NATIONAL BUREAU OF STANDARDS REPORT

9540

Development, Testing, and Evaluation of Visual Landing Aids
Consolidated Progress Report for the Period January 1 to March 31, 1967

By
Photometry Section
Optics Metrology Branch
Metrology Division
Institute for Basic Standards

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT | **NBS REPORT**

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May 31, 1967

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Development, Testing, and Evaluation of Visual Landing Aids

Consolidated Progress Report to

Ship Installations Division
and
Meteorological Division
Naval Air Systems Command
Department of the Navy
and to
Federal Aviation Agency

For the Period
January 1 to March 31, 1967

By
Photometry Section
Optics Metrology Branch
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NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

Development, Testing, and Evaluation of Visual Landing Aids
January 1 to March 31, 1967

I. REPORTS ISSUED

Report No.	Title
9484	Development, Testing, and Evaluation of Visual Landing Aids, Consolidated Progress Report for Period October 1 to December 31, 1966
212.11P-1/67	Electrical Tests of a 200-Watt, 20/6.6-Ampere, Series/Series Transformer
212.11P-2/67	Photometric Tests of an Elongated Cell of the Fresnel-Lens Optical Landing System
212.11P-103/66	Photometric Measurements of "Factory-Aimed" Type PAR-64 Iodine-Cycle VASI Lamps
Letter Report	Report of Test on One Cassegrain System
Letter Report	Taxiway Light Filters
Letter Report	Vibration Tests of Lamps in Type L-850 Fixtures

II. VISIBILITY METERS AND THEIR APPLICATION

Shipboard Visibility Meter.

During this period, the major parts for the construction of the new lamp-photocell assembly were ordered and received. Cast aluminum boxes have been obtained to house this assembly as well as the electronics. Final mechanical design was delayed until the boxes were received since exact dimensions were not available. This is now being completed and actual construction is expected to begin immediately.

The details for interconnecting the various electronic circuits have been worked out and assembly drawings are being prepared. Nearly all the necessary components have been obtained. Delivery has been slow on weather resistant military type connectors. Some non-environmental types may be used until the desired ones arrive. Construction of the final electronic boxes is expected to begin the first week in May.

The system is being designed with various built-in tests. A 1:1 ratio test will be provided by transmitting light from every flash through the reference optical path. The electronic 1:1 test of the log-ratio circuit and averaging circuit will be provided to aid in isolating problems during trouble shooting. A second reference path is being designed to provide a test at another fixed ratio, perhaps 10:1. Built-in test circuits have been provided to balance all operational amplifiers requiring adjustment during the calibration procedure.

Backscatter Visibility Meter Field Tests.

The draft of the final report on this task was revised and forwarded for review. The results reported by the Coast Guard on the tests as fog detectors were included in this draft.

Sperry Rand Laser Visibility Meter Field Tests.

The final report on the field tests of the Sperry Rand laser visibility meter has been completed. The transmissometers have been kept in operation on a minimum maintenance basis. The test bed is available for future projects.

Fog Variability Studies.

There were few low visibility conditions during this reporting period and no visual observations for comparison with transmittances were made. Additional observations are planned for times when suitable

conditions occur.

In the analysis of data, the effects of changes in fog density within short periods of time, the instantaneous transmittance values from one transmissometer were compared with values averaged over ± 30 and ± 60 seconds for two periods of observations made during the previous quarter. The time-averaged values over ± 30 and ± 60 seconds as compared to the instantaneous values showed maximum individual differences of 7.5 and 16 percent of the indicated transmittance for the 30- and the 60- second averages, respectively. The average differences were 2.0 and 4.5 percent. These results show that, for an individual observation, an instantaneous reading may differ appreciably from the time-average condition, but, for a large series of observations, the average of instantaneous readings gives, as would be expected, the same results as the average of the time-averaged readings.

A second consideration in these fog studies is the change of fog density with location. The transmissometer integrates the transmissivity along its baseline and the resulting value is representative of some surrounding area. When determining transmittance for an area in which two or more transmissometers are installed, there is a question of how to weight the values when the readings are not in agreement. Along the 1900-foot range used for observations, three transmissometers on 250-foot baselines and separated by 500 feet were installed. An arithmetic mean of the three transmittances would result in an accurate value only if the transmittances were in close agreement and the observation sampled the entire 1900-foot range. To avoid arbitrary weighting the transmittance values for the various ranges, integral equations were developed to fit all visual ranges less than 1900 feet. Five equations were required to cover the entire 1900-foot range and were based on the assumption that the transmissivity changes linearly between transmissometer baselines. Some of the data will be analyzed using several ways of weighting transmittance values to determine if the more complicated calculations are justified by improvement in results.

To obtain information on the amounts and variation in amounts of fog occurring at the Arcata Airport, the past records of the transmissometer located at the touchdown area of runway 31 were reviewed and the periods of fog were tabulated. For these data, the duration of readings below 0.5 transmittance for a 500-foot baseline was tabulated as the duration of fog conditions. The data were separated into day and night and were totaled by the month and by the year. The yearly amounts by nighttime, daytime, and total for the 10 years from 1957 through 1966 are given in table 1.

Table 1.

Time Summation of Fog Occurring at the Arcata Airport (1957-1966)
(Fog is based on transmittance along a 500-foot baseline of less than 0.5)

Year	Nightime (Hr-Min)	Daytime (Hr-Min)	Total (Hr-Min)
1957	212:45	104:20	317:05
1958	483:10	247:45	730:55
1959	318:30	177:30	496:00
1960	405:35	173:05	578:40
1961	364:45	147:40	512:25
1962	510:20	248:15	758:35
1963	206:10	110:30	316:40
1964	327:55	159:20	487:15
1965	400:05	228:10	628:15
1966	260:20	135:25	395:45
Average	349:00	173:10	522:10
Minimum	206:10 (1963)	104:20 (1957)	316:40 (1963)
Maximum	510:20 (1962)	248:15 (1962)	758:35 (1962)

With the emphasis on Category II and Category III operations, the records for 1965 and 1966 were reviewed to determine the amount and distribution of the occurrence of atmospheric conditions at Arcata Airport that would have resulted in low runway visual ranges (RVR). The conditions selected were for RVRs of less than 1000 feet and less than 800 feet. The results are given in table 2.

Table 2

Low RVR Conditions Occurring at the Arcata Airport (1965-1966)
(Time given in hours and minutes total for the month)

	RVR	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
	Less than													
1965	1000'--Day	6:43	10:42	---	0:44	---	0:34	2:19	4:05	6:15	23:22	0:16	0:30	55:30
	800'--Day	1:45	3:29	---	----	---	----	0:19	1:26	3:33	2:33	----	----	13:05
	1000'--Night	3:09	5:49	---	----	---	----	----	1:40	0:45	13:00	----	----	24:23
1966	1000'--Day	----	----	---	3:29	2:39	----	0:58	4:40	5:01	10:46	6:31	1:12	35:16
	800'--Day	----	----	---	0:35	0:31	----	----	1:06	3:37	2:13	3:44	----	11:46
	1000'--Night	0:54	0:02	0:19	0:02	---	----	----	----	1:29	1:21	0:22	----	4:29

Note: The records did not indicate any time with RVR less than 800 feet at night during this two year period but the dark current from the phototube in the transmissometer from which these data were taken may have concealed some time below this range.

As reported in the previous quarter, elapsed time meters have been installed to record IFR conditions, operation of runway lights on intensity step 5, and transmittances over a 500-foot baseline of less than 0.5 for both daytime and nighttime. For this reporting period, the recorded times totaled 278 hours of IFR, 32 hours of runway-light operation on intensity step 5, 53 hours of daytime with transmittance less than 0.5, and 102 hours of nighttime with transmittance less than 0.5.

Transmissometers (Phototubes).

A group of six replacement tubes has been obtained for use in the NBS transmissometers. During the acceptance tests the sensitivity of the tubes was found to decrease substantially during the first 100 hours of operation. The results of these tests will be reported in more detail next quarter.

"Forward-Scatter" Fog Detector.

This fog detector (described in the Progress Report for October-December 1966, NBS Report 9484) has now operated in the laboratory for several months with a scattering plate between the projector and the detector. There have been no electronic or mechanical failures. However, the stability of its output is marginal if the instrument is to be used as a visibility meter. For example, during a two-week period of laboratory operation under conditions which should result in a constant output, there was a gradual increase in the average reading of about 25%. In addition there were both short and long term variations in sensitivity. A ratio of maximum to minimum readings during a one-hour period of the order of 1.25 occurred frequently. The ratio of the maximum reading to the minimum reading in this period was 1.7. Since the visibility indicated by the instrument is expected to be roughly proportional to the output reading of the instrument, the variations in indicated visibility for constant fog density would be of the same order as the variations reported above. Thus the instrument does not appear to be sufficiently stable to be used as a visibility meter. However, it should be useful as a fog detector and as a portable instrument for use in studying the variation in fog density along a runway.

III. AIRFIELD LIGHTING AND MARKING

Airfield Lighting Maintenance Manual.

Some references and sources of information on airfield lighting equipment and practices have been reviewed and collected for use in preparing the Airfield Lighting Maintenance Manual. Work on the Maintenance section of the manual will be emphasized during the next quarter.

Improved Cable Fault-Locating Set.

Construction of the Test Signal Generator is almost finished, but little progress was made in finishing the Detector Unit because of delays in delivery of components. It is hoped that this project will be completed by the beginning of June 1967.

Literature describing a new Cable Fault-Locator manufactured by the Delcon Division of Hewlett Packard has been obtained. This fault locator is similar in principle to the TSM-11.

Compilation of Intensity Distribution Data.

The initial accumulation of material for inclusion in NBS Report 9350, Compilation of Intensity Distribution of Airport Lights, was updated in part and reorganized. The report has been sent to the printing section and will be issued next quarter.

Improved Heliport Perimeter Light.

Testing was begun on an improved heliport perimeter light using a type M-1 light housing and omnidirectional lens, and a Q6.6A/T3/4CL 100-watt quartz-iodine lamp as a light source. Work was postponed in favor of more urgent work and will be resumed next quarter.

Developmental 210-Watt, 6.6-Ampere, T-14 Bulb Airport Lamps.

Ten 210-watt, 6.6-ampere lamps having a rated life of 300 hours have been received from the General Electric Company. These lamps are intended to replace the 75-hour, the 150-hour, and the 500-hour lamps now being used in the C-1/L819 elevated runway-edge light. Initial measurements have been made of luminous output. An average output of 4690 lumens was obtained. The lamps are now on life test.

"Factory-Aimed" Type PAR-64 Iodine-Cycle VASI Lamps.

Eleven "factory-aimed" type PAR-64 iodine-cycle VASI lamps selected by the factory from a production run were submitted for test. Intensity distribution measurements were made of these lamps. The lamps were judged satisfactory in intensity and alinement for use in the VASI fixtures without individual alinement of the lamps after they are mounted in the lampholder. NBS Test Report 212.11P-103/66 was issued. Figure 1 shows the intensity distribution of a typical lamp in a one-lamp simulated VASI. The lamps were put on life test.

Vibration Testing of Type L-850 Lights.

A study was made of the effects of vibration on the 200-watt, 6.6-ampere, iodine-cycle lamps used in proposed designs of type L-850 lights following reports of failure of the lamps during the vibration tests now required. The lamps were vibrated in turn in three mutually perpendicular planes, one parallel to and two perpendicular to the filament axis. In each position the lamp mounted in the socket of the type used in the fixture was subjected to sinusoidal vibrations over a range of 5 to 2000 Hz during a ten-minute period. The lamps withstood accelerations of 3g without failure. Two lamps also withstood accelerations of 4g and 5g. One lamp failed during its 4g test. The 4g test of the remaining lamp was terminated by an equipment malfunction.

Replacement Filters for Taxiway Lights.

A beneficial suggestion received by the Naval Air Systems Command recommended the use of locally procured blue filters for type L-842 fixtures used as taxiway lights, citing a very substantial saving in cost and stating that the filters performed satisfactorily in service. Tests made of samples of these filters showed that they failed to meet the specification requirements for chromaticity, transmittance and optical quality, and that the filters were not tempered. However, the filter might be satisfactory for the particular conditions of use.

Results of this study were reported in detail by letter.

The results of this study indicate that consideration should be given to the use of non-tempered, heat-resistant glass for such filters and to the procurement of spare filters in quantity on competitive bid.

Model of an Open-Grid Approach Light.

A full-scale plywood model of an open-grid approach light has been completed and will be used to determine the photometric characteristics

of a light of this type. The light was designed to duplicate the intensity distribution of a 300-watt elevated approach light.

Electrical Tests of a 200-Watt, 20/6.6-Ampere Transformer.

Electrical tests were made of an enclosed 200-watt, 20/6.6-ampere transformer intended for use on aircraft carriers as part of the flight deck lighting system. The transformer met the applicable requirements of Specification MIL-T-27535A. Results were reported in NBS Test 212.11P-1/67.

The following tasks are pending:

Tests of Q6.6A/PAR 56/2 Approach-Light Lamps.

Photometric Tests of a Centerline Light for SATS Runway.

Photometric Tests of a Shield for a Runway-End Identifier Light.

Photometric Tests of a Night Vision Floodlight.

Photometric Tests of B-3 and BB-3 Omnidirectional Semiflush Lights.

Development of a Semiflush Taxiway Light for SATS Fields.

Development of a Shield for SATS Circling Guidance Lights.

Electrical Tests of a Controller for Circling Guidance Lights, Manufactured by Bernard Electronics Company.

IV. CARRIER LIGHTING AND MARKING

Computational Methods of Determining Aircraft Paths from PLAT Records.

Work on this project has so far been based on examples of photographs from the Pilot Landing Aid Television (PLAT) system, as used on the USS Oriskany (CVA-34), which was assumed to have typical flight deck dimensions. We have been provided with selected frames of PLAT coverage showing an F8E aircraft at various stages of its landing approach. The object of our analysis of these photographs is, first of all, to be able to determine the distance of the aircraft from the camera being used. More specifically, for each frame, one needs to know the distances to three specific points of the aircraft, in order to take account of variations in its spacial orientation with respect to the camera. Such detailed information is a necessary preliminary step for a later stage of the analysis with the object of determining the flight path of the aircraft.

In terms of visibility, the most useful points in the examples at hand are the outermost edges of the wing flaps and the center of the nose wheel. By using these points, the problem can be formulated mathematically through the following considerations. The three specific points of the aircraft form a triangle which is the base of a long narrow tetrahedron with the camera at its vertex. Thus, at the camera, three vertex angles are formed by the three lines which meet there. The determination of these angles depend on measurements of the three corresponding lines in a photograph, and on the over-all focal length of the camera system. The law of cosines is applied for each of three narrow triangles which are the sides of the tetrahedron. The resulting formulation consists of three quadratic equations which must be satisfied simultaneously.

Although this particular system of quadratics could be solved in closed form, such an approach would definitely lead to two difficulties: round-off and the introduction of extraneous solutions. However, a method has now been found which circumvents both of these mathematical difficulties. In this latter method a reasonably accurate initial estimate for one distance is first obtained by assuming a normal aspect of the aircraft wing, and this estimate is used in just two of the quadratics to solve for estimates of the other two distances. The initial solution so obtained must then be adjusted by an iterative process so that it will satisfy all three quadratics, but it was found that such a process converges quickly to an accurate solution. The avoidance of high powers of the distances prevents excessive round-off.

A program incorporating this iterative approach has now been written and checked out on a digital computer. This program includes special signals to alert the user in case of the occurrence, during solution, of an extraneous configuration (i.e., distance to nose wheel greater than either of the other two distances). However, such an eventuality has not arisen in numerous tests of the program, and thus the formal mathematical and programming aspects of this stage of the problem can be considered solved. However, it should be clear that the problem of providing such a program with sufficiently accurate input data is crucial to the accuracy of the results obtained, and is quite another matter.

As for accuracy of input data, further information is needed, as follows. First, the distance from outer edge of flap to nose wheel must be known as actual point-to-point distance, which requires that any vertical component involved in such a distance be included. It is not clear whether the aircraft dimensions so far provided allow for this factor or not. Any discrepancy in this respect would surely be of a significant size, even though an exact degree of precision for the measurement of distances between points in the photographs

can not be given. Secondly, two cameras are used, and it has been assumed that the appearance of the photographs will always provide a sufficient means of distinguishing between the two cameras. It is necessary to treat them separately in the calculations, since the cameras differ not only in location on the carrier deck, but (very likely) also differ as to the characteristics of the two camera systems. Thirdly, the most important such characteristic for this purpose, the over-all focal length of the system being used must be known, either directly, or indirectly by inference from reliable data. This quantity enters the calculations described above in the first step of obtaining the cosines of the three vertex angles, and is (essentially) the quantity which sets the scale of the results. In other words, if the photographs used have been enlarged by some constant factor, this fact is reflected in a change of the over-all focal length.

Telescope for PLAT System.

An experimental Cassegranian optical system designed to be used with the image orthicon tube of the Pilot Landing Aid Television (PLAT) system was analyzed and the results reported in a letter report. This optical system was found to have high distortion and a relatively low transmittance.

Luminance Standard for Use in Testing Image Orthicon Tubes.

A luminance standard used in the testing of image orthicon tubes was submitted for calibration. The dichroic filter installed in the standard to increase the color temperature of the standard was found to be unsuitable for the purpose. This filter was replaced with a filter of "daylight" glass of suitable thickness. The standard was then calibrated.

Stabilized Glide Path Indicator.

A Stabilized Glide Path Indicator manufactured by the General Electric Company (England) was received on 5 February, 1967, from the Naval Air Engineering Center, Philadelphia, for test.

The Stabilized Glide Path Indicator is an optical device designed to give the pilot of an approaching aircraft a visual indication of the correct descent path. A beam of light is projected up the descent path towards the aircraft and this beam is divided into three differently coloured sectors, red at the bottom, green in the middle and yellow at the top. The green sector is 2° wide vertically and the beam is adjusted so that the centre of the green sector is at the correct descent angle. This setting is at 3° or 4° above horizontal depending on the requirements of the ship and aircraft.

The light projector is suspended from a pendulum-type mounting for stabilization for pitch and roll, and the movement is restrained by special springs and damped by viscous dampers. The stabilizing mechanism is stated by the manufacturer to ensure that the glide path or descent path is indicated within 1/2° of the correct angle during movement of up to 10° tilt in any direction. For protection against sea spray, and to avoid errors due to high winds, the entire stabilized projector is enclosed within a rigidly fixed housing of resin bonded glass fibre, the beam emerging through a window of armour plate glass.

A detachable wire gauze-type dimming screen is fitted over the window. This is not normally used, but may be needed in exceptionally clear weather at night, when it is desired to dim the beam further than is practicable by reducing the supply voltage, that is, beyond the point at which the colour of the lamp filament causes confusion between the red and yellow sectors of the beam.

The lamp is a 24-volt, 150-watt Osram type 439G.

The intensity of the unit showed a maximum of 600 candelas in the green (of those vector directions measured), 1790 candelas in the yellow, and 80 candelas in the red. Beam error for various angles of rotation of the light support are shown in table 1.

Table 1.

Rotation of Light Support	Error in Beam Elevation
1° down (or up)	3/8° down (or up)
2° " "	3/4° " "
3° " "	1° " "
4° " "	1 1/4° " "
5° " "	1 1/2° " "

In each case the beam returned to its zero position whenever the support was moved to its zero position.

Depth-of-Flash Indicator.

The two tri-color glide-path indicators with depth-of-flash indication prepared by the National Bureau of Standards and delivered

to the Naval Air Test Center for tests aboard an aircraft carrier were returned to NBS for repair and realinement. Both units showed the effects of mishandling in transit. The Naval Research Laboratory unit required a new condensing lens, some repair to the wiring, and general alinement. The National Bureau of Standards unit showed less mistreatment. It was re-mounted on a sturdier base less subject to misalinement caused by vibration and more capable of keeping the two sub-units in alinement.

Both units were returned to the Naval Air Test Center, Patuxent River, Maryland, for further tests there and aboard an aircraft carrier.

The Fresnel-Lens Optical Landing System.

A Fresnel-Lens Optical Landing System cell modified to incorporate a triple-width lenticular lens and a more powerful source-light system was received for test. NBS Report 212.11P-2/67 describing this work was issued. Figure 10 from that report is included herein as figure 2.

Two FLOLS cells were modified at NBS for use as "depth-of-flash" cells to be mounted above and below the five cells presently used. Both cells were made to flash by installing externally controlled, solenoid operated shutters giving a 50% on, 50% off duty cycle at 140 per minute. Slits were widened to 0.25 inch. Both cells were set for the minimum virtual image distance allowed by the forward movement of the source light sub-assembly. The resultant vertical beam spread was of the order of 1.0°.

One cell was fitted with a red lenticular, while the other was provided with an aviation-green window in place of the clear window in the "neck" end of the casting.

The two cells along with eight others were turned over to the Naval Air Engineering Laboratory (SI), Philadelphia, for testing of the feasibility of installing depth-of-flash cells on the FLOLS indicator assembly.

Shock- and Vibration-Resistant Homing Beacon.

A task has been established to procure and evaluate a homing beacon (for use aboard aircraft carriers) that will meet the shock and vibration requirements of MIL-S-90K (NAVY) and MIL-STD-167 (SHIPS), respectively, as well as the operational requirements. As the first step of the development, an experimental aircraft anticollision light having an intensity distribution suitable for a homing beacon was obtained and delivered to NAEL(SI) for shock testing.

V. MISCELLANEOUS TECHNICAL AND CONSULTIVE SERVICES

Review of Proposed Specification.

The following proposed specification has been reviewed and our comments were forwarded: MIL-T-26898B Airfield Lighting Systems Test Set Type MM-1.

Several conferences concerned with the measurement of visual range and the development of lighting and marking systems for airports and aircraft carriers have been attended.

VI. MISCELLANEOUS

Approach Lighting Clearance Zone.

At Arcata the Federal Aviation Administration is attempting to obtain the standard clearance zone specified for high intensity approach lights. All of the NBS installations in the approach zone are below runway level, but, since the approach light lane slopes downward from the runway threshold, some of our installations extend into the approach-lighting clearance zone. Two steel towers which were no longer in use have been removed. The approach-zone transmissometer is outside this zone, but the power and signal lines which are on overhead poles between the projector and receiver extend into the clearance zone. These lines will be moved to the other side of the transmissometer units where they will be outside the specified clearance zone. The major problem in obtaining the complete clearance specified is that there is inadequate clearance for vehicles on the highway which crosses the approach zone.

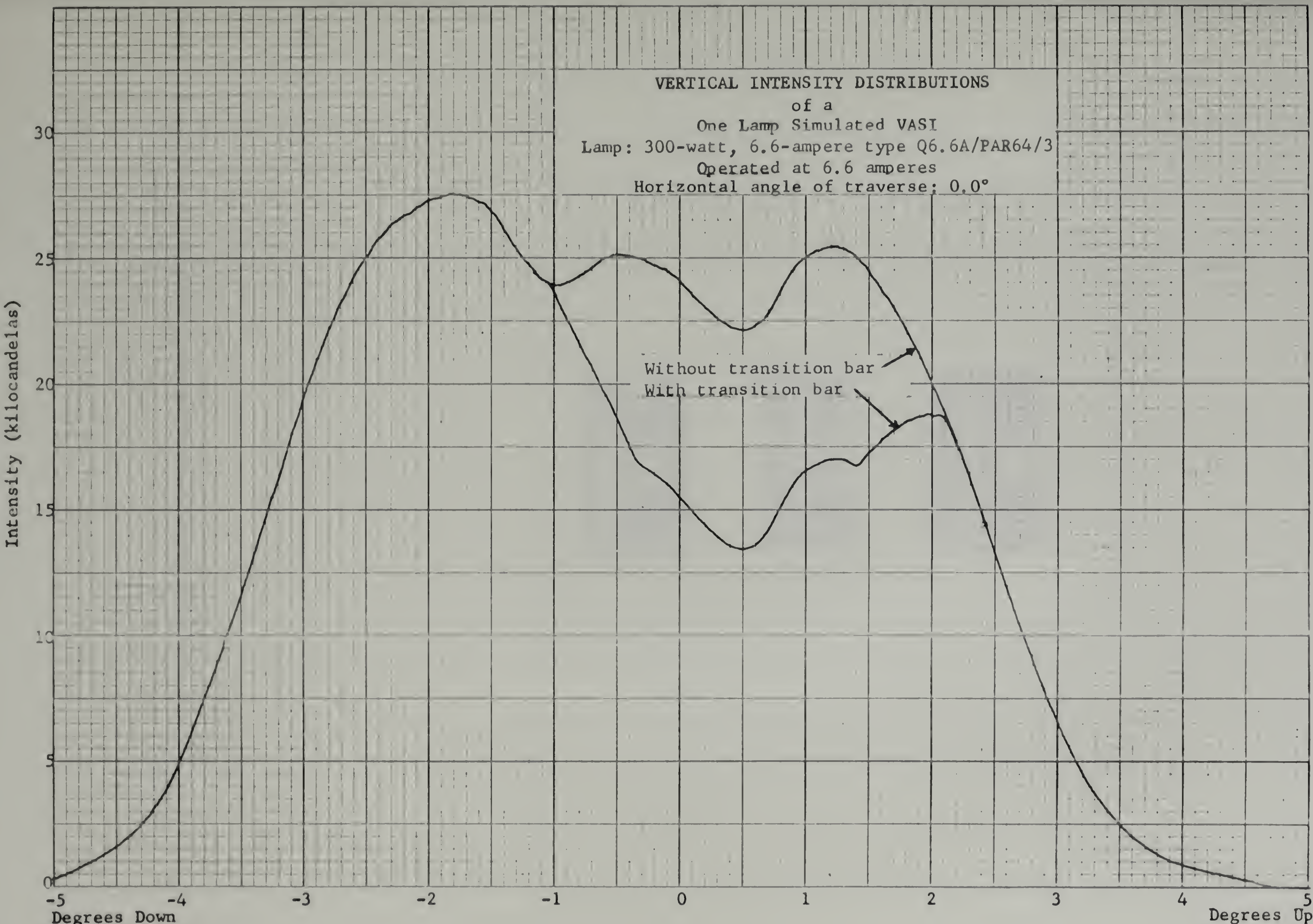
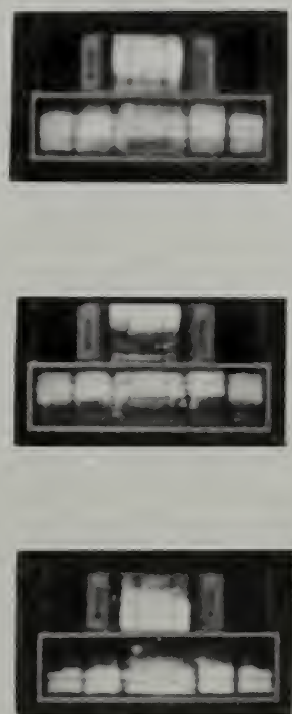

VERTICAL INTENSITY DISTRIBUTIONS
of a
One Lamp Simulated VASI
Lamp: 300-watt, 6.6-ampere type Q6.6A/PAR64/3
Operated at 6.6 amperes
Horizontal angle of traverse: 0.0°
Without transition bar
With transition bar
Intensity (kilocandelas)
30
25
20
15
10
5
0
-5
-4
-3
-2
-1
0
1
2
3
4
5
Degrees Down
Degrees Up

Figure 1



Elongated and regular cell of FLOLS at 258 feet.

NBS Report 9540 Figure 2

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