NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT
0201-20-2327

September 1957

NBS REPORT
5466

Field Tests of Runway Distance Markers

By
John W. Simeroth
Earl F. Bienz
Morton R. Carrothers

Visual Landing Aids Field Laboratory
Photometry and Colorimetry Section
Optics and Metrology Division

Prepared for
Ship Installations Division
Bureau of Aeronautics
Department of the Navy
Washington 25, D. C.
Project No. TED NBS AE-10011

NBS

U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

Field Tests of Runway Distance Markers

By
John W. Simeroth
Earl F. Bienz
Morton R. Carrothers

ABSTRACT

This report gives the results of tests of the visual range and recognition distance of runway distance markers in conditions of restricted visibility. For nighttime use the markers were floodlighted by single floodlights at several levels of illumination and from several lamp positions. The optimum level of illumination and location of the lamp were determined. The performance of markers using fluorescent orange paint was compared with that of markers finished with international orange paint. Although the visual range of the fluorescent orange marker was greater than that of the international orange marker, the recognition distance of the numeral on the international orange marker was greater than that of the fluorescent orange marker.

1. INTRODUCTION

1.1 General

The longer runways and more critical performance of present aircraft have created a need for more accurate information on the length of runway remaining or used. One method of providing this information is by the use of a row of vertical markers along each side of the runway with a numeral showing the distance to the upwind end of the runway. These markers indicate the distance remaining for landing aircraft, and provide checkpoint information on performance of aircraft on takeoff. Navy standards require that the markers be located at 1000-foot intervals on both sides of the runway; that each surface of the marker be marked with the numeral indicating the distance, in thousands of feet, to the upwind end of the runway; that the markers have an orange background with a white numeral; and that they shall be illuminated for use at night.

1.2 Test Objectives

Objectives of these tests were the determination of the optimum position of the lamp used for floodlighting the marker at night; the optimum level of illumination on the marker as a function of meteorological visibility; and the distance at which markers of different finishes are effective as a function of meteorological visibility. Although conditions of observation during tests can not duplicate those in service, the test results should provide a measure of the effectiveness of the markers.

1.3 Method of Illumination

Use of internally illuminated markers has been considered. However, the mass of such a marker is so great that a marker of this type is considered a hazard if mounted near the edge of the runway. Retroreflective markers are often unsatisfactory when the runway is wide, and in restricted visibility. Moreover, such markers can provide little or no information when the aircraft has no landing or taxiing lights. For these reasons the only method of illumination used in these tests was external floodlighting.

2. EQUIPMENT AND INSTALLATION

The runway distance markers (see figure 1) were constructed of 1/4-inch exterior plywood, 48 inches by 48 inches, with a 1-inch by 2-inch wooden frame around the plywood to act as a stiffener. The markers were mounted on low bases to elevate the markers and were hinged to allow the markers to be lowered when they were not being observed. The bottom of both markers was approximately 20 inches above the ground to prevent weeds and runway lights from obscuring the markers. The markers were held in a vertical position by guy wires similar to aircraft safety wire. Construction details of the markers are shown in figure 2.

The plywood was sealed and a primer coat of white paint, which also served as the paint for the numeral, was applied. The numerals were 33 inches high with a 4-inch-wide stroke, using the shapes specified by the Bureau of Aeronautics.* The background paint was applied to the surface outside the number and the number was then outlined with a 1/4-inch-wide black border. Two types of paint were used for the background of the markers. One was International Orange, Federal Standard TT-C-595, No. 1205, applied

*BuAer Instruction 11012.1. Planning Standards for Naval Air Stations, p. 24, S.E. Drawing No. 270.

directly over the white primer paint. The other was NRL Fluorescent Paint Formula No. A-7 applied according to BuAer instructions dated 15 June 1956.* The average reflectances of the white and orange surfaces were 0.20 for the international orange, 0.71 for the white on the international orange marker, 0.31 for the fluorescent orange, and 0.78 for the white on the fluorescent marker.

For nighttime observations the markers were illuminated externally by a single sealed-reflector lamp. A type 75PAR/FL, 75-volt, 75-watt, PAR-38 lamp was used for most observations. A type 300R/FL, 125-volt, 300-watt, R-40 bulb, reflector floodlamp was used when higher illumination levels than could be obtained with the 75-watt lamp were desired. The lamps were mounted in commercial spotlight holders that were adjustable in the horizontal and vertical directions. Installation details of one (the preferred) lighting arrangement are shown in figure 3. The light was located at other positions with respect to the marker to study the effects on uniformity of illumination, specular reflections, and spill light. Figure 4 shows all lamp positions generally used in the test. The distance between the marker and the lamp was chosen so that the main beam of the light covered an area slightly smaller than the marker. The center of the beam was directed toward the center of the marker.

3. TEST PROCEDURE

The markers were installed at Arcata Airport on the left side of runway 31, about 2000 feet from the threshold. The international orange marker was located 20 feet outside the edge of the runway pavement. The fluorescent marker was located beside the international orange marker about 25 feet from the edge of the runway (see figure 1).

For nighttime observations the voltage to the lamp was adjusted by a continuously-variable autotransformer to obtain the desired illumination at the center of the marker. The illumination on the marker was measured with an illumination meter, or was calculated from the brightness measurements of a blotter surface of known reflectance mounted on the marker. The illumination was measured at various points on the surface of the marker to determine its uniformity.

* When the Formula A-7 paint was applied, it wrinkled if the applied coat was too thick.

Observations were made from a vehicle along the centerline of the 150-foot-wide runway. Thus the markers were approximately 100 feet from the line of observation. Visual observations were made and the following were recorded for each test condition.

Detection range - the maximum distance a stationary observer can detect the presence of some configuration on the surface of the marker.

Recognition range - the maximum distance at which the numeral is legible with reasonable accuracy to a stationary observer.

Conspicuous range - the distance at which the driver of a vehicle traveling at a moderate speed can unmistakably read the numeral on the marker at a glance.

The useful range should be between the recognition range and the conspicuous range.

The three visibility ranges defined above were obtained for both daylight and nighttime conditions as a function of the visibility and background brightness during daylight and as a function of the visibility, the illumination on the marker, and the position of the external floodlight at night. The visibility for both daytime and nighttime tests varied from below one-fourth mile to over 10 miles.

4. RESULTS AND DISCUSSION

The distance at which the marker (not the numeral) could be seen as an orange sign depended primarily upon visibility. For visibilities of one mile or more the visual range of the markers was several thousand feet; however, as the visibility decreased, the visual range of the marker approached the visibility. The fluorescent marker could be seen farther than the international orange marker. The visual range of both types of markers seemed adequate. These results are as expected and are in good agreement with the distances predicted by visibility theory.

Since the markers are intended to provide information by means of the numeral, the detection, recognition, and conspicuous ranges were considered much more important than the visual range of the entire marker. The average visibility ranges obtained during the daytime tests are given in table 1. The average detection, recognition, and conspicuous ranges of the fluorescent marker were less than those of the international orange marker.

Table 1

Runway Distance Marker Performance--Daytime
(All Brightnesses)

Visibility	International Orange Background			Fluorescent Orange Background		
	Detection Range	Recognition Range	Conspicuous Range	Detection Range	Recognition Range	Conspicuous Range
(Miles)	(Feet)	(Feet)	(Feet)	(Feet)	(Feet)	(Feet)
Over 1	2200	1800	1200	1800	1200	600
3/8	1800	1300	1000	1650	1100	820
1/8	500	380	180	500	300	120

The average visibility ranges obtained during nighttime are given in table 2. The average detection and recognition ranges of the fluorescent marker were again less than those of the international orange marker. The conspicuous range for the fluorescent marker was not quantitatively observed for most test conditions because earlier observations had indicated that this marker was less effective and incidental observations upheld this assumption.

Table 2

Runway Distance Marker Performance--Nighttime

Average of All Illumination Levels for Three Lamp Positions

Visibility	*Lamp Position	International Orange Background			Fluorescent Orange Background		
		Detection Range	Recognition Range	Conspicuous Range	Detection Range	Recognition Range	Conspicuous Range
(Miles)		(Feet)	(Feet)	(Feet)	(Feet)	(Feet)	(Feet)
Over 1	A	1500	1300	880		--	--
	B	1450	1250	860	1350	1050	--
	C	1550	1350	880	1350	1100	--
3/8	A	1050	860	--	---	--	--
3/16	A	680	540	280	580	480	240

*A, Outside (from runway); B, Center; C, Inside (toward runway).

The nighttime performance of the markers as a function of illumination level is illustrated in figure 5, where the results are shown for meteorological visibilities of three-sixteenths mile and one mile and above. The number beside each point is the number of observations used in determining the point. The curves were drawn through the points obtained from observations of the international orange marker.

Although the visual range of the fluorescent marker was greater than that of the international orange marker, the three ranges of its numeral were shorter because of its lower contrast. The reflectance factors of the white numerals were approximately equal but the brightness contrasts between the numeral and the orange background under clouded sky conditions were 1.5 for the fluorescent marker and 3.0 for the international orange marker. For some conditions of observation the white numeral on the fluorescent marker appeared darker than its orange background. Hence, there are conditions of observation for which the contrast would be so low that the recognition range of the numeral would be too low for the marker to be of value.

When the visibility was one mile or more, the maximum visibility ranges of the numeral of the orange marker were obtained when the incident illumination was 25 to 100 footcandles, but at the higher illumination the marker was so bright that it was uncomfortable to view. For the better visibility conditions there was very little loss in effectiveness of the markers when the illumination was as low as 7.5 footcandles. This lower illumination was preferred by the observers. When the visibility was one-half mile or less, the visibility ranges continued to increase as the illumination was increased to 200 and more footcandles.

The effects of the specular reflection from the semi-glossy surface of the marker for the three lamp positions are shown in table 2. As the angle between the light beam and the normal to the surface of the marker was increased, the three visibility ranges of the numeral were increased, but the improvement was small. A more important factor was the selection of the proper location for the lights. This was determined by the position for which the marker provided the best shielding from bothersome glare on the runway produced by direct light from the illuminating lamp. Glare from these lamps can be a serious problem in clear weather since the intensity of the spill light from these lamps is of the order of ten times the intensity of the main beams of runway lights operated on brightness step 1.

The maximum distances along the runway centerline that direct light from a lamp illuminating the marker was noticeable were as follows: Lamp position A (outside position), 100 feet; lamp position B (center position), 250 feet; lamp position C (inside position), to the end of the runway. Glare was observed on taxiways near the marker for each of the three positions of the lamp. When the lamp was in position A the glare extended over a longer distance than when the lamp was in the other positions. On occasion, at a point on the taxiway and 600 feet from the marker, the glare made driving a vehicle without lights difficult.

At the end of the test period the international orange marker had been exposed 15 months and the fluorescent orange marker had been exposed 11 months. The plywood and finish of both markers were showing the effects of weathering at the end of the test period.

5. CIRCUITRY FOR THE ILLUMINATION OF THE MARKER

The use of 75-watt PAR-38 lamps for floodlighting the runway markers was satisfactory. These lamps have a satisfactory beam spread and will provide an illumination of approximately 60 foot-candles on the center of the marker when operated at rated voltage.

Often it will be desirable to supply the power for illuminating the distance markers from the runway-lighting circuits. If the marker lamp current were directly proportional to the current in the series runway-light circuits, the illumination of the marker at the lower brightness settings would be much too low if the illumination at step 5 is correct. Hence some compensation is required. This compensation may be accomplished by operating the transformers supplying power to the marker lamps in a saturated condition.

(The following discussion is based upon a study of circuit and lamp characteristics made at the National Bureau of Standards laboratories in Washington, D.C. The results of these tests will be reported in a separate report.)

Two convenient circuits for obtaining this compensation using stock isolating transformers and listed lamps are:

1. Connection of two (one for each side of the marker) 30-volt, 75-watt, PAR-38 lamps in series across the secondary of a 200-watt, 6.6-ampere secondary isolating transformer; and

2. Connection of two 75-volt, 75-watt, PAR-38 lamps in parallel across the transformer.

With each of these circuits the illumination on the marker is satisfactory over the range of primary currents used in runway-lighting circuits. The illumination on the marker when the runway lights are on brightness step B-1 (0.2% relative intensity) is about one-fourth that when the runway lights are on brightness step B-5 (100% relative intensity). As shown above, the optimum illumination for the clear weather is about a fourth of the optimum illumination in dense fog.

If a lamp in circuit 1 fails, the other will, of course, go out. If a lamp in circuit 2 fails, the other may be overloaded or burned out if there are several open-circuited isolating transformers in the runway-lighting circuit and the runway lights are operated on brightness steps 4 or 5.

Tests made at the Aeronautical Accessories Laboratory, Wright Air Development Center, and checked by the National Bureau of Standards showed that if the lighting circuit is supplied by some makes of regulators and the lamps are connected using circuit 1, some makes of stock 200-watt isolating transformers will overload the lamps when the primary current is 6.6 amperes even if there are no open -circuited isolating transformers in the circuit, and that the overload will increase with the number of open-circuited transformers to such an extent that satisfactory lamp life will not be obtained. Thus the use of circuit 2 is preferable.

When circuit 2 is used, the lamps will generally be operated slightly below rated voltage when the regulator supplying power is on brightness step B-5. The exact operating voltage is dependent upon the make of the regulator and the isolating transformer used. The illumination on the center of the marker will be approximately 50 footcandles when the regulator is on step B-5 and 15 footcandles when the regulator is on step B-1.

6. CONCLUSIONS

Runway distance markers of the type shown in figures 2 and 3 provide valuable information for accurately determining the amount of runway left on landing and checkpoint information on performance of aircraft on takeoff. Of the two markers tested the one with the international orange background was found to be more effective than the one with the fluorescent orange background. The fluorescent orange paint should not be used as the background for runway distance markers because for some conditions of observation the contrast may be such that the marker will be virtually useless.

The effective range of the international orange marker appears adequate for use in daytime. For nighttime use in visibility conditions of 1 mile or more an externally illuminated marker will provide a fairly satisfactory effective range.

The useful range at night, between 300 and 1400 feet, may be somewhat less than desired, especially for low visibilities. The illumination on the marker should be between 5 and 20 footcandles when the visibility is one mile or more. When visibility is a quarter mile or less, the illumination on the marker should be between 25 and 150 footcandles.

An ideal lamp for illuminating the marker is not available, but the type 75PAR/FL lamp is suitable for this purpose.

The proposed system of illuminating the markers at night does not cause objectionalbe glare on the runway. However, special shielding to eliminate the glare on nearby taxiways will be required.

7. RECOMMENDATIONS

It is recommended that:

The runway distance markers be installed as directed by the Bureau of Aeronautics Instruction 11012.1, using the design shown in figure 2 of this report.

These markers be illuminated using the system shown in figure 3 using two 75-watt, 75-volt, PAR-38 floodlight lamps connected in parallel across the secondary of a 200-watt, 6.6-ampere secondary, isolating transformer when power for illuminating the markers is obtained from the runway lighting circuits.

Studies be made of other types of distance markers in order to obtain markers which will have a substantially greater effective visibility range at night.

RUNWAY DISTANCE MARKERS

Figure 1

DISTANCE MARKER INSTALLATION DETAILS

A. NUMBER ON BOTH SIDFS OF SIGN

B. SCREW EYE

C. GUY WIRE

D. SFF PAGE 24, BUAER INSTRUCTION 11012.1 FOR SIZE OF NUMBERS

E. WHITE NUMBER WITH BLACK BORDER

F. ~~INTERNATIONAL~~ ORANGE BACKGROUND

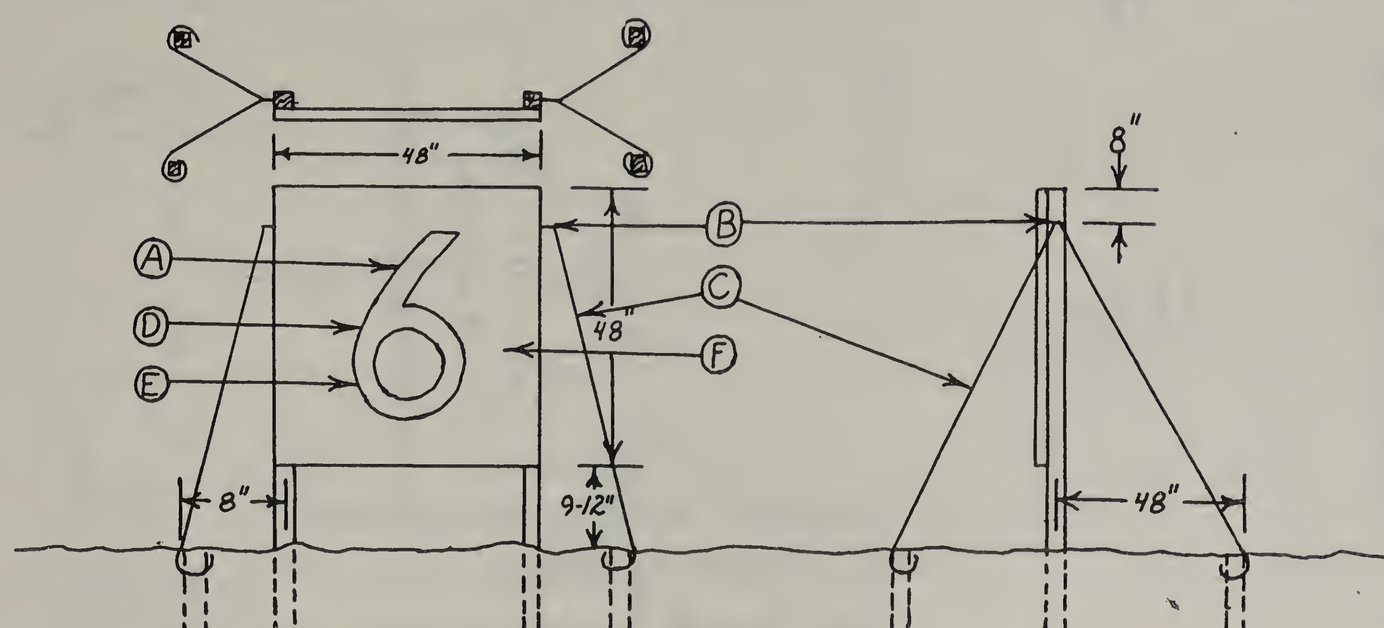


Figure 2

LIGHTING OF DISTANCE MARKERS--DETAILS

A. LAMP, NO. 75PAR/FL, 75-VOLT, 75-WATT, PAR 38

B. PAR 38 LAMPHOLDER, (STONCO NO. 5515, OR EQUAL)

C. 2" x 2" WOOD STAKE FOR MOUNTING LAMPHOLDER

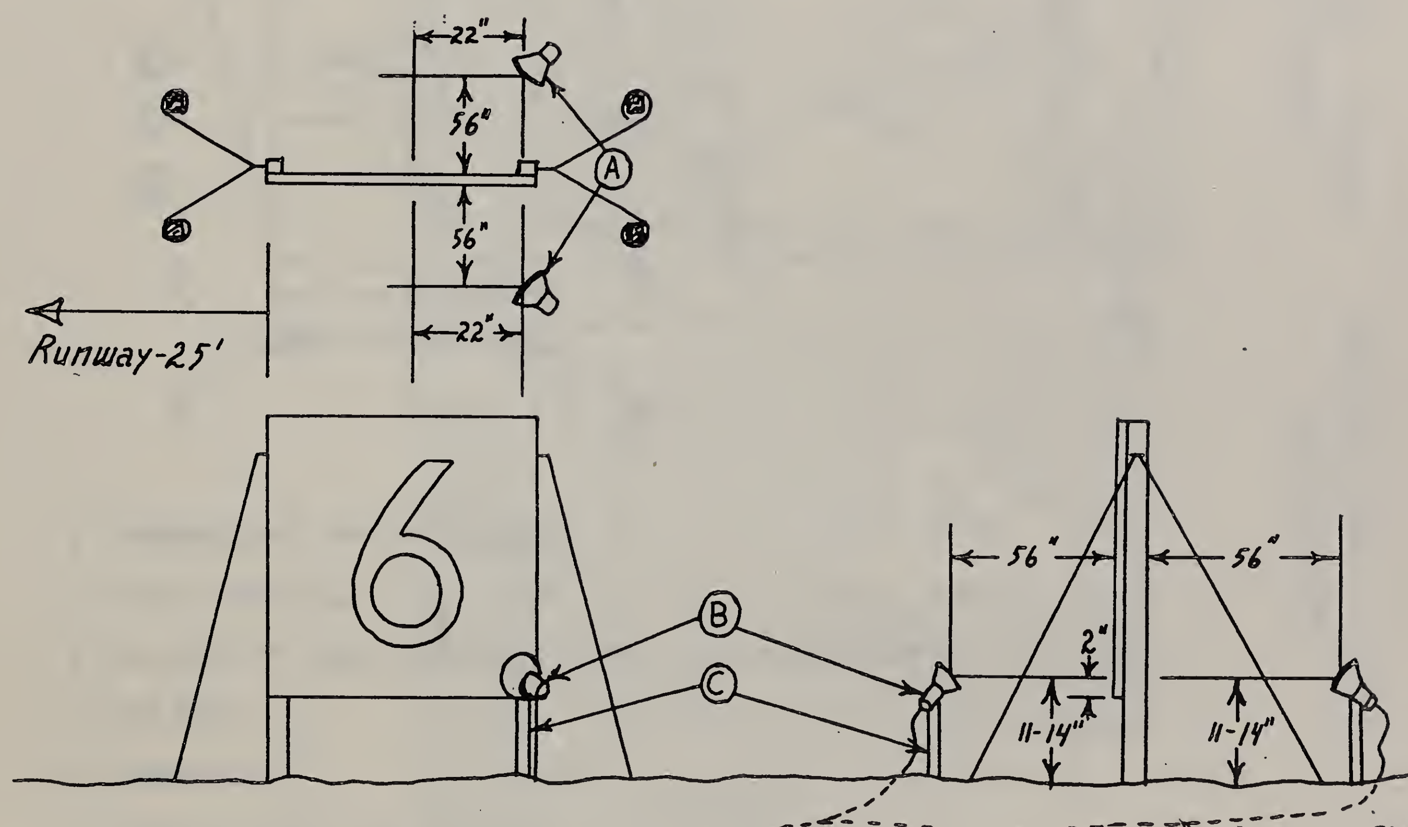
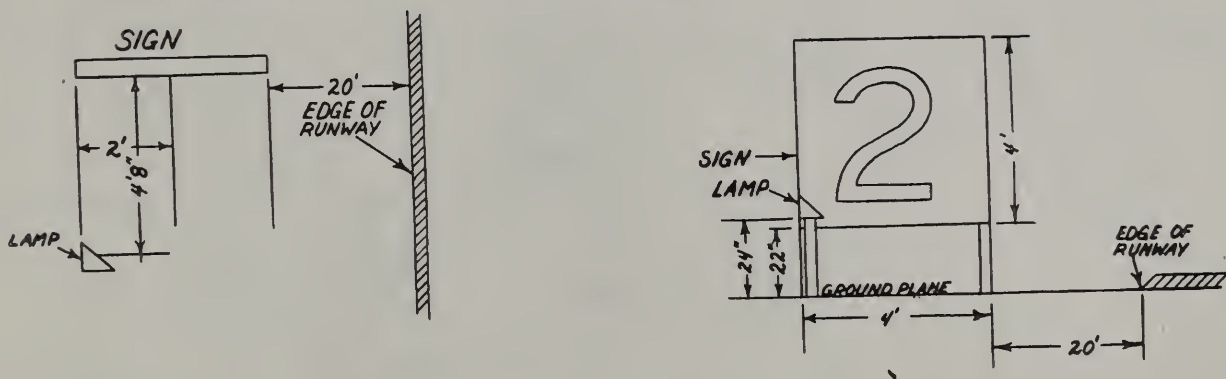


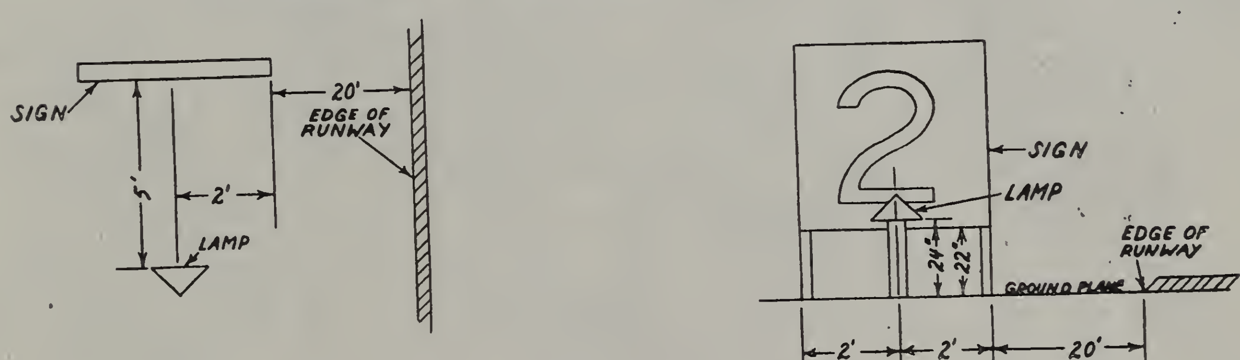
Figure 3

Illuminating Lamp
Test Positions

Position "A", Outside (from runway)



Position "B", Center



Position "C", Inside (toward runway)

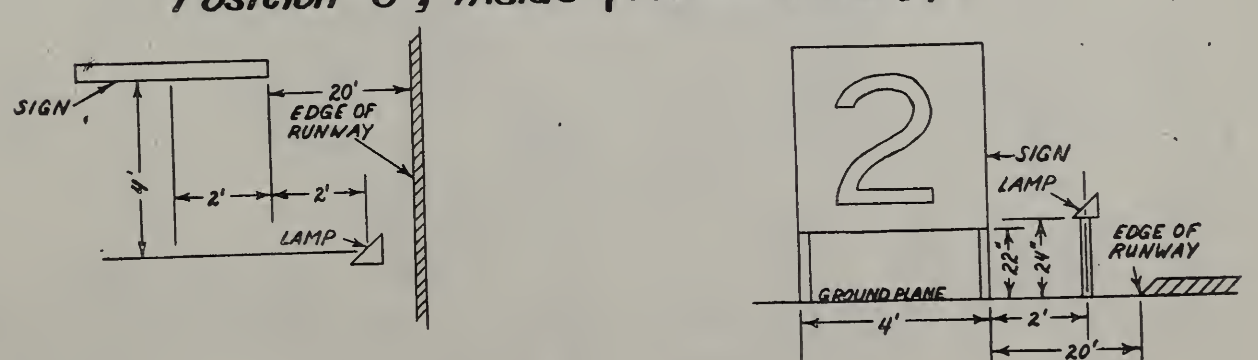


Figure 4

RUNWAY DISTANCE MARKERS--NIGHTTIME
(Illumination vs. Visibility Ranges)

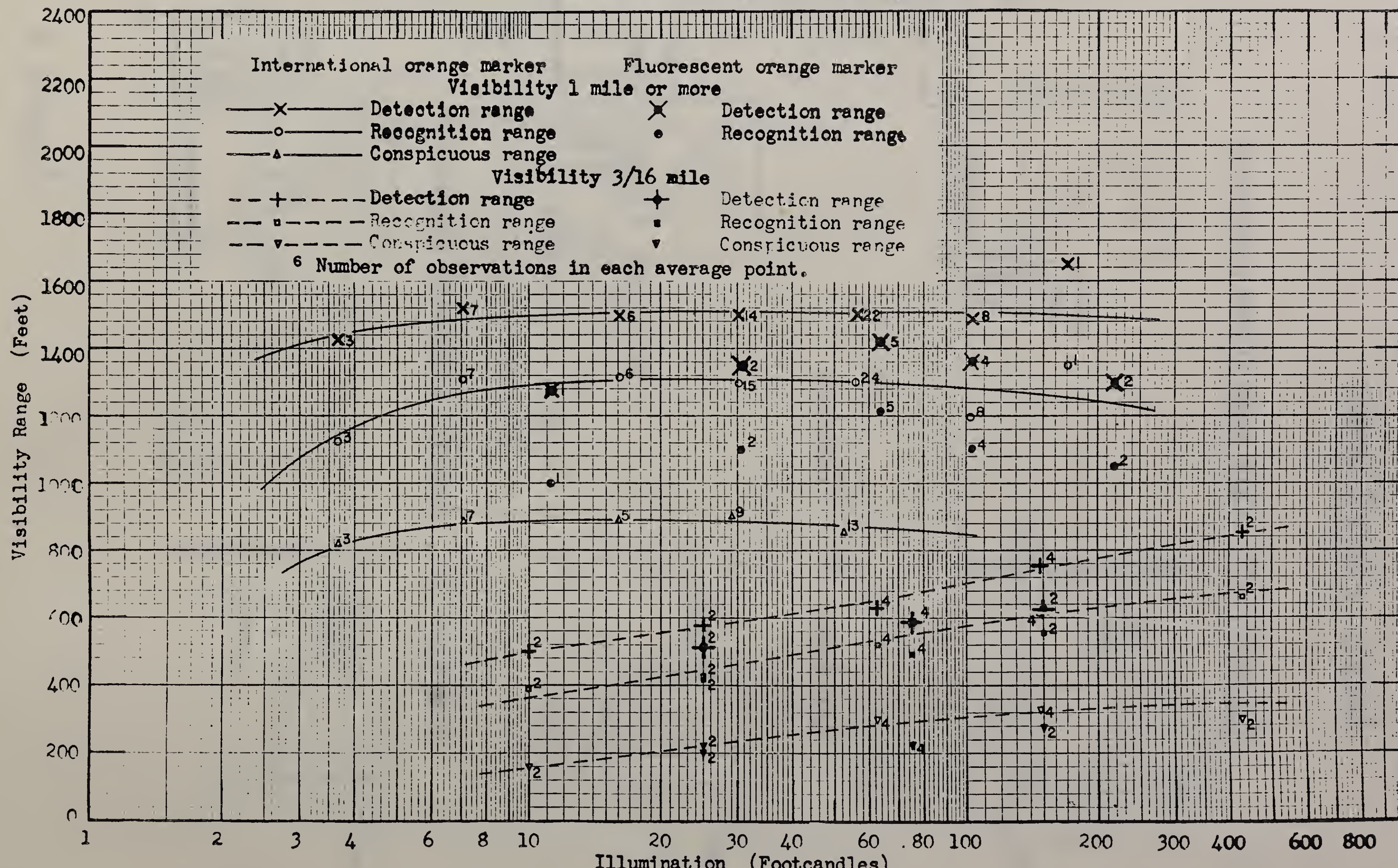


Figure 5