NATIONAL BUREAU OF STANDARDS REPORT

7419

PERFORMANCE CRITERIA FOR A TWO-COLOR
VISUAL GLIDE SLOPE INDICATOR

By
Andrew C. Wall

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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Prepared For
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U. S. DEPARTMENT OF COMMERCE
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ABSTRACT

This report gives the results of a study of the effects of lamp characteristics on the performance of the R.A.E.-type Visual Glide Slope Indicator (VGSI). An alignment procedure is outlined. The data previously presented in NBS Reports 21P-8/61, 21P-31/61, and 21P-36/61 are analyzed as a basis for specification criteria.

1. INTRODUCTION

A type of two-color angle-of-approach indicator system developed by the Royal Aircraft Establishment consists typically of twelve units. The number, design, and placement of the units is, however, subject to considerable variation. The following is a typical installation.

The twelve units are arranged in four groups of three units each in such a manner as to form two transverse bars. The bars are located 500 feet and 1000 feet from the threshhold and are split by the runway.

A unit contains three sealed-reflector lamps. Each lamp has its own separate horizontal-spread lens. The upper 60% of this lens is red while the lower 40% is white.

The lamps used in the units have, by design, an off-focus filament placed to form an image of their filaments in an open horizontal slit in the unit. This two-inch-high slit runs the full width of the 4-1/2-foot-square by 1-foot-high metal box enclosing the components of the VGSI.

The VGSI projects a beam with three components: (1) the upper, which is red; (2) the lower, which is white; and (3) the transition between them, which is pink.

The units are aimed with reference to the glide path of a plane in such a manner that a pilot coming in high sees two white light bars. When he is on the glide path, he sees the nearer bar as white and the farther bar as red. When he is too low he sees both bars as red.

Distinction must be made between the photometric and the visual transition zones. In the photometric transition zone, the presence of light from both the red and white beams can be detected by photometric methods. In the visual transition zone, the mixture of light from the two beams appears pink to an observer located at a distance of a few hundred feet (or more) from the light.

The lamps which were used in this study are listed in Table I.

Table I. Characteristics of Lamps Tested

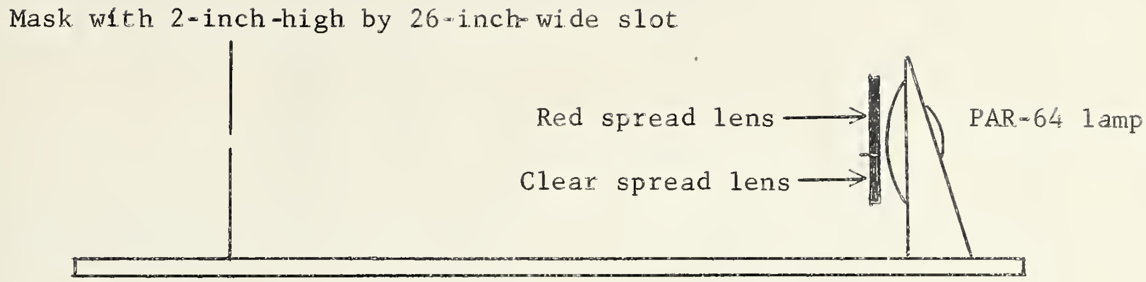
Lamps	Current (amperes)	Power (watts)	Filament	Filament Ahead of Focus (inches)	Lamp Type
1 - 3	6.6	200	CC-6	0.07	(PAR-64)
4 - 6	20.0	300	C-6	0.06	(PAR-64)
7 - 14	6.6	300	CC-6	0.07	6.6A/PAR64/3
15 - 22	6.6	300	CC-6	0.07	(PAR-64)

The effectiveness of an off-focus PAR-64-type lamp in the VGSI is dependent upon the fraction of its luminous flux which passes through a 2-inch-high horizontal slot in a vertical mask intercepting the beam approximately 50 inches in front of the seating plane of the lamp. Three basic methods for studying the characteristics of the lamps were used, namely: (1) a 60-inch integrating sphere was used to measure the total lumen output of each lamp placed individually in the sphere, and also the lumen "input" through a slot in the sphere from each lamp on the outside; (2) a "point-by-point" method was used to determine the luminous flux incident on an area 50 inches in front of the lamp; and (3) vertical and horizontal intensity distribution measurements were used. The latter method was modified by the use of a VGSI simulator. A limited amount of data was obtained to determine the effects of varying some of the conditions of the tests, such as the slit width of the simulator, the orientation of the seating plane of the lamp, or the type of spread lens used in the simulator. However, some of the more sophisticated parameters affecting the intensity of the unit were not appreciated at the beginning of the study.

2. THE VGSI SIMULATOR

2.1 Basic Considerations

To provide proper environmental conditions for testing the lamps designed for use in the VGSI, a simulator was used. Its basic components were: (1) a mount for a single lamp (the VGSI contains three lamps). This held the lamp in a vertical plane with its filament horizontal; (2) a two-color (60% red, 40% white) spread lens; and (3) an opaque mask intercepting the beam of light at right angles to its axis approximately 50 inches in front of the seating plane of the lamp. A horizontal slot 2 inches high by 26 inches wide was cut in the mask (see figure 1). A vertical adjustment permitted the slot to be placed in an optimum position in relation to the "image" of the lamp filament on the mask.



Breadboard Model of an R.A.E.-Type Visual Glide Slope Indicator

Figure 1

At the beginning of the study, the slot-image relationship was determined by eye; the slot was centered on the major axis of the oval-shaped image of the lamp filament projected on the mask. This image is a bright spot roughly the size and shape of a football, with some dark spots caused by the spaces between the turns of the filament coil. When it was found that the lamps could not be re-tested with reproducible results, the validity of this method of positioning was suspect. To overcome this difficulty, an alignment device was designed and a prototype made (see below).

Information received at the beginning of the tests indicated that the British production model of the VGSI incorporated a 3/4" horizontal "transition bar" covering the line of demarcation between the red and clear portions of the spread lens. In order to determine the effects of the transition bar on the intensity distribution of a lamp in the VGSI simulator, measurements were made with and without the bar. A typical set of intensity distribution curves is shown in figure 2.* The "red component" is that projected with the clear portion of the lens blocked, the "white component," with the red portion blocked, and the "composite beam" with no part of the lens blocked.

Tables II and III show the effects of a 3/4" bar on the peak intensities, the beam widths, and the transition zone (that segment of the beam containing both red and white light).#

After the tests were completed, it was learned that the transition bar was actually 9/16" wide. The use of the narrower bar would result in a transition zone of 1.8° (from geometrical considerations) and slightly different values from those shown in Tables II and III for the 3/4" bar.

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*The 0.0° position of the simulated VGSI in the vertical intensity distributions is at right angles to the seating plane of the lamp and is not intended to show the proper operating position of a VGSI unit. In operation the beam would be elevated to the prescribed angle.
#References in this report are to the photometric transition zone, unless otherwise noted.

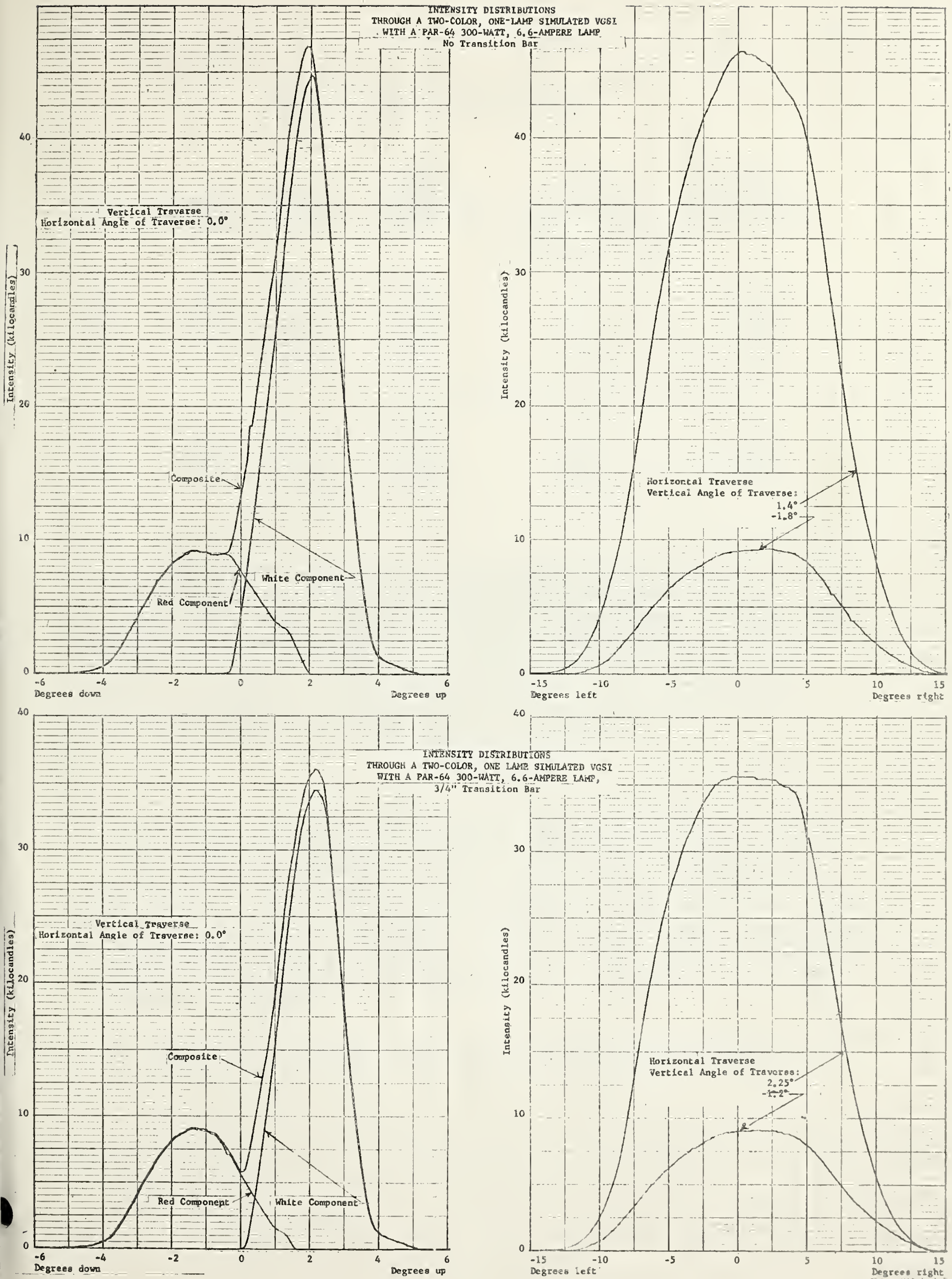

INTENSITY DISTRIBUTIONS
THROUGH A TWO-COLOR, ONE-LAMP SIMULATED VGSI
WITH A PAR-64 300-WATT, 6.6-AMPERE LAMP
No Transition Bar
Vertical Traverse
Horizontal Angle of Traverse: 0.0°
Intensity (kilocandles)
Composite
White Component
Red Component
Degrees down
Degrees up
Horizontal Traverse
Vertical Angle of Traverse:
1.4°
-1.8°
Degrees left
Degrees right
INTENSITY DISTRIBUTIONS
THROUGH A TWO-COLOR, ONE LAMP SIMULATED VGSI
WITH A PAR-64 300-WATT, 6.6-AMPERE LAMP,
3/4" Transition Bar
Vertical Traverse
Horizontal Angle of Traverse: 0.0°
Composite
Red Component
White Component
Horizontal Traverse
Vertical Angle of Traverse:
2.25°
-1.2°

Figure 2

Table II. Peak Intensity of a Simulated Visual Glide Slope Indicator with Spread Lens "A"

Lamp	Power (watts)	Current (amperes)	White Component (kilocandles)	Red Component (kilocandles)	Composite Beam (kilocandles)
				No Transition Bar	
16	300	6.6	36.2	9.6	38.9
18	300	6.6	44.7	9.2	47.0
19	300	6.6	45.2	10.7	47.4
		Average	42.0	9.8	44.4
			With 3/4" Horizontal Transition Bar		
16	300	6.6	27.2	9.5	27.9
18	300	6.6	34.5	9.1	36.1
19	300	6.6	34.9	10.4	36.0
		Average	32.2	9.7	33.3

The red spread lens is made of selenium glass and decreases in transmittance asymptotically as its temperature increases. It was observed on a cursory examination of one British-made red lens used on their production model that the opposite is true; a temperature increase caused a definite, but smaller (than the decrease noted above), increase in transmission through it. The transmission of the red spread lens "A" when it was hot was of the order of 20% of that of the clear lens (NBS Report 21P-31/61).

2.2 VGSI Performance

Table IV gives, for purposes of comparison of the effects of lamp type on the performance of the VGSI, a weighted mean of the peak intensity of the red component (R) and of the white component (W) of the beam. The intensity of the red component is multiplied by a factor of five to correct for the absorption of the red lens. Column 6 shows the ratio (in percent) of the performance factor of each lamp to the average of the 6.6-ampere, 300-watt lamps. This weighted mean, (W+5R)/2, will be used as a measure of the performance of the lamps throughout this report.

The results of a comparative study of the beam widths, both horizontal and vertical, of the four groups of lamps are shown in Table V.

Table III. Intensity Distribution Characteristics of a Simulated Visual Glide Slope Indicator With Spread Lens "A".

Lamp [5]	Vertical Beam Width [1]					Transition Zone (degrees)	Horizontal Beam Width [4]			
	White Component (degrees) (2)	Red Component (degrees) (2)	White Component (degrees) (3)	Red Component (degrees) (3)	Composite Beam (degrees) (3)		White Component (degrees) (2)	Red Component (degrees) (2)	White Component (degrees) (3)	Red Component (degrees) (3)
No Transition Bar										
16	2.2	3.5	3.5	5.5	6.4	2.3	13.7	14.1	21.9	22.5
18	2.1	3.8	3.7	5.6	6.6	2.3	13.9	14.3	21.0	21.5
19	2.2	3.4	3.7	5.4	6.5	2.3	13.8	14.0	20.8	22.0
Ave.	2.2	3.6	3.6	5.5	6.5	2.3	13.8	14.1	21.2	22.0
With 3/4" Horizontal Transition Bar										
16	2.1	3.1	3.1	5.2	6.7	1.5	13.9	14.1	21.0	22.4
18	1.9	3.2	3.3	5.1	6.8	1.5	13.9	14.4	20.3	21.5
19	2.1	3.0	3.4	5.0	6.7	1.5	14.1	14.1	20.5	21.8
Ave.	2.0	3.1	3.3	5.1	6.7	1.5	14.0	14.2	20.6	21.9

(1) In a vertical plane through 0.0° horizontal.
(2) At 50% of maximum intensity.
(3) At 10% of maximum intensity.
(4) Through peak of the component of the beam indicated
(5) For characteristics see Table II.

Table IV. Characteristics of a VGSI Simulator With Three Categories of Lamps[1]

Lamp	Type	Peak Intensity: Red Component R (kilocandles)	Peak Intensity: White Component W (kilocandles)	5R[2] (kilo-candles)	(W+5R)/2 (kilo-candles)	Relative Intensity[3]
1	6.6A 200w	7.5	32.0	37.5	34.8	79
2		7.0	25.8	35.0	30.4	69
3		8.0	32.3	40.0	36.2	82
Average		7.5	30.0	37.5	33.8	
4	20A 300w	11.5	45.0	57.5	51.2	116
5		12.0	55.0	60.0	57.5	130
6		11.0	40.7	55.0	47.8	108
Average		11.5	46.9	57.5	52.2	
7	6.6A 300w	10.5	39.5	52.5	46.0	104
8		(11.3)	(21.7)	(56.5)	(39.1)	(88)
9		10.4	34.0	52.0	43.0	97
10		9.3	33.3	46.5	39.9	90
16		9.6	36.2	48.0	42.1	95
17		9.2	44.7	46.0	45.4	102
19		10.7	45.2	53.5	49.4	112
Average[4]		10.0	38.8	49.8	44.3	

(1) The simulator was designed for one lamp only: a VGSI unit, however, employs three lamps.

(2) Estimate of what the peak intensity of the "red" component would be with a clear lens replacing the red lens.

(3) Relative to the average of (W+5R)/2 of 6.6A, 300w lamps.

(4) Lamp #8 excluded from average. See Section 4.3.

Table V. Intensity Distribution Characteristics of Simulated Visual Glide Path Indicator

Lamp	Power (watts)	Current (amps.)	Vertical Beam Width(degrees)[1] White[2]	Red[2]	White[3]	Red[3]	Composite Beam[3]	Transition Zone	Horizontal Beam Width(degrees)[4] White[2]	Red[2]	White[3]	Red[3]
						With Spread Lens "A"						
1	200	6.6	2.7	3.4	4.6	5.6	7.8	2.3	14.2	14.1	21.5	21.5
2	200	6.6	2.7	2.9	4.6	5.2	7.5	2.2	14.5	14.2	22.8	21.0
3	200	6.6	2.1	3.5	3.4	5.9	6.7	2.2	14.0	14.5	21.3	21.5
Average			2.5	3.3	4.2	5.6	7.3	2.2	14.2	14.3	21.9	21.3
4	300	20	1.9	3.4	3.1	5.4	6.0	2.2	13.8	13.8	23.0	22.0
5	300	20	2.0	3.2	3.5	5.3	6.2	2.2	13.8	14.1	22.3	23.5
6	300	20	1.9	3.7	3.0	5.8	6.2	2.3	14.0	14.5	23.8	24.5
Average			1.9	3.4	3.2	5.5	6.1	2.2	13.9	14.1	23.0	23.3
7	300	6.6	2.1	3.2	3.4	5.2	6.0	2.3	13.5	13.9	21.2	22.8
8	300	6.6	(1.6)	(3.2)	(2.6)	(5.2)	(5.6)	(2.3)	(13.5)	(14.0)	(20.8)	(21.5)
9	300	6.6	2.0	3.2	3.2	5.2	5.7	2.3	13.5	14.2	20.8	21.5
10	300	6.6	2.0	3.4	3.2	5.5	5.9	2.3	14.0	14.5	21.8	22.0
16	300	6.6	2.2	3.5	3.5	5.5	6.4	2.3	13.7	14.1	21.9	22.5
17	300	6.6	2.1	3.8	3.7	5.6	6.6	2.3	13.9	14.3	21.0	21.5
19	300	6.6	2.2	3.4	3.7	5.4	6.5	2.3	13.8	14.0	20.8	22.0
Average (#8 excluded)			2.1	3.4	3.4	5.4	6.2	2.3	13.7	14.2	21.2	22.0

(1) In a vertical plane through 0.0° horizontal.
(2) At 50% of maximum intensity.
(3) At 10% of maximum intensity.
(4) Through peak of the component of the beam indicated.

2.3 Characteristics of British-Made Spread Lens

For purposes of comparison, intensity distribution measurements were made of a lamp (#1) in the VGSI simulator with a spread lens from a British-made unit. The results of measurements, shown in figures 3 and 4, indicate only slight difference between the British-made and the American-made lens.

3. ALIGNMENT PROCEDURE

3.1 The Alignment Device

To eliminate the uncertainties of positioning the filament image with respect to the slot by eye, photoelectric methods of optimizing the alignment were studied. An alignment device that mounts in the slot of the VGSI proved to be the most suitable aid (other than direct measurements of the vertical intensity distribution) in positioning the lamps. It consists of a sheet metal holder with a lip appropriately placed for holding the device behind the slot (figure 5). Mounted on the holder are two rectangular photocells with 3/4" by 1-5/8" sensitive areas exposed to the light in the slot. In position each cell has a 1-5/8" edge adjacent to an edge of the slot. The cells are connected in parallel and their combined output read on a milliammeter.

During alignment the lamps were operated at half current (or less) to keep the device on scale, i.e., the output of the photocells below 1 ma., and to insure linearity of the device. (Note: Although the ultimate tests of the lamps in the VGSI were made using the two-color spread lens, the lens was not used during the alignment.)

If the two-color lens had been used, the 5 to 1 ratio of white beam intensity to red would have resulted in the white beam alone controlling the alignment rather than both beams. A dark red filter in front of both photocells could, however, be used to permit alignment by the device without the necessity of removing the spread lens from a VGSI unit. If the adjustment is made using such a filter and the spread lens, the lamp current will have to be reduced only a small amount, if any, and not the 50% mentioned above.


Vertical Intensity Distributions
Showing Effects of Different Spread Lenses
Without Transition Bars
Intensity (kilocandles)
40
30
20
10
0
-4
-2
0
2
4
Degrees Down
Degrees Up
Through British-made spread lens
Through American- made spread lens

Figure 3

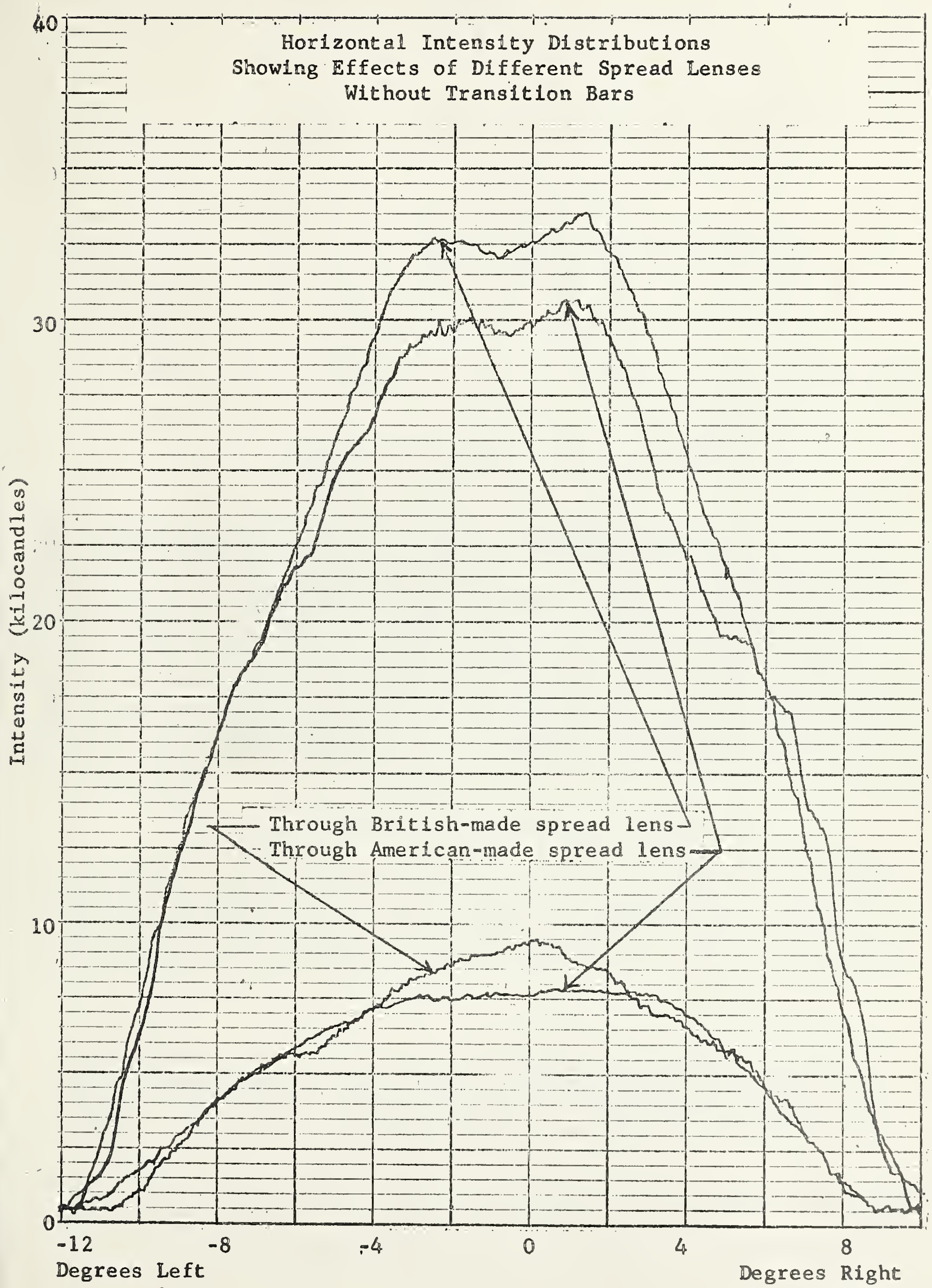
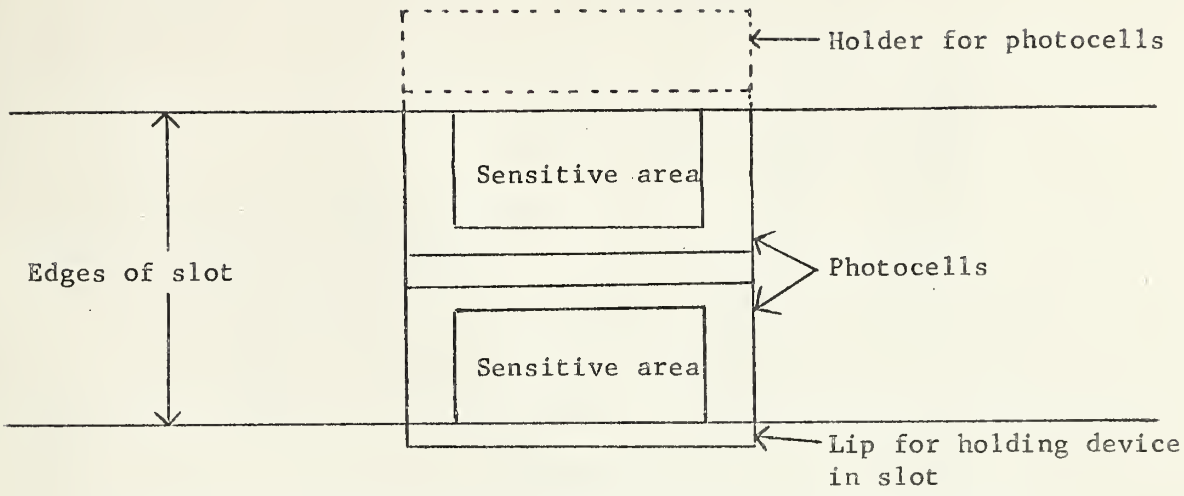

Horizontal Intensity Distributions
Showing Effects of Different Spread Lenses
Without Transition Bars
40
30
20
10
0
Intensity (kilocandles)
Through British-made spread lens
Through American-made spread lens
-12
-8
-4
0
4
8
Degrees Left
Degrees Right

Figure 4

Figure 5



Device for Aligning PAR-64 Lamp in VGSI for Optimum Output

The optimum position of the filament image with respect to the slot was taken to be that which produced a maximum intensity in the red component from the simulator. In order to test the performance of the alignment device, the spread lens was removed from the simulator and the lamp-slot relation was adjusted for maximum reading on the device. A vertical intensity distribution measurement was then made of the simulator with the spread lens replaced. The axis of the beam of the lamp was then raised 0.5°, 1.0°, and 1.5°, and lowered by the same increments. An intensity distribution measurement of the simulator with the spread lens in place was made after each change.

3.2 Results of Alignment Study

The results of the alignment study are shown in the intensity distribution curves of figure 6, from which the information contained in Table VI is taken.* The definitive indicator readings at 0.0° indicate that a misalignment of the order of 0.2° should be detected with the device.

> Note: Misalignment of the lamps <u>does not affect the position of the photometric transition zone</u>. Such misalignment does affect the intensity of the red and of the white components of the beam and hence may have a small effect on the position of the visual transition zone.

*The transition bar mentioned in the table is referred to in Section 2.1.

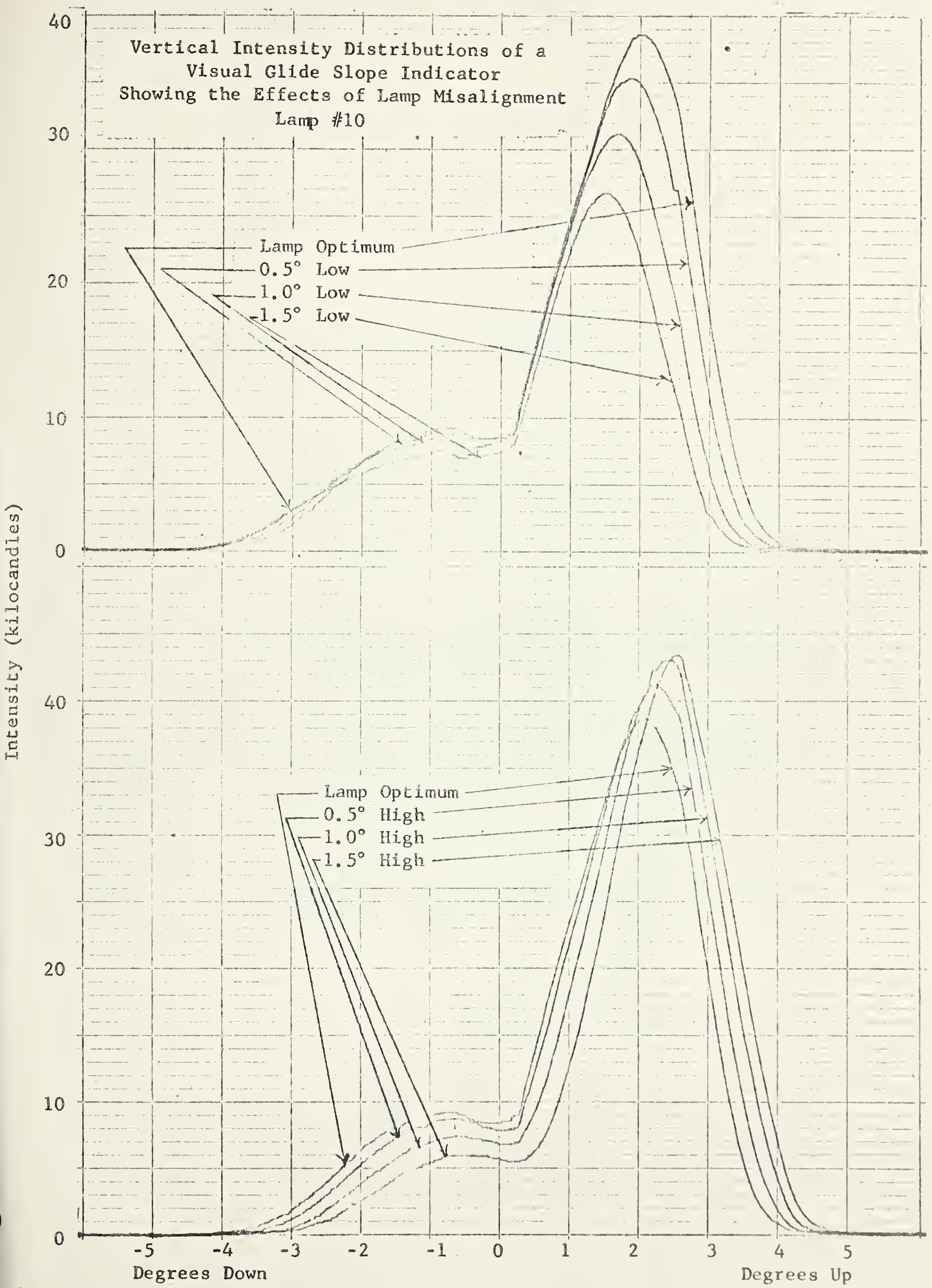

Vertical Intensity Distributions of a
Visual Glide Slope Indicator
Showing the Effects of Lamp Misalignment
Lamp #10
Lamp Optimum
0.5° Low
1.0° Low
1.5° Low
Lamp Optimum
0.5° High
1.0° High
1.5° High
Intensity (kilocandles)
40
30
20
10
0
40
30
20
10
0
-5
-4
-3
-2
-1
0
1
2
3
4
5
Degrees Down
Degrees Up

Figure 6

Table VI. Effects of Misalignment of Lamp on Performance of VGSI Simulator

Position of Image	Indicator Reading (ma)	Peak Intensity In Kilocandles: Red Component	Peak Intensity In Kilocandles: White Component	$\frac{5R+W}{2}$	Indicator Reading (ma)	Peak Intensity In Kilocandles: Red Component	Peak Intensity In Kilocandles: White Component	$\frac{5R+W}{2}$
		Lamp #7				Lamp #8		
1.5° low	.70	9.2	25.0	35.5	.60	8.8	11.3	27.6
1.0° low	.76	10.1	32.3	41.4	.67	10.1	16.4	33.4
0.5° low	.82	10.8	39.3	46.6	.72	11.1	22.9	39.2
0.0°	.84	10.8	43.4	48.7	.74	11.4	28.9	43.0
0.5° high	.82	9.8	46.5	47.8	.72	11.1	35.6	45.6
1.0° high	.74	7.6	47.9	43.0	.68	9.8	41.7	45.4
1.5° high	.71	5.7	47.9	38.2	.61	8.0	45.3	42.6
		Lamp #9				Lamp #10		
1.5° low	.69	8.4	21.6	31.8	.69	7.5	26.8	32.2
1.0° low	.76	9.5	26.7	37.1	.78	8.4	31.1	36.6
0.5° low	.81	10.2	32.8	41.9	.83	9.0	35.3	40.2
0.0°	.82	10.4	37.7	44.8	.85	9.2	38.6	42.3
0.5° high	.81	10.0	42.0	46.0	.83	8.8	41.3	42.7
1.0° high	.76	8.4	45.5	43.8	.77	7.4	43.0	40.0
1.5° high	.59	6.5	48.1	40.3	.68	5.9	43.3	36.4
	Lamp #10 With Transition Bar							
1.5° low	.69	7.2	15.0	25.5				
1.0° low	.78	8.0	18.8	29.4				
0.5° low	.83	8.5	22.6	32.6				
0.0°	.85	8.6	25.3	34.2				
0.5° high	.83	8.1	28.0	34.2				
1.0° high	.77	6.9	30.9	32.7				
1.5° high	.68	5.2	33.4	29.7				

3.3 Field Use of the Alignment Device

The alignment device was satisfactory for positioning the lamps in the simulator for maximum intensity of the red component of the beam. This work, however, was done in a darkened laboratory. The device can be used without modification in the field under nighttime conditions. Its use under daytime conditions will depend on the construction of the VGSI unit. If the lamps can be adjusted without removing the whole top of the unit, the device can be used, with precautions being taken to cover the slot to keep out stray light. If, however, the top must be removed for the adjustments, some provision must be made for darkening the area between the lamps and the slot.

The procedure outlined in the above paragraph assumes the removal of the spread lens from the VGSI for the alignment process. To keep the device linear, the lamps were operated at half-current. This can be accomplished in the field either by a choice of a suitable brightness step on the regulator, or, in the absence of such a position, by shunting another 6.6-ampere, 300-watt lamp across the lamp being adjusted, thereby reducing the current in each to a half.

An alternate method to the above, retaining the spread lens in position and operating the lamp at full intensity (rated current) would require the use of a dark red filter of the proper density between the spread lens and the lamp being adjusted. The required density would be that necessary to eliminate the effects of the difference in transmission between the red and white spread lenses and to reduce the illumination on the photocells to a satisfactory level.

4. LAMP CHARACTERISTICS AND METHODS OF INSPECTING LAMPS

4.1 General Considerations

At the suggestion of the Federal Aviation Agency, the work at the National Bureau of Standards was in the direction of devising a method which would not require a full length photometric range and the taking of intensity distribution measurements for inspecting the sealed reflector lamps for use in the VGSI. Intensity distribution measurements of a VGSI unit containing one or more lamps would require, from an analysis of the geometry of the projected beam, a range of at least 100 feet for a reasonable degree of accuracy.

A preliminary investigation was made using a 50-foot photometric range to determine the general characteristics of the lamps. Three photocells were used: #1 was mounted on the beam axis facing the lamp; #2 was mounted 2° above the beam axis; #3 was mounted 2° below the beam axis. With a view to keeping the procedure simple,

only one meter was used to read the output of the photocells in parallel.

The output from all three cells, as well as from #1 and #2 paired, #1 and #3, and #2 and #3), was compared with intensity distributions of the lamps in the simulator with the spread lens. None of the combinations gave results that were both valid and reliable measures of the performance of the simulated VGSI.

4.2 Lumen Measurements

4.2.1 Measurements Using Sphere With Slot.

a. A 60-inch integrating sphere was used to determine the total luminous output of the 6.6-ampere, 200-watt lamps and the 20-ampere, 300-watt lamps by mounting the lamps, in turn, within the sphere.

b. The lamps were mounted individually outside the sphere, at a distance of 50 inches, to determine the percentage of "usable" flux emitted by the lamps. The 2" by 26" slot was mounted in the access door opening, and the lamps were then positioned for maximum flux into the sphere. (Because of the dimensions of the access door, the slot was placed vertically and the lamps were burned with their filaments vertical and parallel to the slot.)

The integrating sphere method was awkward to control and the slot in the door was felt to introduce an appreciable error in the measurements shown in Table VII. There was no correlation between the lumen "input" through the slot and the weighted average peak intensities through the VGSI simulator for either the 20-ampere, 300-watt lamps, or the 6.6-ampere, 200-watt lamps. (Note: These two types of lamps were the only ones used in this part of the test.)

Table VII shows the total lumen output for the six lamps tested, lumen "input" to the sphere, and the percent of lumen output passing through the slot as compared to the performance factor (W+5R)/2. (Column 7 of Table VII is explained in the following section.)

4.2.2 Point-By-Point Method and Results.

The second method employed was the measurement of the luminous flux incident on a specified portion of the image plane of the lamp, an area 2" high by 10" wide. The flux incident on this area was most of the flux which would have gone through a slot similarly placed. The axes of the area were centered by eye as nearly as possible on the major and minor axes of the oval-shaped image of the filament projected on the image plane of the lamp. A color-corrected photocell with

a 1"-square sensitive area exposed was used to measure the luminous flux incident on each of the twenty 1"-square areas of the test area. The total flux incident was taken as the sum of these twenty values.

Because of the high illumination on the photocell, it was necessary to use a 1%-transmission sector disc in front of the photocell. The sensitivity of the system was found to be somewhat dependent on the speed and position of the sector disc. The former difficulty was allayed through the use of a capacitor across the input resistor, the latter by proper placement of the sector disc.

The use of this method gave results of the same magnitude as those obtained with the sphere (see Table VII) but the area sampled was from only the bright area of the filament image. The larger area of the slot-in-the-sphere method (52 square inches against 20 square inches) resulted in larger lumen readings.

The point-by-point method was not developed because of the time required to adjust the sector disc for each of the twenty measurements; furthermore, although the method agreed basically with the results obtained using the sphere, it was no improvement over that method.

Table VII. Luminous Flux Measurements of Six Lamps

Lamp	Watts	Amperes	Total Luminous Flux(1) (lumens)	Luminous Flux Through Slot(2) (lumens)	Fraction of Flux Through Slot (%)	Luminous Flux on Measured Area(3) (lumens)	$\frac{W + 5R}{2}$(4)
1	200	6.6	4060	940	23.1	780	34.8
2	200	6.6	3640	780	21.5	700	30.4
3	200	6.6	3760	860	22.9	750	36.2
Ave.			3820	860	22.5	743	33.8
4	300	20	6900	1370	19.8		51.2
5	300	20	6610	1420	21.4		57.5
6	300	20	6590	1350	20.5		47.8
Ave.			6700	1380	20.6		52.2

(1) Using 60" integrating sphere.
(2) 2" wide by 26" high slot in door of sphere.
(3) 2" high by 10" wide area 50" forward of lamp.
(4) (W+5R)/2 = weighted average of two intensities, from Table IV.

4.3 Measurements of Lamps Through a 2-Inch Slot

The intensities at three points and their mean, together with the beam widths, both vertical and horizontal, of the lamps through a 2-inch-high horizontal slot are given in Table VIII. The intensity distribution measurements from which these data were taken were made using the simulator with the spread lens removed. There was a positive correlation between the average intensity and the (5R+W)/2 performance factor for the 6.6-ampere, 200-watt lamps. There was no correlation for the 20-ampere, 300-watt lamps tested.

There was, however, a somewhat negative correlation for the 6.6-ampere, 300-watt lamps, but only in the sense that the highest average-intensity lamp of the group had the lowest performance factor.

Except for the performance factor included in Table VIII, the data presented gives the performance of the lamps alone, independent of the spread lens, which influences the operating characteristics of the units.

The beam intensities of the lamps through the 2-inch slot at three selected beam spreads are shown in Table IX. Note should be taken that lamp #8 is not typical of the group. Although the intensity values for this lamp shown in Table V are high, the characteristic "dip" between the lower and upper peaks of the intensity distribution is missing. In the VGSI simulator with the spread lens, this lamp produced a slightly greater peak intensity than the other lamps in the red, but a marked lower intensity in the white. The performance of this lamp indicated that its filament was closer to the focus than is considered desirable.

5. DISCUSSION OF LAMP SPECIFICATION REQUIREMENTS

5.1 300-Watt Lamps

The results presented in Table IV show that the increase in peak intensity resulting from use of 300-watt, 20-ampere lamps is somewhat greater than the increase in power consumption (as compared with the 200-watt lamps). The 300-watt, 6.6-ampere lamps, however, show approximately a 30% increase in peak intensity for a 50% increase in power consumed. Since both lamps have the same envelope size, the 200-watt lamps may be replaced by 300-watt lamps with no change in fixture design.

The data presented in Table IV were, however, not corrected for any difference in the design life of the groups of lamps tested. This type of correction could affect the relative performances of the groups.

Table VIII. Intensity and Beam Spreads of Lamps Through A 2-Inch Horizontal Slot

Lamp	Current (amps)	Power (watts)	Intensity: Lower Peak (kilocandles)	Center Min.	Upper Peak	Average Intensity(1)	$\frac{5R+W}{2}$ (2)	Beam Width: Vertical(3) (degrees)	Horizontal(4)
1	6.6	200	107	40	57	68	34.8	8.9	7.2
2			92	30	47	56	30.4	8.8	7.9
3			77	56	111	81	36.2	7.4	8.0
Average			92	42	72	68	33.8	8.4	7.7
σ (7)						12.5			
4	20	300	212	183	185	193	51.2	5.5	7.3
5			194	121	186	167	57.5	6.0	9.6
6			146	142	212	167	47.8	6.0	9.2
Average			184	149	194	176	52.2	5.8	8.7
σ						12.2			
7	6.6	300	120	108	130	119	46.0	5.2	5.8
8			(121)	(123)	(150)	(131)	(39.1)	(4.5)	(5.6)
9			130	113	138	127	43.0	5.0	5.8
10			105	84	110	100	39.9	5.6	6.9
11			109	92	102	101		5.5	6.4
12			120	94	114	109		5.4	6.2
13			125	102	114	114		5.1	6.1
14			122	106	123	117		5.1	6.2
15			113	81	100	98		6.0	6.8
16			99	83	101	94	42.1	6.0	7.8
17			116	95	116	109	45.4	5.6	6.8
18			106	73	120	100		6.4	6.2
19			119	87	113	106	49.4	6.2	6.8
20			128	97	116	114		5.4	-- (5)
21			120	96	114	110		5.7	6.2
22			112	87	105	101		5.8	6.5
Average(6)			116	93	114	108	44.3	5.6	6.5
σ						8.8		.4	.6

(1) Average intensity taken as mean of 3 preceding values.

(2) Data from table IV for comparison purpose; information not available for all lamps.

(3) Through 0.0° horizontal; at 50% of average intensity

(4) Through peak of (1); at 50% of peak intensity.

(5) Lamp damaged in test.

(6) Lamp #8 omitted from average.

(7) $\sigma = [\sum(X-\bar{X})^2/n]^{1/2}$ where X = value of each item, $\bar{X}$ = average of all items, n = number of items.

Table IX. Beam Intensity of 300-Watt, 6.6-Ampere Lamps Through A 2-Inch-High Horizontal Slot at Three Selected Vertical Beam Spreads (1)

Lamp	4° Spread (kilocandles)	5° Spread (kilocandles)	6° Spread (kilocandles)
7	103	69	34
8	(92)	(40)	(9)
9	106	62	21
10	97	71	40
11	93	68	35
12	101	70	36
13	100	71	23
14	99	63	28
15	95	76	48
16	92	75	48
17	104	79	39
18	105	92	63
19	109	90	39
20	103	72	32
21	104	81	42
22	101	78	46
Average (#8 omitted)	101	74	38
σ (2)	4.7	8.3	10.3

(1) At horizontal angle of 0.0°.

(2) $\sigma = [\sum(X-\bar{X})^2/n]^{1/2}$ where X = value of each item, $\bar{X}$ = average of all items, n = number of items.

5.2 Specifications for Lamps for Use in the VGSI

Mean values and standard deviations taken from Tables VIII and IX were used to determine minimum values of beam widths and intensities of 300-watt lamps for use in the VGSI. Data for Tables VIII and IX were taken through a 2-inch-high horizontal slot. The following is submitted as a basis for establishing minimum requirements for the VGSI lamp, with a view toward excluding such lamps as #8. The standard deviation (σ) was used to determine the suggested minimums. A normal distribution was assumed.

Mean values are of the fifteen "typical" 300-watt, 6.6-ampere lamps; minimum values were set at 1.65σ below the mean values and will include 95% of the lamps while still excluding atypical lamps of the type mentioned above.

This procedure gives a minimum lamp intensity through a 2-inch-high horizontal slot 50 inches ahead of the lamp of 60 kilocandles at a 5° vertical beam spread, of 20 kilocandles at a 6° vertical beam spread, a minimum average intensity (of the two peaks plus the minimum between them) of 94 kilocandles, a minimum vertical beam width of 4.9°, and a minimum horizontal beam width of 5.5°. Note: Both beam widths are to 50% intensity points.

The following items are suggested for inclusion in specifications for the off-focus 300-watt PAR-64-type lamps for use in the VGSI:

(1) A minimum vertical beam width at the 50% points of 5.0°.
(2) A minimum horizontal beam width at the 50% points of 5.5°.
(3) A minimum intensity of 60 kilocandles at 5° vertical beam spread.
(4) A minimum intensity of 20 kilocandles at 6° vertical beam spread.
(5) A minimum average intensity (the two peaks and the minimum between them) of 95 kilocandles.

6. SUMMARY

This study brought out (1) the advantages of the use of the 300-watt lamps over the 200-watt lamps in the R.A.E.-type Visual Glide Slope Indicator, (2) the effect on intensity distribution of the transition bar, and (3) the only slight difference between the British-made and American-made spread lenses used in the test.

A simple device was developed for aligning the lamps in the VGSI for optimum utilization.

Minimum values of several test criteria are presented for use in drawing specifications for the lamps.

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U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

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

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