NATIONAL BUREAU OF STANDARDS REPORT

8921

Development, Tests, and Characteristics
of
Formation Lights for the UH-1 Model Helicopter

by
Photometry and Colorimetry Section
Metrology Division

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NBS PROJECT		NBS REPORT
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Development, Tests, and Characteristics
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Formation Lights for the UH-1 Model Helicopter

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Test 212.11N-27/65

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I. Introduction:

The lack of a satisfactory lighting system to permit tactical night formation flying has long limited exploitation of the helicopter for many of its military potential uses. Only recently has the solution of the technological problems permitted practical installations. One of the main problems heretofore was that of blade-tip lighting, which is considered essential for an effective formation lighting system. It involved methods of control as well as development of suitable light fixtures and blade wiring that would withstand the rigorous centrifugal environment. Recent tests have indicated that these problems, to a large extent, have been overcome. Miniature instrument-type incandescent lamps have been found to perform satisfactorily on the blades, while new structural adhesives make practical the installation of electrical wiring either inside of or on the external surface of the blades.

The UH-1 formation-lighting project followed similar investigative programs on the H-34 and CH-46 helicopters where many of the problems such as the types of lamps to use and intensity levels, had already been investigated. Consequently, the UH-1 installation was primarily a matter of fabricating a suitable slip ring, installing proper wiring, and determining the optimum fuselage lighting configuration peculiar to this model aircraft. The design objectivewas to provide a lighting arrangement which would permit satisfactory tactical night formation flying while simultaneously restricting visual range and maintaining security from above and from the ground.

II. System Description.

The lighting system consists of main rotor blade-tip lights, and of lights mounted on the fuselage and tail of the aircraft. The light display pattern and installation arrangement are depicted in figure 1. Incandescent lamps are used on the blades while electroluminescent lamps are used on the fuselage and tail. Both types of lamps are powered from the aircraft's electrical system through separate controls which permit each type to be dimmed independently.

A) Blade-Tip Lights.

Each of the two blade tips is equipped with a light fixture containing four #CM-680 miniature incandescent lamps embedded in clear acrylic plastic. The fixture is partially enclosed in a stainless steel jacket which provides erosion protection and blocks emission of light in undesired directions. Overall dimensions of the fixture are approximately 3 x 7/8 x 9/16 inches. The weight, including the electrical plug-in connector, is about one ounce. Lamp life at this voltage is estimated by the manufacturer at 60,000 hours. For the flight tests, voltage to the lamps was made continuously variable from zero to 8.0 volts. At the maximum voltage setting, current per fixture was 0.32 ampere resulting in a power dissipation of about 2.5 watts. Lamp life is considerably shortened by operation at the higher than rated voltage, but should still be several hundred hours. Light is emitted throughout 360 degrees of azimuth from a small area around the upper periphery of the fixture. Maximum intensity in any direction when the lamps are operating at 8.0 volts is approximately 0.6 candela. The bulk

of the emitted light is contained within a vertical angle extending from about 10° below to about 30° above the rotor-path plane. Because there are no sharp cut-offs, some light is emitted beyond these angles; however, its luminance in these areas is too low to be objectionable. In the normal "step-up" formation flight position, rotation of the blades gives the appearance of a continuous ring of light when viewed from trailing aircraft in the echelon. Figure 2 is a drawing of the light fixture. Figure 3 is a photograph showing an end view of a portion of a blade with the fixture installed. The 1/8 inch light emitting portion of the fixture protrudes above the upper surface of the blade, and the fixtures are positioned slightly forward of the quarter-chord of the blade.

B) Fuselage and Tail Lights

The fuselage and tail lights consist of four flexible electroluminescent light panels mounted to form an elongated diamond-shaped pattern on the top of the aircraft. Dimensions of each fixture are about 1 1/2 inches wide and 5 inches long with the longest dimension mounted parallel to the longitudinal axis of the aircraft. Some UH-1 helicopters are equipped on the starboard side with a hoist which extends above the fuselage in the direction of trailing aircraft on the starboard side of the echelon. In order to attain proper visual clearance on helicopters so equipped, the forward light was placed on a mast extending about 12" above the fuselage. Approximate locations of these lights are as shown in Figure 1. Figure 4 shows one of the lights installed on the tail pylon. The three lights on the fuselage proper are green while the tail light is either yellow or white. When operated at rated voltage, luminance of the green lights is about 20 footlamberts and of the tail light (yellow or white) about 10 footlamberts. The luminance decreases with operating time and it takes about 1000 hours to reach 1/2 initial luminance when operating at full voltage. However, a large portion of the time the lamps will be operated at less than rated voltage and this improves the luminance maintenance. Also decreases in luminance can be compensated by increasing the applied voltage from the control. The lamps are rated at 115 volts 400 cps input, and at this voltage the current per fixture is about 0.007 ampere. Total current for the four fixtures operating at rated voltage therefore, is about 0.028 ampere. Consequently, less than 3.5 watts are expended in the four light fixtures. The light panels for the flight tests were taped to the skin of the aircraft so that they could be conveniently moved until the optimum positions were determined.

C) Display Information.

Information displayed by the blade lights is twofold. First, they provide a measure of safety by indicating the outer limits of the rotor path, and second, they automatically provide flight maneuver information in that the light ring generated by the revolving blades tilts in the direction of the maneuver. If the aircraft turns right, the light ring tilts right with respect to the horizontal. Likewise, a left turn causes the ring to tilt left, etc.

Information provided by the electroluminescent lights is also twofold. They indicate the formation alignment position, and also present clues as

to the aircraft's orientation. The tail light being of a different color from the other lights immediately indicates the aircraft's heading. Position alignment information is obtained from the green lights. These three lights form a rearward-facing 70° included angle bisected by the longitudinal axis of the aircraft. Proper angular alignment is obtained by aligning the forward light with the light which is on the same side as the trailing aircraft. The port wingman aligns the leading and port fuselage light while the starboard wingman aligns the leading and starboard fuselage light.

III. Electrical Wiring.

Conventional wiring was used in powering the fuselage and tail lights since they require only normal aircraft wiring procedure. Size # 20 wire was used in the test installation because it was readily available. The circuit consisted of a single conductor to each fixture through an on-off switch, dimming transformer and protective fuse. The aircraft structure was used as ground return. Figure 5 gives a typical circuit control diagram, although it is not exactly the circuit used in the test installation.

Wiring for the blade-tip lights required greater attention because of the complexity of the problem and the wiring environment. Wiring for the rotor head was placed external to the drive shaft, where it had to navigate several flexure joints, and was exposed to certain mechanical stresses; while that on the rotor blades was subjected to considerable centrifugal force. These conditions necessitate the use of wires that remained flexible under extremes of environment, had to be securely anchored, and possessed adequate strength to withstand the mechanical stresses. Size #18 wire was used on the vertical run from the slip ring along the drive shaft and rotor head, while size #26 was used within the blade spar. The blade-wires contained 19 strands of #38 wire, and the shaft wire contained 105 strands of #38 wire. The shaft wire was larger than electrically required, but it was used to obtain better mechanical strength. Wire having silicone insulation was used so as to maintain flexibility at low temperatures. The blade wires carried conventional vinyl insulation.

The blade wires were held in place by an adhesive with which they were coated upon installation. The adhesive is designated as #EC-847 and manufactured by the Minnesota Mining and Mfg. Co. Wiring along the drive shaft and movable controls was secured with conventional cable clamps where possible, and with a mixture of Minnesota Mining and Mfg. Co. epoxy adhesives EC 2216A and EC 2216B at other locations. Figure 6 is a photograph of the rotor-head wiring.

Circuitry for the blade-tip lights was similar to that for the fuselage and tail lights except that the output voltage of the transformer was lower and the power was transmitted through a single-conductor slip ring mounted on the swash plate of the aircraft. Ground return was through the blades and bearings of the main rotor. Figure 7 gives a typical control circuit with recommended voltage or dimming steps.

IV. System Evaluation and Results.

The lighting system was evaluated during a series of flight tests by Pilots of Marine Corps Squadron HMX-1, Quantico, Virginia. Results of the tests will be fully covered in a report from that activity. From a lighting standpoint, the system as finally evolved is considered satisfactory

and is recommended for service. However, from an engineering standpoint, improvements can and should be made. The test installation was intended primarily as a means to determine the optimum geometry, intensity distribution patterns, and the practicality of the installation. No attempt was made to optimize the design of the individual components. Figure 8 shows an overall view of the lighted helicopter.

A) Blade-Tip Lights.

Performance of the blade-tip lights was satisfactory throughout the series of flight tests except for a small amount of erosion of the plastic near the top of the leading edge of the fixtures. This did not materially detract from the effectiveness of the lights during the tests. However, in service installations it is suggested that the shield be extended to cover the exposed leading edge of the plastic fixture. Intensity levels and distribution patterns were considered excellent. A graph of the light distribution pattern of one of the fixtures is given in figure 9. This distribution, and distributions of similar fixtures designed for the CH-46 helicopter served as a basis for the preparation of general requirements for blade-tip lights. These requirements as recommended for design purposes are given in figure 10.

To meet these requirements, it is felt that the light fixture design can be simplified and miniaturized. For example, by positioning the lamps vertically in the fixture instead of nearly horizontal, the fixture's width could be substantially reduced, resulting in savings in both weight and frontal projection area. Tests indicate that the lamps will survive the forces involved equally as well when mounted vertically if care is taken in positioning the lamps such that the plane containing the two filament supports is perpendicular to the centrifugal force. Except for areas of light emission the fixtures should be completely enclosed in a suitable shield to prevent "ram-air" erosion and to prohibit light leakage in undesired directions.

B) Fuselage and tail lights.

No attempt was made to fabricate suitable service fixtures for the electroluminescent lights, and all but the forward one were surface-mounted and taped into position. Performance of the fixtures was considered satisfactory and their luminance levels are shown in figure 11. The color green (General Electric electroluminescent lamp or equivalent) was selected for the three forward lights while yellow or white was selected for the tail pylon light. For the Marine type helicopters, it was necessary to place the leading fuselage light on a 12" mast to obtain proper visual clearance above the hoist on the starboard side, and although a round unit was used in the test installation, it is felt that a more appropriate fixture and mast can be designed. For instance, a streamlined, tear-drop-shaped fixture and mast, with the lamp mounted in its upper portion would be preferable and would serve equally well. Further, fiberglass material might be considered for the mast rather than metal as was used in the test installation. Helicopters without the hoist would require no mast. It is recommended that the luminous area of the fixtures should not be less than 5 square inches and that the luminous area of the tail light should be about 1 1/2 times the others to compensate somewhat for reduced luminance of the

yellow or white color.

C) Slip Ring.

An open-type slip ring and brush assembly, mounted on the aircraft swash plate was utilized during the test and was exposed to the elements, as well as to grease and other foriegn matter. Although this arrangement worked fairly well, some problems were experienced with intermittent electrical contact. Also, brush wear seemed excessive. This was probably caused by the strong brush springs which were used to assure against contact interruption resulting from wind pressure and vibration. For a service installation, it is suggested that means be explored for covering the slip ring, or possibly placing it within the hollow drive shaft. Further, a dual-conductor slip ring is recommended to eliminate the necessity of returning the ground of the circuit through the main rotor bearings.

D) Blade and Rotor-Head Wiring.

The blade wiring operated trouble free during the series of tests. Operation of the rotor head wiring was also free of problems. However, the rotor head wiring as installed did present certain maintenance problems to the helicopter in that no provisions were made for blade and head disassembly without cutting the wires. This can be avoided by use of plug-in connectors and quick-disconnect fasteners at appropriate places in the leads.

E) Switches and Controls.

Each complement of lights (blade-tip and fuselage-tail combination) was provided with its own on-off switch, dimming control, and protective fuse. The controls were placed in individual boxes and installed temporarily in the aircraft within convenient reach of the pilot. The circuits operated well and presented no significant problems. For a service installation, however, the controls should be compatible with, and integrated into, the existing instrument console arrangement. The assembly should be complete with its own illuminated plastic lighting plate, the lamps of which are powered from the existing instrument lamp circuit.

V. Discussion.

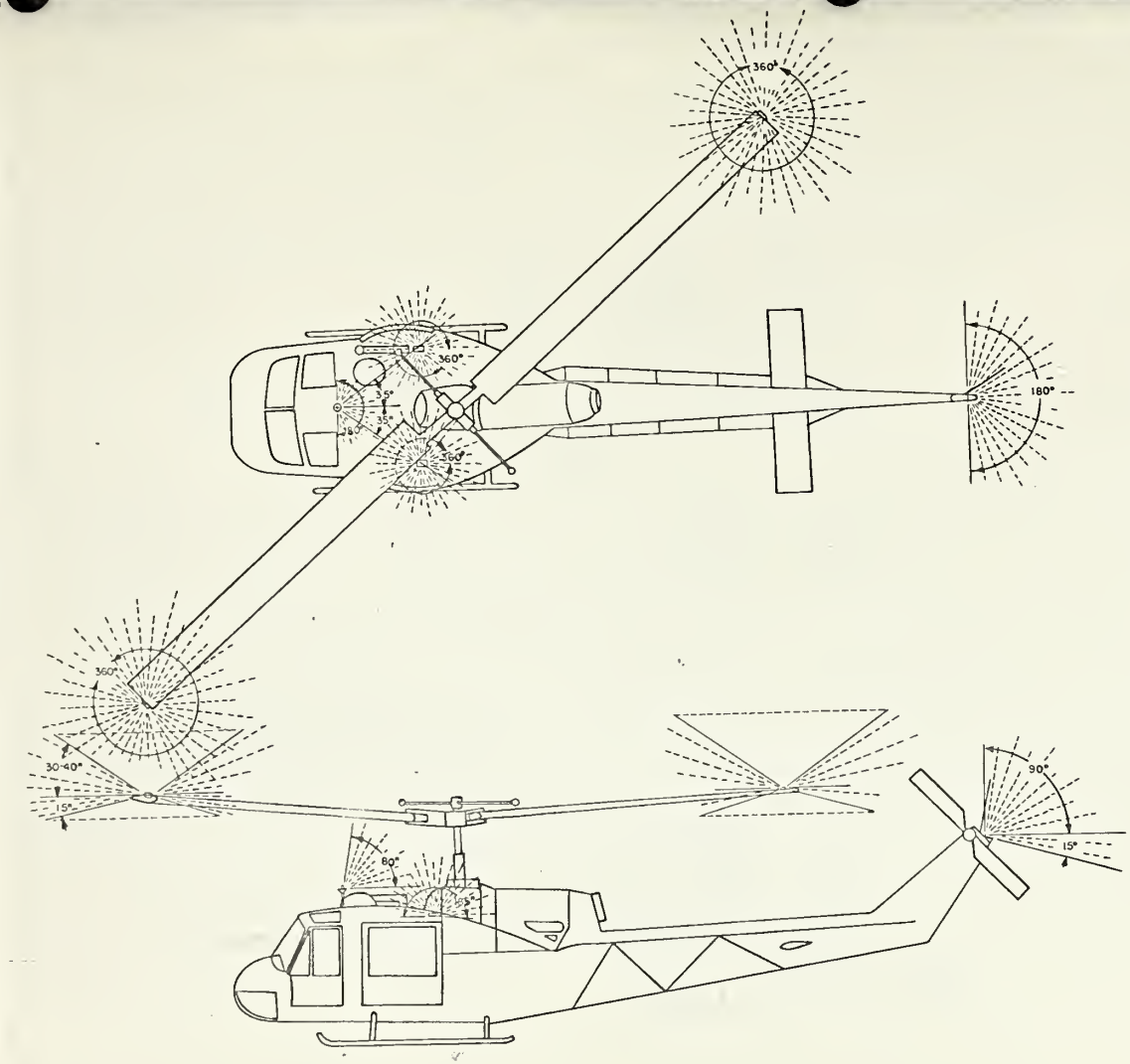
The characteristics of the formation lighting system designed for the UH-1 helicopter was proved satisfactory during more than 80 hours of flight tests. With this system, formation flying at night was reported to be as easily and routinely accomplished as daylight flying. Some pilots stated that night flying was easier in that the position of the blade tips cannot be as readily determined during daylight.

The system was found to offer several advantages over the presently used navigation lights. Among these are maneuver and angular alignment information plus visual security from the ground, and from directly above the aircraft. Further, a measure of safety is gained by outlining the rotor-path plane. Also, better depth perception and altitude information of the lead aircraft is afforded by judging variations in the shape of the ellipsoidal light ring. Moreover, the simplicity of installation makes the

system as adaptable and as practical for retrofit as for new aircraft. With improved component design, service installations of this system are recommended.

VI. Acknowledgments.

Appreciation is hereby expressed to the personnel of Marine Corps Squadron, HMX-1 for their outstanding cooperation and the exemplary manner in which the flight tests were conducted. Special appreciation is directed to Capt. W. S. Smith, Project Officer, whose competence and continued cooperation led to the successful conclusion of the project.



ORIGINAL DATE OF DRAWING			
REVISIONS			
NO	E C N	CHANGE	DATE
1			
2			
3			
4			

1. BLADE TIP LIGHT
   1. FOUR NO. 680 LAMPS PER BLADE POTTED IN CLEAR ACRYLIC PLASTIC.
   2. INTENSITY VARIABLE FROM 0-0.5 CANDELA.
   3. VOLTAGE VARIABLE FROM 0-7.0 VOLTS.
   4. COLOR: WHITE
2. FUSELAGE & TAIL LIGHTS
   1. ELECTROLUMINESCENT LAMP
   2. VOLTAGE VARIABLE FROM 0-115 VOLTS AT 400 CPS
   3. LUMINANCE 0-20 FOOTLAMBERTS.
   4. COLOR: FUSELAGE-GREEN
      TAIL - WHITE OR YELLOW

PIECE NO.	NOMENCLATURE	NO. REQ'D

NATIONAL BUREAU OF STANDARDS
WASHINGTON 25 D.C.

FORMATION LIGHTS
FOR HELICOPTER

MODEL UH-1	TYPE	SCALE NONE
DIMENSIONS IN INCHES (Unless otherwise specified)	DRAFTSMAN WJR	CHECKER
TOLERANCES (Unless otherwise specified)	PROJECT ENGR WFM	PROJECT ENGR
DECIMALS ± .005 FRACTIONS ± .015 ANGLES ± ½°	SUBMITTED BY	CHIEF SEC
DO NOT SCALE THIS PRINT	EXAMINED BY	CHIEF ENGINEER
DIV. SEC. THIS PRINT ISSUED	APPROVED BY	CHIEF DIV.

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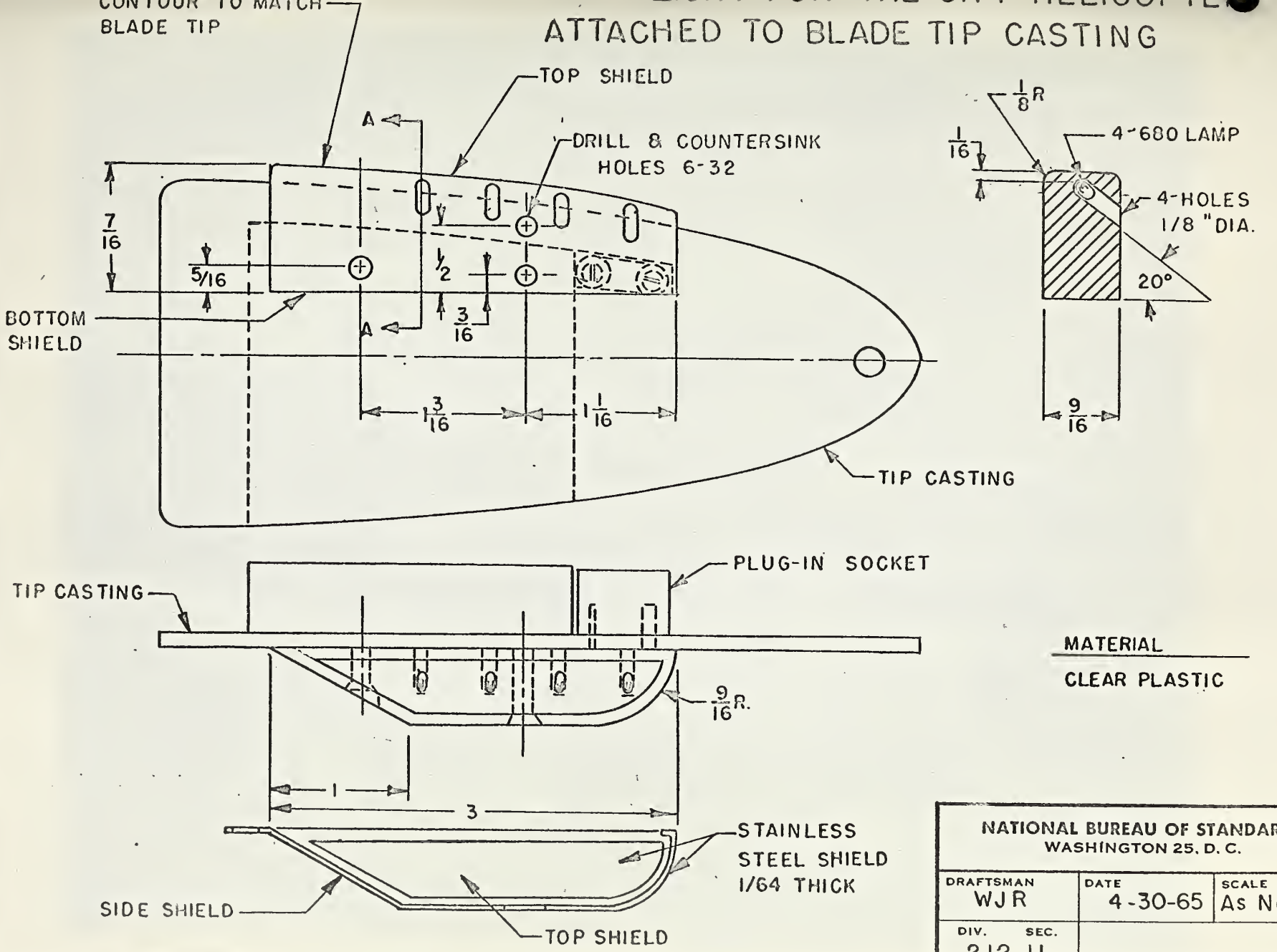
FIGURE # 1

ATTACHED TO BLADE TIP CASTING



MATERIAL

CLEAR PLASTIC

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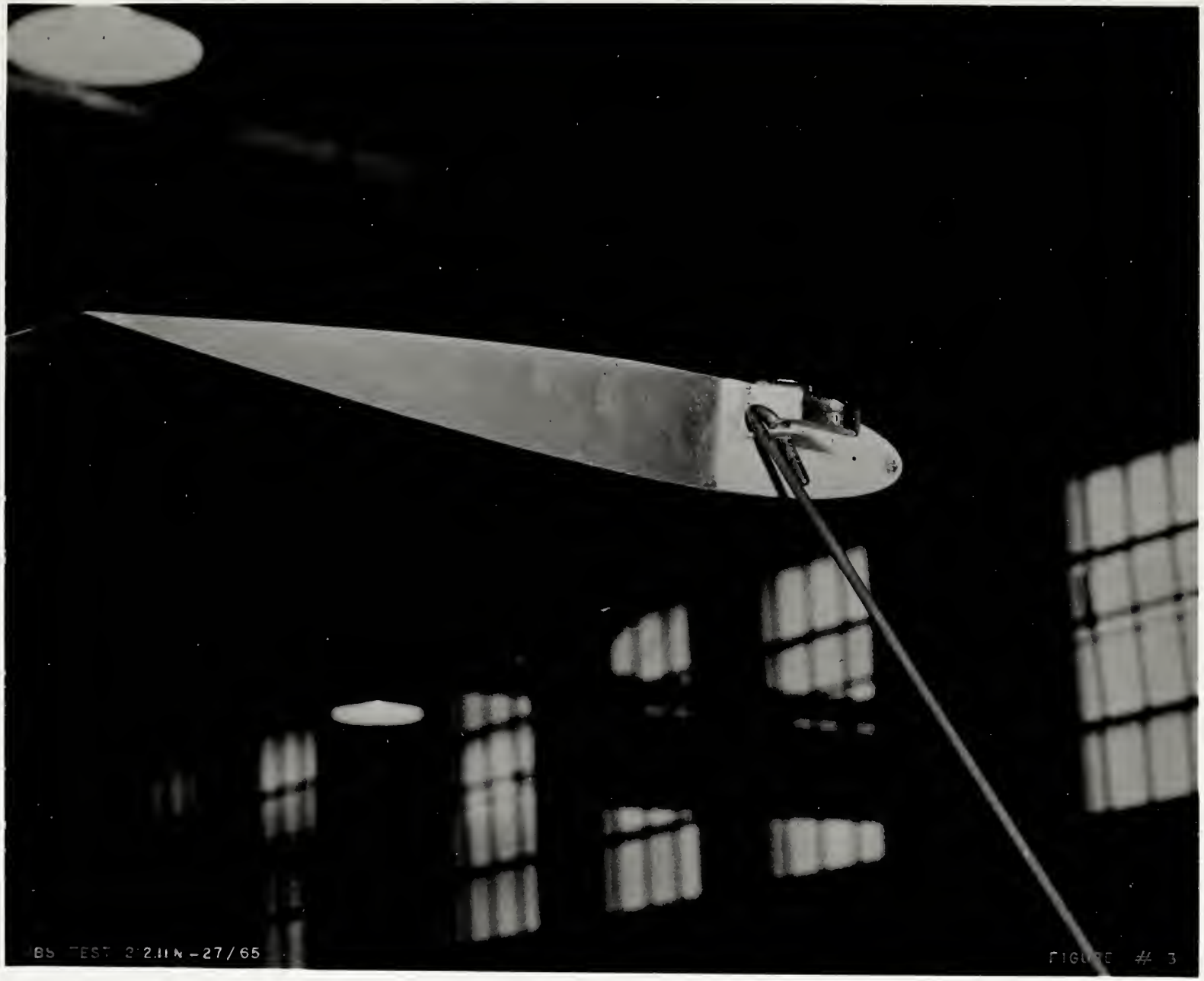
DIV. SEC. 212.11		



#5


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FIGURE #. 4

FOR

ELECTROLUMINESCENT FUSELAGE FORMATION

LIGHT UH-1 HELICOPTER

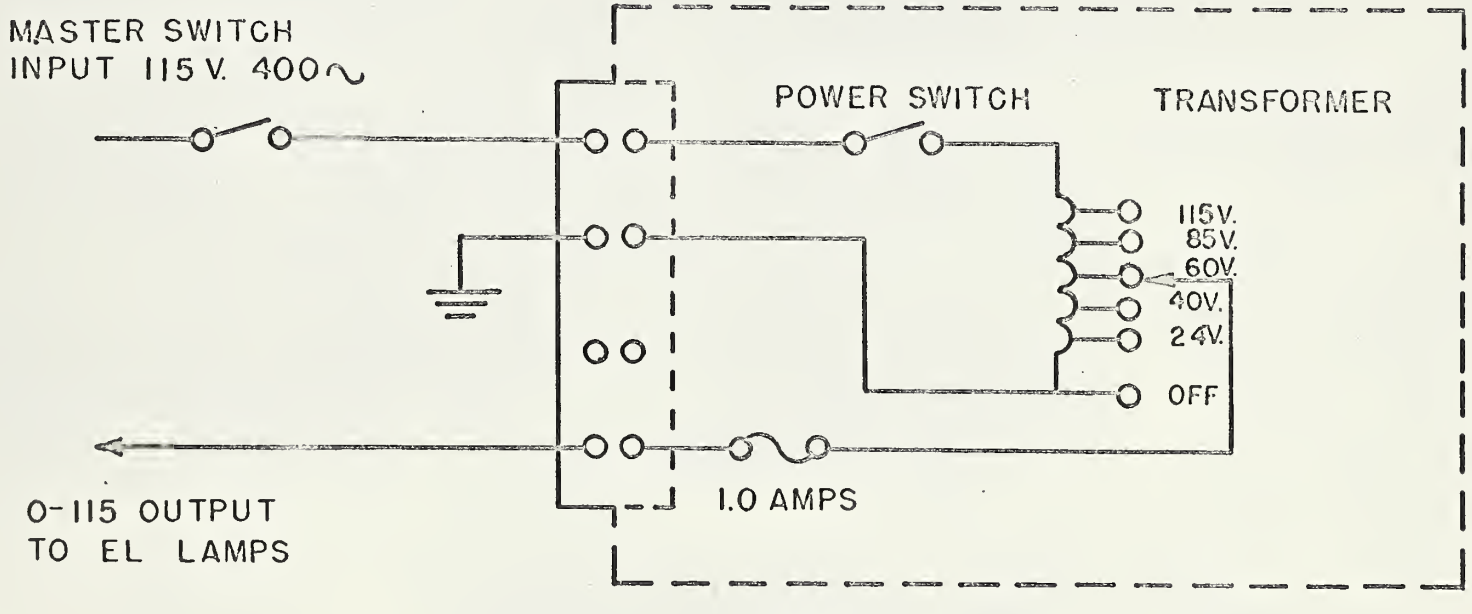

FIGURE #5

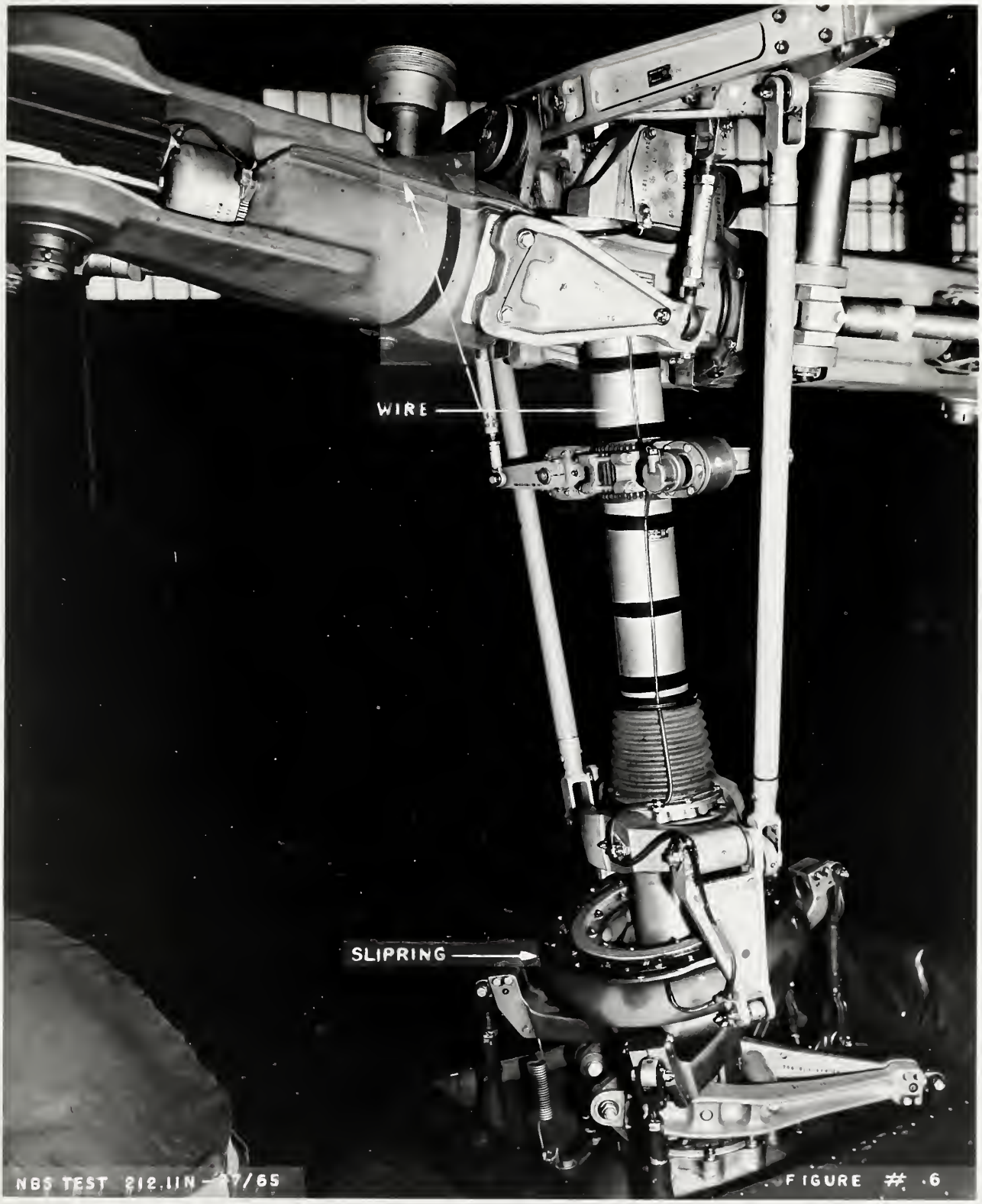

FIGURE # 6

FOR

ROTOR BLADE TIP FORMATION LIGHT
UH-1 HELICOPTER

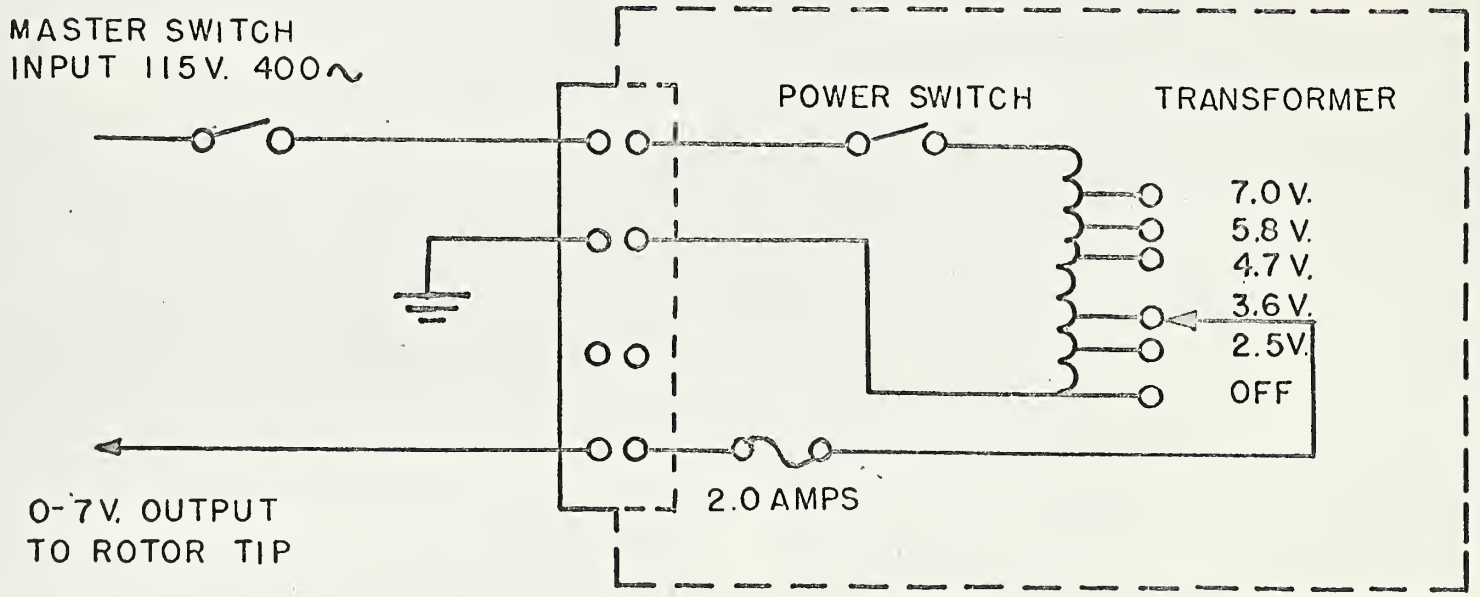

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FIGURE # 8

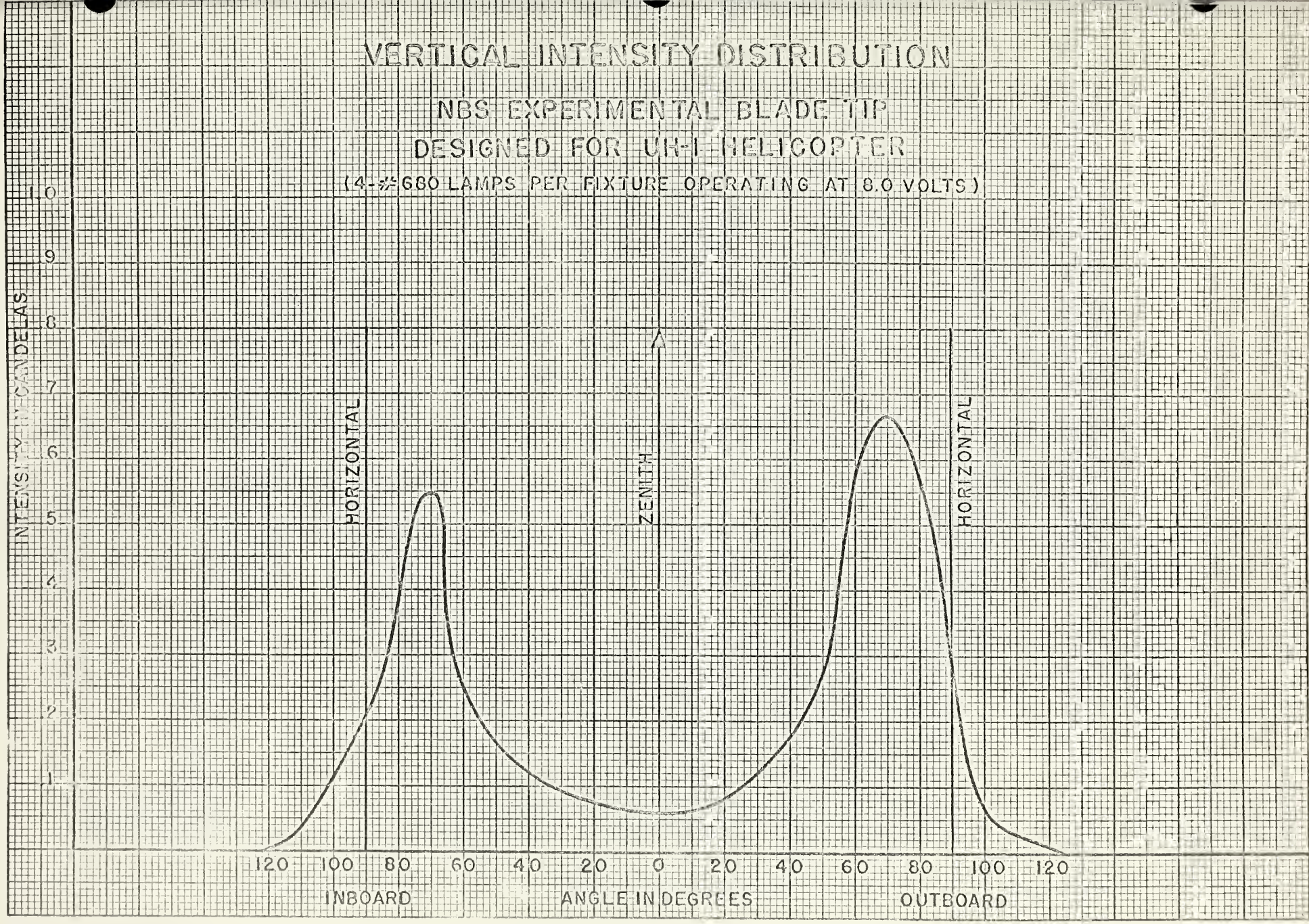

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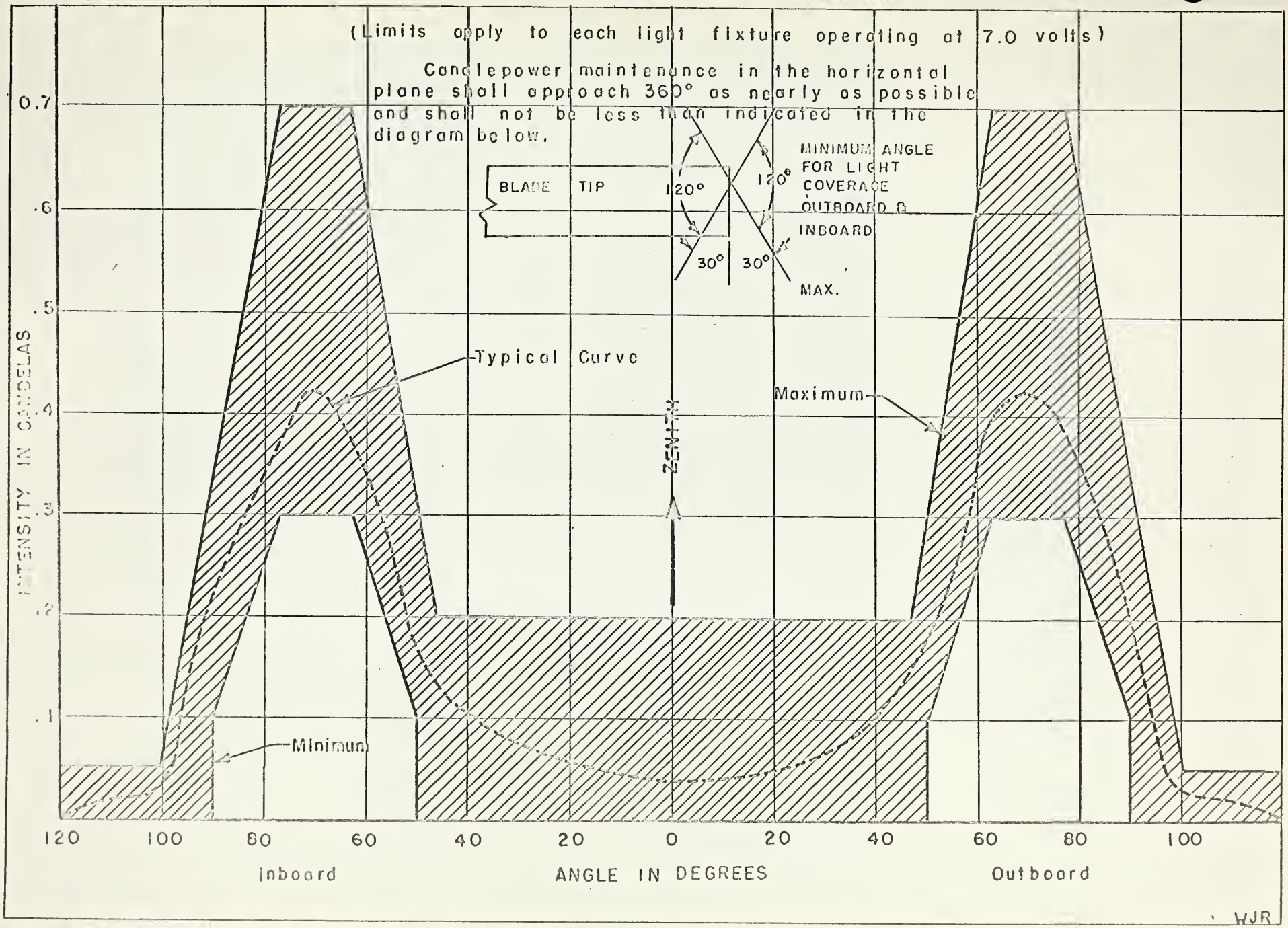
FIGURE # 9

HELICOPTER BLADE TIP FORMATION LIGHTS

(Limits apply to each light fixture operating at 7.0 volts)

Candlepower maintenance in the horizontal plane shall approach 360° as nearly as possible and shall not be less than indicated in the diagram below.



WJR

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FIGURE # 10

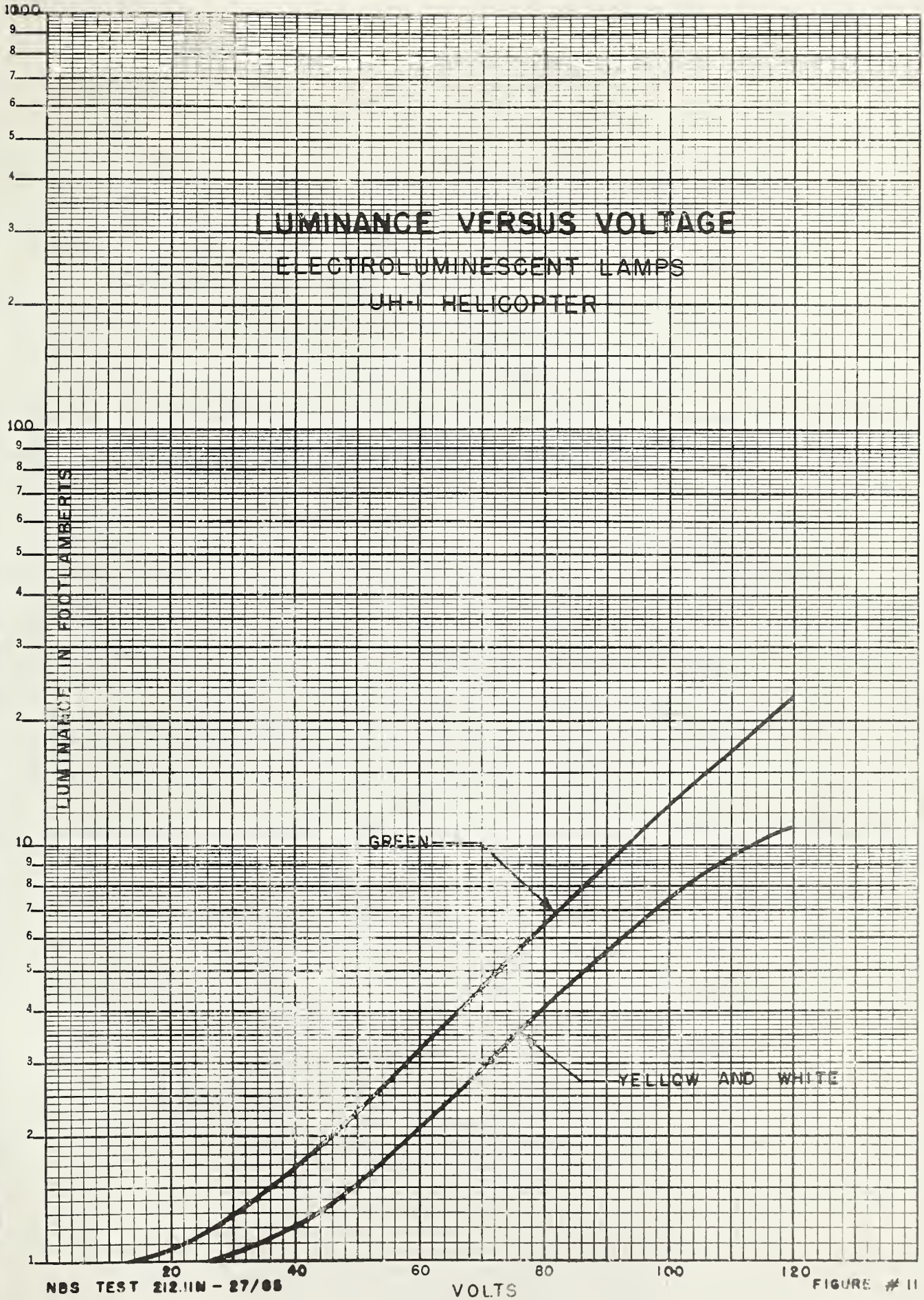
LUMINANCE VERSUS VOLTAGE
ELECTROLUMINESCENT LAMPS
UH-1 HELICOPTER
LUMINANCE IN FOOTLAMBERTS
1000
100
10
1
GREEN
YELLOW AND WHITE
20
40
60
80
100
120
VOLTS
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FIGURE # 11


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