NATIONAL BUREAU OF STANDARDS REPORT

8940

Development, Testing, and Evaluation of Visual Landing Aids
Consolidated Progress Report for the Period April 1 to June 30, 1965

By
Photometry and Colorimetry Section
Metrology Division
Institute for Basic Standards

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
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Development, Testing, and Evaluation of Visual Landing Aids

Consolidated Progress Report to
Ship Aeronautics Division
and
Meteorological Management Division
Bureau of Naval Weapons
Department of the Navy

and to
Federal Aviation Agency

For the Period
April 1 to June 30, 1965

By
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Development, Testing, and Evaluation of Visual Landing Aids
April 1 to June 30, 1965

I. REPORTS ISSUED

Report No.	Title
8920	Development, Testing, and Evaluation of Visual Landing Aids, Consolidated Progress Report for the Period January 1 to March 31, 1965
212.11P-81/65	Photometric Tests of a Lens Cell of the Fresnel-Lens Optical Landing System with a Multiple-Element Glass Lens System
212.11P-82/65	Lumen Output Measurements and Life Tests of Nine Developmental, 200-Watt, 6.6-Ampere, T-14 Runway Light Lamps
212.11P-88/65	Photometric Tests of a Lens Cell of an Optical Approach Slope Indicator for a Heliport Guide Light System
	Proposed Standard for Taxiway Guidance Systems

II. VISIBILITY METERS AND THEIR APPLICATION

Slant Visibility Meter.

There was no activity on this task because of the emphasis on installations for new projects in preparation for the approaching fog season. The collection of data has been completed and much of the analysis is finished. Work on the preparation of the formal report will begin soon.

Transmissometers.

High Pulse Rate Receiver. Tests are being conducted of the feasibility of replacing the phototube in the photopulse unit with a photomultiplier in order to obtain higher pulse rates. A circuit for connecting a photomultiplier into the photopulse unit has been designed, and a receiver using this circuit has been constructed and installed at the National Bureau of Standards in Washington. Pulse rates five times the normal rate are easily obtained. However, problems have been encountered in obtaining a stable 100 percent setting.

Air Force 100-Percent-Setting Calibrator. Some additional 100-percent-setting measurements were made with the calibrator obtained from the Air Force. The average value of the 100-percent setting indicated by the calibrator agrees within ± 2 percent with carefully observed indications. However, the difference may occasionally be 5 percent or more even for measurements carefully made during fairly stable conditions. The error in the calibrator reading is probably caused primarily by sampling errors of place and time. The factor of time is the more difficult to evaluate or control because 10 to 20 minutes are normally required to make a careful measurement when the units are mounted on 14-foot stands.

250-Foot-Baseline Transmissometer. The two 250-foot-baseline transmissometers were installed at the Arcata Airport for the runway visual range assessment program. The 250-foot-baseline transmissometers are installed end-to-end alongside and ten feet away from the 500-foot-baseline Weather Bureau transmissometer for runway 31. The field units are all mounted on 14-foot stands putting the three installations at the same height above the ground. The receiver of one 250-foot installation and the projector of the other are mounted on the same stand. The indicators and recorders are located in the laboratory. The purpose of this phase of the assessment program is to provide data for the evaluation of the correlation of atmospheric transmission when it is measured over these different baselines. Theoretically, the product of the transmittances from the two 250-foot instruments should equal the transmittance from the 500-foot baseline instrument.

In addition to the transmittance, a day-night indication and a common timing pulse at hourly and 10-minute intervals are recorded. The hourly cutoffs are simultaneous. An automatic range control has been installed on the 500-foot-baseline unit to increase the sensitivity by a factor of five during dense fog. Later, electronic counters and a photopanel are to be installed to simplify collection of data.

Field Tests of the Hoffman Backscatter Fog Detector Sets.

Four backscatter fog detector sets, constructed by Hoffman Electronic Corporation on an Air Force-Coast Guard contract, were delivered to the Visual Landing Aids Field Laboratory at Arcata, California, on April 5. These sets consist of three major units, a transmitter assembly, a receiver assembly, and a control unit. The light source is a gallium-arsenide diode which emits radiation of approximately 900 nanometers, which is modulated at 8000 cycles per second for detection in the presence of daylight. The projected beam is one degree wide and the backscatter is viewed by the detector with axes of the beams crossing about 10 meters ahead of the units. The detector is a silicon photovoltaic cell. The control unit houses the components of

the all-transistorized circuits and the controls. Most of the components are mounted on slide-out printed circuit panels. The units require a 11- to 16-volt direct-current power source, but use only four watts each if heaters are not needed to prevent condensation on the mirrors and cover glasses.

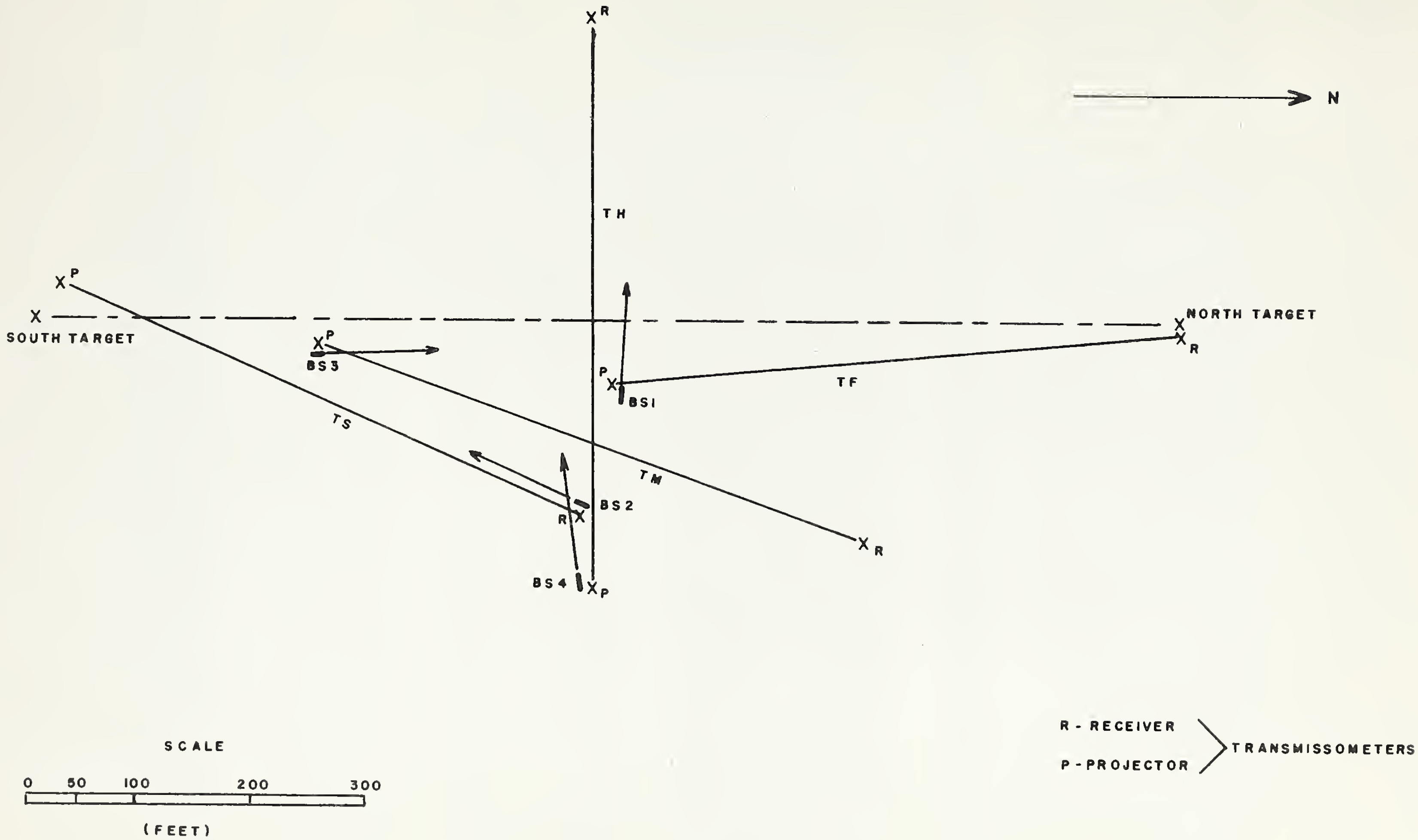
The sets are designed to function as fog detectors or to measure the amount of backscattered light. As a fog detector, the backscatter signal is balanced by a sample of the direct radiation from the source measured by a reference cell. The set activates an alarm circuit when the atmospheric transmittance decreases to a selected level. If the reference cell is disconnected, the signal from the detector is amplified and can be measured as a direct-current output signal which ranges from zero to eight volts or more. A decrease in atmospheric transmittance increases the output voltage. During this period, the emphasis has been on measuring the strength of the backscattered signal as a function of atmospheric transmittance.

The three major units of a set are mounted in the field by clamping them to a 2- to 3-inch-diameter pipe which is installed vertically in a concrete base. The four sets have been installed in the fog-variation-study test area with a set located at either a projector or a receiver site of one of the transmissometers. See figure 1. A 12-volt automobile battery is used as the power source for the four sets. The original equipment required a high-input-impedance instrument for measuring the output signal. The available recorders were not suitable for directly measuring the output signal. Later, buffer amplifiers were furnished by the manufacturer for isolating the output circuit from the recorders. A more convenient method of recording the signal has been to use a high-input-impedance amplifier to drive the recorder. The recorders are located in the office of the Field Laboratory, with the amplifiers in an instrument shelter near the test area. The arrangement was required because the long (4000 feet) signal lines between the output of the backscatter units and the input of the amplifiers pick up stray signals which affect the amplifier output.

Results show that the backscatter increases as the transmittance decreases for most atmospheric conditions.

A number of problems and deficiencies have been noted. These are listed even though the sets were designed and constructed to be used only as feasibility models, not prototypes, since the problems which have arisen should be considered during the design and construction of prototypes.

1. The noise level is high and variable, particularly in daylight. This makes the signal difficult to evaluate, especially in clearer atmospheric conditions.



INSTRUMENT LOCATION LAYOUT FOR BACKSCATTER DEVICE TEST

NBS Report 8940

Figure 1

2. Different sets do not have the same sensitivity. Proper gain adjustment may correct for this variation.

3. A method for calibrating the performance of a set is needed.

4. Condensation on the mirrors and cover glasses must be eliminated. The 16-volt, 12-watt strip heaters for mounting inside the tubular housings of the transmitter and detector provided by the manufacturer were definitely inadequate when energized at 12 volts. Appliance heaters rated at 115 volts, 32 watts, were mounted on the backs of each mirror and in the center of each cover glass. These heaters (total four per set) were connected in series and in series with a 100-ohm resistor across 115 volts. They have prevented condensation on the surfaces in the conditions encountered to date.

5. The response to larger particles such as rain may differ significantly from the response to smaller particles such as fog for equivalent transmittances.

6. The components and the housing are unsatisfactory for indefinite exposure to field conditions, although many components were selected for this purpose. Some deficiencies were: moisture getting into the transmitter and detector housings and the control unit; deterioration of the surfacing of the mirrors; corrosion of components, especially of cable connections; stains on the windows of the transmitting diode and solar cell, apparently from iron oxide from the housing of these small components. All connectors should be weatherproof and provide protection even if the cable is disconnected.

7. The output is affected by radio frequency interference.

8. For use on airfields, a power supply to operate from 115 volts a.c. would be desirable.

9. In some cases, the output is affected by the operation of the charger for the battery.

10. Provision for the recording of the output of the sets is needed.

11. The small coaxial cables are easily damaged and difficult to connect. Larger, more sturdy cables are needed even if some loss in signal occurs.

Records from these units were obtained for various atmospheric conditions with transmittances on a 500-foot baseline down to 0.05, but very dense fog conditions have not occurred. The initial phase of testing these units should be completed early next quarter.

Shipboard Visibility Meter.

Arrangements have been made to have two backscatter visibility meters suitable for field use constructed by the Measurement Engineering Division. The work is in the initial design stages. A study is being made to determine the most suitable method of obtaining an instrument with a time constant long enough to smooth out the fluctuations in readings caused by the small-volume variations in fog density and by noise and at the same time an instrument which will respond to rapid large-volume changes in fog density.

Variation of Fog Studies.

Analysis of data was delayed in order to make preparations for the new fog season at Arcata. A very careful check will be maintained on instruments, to avoid possible instrument errors. The transmissometer signals have been remoted to the laboratory, where the indications can be more effectively monitored and used.

The variation of fog phenomenon is a very complex function. Most fogs vary greatly with location and time. The magnitude of these variations may change visual range from several percent to several hundred percent in time intervals from less than a minute to several minutes. In addition to the changes within the atmospheric mass, local terrain features may greatly affect the fog conditions. Slight changes in elevation or slope or vegetation may markedly change transmittance at considerable distances away at one time and have little effect at another time under apparently similar conditions. The uncertainties in fog changes in magnitude, location, and time make forecasting the visual range for a pilot approaching for a landing very difficult, especially at the lower minimum ranges now being considered. More study of the nature and causes of these variations and evaluation of the maximum acceptable inaccuracies in the measurements and in a short-time forecast are necessary.

Visibility Thresholds.

Analysis of the data relating the visual range of black objects by day and 25-candela lights by night with transmissometer readings has continued. The effects of systematic variations in fog density on the reliability of visibility determinations are being included in the study.

III. AIRFIELD LIGHTING AND MARKING

Navy Taxiway Standard.

The Proposed Standard for Taxiway Guidance Systems has been completed and forwarded to the Bureau of Naval Weapons for review and action. The proposed standard was reviewed in detail at a conference with personnel of Yards and Docks and the Bureau of Naval Weapons. The draft standard proposes elimination of the double lights at taxiway entrances; closer spacing of edge lights on sections 300 to 800 feet long; use of centerline lights at complicated intersections; and placing destination signs on the near side, instead of the far side, of intersections.

Stub Approach Beacon.

The draft of the stub approach beacon report has been started. The stub approach beacon has the drive mechanism installed in a pit with only the lamps above the surface and is located on the extended centerline of the runway. The recommended arrangement is five equally spaced lamps rotated about a vertical axis at 12 revolutions per minute - 60 flashes per minute. The beam characteristics of the lamps should be approximately 50,000 candelas peak intensity, with a beamspread of 40 to 60 degrees horizontally and 20 degrees vertically. A lamp life of 1000 hours or more is desirable. The lamps are operated at rated intensity in daytime and should be operated at approximately 20 percent of rated intensity for clearer nighttime conditions. If the beacon is used in conjunction with a visual approach slope indicator (VASI) an intermediate intensity is desirable. The intermediate intensity would also be useful in restricted visibilities at night.

It is frequently difficult at night and under low ceilings in daytime for the pilot to locate and keep oriented with the end of the runway during circling approaches, especially if the airport beacon is not located near the runway threshold. The stub approach beacon is useful to him at such times. Many pilots report that the stub approach beacon is also a useful supplement to the VASI for alignment with the runway centerline where centerline runway lights are not used. One pilot did report that the flashing of this beacon may tend to cause vertigo.

Modified Cell of the Source-Light Indicator Assembly of the Mark 6 (Shipboard) Fresnel-Lens Optical Landing System for Use as a Heliport Landing Aid.

Photometric measurements were made of a cell of a source-light indicator of the Mark 6 Fresnel- lens optical landing system modified to augment the vertical field angle. A maximum intensity of 7.0 kilocandelas and a vertical 50% beam spread at 3.5 kilocandelas of 1.4° was obtained. Photometric distances were measured from the position

of the vertical image, which was 28 feet behind the Fresnel lens. Detailed results are reported in NBS Test Report 212.11P-88/65.

Runway Identification Lights.

The modified synchronized runway identification lights have been mounted on the roof of the East Building at NBS (Washington). Preliminary observations have been made. These observations indicate that a set of counter-rotating beacons will not be a sensitive indicator of alignment when viewed from heights which place the aircraft well above the main beam of the light. Therefore, sufficient vertical beam spread must be provided in the lights of the system so that the main beam will extend upward to the cockpit-cutoff angle. The system was relatively insensitive to deviations in alignment of about 5° from the indicated path, but gave a strong indication of deviations of the order of 10°. The sensitivity is a function of the angular separation of the lights. The equipment is now ready for inspection and demonstrations.

Lightweight Regulators for SATS Lighting Systems.

Two solid-state, constant-current regulators developed and constructed by Bernard Electronics Company, Washington, D. C., were tested. The 6.6-ampere unit was rated at 4 kw., and the 20-ampere unit was rated at 15 kw. Each unit was designed for operation on a 208-volt, 60-cycle input. The characteristics of each unit were measured under various combinations of loads, intensity steps, and circuit conditions. One of the circuits included a saturable transformer with multiple lamps as loads in its secondary, a condition to be expected in field use. A report of the test results will be prepared during the next quarter.

Temperature Rise Test of L-845 Light in Small Base.

A task to measure the temperature rise at various points on a flush light installation using a type L-845 light and a 300-watt lamp in a standard small base has been established. The equipment and materials were received at the end of this period. This test and the report should be completed during the next quarter.

Factory-Aligned PAR-64 Iodine-Cycle Lamps for VASI Systems.

Photometric tests were made on 10 factory-aligned PAR-64 iodine-cycle lamps for use in VASI systems. The lamps were individually mounted in a NBS-constructed one-lamp simulator with a 2"-high slot, an all-white spread lens and a transition bar, all positioned according to FAA drawings. Tests showed that the factory aligning technique was satisfactory for the ten lamps tested.

A proposed test inspection method for VASI lamps was presented as follows:

1. Each lamp should be tested at rated current in a 50-inch, one-lamp simulator with an all-white spread lens, a 2-inch-high horizontal slot, and a transition bar, all properly placed.

2. The individual and integrated output from two calibrated photocells spaced vertically ± 2° from the optical axis of the simulator and at least 25 feet from the slot should be obtained. The vertices of the vertical angles are at the slot end of the simulator.

3. The combined readings of #2 should not be less than 50 kilocandelas, nor should any reading be less than 20 kilocandelas.

The aim was to develop a test inspection method that would involve measurement of only the lamp itself, but it was found that to evaluate properly the characteristics of the VASI lamps it was necessary to project the beam through the slot of the simulator with the spread lens and transition bar in their proper places in the beam. Measurements were made of the lamps themselves and of the lamps in the simulator without the spread lens, but there was no correlation between these measurements and measurements made as in the proposed method above. Measurements made with the all-white spread lens correlated with those made with a red-white spread lens without the transmittance-temperature problem of the latter lens.

Q20A/PAR56/2 Lamps.

Photometric measurements were made of four Q20A/PAR56/2 (300-watt, 20-ampere, stippled-cover approach light) lamps. The average power consumed was 311 watts. The average peak intensity was 146 kilocandelas. Maximum deviations of the peaks from the lamps' axes were -0.3° and +0.9° horizontally and -1.5° and +0.8° vertically. Detailed results will be reported in NBS Test Report 21P-111/65.

6000-Hour, 700PS40 Lamps for the 300-mm Code, or Hazard, Beacon.

Life testing was stopped on the six remaining 6000-hour, 700PS40 lamps for the 300-mm code, or hazard, beacon, after approximately 6000 hours. NBS Test Report 212.11P-34/65 has been drafted. Lamp #2 burned out at 3606 hours (erroneously reported last quarter as 2606 hours) and lamp #4 at 4316 hours. Average lumen maintenance of seven lamps at 70% of rated life was 64%.

200-Watt, 6.6-Ampere Runway Light Lamps.

Measurements were made of the luminous output and the life of nine lamps designed for use in the type C-1 (L-819) runway edge light by the Radiant Lamp Corporation. The lamps were stated to have a rated output of 5000 lumens and a rated life of 400 hours. The average luminous output was 5140 lumens initially and 2260 lumens after 316 hours of operation.

IV. SEADROME VISUAL LANDING AIDS

No work was conducted in this field during the quarter.

V. CARRIER VISUAL LANDING AIDS

Multiple-Element Lens for the Source-Light Indicator Assembly of the Mark 6 Fresnel-Lens Optical Landing System.

Average relative luminance measurements were made of a prototype source-light indicator assembly of the Mark 6 Fresnel-lens optical landing system with a multiple-element glass lens replacing the plastic Fresnel lens. The intensity of the "meatball" of the modified lens cell was approximately 60% of the intensity of the "meatball" of an unmodified cell. The "meatball" of the modified cell was somewhat sharper than that of an unmodified cell and the stray light intensity of the modified cell was about half that of an unmodified cell. NBS Test Report 212.11P-81/65 was issued.

Computational Methods for Computing Aircraft Paths from PLAT Records.

A study is being made of the feasibility of designing a computer program for the analysis of aircraft flight paths using data obtained from PLAT (pilot landing aid television) records.

The problem presented is essentially one of analyzing data obtained from sequential pictures of aircraft approaching and landing on a carrier flight deck. From each frame of the picture the range, elevation, and azimuth angle are to be determined. From a sequence of frames the rates of change of these three quantities are to be determined. Moreover, the departure of the flight path of the aircraft from a straight line moving with the carrier is also to be determined.

The problem splits naturally into two separate parts: (1) the determination of range, elevation and azimuth from individual frames, and (2) the determination of rates and flight paths from a sequence of frames. Both require fairly complicated computational techniques and therefore, for rapid and accurate results, some sort of digital computer is called for.

Since (2) is easier, it will be considered first. Given range, elevation and azimuth data on each frame and assuming that the time interval between the successive frames is constant, the approximate value of the instantaneous rate of change of each quantity can be determined by difference methods. The simplest approach makes use of

first differences. For more accurate determinations, higher order differences can be used. These have the advantage of smoothing out random errors that occur in recording and measuring the individual frames. If desired, the resulting information can be expressed in terms of velocity vectors.

For determining the departure of the flight path from a straight line, fitting the range, azimuth, elevation data by least squares to the equation of a straight line, thus obtaining that straight line that most closely approximates the flight path, is desirable. The deviations as well as their rates of change can be computed if desired.

These procedures are well known and for many commercially available computers subroutines are already available.

Part (1) is the more troublesome item in this problem. Two approaches are possible, a 2-point method and a 3-point method. The 2-point method is the standard method for estimating the range of an aircraft. Two easily distinguishable points on the aircraft are selected and the distance between them measured. If the line of sight is normal to the line connecting the two points on the aircraft, then the range is proportional to the cotangent of half the angle subtended by the two points. The weakness of this method is that errors are introduced if the line connecting the two points is not normal to the line of sight. Moreover, the error is biased -- it will always result in a value of range that is larger than it should be.

The 3-point method is not yet a fait accompli. Exploratory calculations, however, have indicated that it is possible. Instead of two points on the aircraft, three are used. The observer sees then a spherical triangle, the solution of which involves solving a system of three simultaneous quadratic equations. This, upon eliminating two of the equations, yields an octic polynomial which usually is hopeless. However, in this case, the octic is in the form of a quartic in a squared variable which is solvable, albeit with considerable difficulty. The 3-point method has the advantage of providing information on the attitude of the aircraft as well as a more accurate measure of its range.

Consider now the form of the data itself. As the individual pictures are obtained by photographing the face of a television picture tube, they are characterized by a considerable amount of noise and rather low resolution. Moreover, the field of view is distorted in a rather peculiar way. It is clear that measurements made from this kind of record are subject to large error. It is therefore pointless to consider a 3-point method for this type of problem, and, accordingly, the 2-point method will be used.

Frame and Window Assembly for PLAT Camera.

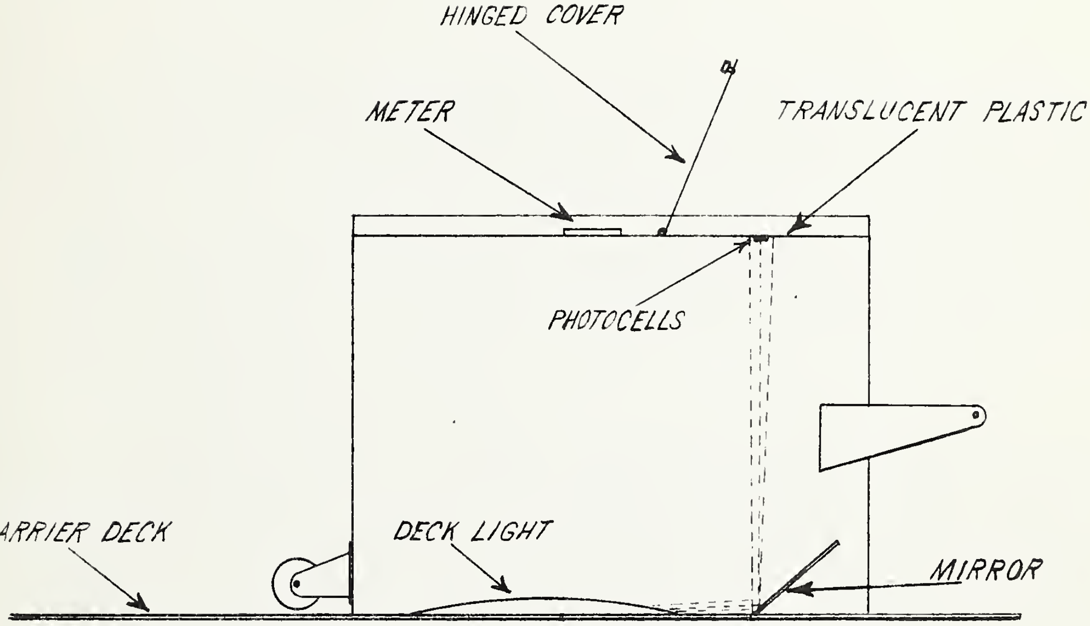
Consideration has been given to the optical requirements for the glass of the window and frame assembly for the PLAT camera. Study of photographs of presentations on the picture tube indicates that because of the poor image quality and the amount of distortion present (due primarily to the cathode ray tube and the associated electronics) good quality plate glass will be a suitable material for the window. The window should, of course, have a hard-coated front surface.

Portable Photoelectric Photometer for Measuring the Output of Carrier-Deck Lights.

A portable photoelectric photometer for determining the intensity of carrier-deck lights has been designed and is being constructed. This device is intended for the use of the maintenance crews in determining when the lenses need cleaning or the lamps need replacing. The device consists of a bottomless light-tight aluminum box that is placed directly over the light to be measured. See figure 2. The beam of the light falls on a mirror in the box and is directed up to a bank of photocells mounted on a sheet of translucent plastic. By viewing the position of the beam on the plastic it is possible to determine to some extent the elevation of the beam. The intensity of the light is measured by reading the output of the photocells on a meter located on top of the box. This reading is then compared to a predetermined value for the type of light being tested. A selector switch on top of the unit is set to correspond to the type of light being measured to allow for intensity differences of the different light types. The photometer is sufficiently light tight that it can be used in daylight.

Catapult Hookup Light.

Tests were resumed on a catapult hookup light with modified lamps furnished by the lamp manufacturer. The light is used in illuminating the underside of an aircraft when it is being attached to the catapult. Trouble had been experienced in that the solder holding the prefocusing rings would not stand the temperatures generated inside the lights. The new lamps were hand soldered and proved satisfactory. Peak intensities of the order of 8 candelas were recorded. NBS Test Report 212.11P-16/65 has been drafted.



Portable Photometer for Carrier-Deck Lights

VI. MISCELLANEOUS TECHNICAL AND CONSULTIVE SERVICES

Review of Specifications.

Review of specifications and drawings for proposed revisions has continued. Particular attention has been given to the development of performance tests for the items specified in MIL-B-8954, Base and Accessories, Airport Marker Lights, General Specification for. Results of the studies to date are given below.

Load Tests for Bases. Load tests were performed on the L809 and L837 light bases and transformer housings. In these tests, strains exceeding the uniaxial yield strain were measured for applied loads as low as 5,000 to 10,000 pounds for L809 bases and 10,000 to 20,000 pounds for L837 bases. These high localized strains are not unexpected in structures of this type, but their presence makes it difficult to evaluate workmanship through arbitrary load tests. Since these light bases appear to be serviceable in field installations, it is suggested that other methods of evaluating workmanship should be employed.

Tests for Frangible Couplings.

National Bureau of Standards Report No. 5239 described apparatus used to make dynamic tests of frangible couplings to determine the energy required to fracture. This pendulum apparatus was satisfactory for investigating properties of adapters in a laboratory environment. However, it is believed that because of the care required to assemble and operate this apparatus it would be difficult and expensive to duplicate the test conditions in another laboratory or in an industrial environment.

It is recommended that a "go," "no-go" type test be devised for use in procurement specifications. This test would require that samples not fracture when impacted under specified conditions and that other samples fracture when impacted under similar conditions but at a higher energy level. The "dropped weight" test appears promising. Details of test conditions which should be specified include:

1. Description of the dropped weight and the height from which it is to be dropped.
2. Description of the post to be attached to the adapter and struck by the weight.
3. Description of plate and foundation to which the adapter is to be mounted.

Experimental work would be required to verify the applicability of the tests and apparatus and to provide quantitative descriptions of these conditions.

VII. MISCELLANEOUS

Visitors.

There have been several visitors to the Arcata Field Laboratory from the Air Force, Coast Guard, and Hoffman Electronics Corporation, primarily in connection with the backscatter meter project.

NBS Instruments at Fog Chamber.

The indicator of the transmissometer used at the FAA Fog Chamber at the University of California has been converted to an expanded scale indicator in order to provide a more satisfactory record of dense fogs. The brightness meter has been overhauled and a new phototube and luminosity filter have been installed.

Photometry of Colored Light.

A resumé of the work on the photometry of colored light was given at the IES Aviation Committee meeting at Atlantic City, New Jersey.

Review of Third Meeting of Visual Aids Panel.

The results of the Third Meeting of the Visual Aids Panel were reviewed at the Spring Meeting of the IES Aviation Committee.

Visibility of Lights.

A brief general review of the factors affecting the visibility and conspicuity of lights was given at the FAA meeting on runway centerline lighting on April 7.

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