NAVY DEPARTMENT
DAVID TAYLOR MODEL BASIN
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PHOTOGRAPHIC METHODS OF OBSERVATION AT THE DAVID TAYLOR MODEL BASIN

PART 3

A COMPARISON OF TWO PHOTOGRAPHIC FLASH LAMPS USED IN PHOTOGRAPHING OBJECTS MOVING AT VERY HIGH SPEEDS

by

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PERSONNEL

The tests described in this report were performed by F.B. Kaye with the assistance of C.H. Johnson. The report was written by Mr. Kaye.

FOREWORD

This is the third report of a series in preparation to make available to other experimental and research activities the results of developments at the David Taylor Model Basin in the photographic recording of technical data.

PHOTOGRAPHIC METHODS OF OBSERVATION AT THE DAVID TAYLOR MODEL BASIN

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ABSTRACT

A comparison is made of the photographic characteristics of two flash lamps, the General Electric Photolight and the General Radio Microflash, designed to provide a light flash of short duration and high intensity so that rapidly moving objects can be photographed. The characteristics studied are the maximum lamp-to-subject distance at which photographs of equal areas may be obtained in air, the maximum velocity of a moving object which may be photographed without excessive blur, and the quality of photographs made under water.

In photographing a subject from a given distance both lamps are considered to be equal in performance. The General Radio Microflash has one-half the light duration of the General Electric Photolight; therefore, it produces photographs of rapidly moving objects with less blur. It is considered inadvisable to attempt to photograph underwater subjects more than 1 foot in diameter and at a lamp-to-subject distance of more than 8.5 feet with either lamp.

INTRODUCTION

The study of objects in motion frequently requires some means of actually observing the rapidly moving parts. When illumination is supplied by a light flash of short duration and high intensity, photographs can often be obtained in which the moving object appears to be stationary. For these photographs, the shutter is opened before the flash occurs and is left open, so that the duration of the flash, and not the shutter speed, is a measure of the exposure. The quantity of light is determined by the intensity of the flash and by the diaphragm opening.

The David Taylor Model Basin has used two commercially available flash lamps which were designed for high-speed photography. These lamps produce flashes with a duration of the order of microseconds. It is the purpose of this report to compare the photographic performance of these two lamps.

A systematic study was made in which the following factors were measured and compared:

1. The maximum lamp-to-subject distance at which photographs of equal areas may be obtained in the air when the camera-to-subject distance is constant.

2. The maximum velocity of any object which may be photographed without excessive blur.

3. The photographic characteristics of the lamps when used for underwater photography. Information was obtained on camera-to-subject and lamp-to-subject distances at which photographs can be obtained with equal and acceptable overlayers of water haze.

The literature furnished by the manufacturers of the equipment lacked definite information on these performance factors and advocated tests to establish the capabilities and limitations of their respective products.

For the benefit of other activities who may wish to avail themselves of the new devices, the two lamps are described briefly in this report.*

Figure 1a - Front View of Photolight Showing the High-Pressure Mercury-Vapor Tube in Its Reflector

The Photolight is approximately 15 inches long, 10 1/2 inches wide, and 10 3/4 inches high and weighs 33 pounds.

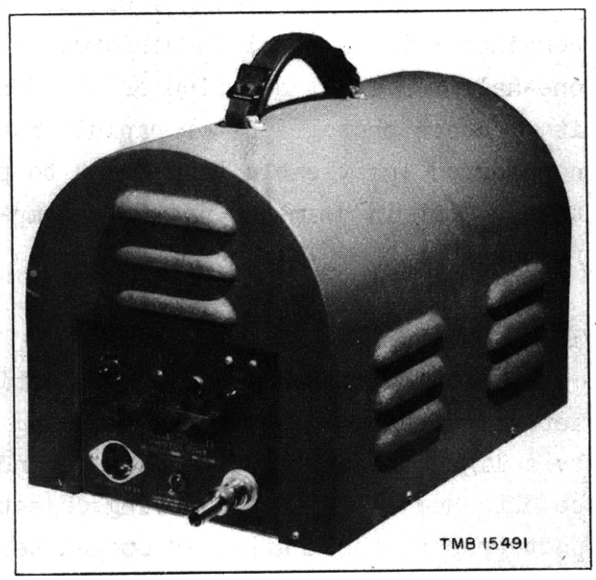

Figure 1b - Rear View of Photolight Showing the Operating Panel

On the left of the bottom row is the power input plug, in the center is the power switch, and on the right is the microphone trip input plug. In the center row of terminals are miscellaneous external wire contacts. On the left of the top row is a sensitivity switch for use with a microphone trip, in the center are two indicator lights, and on the right is a flash push button.

Figure 1 - General Electric Photolight

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* Further information on this equipment can be obtained from the manufacturers.

COMMERCIAL UNITS TESTED

The General Electric Photolight (1)* and the General Radio Microflash (2) are the lamps discussed in this report.

The General Electric Photolight is shown in Figure 1. The flash-lamp reflector, power supply, and controls are housed in one metal case. The flash lamp, a high-pressure mercury-vapor tube, General Electric Type A-H6, is housed at the opposite end of the case from the operating panel. The operating panel contains a power input socket, power switch, microphone trip connection and sensitivity switch, flash button, and indicator lamp. The power requirements of the Photolight are 60 watts at 110 to 120 volts, 60-cycle alternating current.

The General Radio unit, Type P-509, shown in Figure 2, is called a "Microflash." The power- and lamp-assemblies of the Microflash, while separate, are designed to fit together as one unit.

The power requirements are 50 watts at 110 to 120 volts, 60-cycle alternating current.

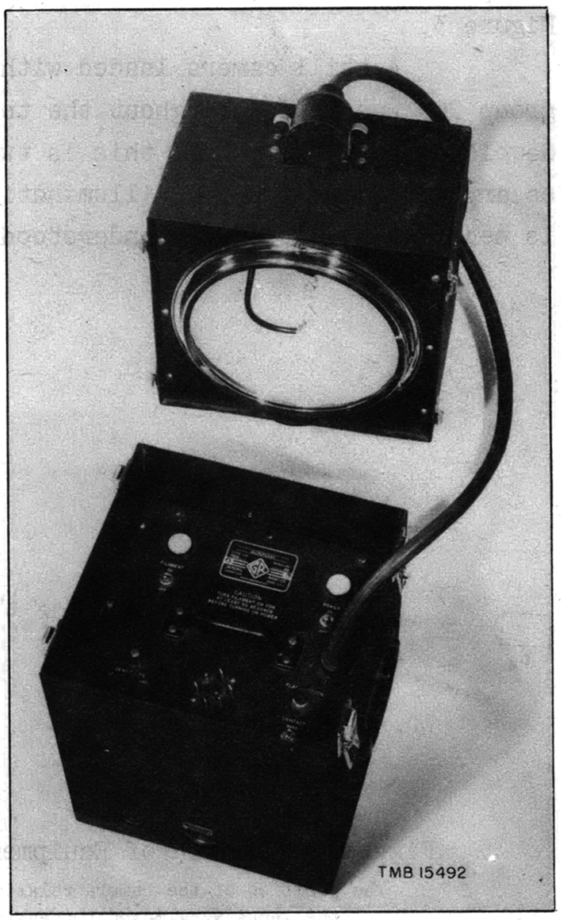

Figure 2 - General Radio Microflash Showing the Lamp Assembly and the Power Assembly

In the lamp assembly, the upper unit in this view, can be seen the argon flash tube in the reflector, the electric connection to the tube, and the cable connection on the top of the case.

On the lower front edge of the power assembly, the lower unit, can be seen the external connections. On the left is the microphone trip socket, in the center is the power input socket, and on the right is the plug for a remote-control cable.

The operating panel is shown on the top of the power assembly. Located in the upper left are the filament switch and its indicator light. To the right is the power switch with its indicator light. At the lower left is the sensitivity switch above which is the safety fuse. At the lower center is a dummy plug for securing the lamp cable when the unit is in transit. At the lower right is the selector switch for make-or-break firing circuits. Above this switch is the manually operated flash button.

The two units are connected by a 3-wire cable 7 feet long which is permanently connected to the power assembly and is plugged into the lamp.

The lamp assembly is 12 inches high, 12 inches wide, and 8 inches deep and weighs 20 pounds. The power assembly is 14 1/2 inches high, 12 inches wide, and 12 inches deep and weighs 50 pounds. When assembled, the entire unit weighs 70 pounds and is 22 1/2 inches high, 12 inches wide, and 12 inches deep.

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* Numbers in parentheses indicate references on page 15 of this report.

TEST SETUP AND PROCEDURE

Since there was no standard test equipment for measuring the factors desired, it was necessary to devise means for obtaining this information.

MEASUREMENT OF LAMP-TO-SUBJECT DISTANCE

Before proceeding with the first requirement of these tests, that of establishing the maximum distance from a subject at which the lamps are photographically effective, it was necessary to arrive at some specific distance at which the lamps would give satisfactory exposures.

Sensitometric studies were first undertaken to determine the lamp-to-subject distance at which a correctly exposed negative could be made.

To determine this distance a photographic gray scale was used as the subject. The gray scale consisted of a series of 10 photographic-paper prints. Each print covered an area of 1 square inch and was made up of decreasing steps of reflection density from black to white, each step reflecting approximately one-half the density of the preceding one.

The setup of the equipment for the sensitometric test is shown in Figure 3.

A still camera loaded with Agfa SSS Panchromatic film in speed group 200 was used throughout the test. The film was developed in Agfa 47 developer for 20 minutes; this is twice the prescribed developing time necessary for other types of illumination. Why the increased developing time is necessary is not fully understood, but it is believed that the blueness

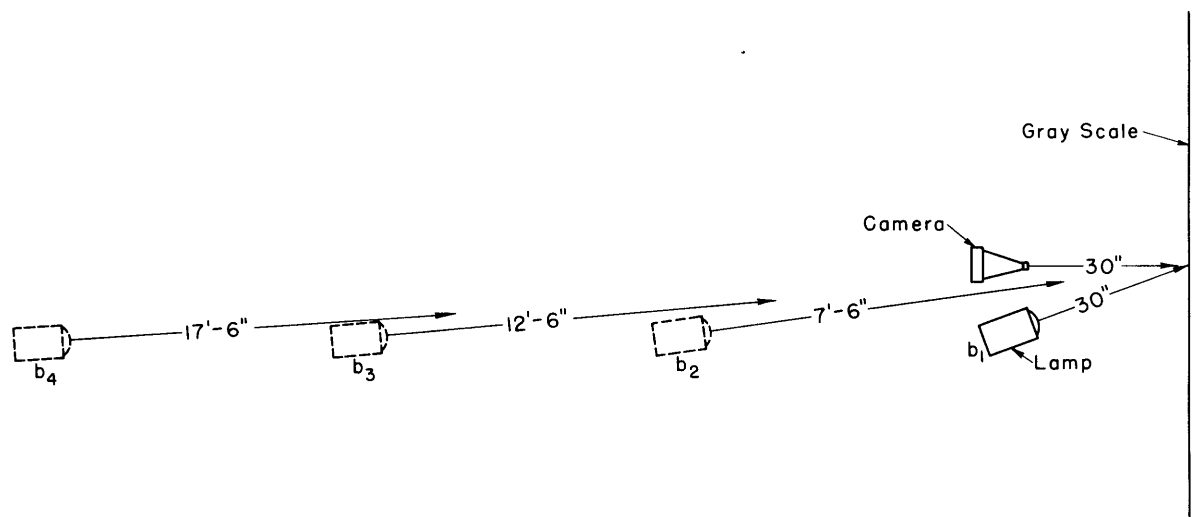

Figure 3 - Sketch of Equipment Setup for Sensitometric Tests

The position of the camera relative to the gray scale remained constant; the lamps were moved successively to the stations b_1, b_2, b_3, and b_4, where the exposures were made.

of the light is responsible. This belief is substantiated by the fact that, when using a C5 blue filter in color work, additional time is required to develop the negative.

In the tests to determine the area covered by the lamps, a piece of white paper 13 feet long and 6 feet high was fastened to a vertical wall; on the paper were drawn, with black crayon, 8 concentric circles with diameters progressively increasing by 1 foot. The smallest circle was 1 foot in diameter, and the largest circle was 8 feet in diameter.

The lamps were placed on a tripod 8 feet from the center of the circular target, as shown in Figure 4. To ensure equal processing of the films exposed by the two lamps, two exposures were made on one film, one exposure by each lamp. This was accomplished by covering one-half of the film in the camera while the other half was being exposed; the process was then reversed, and the previously protected half of the film was exposed by the other lamp. In this way comparable results from both lamps were ensured.

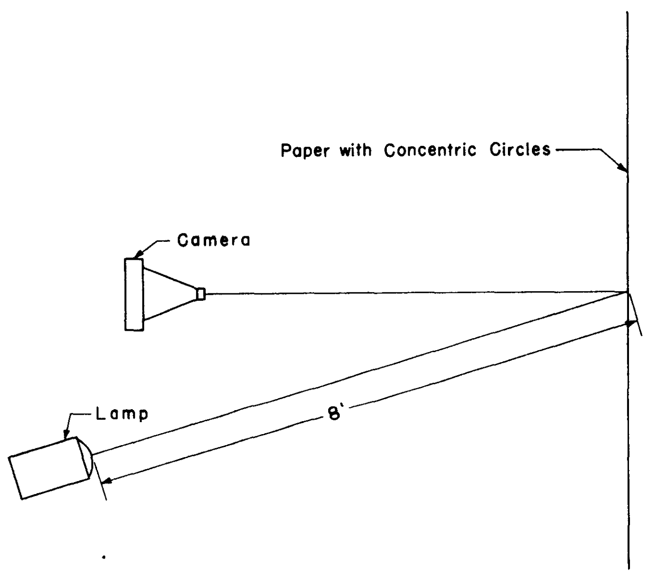

Figure 4 - Diagram of Equipment Setup for Lamp-Coverage Tests

VELOCITY TESTS

For the tests to determine the maximum velocity at which a moving object may be photographed without excessive blur, a subject having a high, controllable velocity was required. Several types of objects illustrating high-velocity motion were considered, such as rifle bullets, acoustic waves in water and in air, and cracks propagating in glass. A 10,000-RPM 1-HP motor, available in the laboratory, was selected for the experiment. A metal disk 12 inches in diameter and of thickness varying from 1/2 inch at the hub to 1/8 inch at the outer rim was attached to the motor shaft. At 10 stations equally spaced around the disk were 10 white-ink lines, starting at the rim and extending approximately 1 inch radially toward the center of the disk as shown in Figure 5. Figure 6 shows the setup of the camera, the flash lamp, the Strobotac, and the motor and disk used in the velocity tests. The Strobotac was used to determine the speed at which the disk was rotating. Since very little motion was anticipated, full-size film images of the lines were made and were enlarged 10 diameters so that movement could be more readily detected.

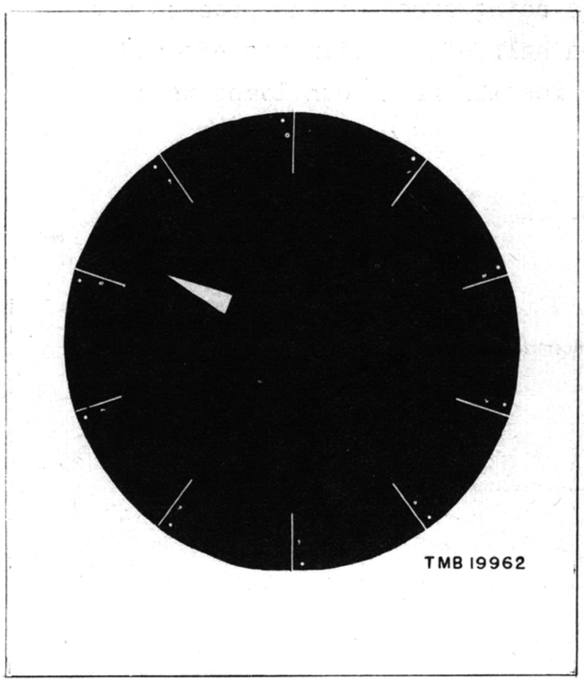

Figure 5a - Photograph of Steel Disk

There are 10 equally spaced ruled lines, which are numbered for purposes of identification; see the photograph at the right.

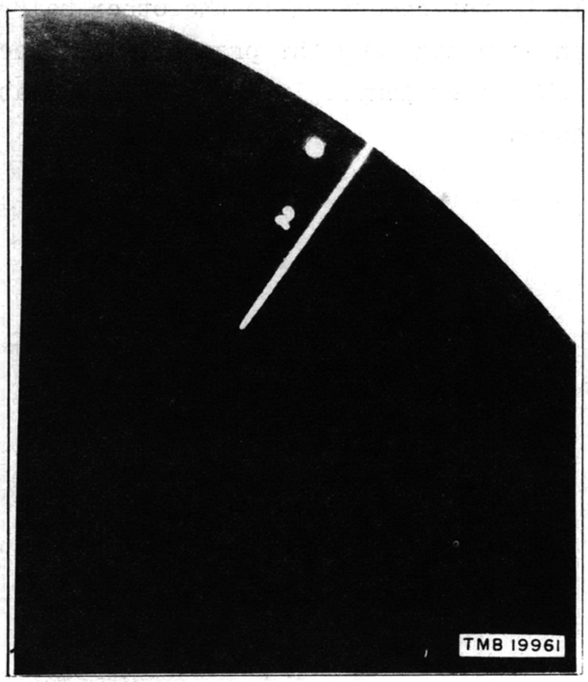

Figure 5b - Sectional View of Disk Showing Detail of Lines

Figure 5 - Revolving Steel Disk Used in Velocity Tests of Flash Lamps

Preliminary photographs led to the discovery that different diaphragm openings altered the sharpness of the image. Consequently, photographs were taken at various stops until there was just enough image to print. The smallest stop, f/22, was three steps below, or 1/8 of the normal opening.

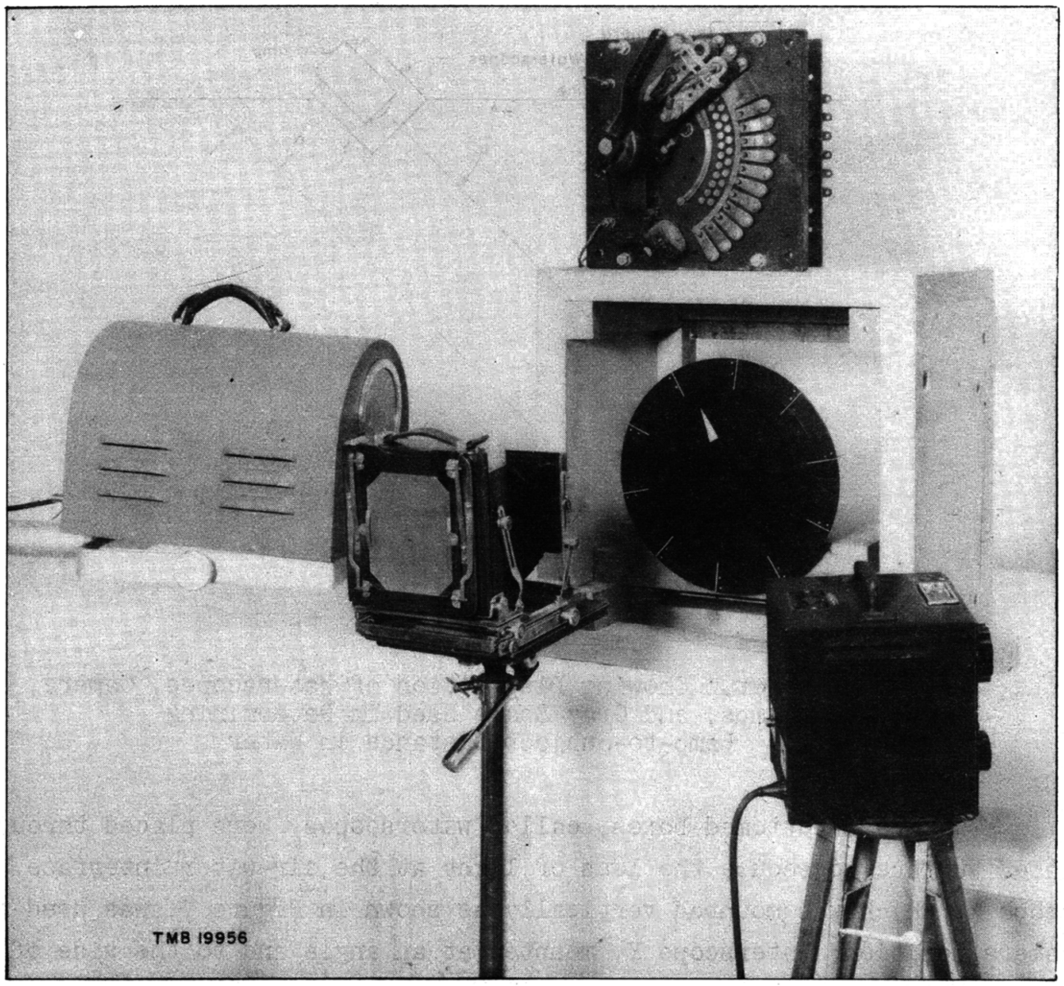

Figure 6 - Equipment Used in Speed Tests

This photograph shows the position of the disk, the rheostat, the Strobotac, the flash lamp, and the camera used in making the speed tests. The disk is mounted on the shaft of the 1-HP motor.

DETERMINATION OF UNDERWATER CHARACTERISTICS

To determine the photographic characteristics of the lamps when used for underwater photography, the setup shown in Figure 7 was used.

A gray scale, similar to that used in the determination of the lamp-to-subject distance in air as previously described, was suspended horizontally under water. When the lamp-to-subject distance at which a correctly exposed negative could be obtained under water had been determined, the gray scale was replaced by a 4- by 5-foot piece of masonite. The masonite was painted flat white and served the same purpose as the paper target on the wall; see Figure 4.

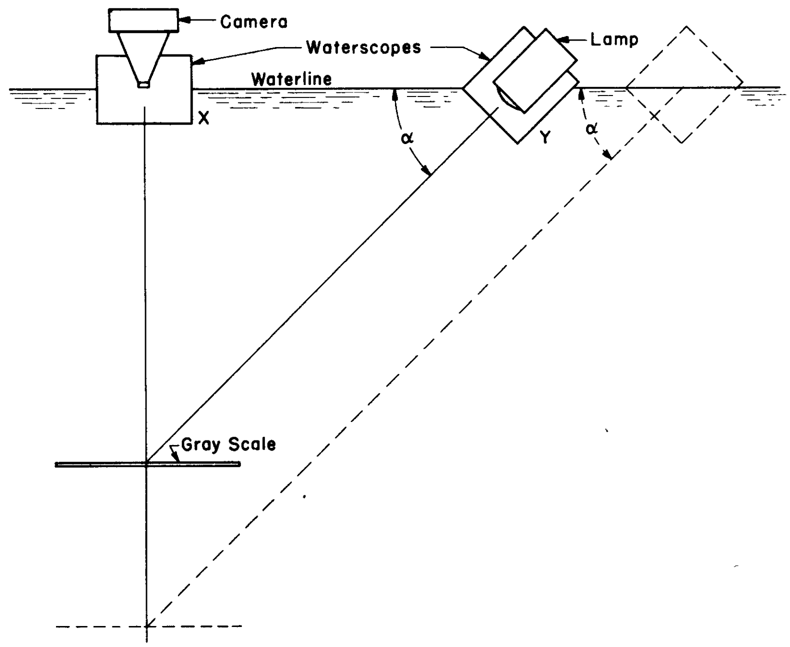

Figure 7 - Setup Showing Disposition of Waterscopes, Camera, Lamps, and Gray Scale Used in Determining Lamp-to-Subject Distance in Water

Glass-bottomed boxes, called waterscopes, were placed through the water surface to reduce the loss of light at the air-water interface. Waterscope X, which was mounted vertically as shown in Figure 7, was used for the camera position; Waterscope Y, mounted at an angle and to the side of the camera waterscope, was used for the lamp.

Waterscope Y was inclined at an angle α so as to allow the lamps to illuminate the gray scale suspended beneath the camera waterscope. The angle α remained constant throughout the tests; the camera-to-subject and lamp-to-subject distances varied.

With a water temperature of 68 degrees fahrenheit, the transmission value of the water was 96. The photographs were made at a lens aperture of f/4.5.

TEST RESULTS AND DISCUSSION

The results obtained in the tests to determine the lamp-to-subject distance, the maximum velocity of moving objects which can be satisfactorily photographed, and the photographic characteristics of the lamps when used for underwater photography are given separately in the following sections.

LAMP-TO-SUBJECT DISTANCE

Figure 8 shows curves derived from the sensitometric data obtained during the tests to determine the maximum distance at which photographs of equal areas can be obtained. Figures 8a and 8b are curves obtained with the two lamps; Figure 8c is the ideal curve which would be obtained from a carefully exposed and processed film. The ideal curve is divided into three parts: AB, the toe or inertia portion which is caused by underexposure; BC, the straight-line portion which is the useful range of the negative; and CD, the shoulder or overexposed portion where density no longer continues to increase by continued processing.

On examining the curve for a lamp distance of 2.5 feet in Figures 8a and 8b, the condition of overexposure can be observed. The 5-foot curve follows the BC or straight-line portion of the characteristic curve and could be considered as having normal exposure. The 10-foot curve embraces part of

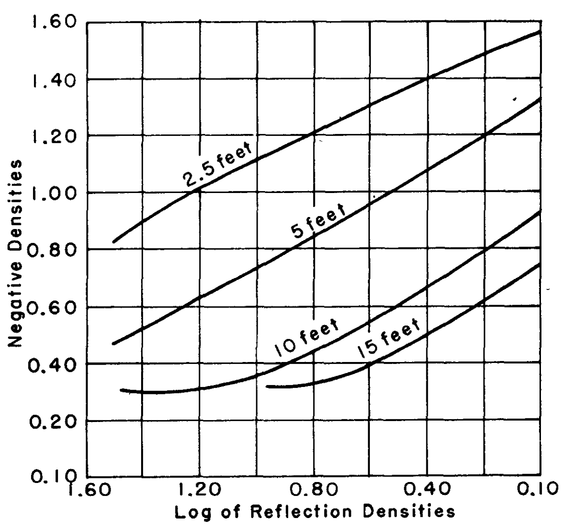

Figure 8a - Data for General Electric Photolight

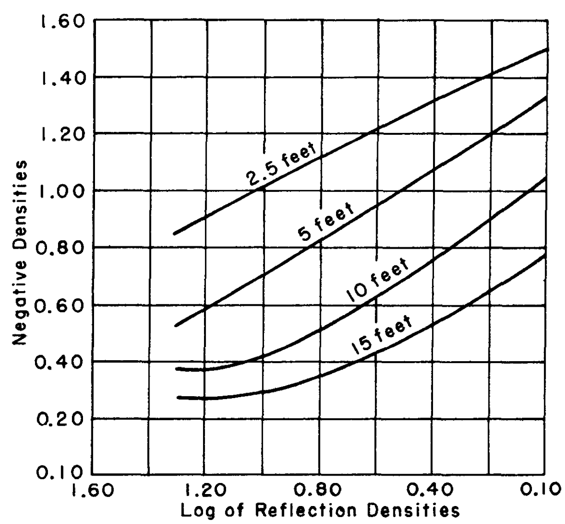

Figure 8b - Data for General Radio Microflash

Figure 8 - Curves Showing Photographic Response of Agfa SSS Panchromatic Film to General Electric and General Radio Lamps

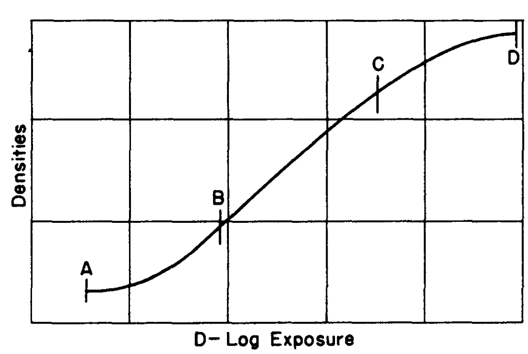

Figure 8c - Characteristic Curve Showing Underexposed Portion AB, Ideally Exposed Portion BC, and Overexposed Portion CD the toe but also a usable part of the BC portion. A negative of this type is acceptable when shadow detail is not so essential. Exposures with the lamp 15 feet from the gray scale produced a curve lying mostly in the AB, or underexposed, region.

Values on which the curves were constructed were obtained by photographing a gray scale of increasing steps; the log of their reflection densities was the horizontal scale of the graph. Transmission densities were used as the vertical scale; these values were determined from the negatives. From these results an exposure factor, or guide number, was determined for the film used.

Figure 9 shows photographs of equal areas illuminated from equal distances by the two lamps. The gray scale seen in the center of the target was a further check on the exposure. The covering powers of the lamps were found to be much greater than expected. The whole length of the paper

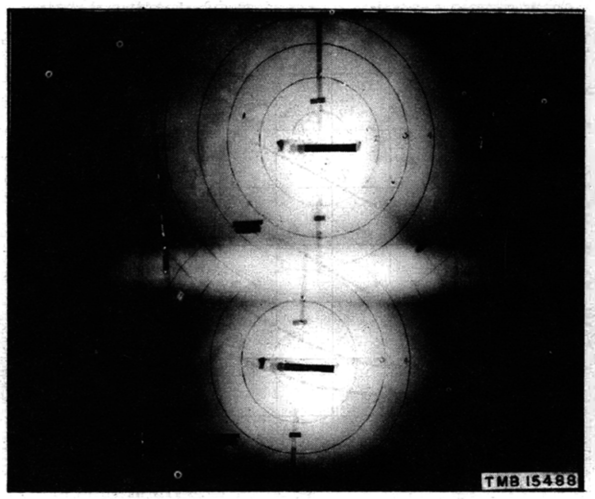

Figure 9a - Without Diffuser

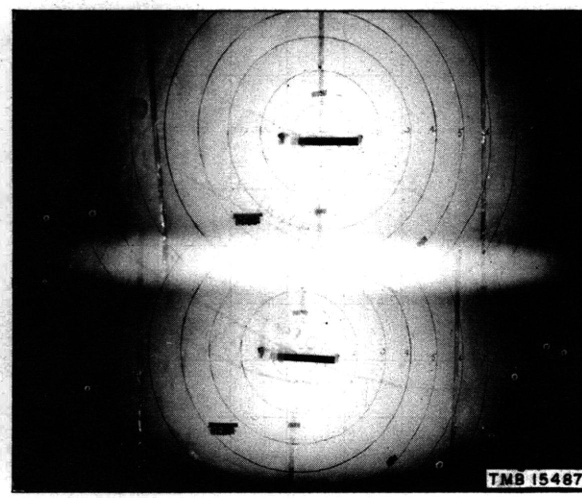

Figure 9b - With Diffuser

Figure 9 - Photographs Showing Results of Coverage Test

In each photograph the upper set of concentric circles shows the spread of the General Electric Photolight and the lower set that of the General Radio Microflash.

The subject area illustrated is a piece of white paper, 6 feet by 13 feet. The 8 concentric circles have diameters progressively increasing from 1 foot to 8 feet.

produced an appreciable density in the negative. By limiting the acceptable density to one-half maximum density, which occurred in the central or 1-foot circle, it was found that the area covered by the 8-foot circle was acceptable.

This conclusion may not be assumed to cover all classes of subject. In this test the paper, although white, did not reflect 100 per cent of the incident light.

To illustrate, two subjects were selected for a practical test, the results of which are shown in Figures 10 and 11. Each of these subjects was photographed with both lamps. Figures 10a and 11a show a piece of machinery having some dark areas, Figures 10b and 11b a similar subject painted with aluminum paint. The effect of subject brightness is apparent. No reflected light was redirected to the subject in these photographs.

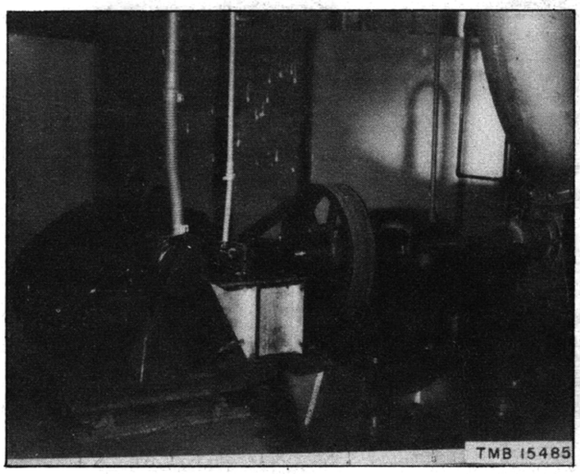

Figure 10a
The subject photographed was of a dark color, lacking contrast and light reflective surfaces.

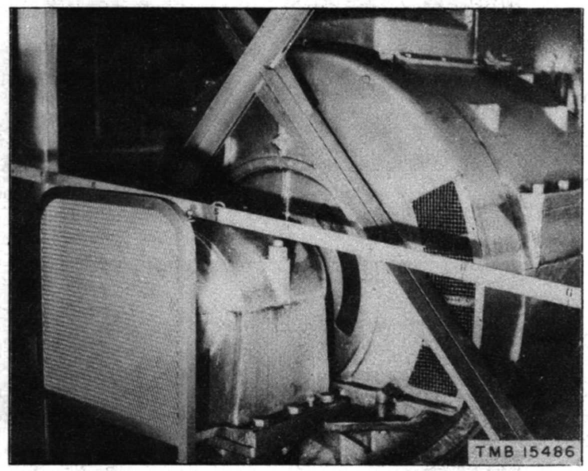

Figure 10b
The subject was painted with aluminum paint which is highly reflective.

Figure 10 - Practical Test of Subject Brightness with General Electric Photolight

For both photographs the lamp was 8 feet from the subject. The scale shown is in feet.

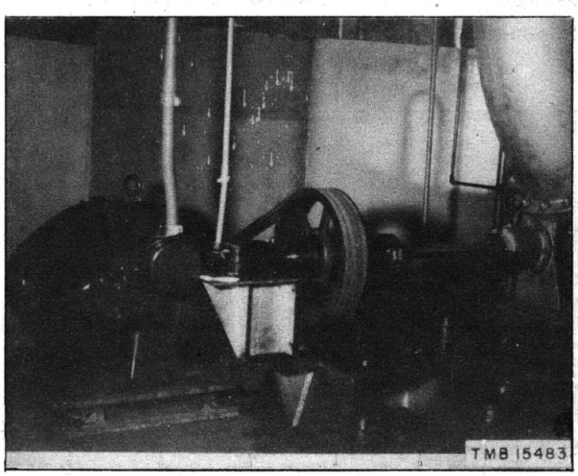

Figure 11a
The subject photographed was of a dark color, lacking contrast and light reflective surfaces.

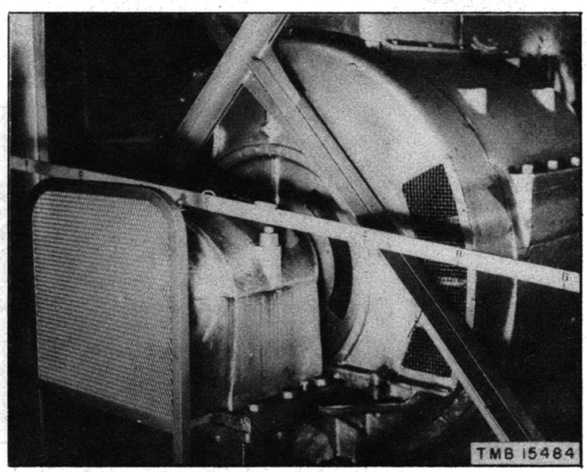

Figure 11b
The subject was painted with aluminum paint which is highly reflective.

Figure 11 - Practical Test of Subject Brightness with General Radio Microflash

For both photographs the lamp was 8 feet from the subject. The scale shown is in feet.

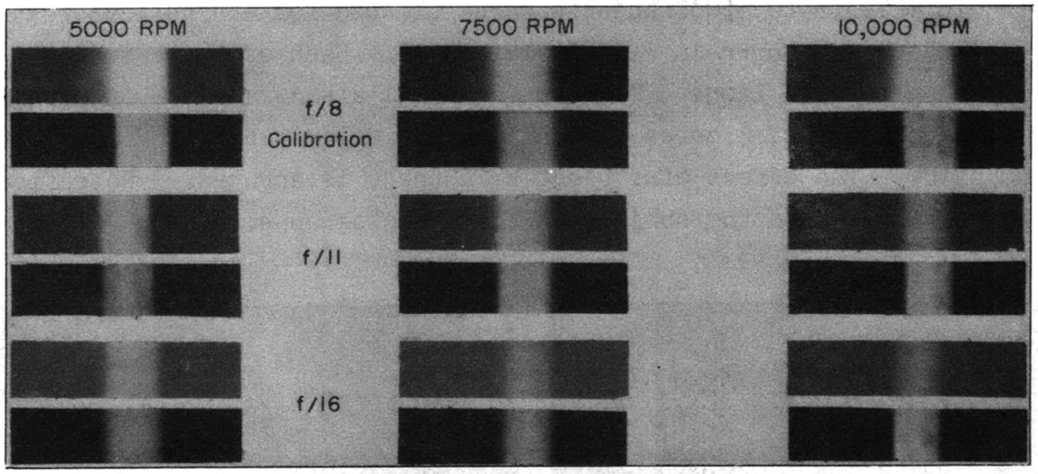

Figure 12a - Photographs Obtained with General Radio Microflash

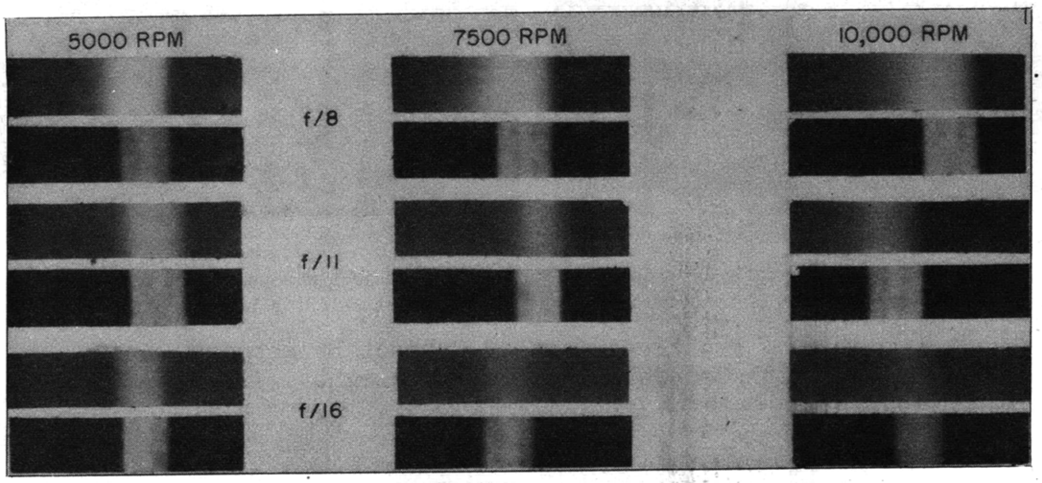

Figure 12b - Photographs Obtained with General Electric Photolight

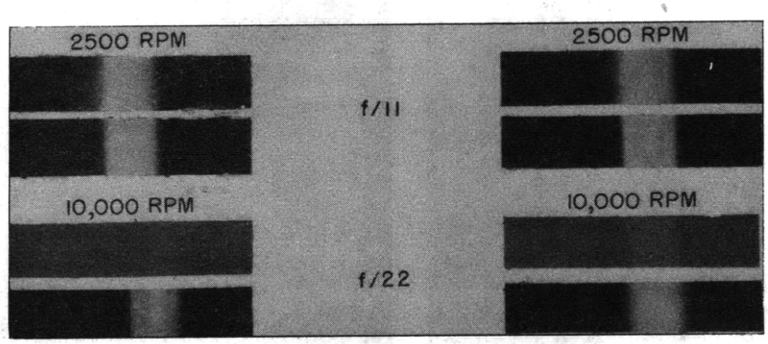

Figure 12c - Comparison of Photographs Obtained with the Two Lamps
The photographs in the left-hand group were obtained with the General Electric Photolight, those in the right-hand group with the General Radio Microflash.

Figure 12 - Enlarged Portions of Photographs of Moving Disk Obtained with the Two Lamps

The light vertical band in the center of each small picture is a portion of the radial white line on the disk. The upper photograph in each pair was taken while the disk was in motion, the lower photograph while it was at rest. The speed of rotation of the disk is given over each column of photographs. The number with each row of photographs indicates the stop. The disk was rotating clockwise.

VELOCITY TESTS

Figure 12 shows enlarged portions of the photographs of the white line ruled on the rotating disk.

The effective illumination from the General Radio Microflash has a more rapid response and less persistence than that from the General Electric Photolight. This fact is shown by the rather sharp image of the line followed by blurring, which is evident in the photographs with the General Radio Microflash. In the photograph made with the General Electric Photolight, there appears an appreciable amount of blur on the leading edge of the line and considerable blur following the line. These effects are evidently caused by a slower rate of development of the effective light and a longer persistence after the flash than with the General Radio Microflash.

By reducing the exposure, that is, by using a smaller lens aperture, some of the blur was eliminated but the image density was decreased.

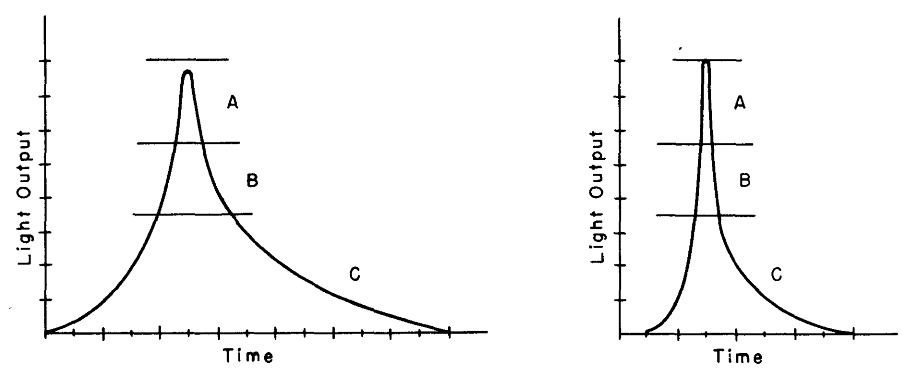

Figure 13a - Light Output of General Electric Photolight

Figure 13b - Light Output of General Radio Microflash

Figure 13 - Curves of Assumed Light Output for the Two Lamps

From the preceding discussion, the variations of light output with time for the two lamps are assumed to have the forms shown in Figure 13. The small openings at f/16 record only the peak of the light output, indicated by A in Figure 13. The slightly larger openings at f/11 record the peak and the middle portion of the curve as indicated by B. Full opening includes a portion of the broad base of the curve; this accounts for the tailing effect evident in some photographs.

UNDERWATER CHARACTERISTICS

Figure 14 shows photographs of the white masonite suspended under water and illuminated by the two lamps. By comparing these photographs with

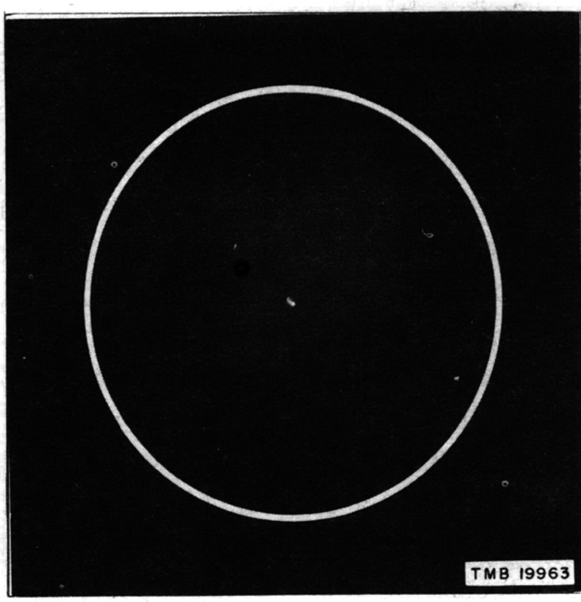

Figure 14a - Photograph Obtained under Water with General Electric Photolight

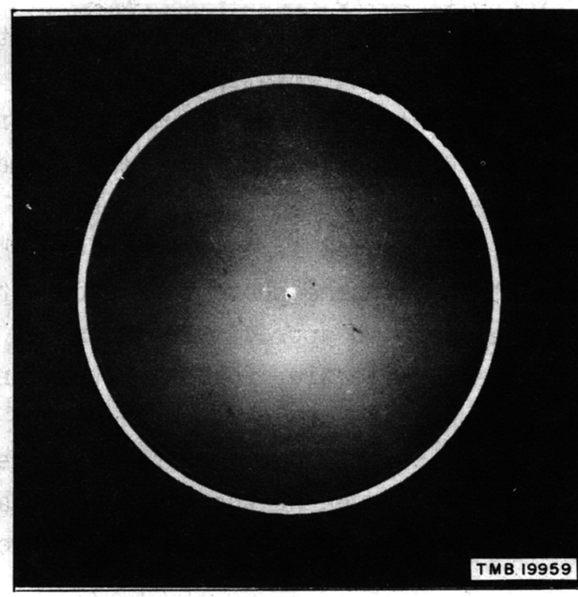

Figure 14b - Photograph Obtained under Water with General Radio Microflash

Figure 14 - Photographs Showing Area of an Underwater Surface Illuminated by the Two Lamps

The subject of these photographs was a piece of white masonite. The lamp-to-subject distance was 8.5 feet, and the camera-to-subject distance was 6 feet. The white circles were drawn on the negatives to show the areas illuminated by the lamps. The circles are 1 foot in diameter. These photographs may be compared with those obtained in air, Figure 9a on page 10.

those taken in air,* shown in Figure 9a, it is apparent that the light beam in water is greatly restricted, and that thus only a very small area receives sufficient light to produce satisfactory density on the photographic film. The decreased area of illumination in water is due to the refraction of the light as it enters the water. This phenomenon has the effect of concentrating the light rays on a smaller area and should increase the intensity of the light. However, there are other, more overpowering factors which nullify this effect. The most troublesome of these factors is suspended particles in the water. These particles scatter the light, thus producing water haze which reduces contrast. Light is also reflected as it enters the water through the glass-bottom of the waterscope; this reflection further dissipates the light (3).

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* In the course of the test just previous to the underwater tests it became necessary to replace the lamp in the General Electric Photolight. A recheck of the light output indicated a reduction of 50 per cent in the intensity of this lamp. This factor must be taken into account when comparing the results in air with those in water.

CONCLUSIONS

In a physical comparison, the two lamps are quite different. The General Electric Photolight weighs 33 pounds, is in one unit, and has a 3-inch reflector and a small flash tube which produces as much active light and covers as much area as the General Radio Microflash. The two-unit General Radio Microflash weighs 70 pounds, and its large reflector measures 8 3/4 inches across. Its larger flashing tube would indicate a larger light output than the General Electric Photolight. In photographing a subject from a given distance both lamps are considered equal in performance.

By the use of reflectors, mirrors, and other devices designed to redirect the light propagated by the lamp onto the subject being photographed, acceptable photographs may be obtained at greater lamp distances and covering larger areas than those reported here. As the ultimate use of photographs at the Taylor Model Basin is for reproduction in technical reports, only normally exposed negatives have been considered.

It is evident that, by special processing and other means, these limitations may be exceeded, especially when the resulting negatives are used for measurement purposes only.

Comparing the line photograph made with the General Radio Microflash at 10,000 RPM, f/8, with that made with the General Electric Photolight at 5000 RPM, it is concluded that the General Radio Microflash has one-half the light duration or effective speed of the General Electric Photolight.

The area covered by these lamps in underwater photographs is obviously small. The results of these tests indicate that it is not advisable to attempt to photograph underwater subjects more than 1 foot in diameter and at a lamp-to-subject distance of more than 8.5 feet with these lamps.

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(1) "Instructions GEI-20293 General Electric Photolight Catalog 8297632G1," General Electric Company, Schenectady, N. Y., November 1944.

(2) "Operating Instructions for Type P-509 Microflash. Form 564-B," General Radio Company, Cambridge 39, Massachusetts.

(3) "Undersea Cinematography," by E.R.F. Johnson, Journal of the Society of Motion Picture Engineers, Vol. 32, January 1939, pp. 3-17.