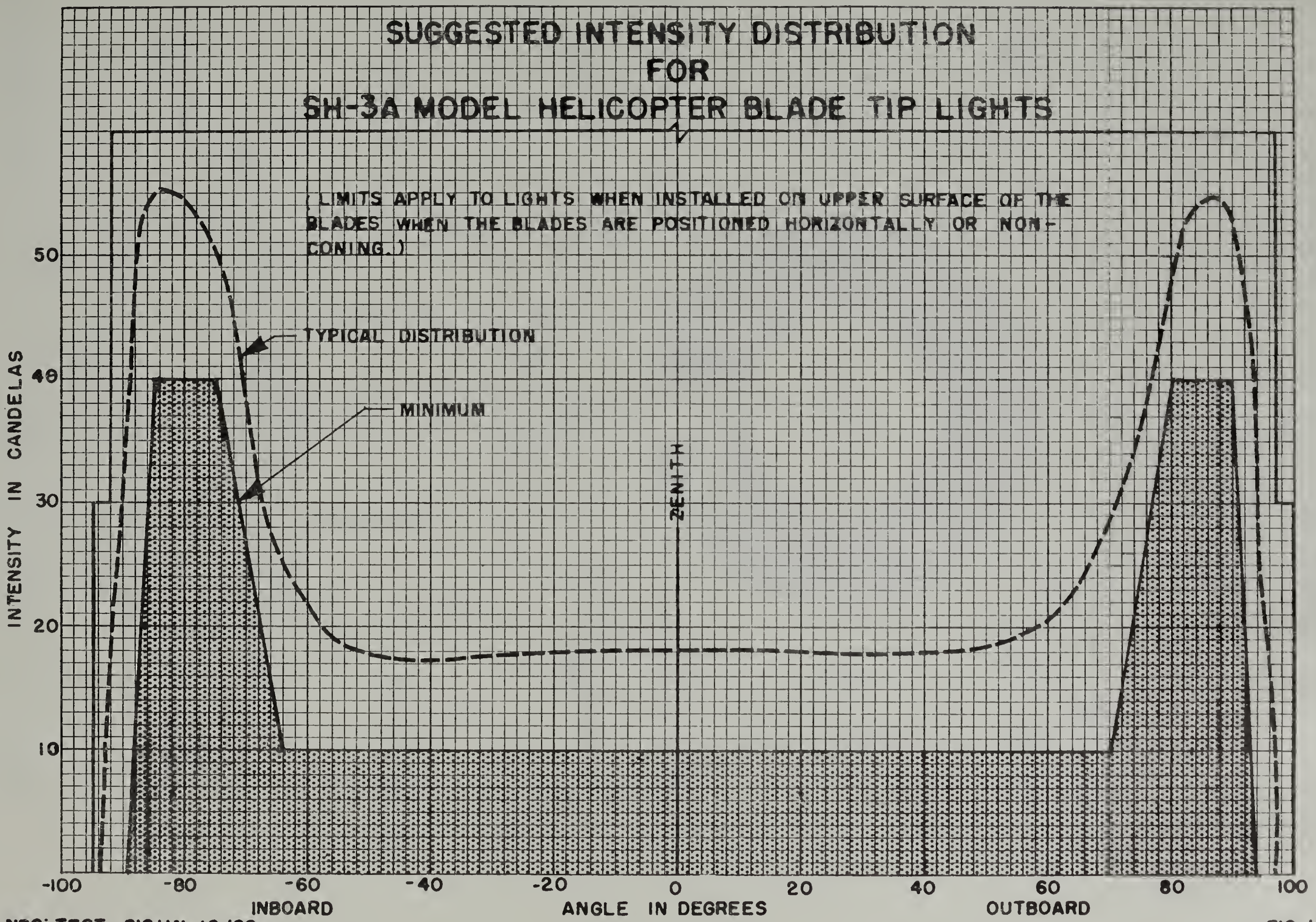
FIG. 10

SUGGESTED BLADE LIGHT DESIGN
FOR
ASW HELICOPTORS



NBS TEST 212.11N-12/66

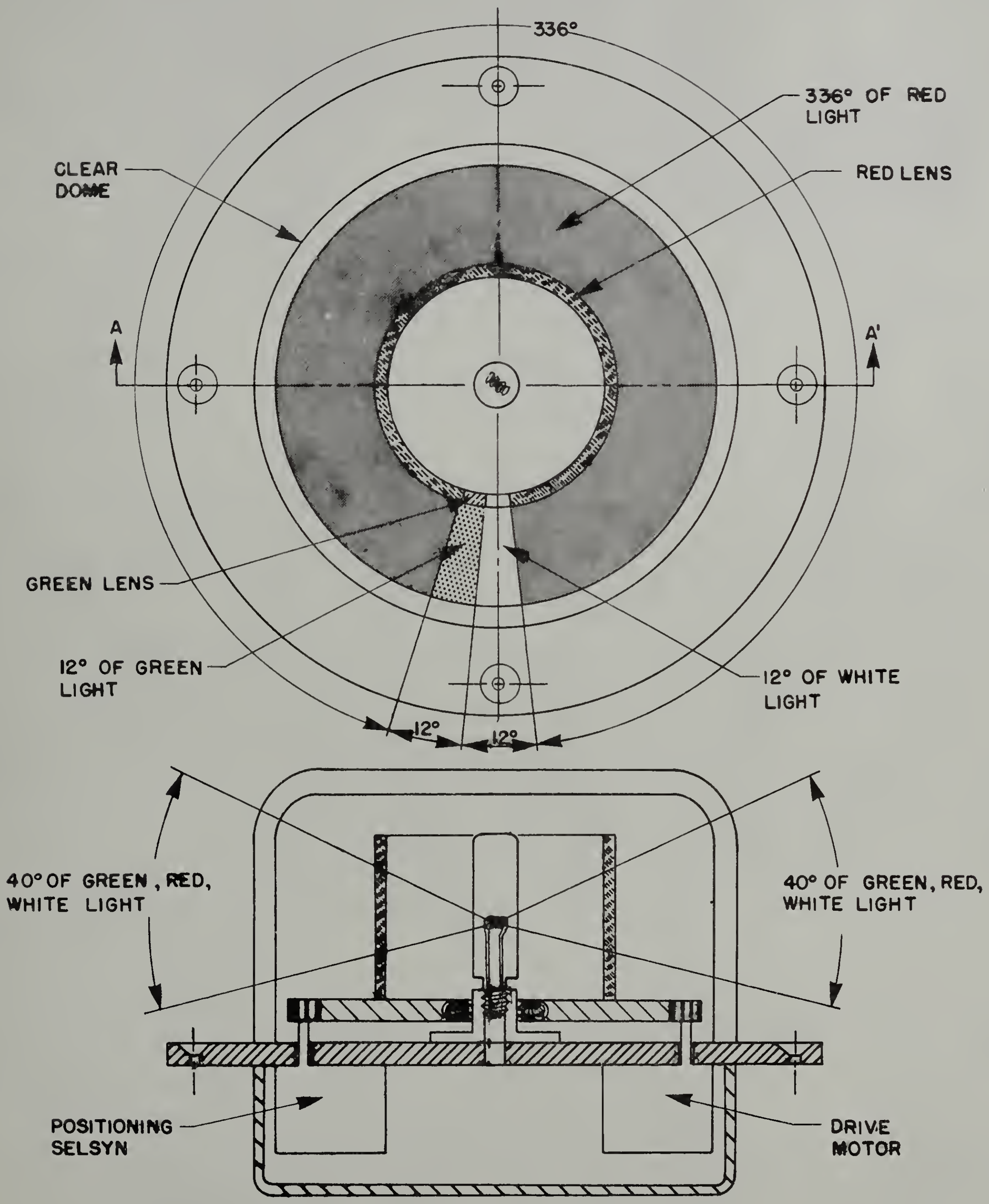
FIG. 11



NBS TEST 212.11N-12/66

FIG. 12

SUGGESTED BEARING-LIGHT DESIGN
FOR
ASW HELICOPTERS



SECTION A-A'

NBS TEST 212.11N-12/66

FIG. 13

DEPARTMENT OF COMMERCE ★ NATIONAL BUREAU OF STANDARDS ★