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NATIONAL BUREAU OF STANDARDS REPORT

6835

Preliminary Report
On The Development
of
Helicopter Blade Tip Lights
For Formation Flying

By
Photometry and Colorimetry Section
Optics and Metrology Division

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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Preliminary Report
On The Development
of
Helicopter Blade Tip Lights
For Formation Flying

By

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1. Introduction.

During 1955 the Department of the Navy requested that the National Bureau of Standards conduct an investigation to determine the feasibility of illuminating the rotor-blade tips of helicopters to aid in night formation flying. It was thought that the ring of light created by the revolving luminaires would be a safety measure in outlining the outer limits of the blade tips, and that the inclination of the light ring with respect to the horizontal would be of considerable value in anticipating the maneuvers of the leading craft in the formation.

The general requirements as outlined by the military for the blade tip lights are as follows:

1. The ring of light generated by the luminaires should be visible at a distance of approximately 1000 feet.

2. The light should be visible only in the upper hemisphere.

3. The lights and associated equipment should be capable of withstanding continuous accelerations of the order of 500 G's.

4. Installation should be simple and maintenance held to a minimum; the use of slip rings and wires through the blades is undesirable.

5. The installation and operation of the equipment should not be detrimental to the performance of the aircraft except as necessitated by the additional power consumption and weight.

The National Bureau of Standards decided to investigate the practicality of using phosphorescent materials on the blade tips and activating them from an ultraviolet light source located on the fuselage of the aircraft. A UV filter located on the underside of each tip would permit the UV light to pass through and activate a phosphorescent-coated plastic panel located on the top of each tip; the purpose of the filter was to prevent the activated phosphor from being seen in the lower hemisphere. The UV source would be installed in such a manner that the phosphorescent materials would sweep through its beam once per revolution. The phosphor would retain a considerable portion of its luminance until again passing through the beam thus generating a ring of light. Initial tests on laboratory models, as well as later flight demonstrations indicated such a system to be practical. A procurement specification was

prepared and the department of the Navy issued a contract to an aircraft lighting company for final engineering of the system. The progress of the work done by the company receiving the contract has been followed closely and the difficulties encountered in their efforts to design a suitable lightweight ultraviolet light source prompted the National Bureau of Standards to seek an alternate method of solving the blade-tip lighting problem.

Described in this report is a lighting system, conceived by the National Bureau of Standards, which appears to offer several advantages over the ultraviolet-phosphorescent method. In this system the light on each blade tip consists of small incandescent lamps embedded in clear plastic and powered by an air-driven generator in each tip.

II. Design and Construction.

The air driven generator system, as conceived, consists of four component parts or assemblies. 1) Light source, 2) Generator and impeller, 3) Light switching circuit, 4) Device for supplying the switching circuit signal. At the present time only the light source, and generator and impeller have been investigated. The approach has been to determine if sufficient light could be obtained by using small incandescent lamps, and further, to determine if the lamps and generators could withstand the acceleration encountered when installed in the tips of the rotor blades. It was thought that these parameters should be resolved first, after which attention could be directed to devising a method of remotely switching the lamps on and off and of mechanically locking the generator armature for those flights when the lights are not required.

Construction of the equipment is as follows. The light source consists of a 2 1/2" x 5 1/2" x 3/16" clear plastic panel in which are embedded four Type 680 incandescent lamps. A 1/4 inch border is milled around the periphery of the panel to allow flush fitting into a 2" x 5" window opening cut in the blade tip. The underside of the panel is painted white to reflect the incident light flux out of the top. The lamps are equally spaced along the panel and their filament leads are soldered to two wire conductors which are recessed in the back of the panel and which terminate at one end of the fixture with machine screws to accept the generator leads. The type 680 lamp was selected because of its small size and long life. It has a size T-1 bulb, a C-2R filament, and wire terminal leads. It is rated at 5 volts, 0.060 amperes and when operated at this voltage the luminous output is about 0.04 spherical candle.

Present plans are to operate the lamps at about 8.0 volts, at which the output is about 0.3 spherical candle each. A total of 16 lamps (four per blade) are used on each helicopter. Assuming losses due to stray light, absorption, reflectance and transmittance in the assembly to be about 50%, this would produce about 30 lumens of flux in the ring of light. Accelerated life tests conducted at the National Bureau of Standards indicate that the life of the type 680 lamps when operated at 8.0 volts would exceed 5000 hours.

Alternating current generators with permanent magnet rotors were designed and manufactured for this project by the Globe Mfg. Co. Dayton, Ohio. They are designated as part No. AC236541 and are rated at 7.4 volts, 2.5 watts when driven at approximately 9000 revolutions per minute. Each generator weighs about 2 1/4 ounces. They incorporate special thrust bearings selected to withstand the high accelerations which are produced when the mounting position of the generators in the blade tips is such that the acceleration is parallel to the shaft of the generators.

Each generator is driven by a vaned wheel impeller attached to its shaft. The generator is mounted inside the blade-tip of the helicopter in such a manner that the lower vanes of the wheel protrude through an opening in the under surface of the tip into the air stream. Installation of the light and generator assembly in an early model is shown in Figures 1 and 2. In operation, air impinges on the protruding vanes and drives the generator armature, thus furnishing power for the lamps. Four sets of impellers, the protruding vanes of which differ on each set, have been constructed and evaluated. The impellers were made of aluminum, each variation of which had 12 individual blades. The differences in design were in blade pitch, blade width, or total wheel diameter as follows.

Impeller Type Number	Vane Pitch (angle)	Vane Width (inch)	Impeller Diameter (inches)
1	35°	5/16	1 9/16
2	35°	5/16	1 7/16
3	35°	3/16	1 9/16
4	55°	5/16	1 9/16

Design of the system for remotely switching the lights on and off during flight or for mechanically locking the generators prior to flight has not been completed. However, the plans are to control the lights by means of a static switching circuit

employing transistors and a photoelectric detector. The detector will be installed on the under side of the blade tip and will be activated by an infrared lamp mounted on the tail of the helicopter. Also, a mechanical locking device screwdriver actuated and accessible from the outside of the blade tip, is contemplated for locking the generator during those flights where the lights are not needed.

The generator, its mounting, and the light assembly add about 5 ounces to the weight of each blade tip. Installation of the special switching features is expected to add another 3 ounces.

The sketch in Figure 3 shows an alternate method of generator assembly mounting in which the generator and impeller are enclosed in an open tube through the rotor tip. Present plans are to evaluate this arrangement at a later date.

The HRS type helicopter on which the lighting system will be installed for flight tests has a rotor-blade span of 56 feet. Under normal cruise conditions the blades have a pitch of about 8° and rotate at approximately 220 revolutions per minute. This radial velocity corresponds to about 650 linear feet per second at the tip where the acceleration is approximately 470 G's. For practical purposes the linear speed is considered equivalent to air speed. For this helicopter, the maximum acceleration expected is about 560 G's, corresponding to a rotor speed of 240 RPM. This sometimes occurs when the helicopter is heavily loaded. Under no circumstances is the rotor speed supposed to exceed 258 RPM. For testing purposes, an acceleration of 600 G's was considered the design minimum.

III Test Procedure and Results.

The paragraphs which follow give the procedure and results of tests which have been conducted thus far to determine the feasibility of the lighting system, as well as the ability of some of the components to withstand the rigors of flight.

A) Centrifugal Tests On Lamps.

The incandescent lamps were subjected to centrifugal tests with accelerations up to 1000 G's. The tests were conducted on a 6 inch diameter vertical centrifuge as shown in figure 4. The centrifuge was made of a plastic disc and the lamps under test were installed in small holes which had been drilled in radial directions near the periphery. The mounting of the lamps was such that the terminals were toward the center of rotation. An EMF of 8.0 volts was applied through slip rings and the lamps were alternately energized and deenergized. One group of four lamps were subjected to the acceleration tests as shown below.

Acceleration (G's)	Time Duration of Tests (Hours)	Lamp Burning Cycle (Minutes) ON	OFF
475	1	30	30
575	1	15	15
600	11	15	15
1000	2	15	15

While burning at 8.0 volts, four additional lamps were subjected for 15 minutes to a 600G acceleration. The lamp current was measured before and after this test to determine the effect upon the operational characteristics of the lamps. After each of the above tests, the filaments of the lamps were examined under a microscope for stretch, symmetry, shorted turns, etc.

As expected, the filament coils of the lamps stretched under the high accelerations encountered during the centrifugal test. It is significant, however, that there were no lamp failures. Once the coil makes contact with the glass envelope, further moving and stretching is apparently restricted. Figure 5 is a photograph of the filaments of three lamps after being subjected to the accelerations indicated. For comparison the filament of a lamp which was not tested is also shown. The photograph shows the filaments enlarged about 25 diameters. The four lamps, whose filament coils were measured before and after the centrifugal tests, showed a residual increase in length averaging 0.02 inch as measured from the filament supports to the apex of the coil. Before the test the average length was 0.061 inch as compared to 0.081 inch after the test. Filament current at the same time increased from an average of 0.079 ampere per lamp to 0.082 ampere. This slight increase in current is not considered serious.

B) <u>Wind Tunnel Tests.</u>

Wind tunnel tests were conducted to determine the generator's load voltage as a function of wind speed when driven with a certain impeller configuration. The impeller used is listed as No. 1 in the table showing differences in impellers; it had a diameter of 1 9/16 inches, a width of 5/16 inch, and a vane angle of 35° with respect to a plane parallel to its mounting axis. Voltage measurements were made with the blade tip at zero pitch(feathered condition) and at a 10° pitch simulating a loaded helicopter during flight.

Results of the wind tunnel test, where generator load voltage was measured as a function of air speed are shown in Figure 6. The highest wind velocity that could be obtained in the tunnel was 265 feet per second which is less than half the 650 feet per

second tip speed of the helicopter while cruising. The results indicated, barring turbulence etc, that the speed of the generators when mounted on the helicopter would be too high if driven by impellers of this design.

C) Helicopter Ground Test.

Two blade tips equipped with lights and generators were installed on an HRS type helicopter for a ground-spin feasibility test. The impellers on the generators were of the same type or those which were used during the wind tunnel tests. Visual observations of the ring of light were made while the rotor blades were being rotated at various speeds up to 190 revolutions per minute.

Figure 7 shows the ring of light photographed from a position about 15° above the helicopter and approximately 70° to the starboard. The regular position lights are shown inside the ring. The opinion of the observers (Marine Pilots and NBS lighting personnel) was that the ring was too bright for close formation flying. With a complete set of four lights and the cruising-speed rotation of about 220 rpm the ring would be much brighter. This ground test substantiated the opinion reached during the wind-tunnel tests, that the speed of the generators should be reduced.

D) Impeller Selection Tests.

The four different variations of impellers described in the Design and Construction section of this report were fabricated for the purpose of determining which type would drive the generators nearest to the speed which would provide the desired voltage. The facilities of the Sikorsky Aircraft Co., Bridgeport, Conn. were used for the tests. Four blade tips were equipped with the air-driven-generator light system. All of the assemblies were identical except that the generator in each was driven by an impeller of different design. The tips were mounted on regular HRS helicopter blades which were installed on the production blade-testing stand and were rotated at various rotor speeds and angles of pitch while the voltages from each generator was monitored.

Of the four impeller designs which were tested to determine the best type suited to drive the generators, #3 type (the one with the narrowest vanes) was selected. The generators equipped with the other type impellers gave voltages much too high, indicating excessive generator speed. The performance data of the type selected is given in Figure 8, The highest rotor-blade speed that could be obtained on the test stand was 190 RPM.

Examination of the figure shows that approximately 7.8 volts is obtained at this speed when the pitch of the helicopter rotor blades is 8°. Extrapolation of the curve indicates that with the same rotor blade pitch, and rotating at the cruising speed of 220 RPM, about 10 volts would be obtained.

Light assemblies equipped with the selected type of impeller (#3) were installed on all of the rotor blades on the test stand, and brightness measurements were made of the ring of light while the blades were rotated at 190 rpm (the highest speed obtainable with the test stand). It should be pointed out that the rotor test facility had only three blades, whereas the HRS type helicopter on which the light assemblies will eventually be installed has four blades.

The brightness of the ring of light as measured with a Luckiesch-Taylor brightness meter at the 190 rpm speed and 8° pitch was of the order of 1 footlambert. With the lighting units on four blades rotating at the cruising speed of 220 rpm, the brightness will be about 2 footlamberts. If evaluations during flight tests indicate that this brightness is excessive impellers with narrower vanes will be fabricated and installed to decrease the Generator speed. The dimming could be accomplished by placing resistors in the lighting circuit, but a reduction in speed should increase the life of the generators.

IV. Present Status.

The construction of a complete set of four blade tips equipped with the air driven generator powered lights has been completed and sent to the Sikorsky Aircraft Company for dynamic balancing and for airworthiness tests. Upon completion of this work, comparative flight evaluation tests between this system and the UV-phosphorescent system being built by the Grimes Mfg. Co., will be conducted at the U. S. Marine Corps Schools, Quantico, Virginia.

V. Remarks.

We wish to express appreciation to the HMX-1 Projects personnel of the U. S. Marine Corps Schools for the continuous cooperation and assistance they have extended throughout this program; and also to the Sikorsky Aircraft Company for the use of its test facilities.

View of Helicopter Blade Tip Showing
Installation of Impeller, Generator
and Light Panel in Early Model

Figure 1

Exterior View Showing Typical
Installation of Light Panel
In Helicopter Blade Tip

NBS Report 6555 Figure 2

AIR-DRIVEN GENERATOR IN HELICOPTER BLADE TIP

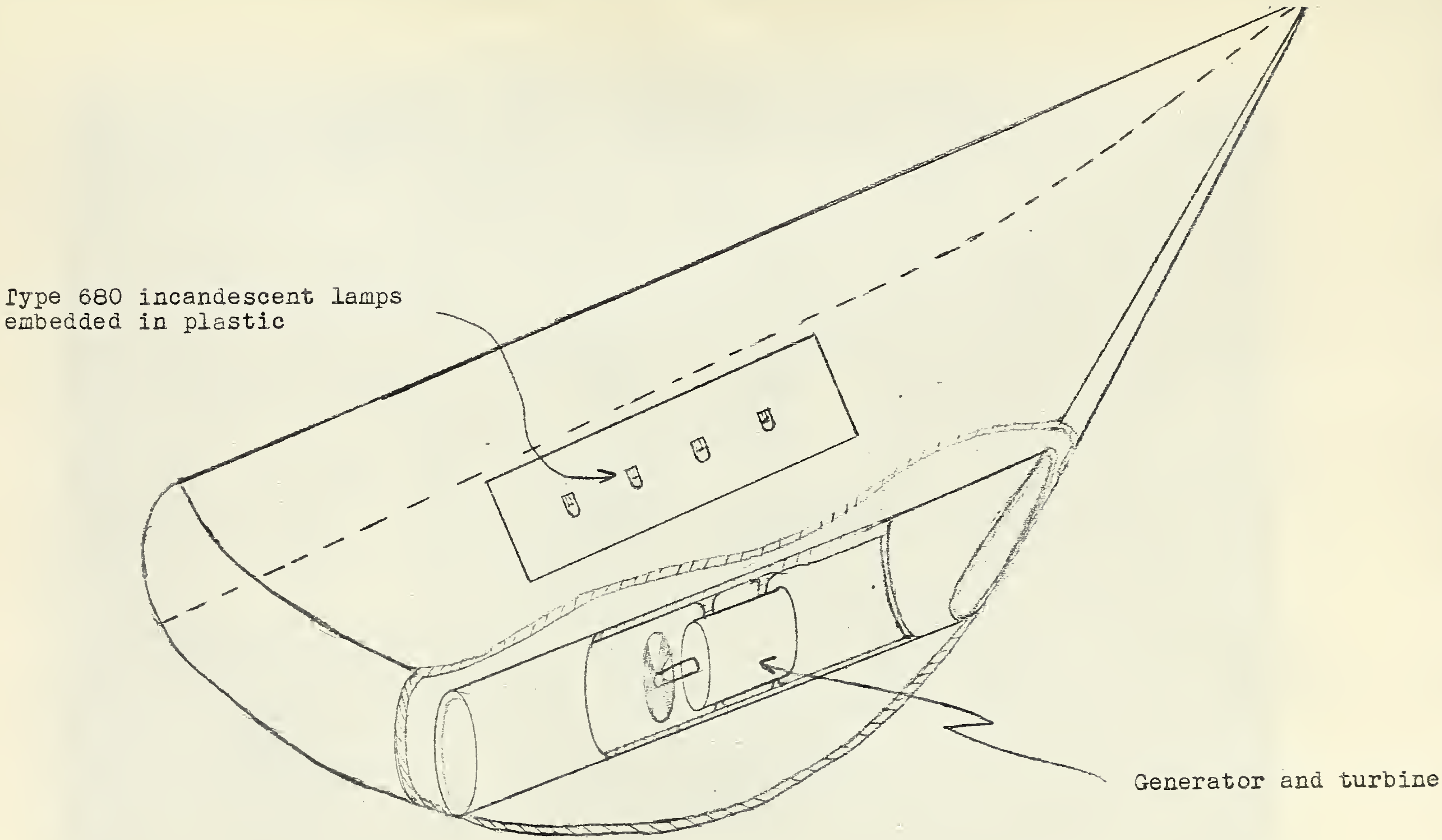

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Figure 5

Six Inch Vertical Centrifuge
On Which The Type 68C Lamps Were Tested

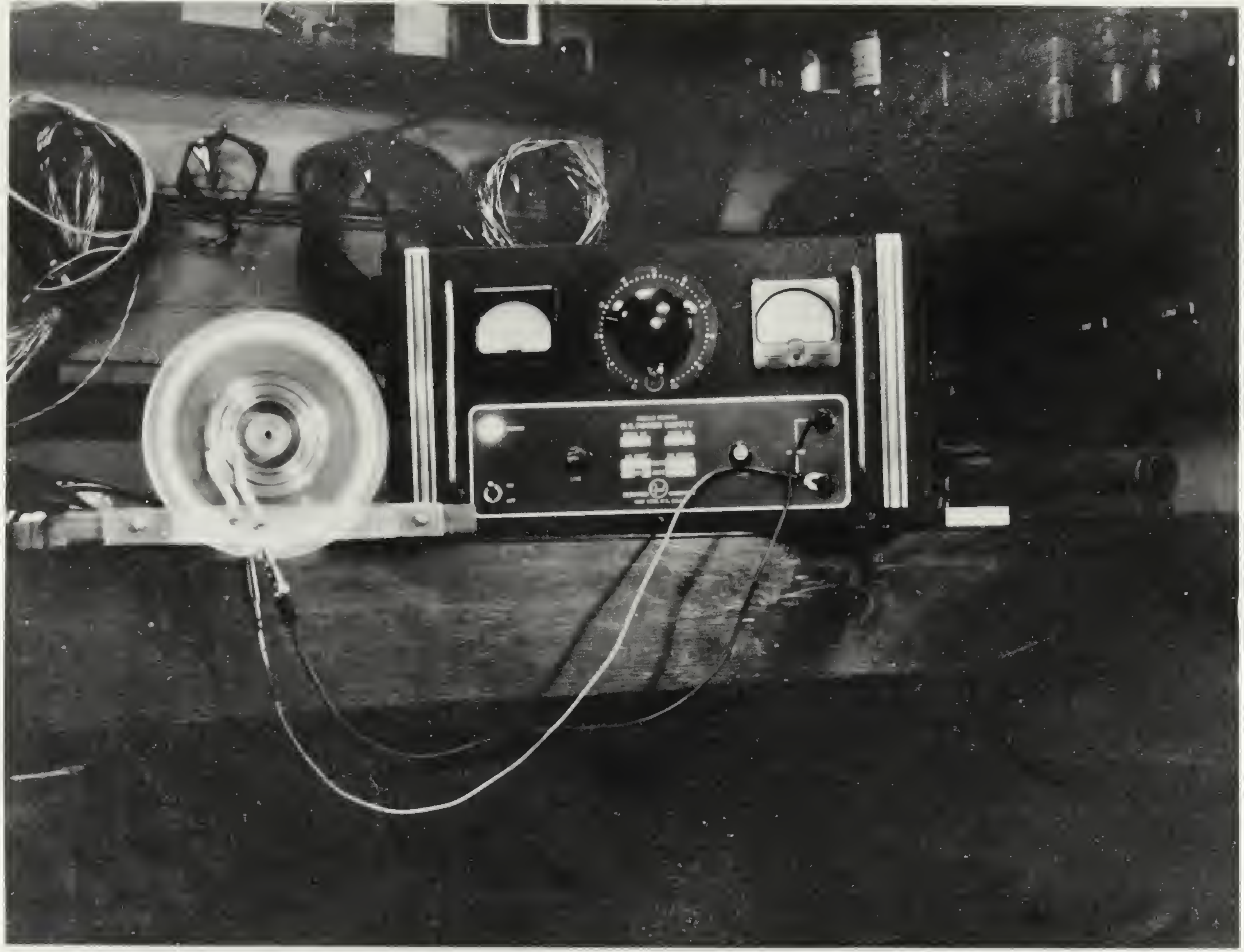
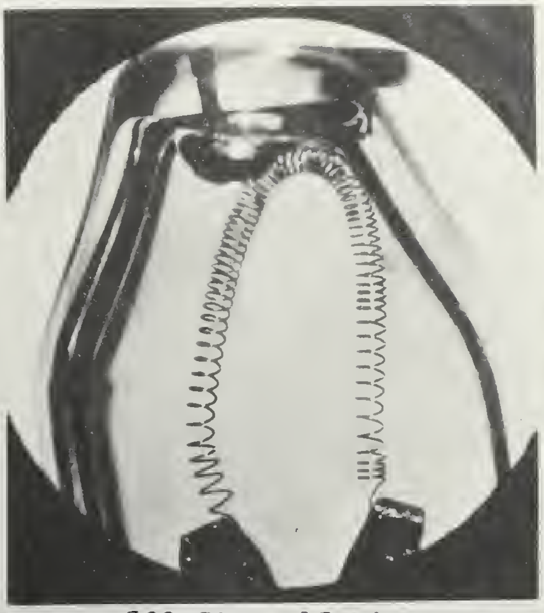


Figure 4

600 G's---15 Min.
Lamp Operating At 8.0 Volts



500 G's---15 Min.
Lamp Operating At 8.0 Volts

FILAMENTS SHOWN ENLARGED 25 TIMES

(Photographs taken after completion of tests)

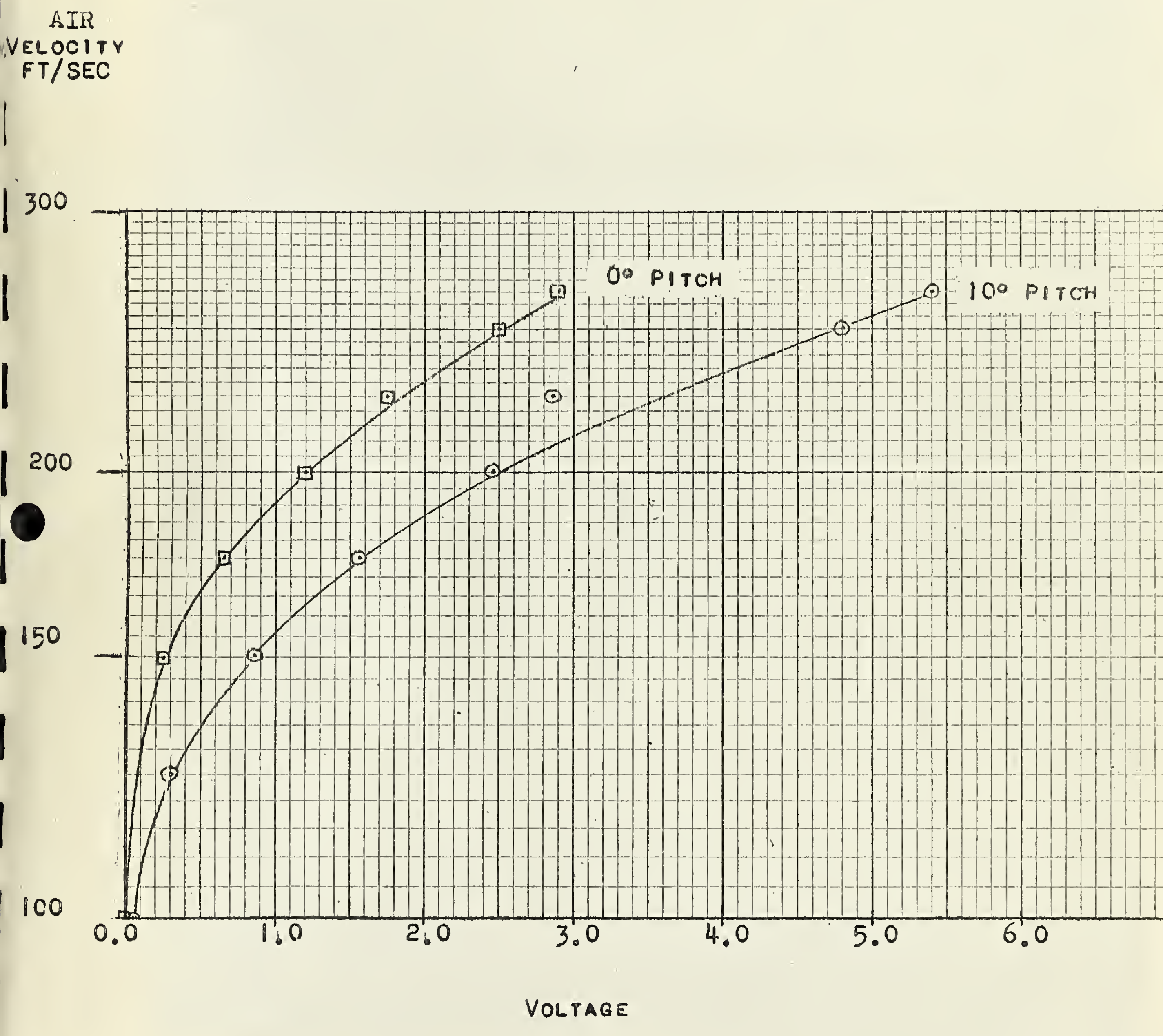
Not Tested

600 G's---11 Hours
1000 G's----2 Hours
Cycle-15 Min. "ON" 15 Min. "OFF"

Effects of Acceleration on Filaments
Of Type 680 Incandescent Lamps

VOLTAGE DEVELOPED ACROSS LAMPS AS A FUNCTION OF AIR VELOCITY
AND
HELICOPTER ROTOR-BLADE PITCH

(IMPELLER No. 1)



Light Ring Generated By Helicopter Blade Tip Lights
The Three Center Lights Are The Regular Helicopter Position Lights

NBS Report 6835 Figure 7

VOLTAGE DEVELOPED ACROSS LAMPS AS A FUNCTION OF PITCH
AND
R.P.M. OF THE HELICOPTER ROTOR BLADES

(Impeller No. 3)

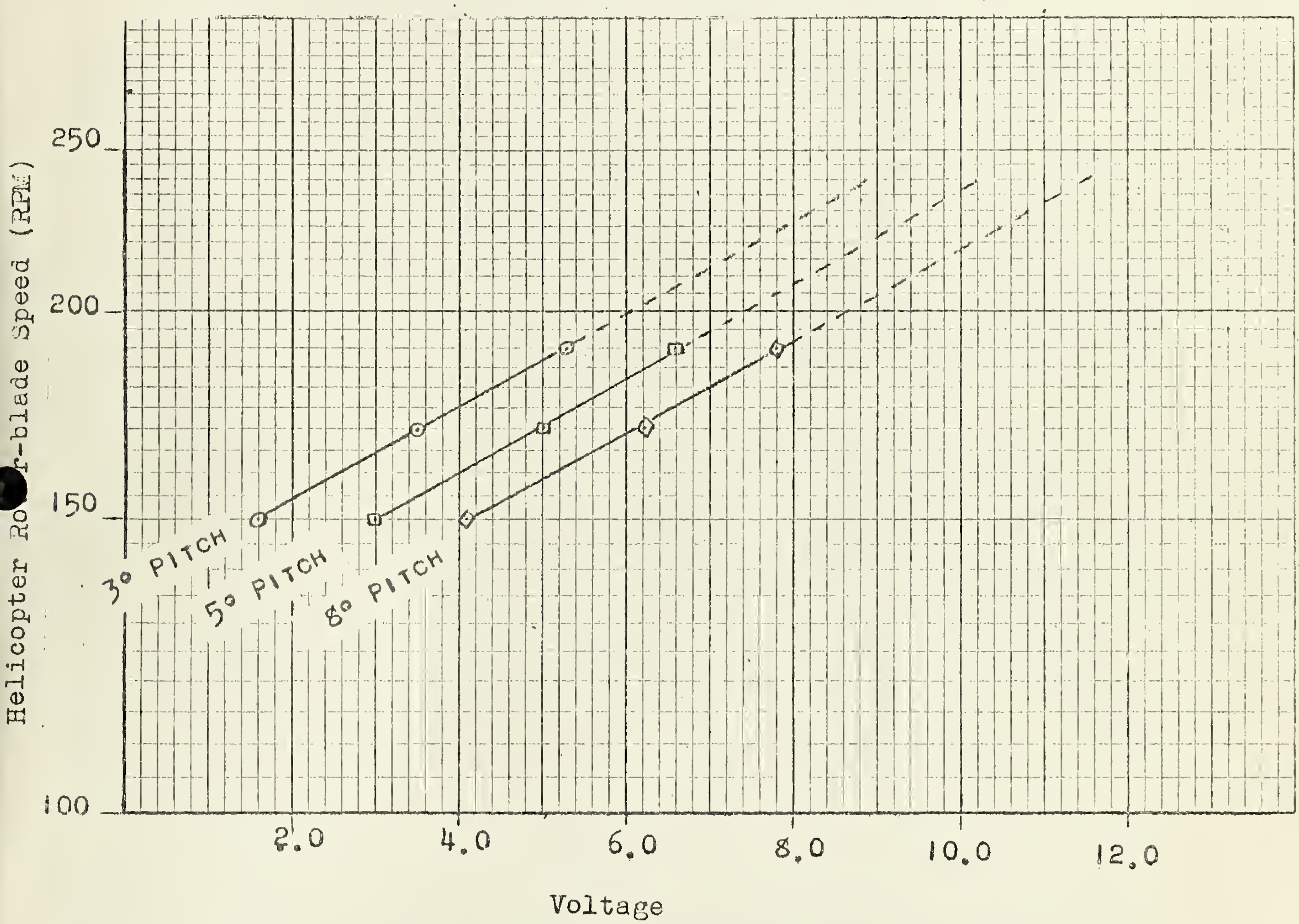


Figure 8

U.S. DEPARTMENT OF COMMERCE
Frederick H. Mueller, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colo., is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D.C.

ELECTRICITY. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics.

METROLOGY. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

HEAT. Temperature Physics. Heat Measurements. Cryogenic Physics. Rheology. Molecular Kinetics. Free Radicals Research. Equation of State. Statistical Physics. Molecular Spectroscopy.

RADIATION PHYSICS. X-Ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

CHEMISTRY. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

MECHANICS. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Combustion Controls.

ORGANIC AND FIBROUS MATERIALS. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.

METALLURGY. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

MINERAL PRODUCTS. Engineering Ceramics. Glass. Refractories. Enameled Metals. Constitution and Microstructure.

BUILDING RESEARCH. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials.

APPLIED MATHEMATICS. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

DATA PROCESSING SYSTEMS. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Applications Engineering.

ATOMIC PHYSICS. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics.

INSTRUMENTATION. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Office of Weights and Measures.

BOULDER, COLO.

CRYOGENIC ENGINEERING. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

IONOSPHERE RESEARCH AND PROPAGATION. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services.

RADIO PROPAGATION ENGINEERING. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

RADIO STANDARDS. High frequency Electrical Standards. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time Standards. Electronic Calibration Center. Millimeter-Wave Research. Microwave Circuit Standards.

RADIO SYSTEMS. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems. Space Telecommunications.

UPPER ATMOSPHERE AND SPACE PHYSICS. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

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