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WAR DEPARTMENT

REPORT NO. 746

CONTROL OF COASTAL LIGHTING
IN
ANTI-SUBMARINE WARFARE

GN 373

April 30, 1943

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Does not rep[illegible] recommenda-
tions or conclusions [illegible]
Office, Ch[illegible]

THE ENGINEER BOARD
Corps of Engineers, U. S. Army
Fort Belvoir, Virginia

6 1451—FORT BELVO

Report No. 746

CONTROL OF COASTAL LIGHTING
IN
ANTI-SUBMARINE WARFARE

Project No. GN 373

Study of Control of Coastal Lighting and
Joint Army-Navy Investigation

April 30, 1943

Submitted to

The Engineer Board

Fort Belvoir, Virginia

Captain Oscar P. Cleaver
Corps of Engineers, U. S. Army,
Fort Belvoir, Virginia

Report in 123 pages and 9 appendices.

Copy 34 of 70 copies.

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SYLLABUS

1. Preparation.- After careful review and analysis of other sky glow investigations and in consultation with the Navy Department, a program of field tests was devised for the purpose of obtaining basic information concerning the characteristics of sky glow from artificial sources, evaluating the extent to which sky glow and shore lights are a factor in aiding enemy submarines, establishing amount of sky glow produced by various lighting and the degree of dimming required of such lighting, and investigating the utility and practicability of light control methods.

2. Procedure.- a. Sky glow was created by light from a known number of lamp units (sealed beam vehicular type) concentrated in an area of pre-determined size. Measurements of sky glow, and sea observations on visibility of ships silhouetted against the sky glow background, were conducted from locations in pre-determined relationship to the source of upward light during known atmospheric conditions under controlled situations with respect to arrangement and treatment of the lighting units and positions of the boats.

b. Tests of light sources or illuminated surfaces visible from the sea were conducted, in conjunction with the sky glow studies, in order to evaluate candlepower or brightness limits not helpful to enemy submarines.

c. A target boat and a boat for naval observers were employed in all investigations of hazards to ships resulting from sky glow or revealing shore lighting. In these studies, the target boat maneuvered back and forth at distances of two and five miles offshore with the observation boat at various distances beyond it.

d. The amount of sky glow contributed by various types of lighting, together with various dimout treatments, was investigated both in the field and in the laboratory.

3. Test Results.- a. The report provides methods for the evaluation of sky glow brightness produced at any distance from upward light of known amount and distribution for any atmospheric condition. The necessary relationships are expressed in three fundamental laws. The tremendous influence of atmospheric transmission is revealed.

b. The relative contributions to sky glow of vehicle headlamps, street lighting, lighted show windows, traffic signals, building windows, outdoor commercial lighting, and industrial floodlighting are set forth.

c. The test data indicate that density of atmosphere, distance from shore, and distance between the submarine and its prospective target are major factors which govern the magnitude of background brightness which is sufficient to reveal to submarine personnel the information on type of ship, course, and speed as

9(

the necessary prelude to attack. The required background brightness increases with increase in atmospheric density, distance from shore, and distance between submarine and possible victim.

d. For various conditions encountered during the tests, the actual maximum background brightnesses which were not sufficient to enable naval observers to gain the information necessary for effective hostile action against a passing ship ranged from 45 to 110 micro-footlamberts for variations in the three factors set forth in sub-paragraph c above. Such brightnesses were the sum of natural horizon brightness and the apparent brightness of the artificial sky glow.

e. Investigation of ship hazard resulting from vehicle lighting, traffic signals, minor aids to navigation, and illuminated vertical surfaces of various sizes established the fact that virtual blackout must be imposed in shore areas to eliminate aid furnished submarines by lighting directly visible from the sea.

4. Conclusions.- a. Analysis of data on background brightness, on the basis of factors enumerated in sub-paragraph 3 c above, indicates a range of brightnesses from 30 to 220 micro-footlamberts which would not provide sufficient delineation of a passing ship under particular conditions to enable a submarine to initiate offensive action. The low of 30 micro-footlamberts would obtain for the conditions of 99 per cent per 1000 foot atmospheric transmission, target boat two miles offshore, and 1000 yards between target boat and observer. The high of 220 micro-footlamberts would obtain for the conditions of 60 per cent atmospheric transmission per 1000 feet, target boat 17 miles offshore, and 6000 yards between target boat and observer. A background brightness greater than 220 micro-footlamberts will under generally prevailing conditions of atmosphere render passing ships visible to submarines by silhouette. Moreover, perception becomes easier and attack by submarines correspondingly less difficult as background brightness increases above this value.

b. Natural horizon brightnesses prevailing on moonless nights are within the above range, and are generally nearer the lower limit; therefore, elimination of artificial sky glow will reduce the silhouetting effectiveness of the background to that inherent in natural horizon brightness and, in many instances, will completely remove this hazard to shipping.

c. The drastic curtailment of all lighting necessary for considerable distances inland to eliminate artificial sky glow apparent at shipping lanes, while effective for 50 per cent or less of the dark hours, may result in waste and loss of life on land more detrimental to the war effort than losses at sea directly attributable to existence of sky glow. Selective dimout programs, such as dimout scheduled to conform to phases of the moon or enemy submarine activity, may serve to alleviate this condition. Since the over-all war effort is dependent not only on safety of shipping off the coasts but on maintenance of essential activities on land, a basic dimout policy which strikes the proper balance needs be established.

d. Fundamental data set forth herein are considered adequate for preparation of dimout regulations after basic policy has been established; for the evaluation of amount of sky glow from any type, amount, and distribution of lighting; and for delineation of the inland limits of the dimout zone and the amount of light control necessary in each division thereof. However, specific problems arising from local conditions must be investigated as they arise in order to design proper dimout treatment in conformity with fundamental data and the purpose of the lighting.

e. In shore area, a virtual blackout is necessary to eliminate hazard to shipping resulting from exposed lights or sky glow.

f. The zone requiring dimout treatment depends on sky glow brightness permissible at shipping lanes as established by basic policy, but under most restrictive sky glow limitations will probably extend inland as far as 80 miles from the shipping lanes.

g. In the interest of maintaining safety and activities contributing to the war effort, dimout should be accomplished insofar as possible by elimination of non-essential lighting. Data indicates that elimination of non-essential lighting will reduce sky glow on the order of 18 to 58 per cent with an average reduction of 38 per cent.

h. Dimout treatment applied to essential lighting should effect necessary reductions in sky glow with maintenance of reasonable lighting efficiency.

5. Dimout Regulations.- Final regulations based upon the investigations described in this report will be prepared upon establishment of a basic dimout policy. For the meantime, interim dimout regulations are included to aid Defense Commands in their light control activities.

I. SCOPE OF REPORT

6. Factual Data and Recommendations. This report presents factual data pertaining to the characteristics of sky glow; reveals the natural laws controlling sky glow; sets forth data concerning the contribution to sky glow by specific light sources; evaluates the maximum brightness of a lighted background which will not cause a ship to be visible by silhouette to submarine observers; appraises the hazard to shipping produced by various light sources on or near the shore, including aids to navigation; determines the maximum brightnesses of vertical surfaces of various sizes when visible from the sea which will not reveal passing ships; establishes allowable illumination levels on horizontal surfaces, such as roadways, in locations visible from the sea; and recommends regulations, methods, and a program for the control of coastal lighting as an anti-submarine measure.

7. Studies and Tests. This report is the result of study of available literature on the problem of sky glow, analysis of the lighting control directives of the several Service Commands, laboratory tests of various light sources typical of city conditions, and full scale field tests conducted jointly by the Engineer Board and the Navy Department at Point Pleasant, New Jersey, from November 12 through 19, 1942, and at Jacksonville Beach, Florida, from January 4 through 16, 1943.

II. AUTHORITY

8. Preliminary Authorization. Letter from Office, Chief of Engineers, dated October 20, 1942, file CE 383 (Blackout) SPEEF, to the Navy Department, Subject: "Joint Army-Navy Investigation of Sky Glow and Related Matters Pertaining to the Control of Coastal Lighting", quoted in part as follows:

"2. A War Department directive, dated June 13, 1942, to the appropriate tactical and service commands covers the various points which the Navy Department has particularly pointed out as weaknesses in the anti-submarine measures now being taken along the coasts.

"3. There is inclosed a letter to this office from the Engineer Board, dated July 8, 1942, with subsequent indorsements thereon, in which a proposal to conduct investigations on skyglow illumination is discussed.

"6. This office is taking necessary steps to set up this project under the Engineer Board at Fort Belvoir. . . ."

9. Directive. Letter from Office, Chief of Engineers, dated November 24, 1942, file SPESD, to the President, the Engineer Board, Subject: "Study of Control of Coastal Lighting and Joint Army and Navy Investigation" quoted in part as follows:

"1. The rate at which sinkings have occurred off our coast has made it imperative that studies of skyglow and measures of coastal lighting control be made. As a considerable portion of the sinkings have occurred at night, it is quite possible that this is due to the ships being silhouetted against skyglow and direct light emanating from the shore.

"2. The Construction Division of the Office, Chief of Engineers, has made informal arrangements with the Navy Department for a joint investigation of skyglow and related matters pertaining to the control of coastal lighting. A request for this cooperation was forwarded to the Navy Department by letter of October 20, 1942. . . .

"3. It is directed that necessary action be taken by the Engineer Board to set up an investigational project for the study of control of coastal lighting and anti-submarine precaution.

"4. There are certain weaknesses which are found evident in the anti-submarine measures which are now being taken along the coast and which are referred to by letter of July 17, 1942, from the Chief of the Bureau of Yards and Docks and War Department directive, subject, "Control of Lighting", dated June 13, 1942. . . .

"5. Project No. GN 373. Title, "Study of Control of Coastal Lighting by Joint Army and Navy Investigation", is assigned to this project, with a priority of GN-1.

"6. Scope of Project:

a. Determination of the extent to which skyglow brightness is a factor in rendering ships visible to submarine observers.

b. Frequency of weather conditions and influence of moonlight which would affect visibility.

c. Distance from shore at which skyglow is a hazard.

d. Information determined on safe limits of skyglow and the amount produced by various forms of controlled illumination.

e. Application of factors and the determination of policy with regard to studies already conducted on coastal lighting problems.

f. Such other data which would be found helpful in combating the submarine menace.

"7. Direct communication with the Navy Department is authorized for this project. It is believed Naval Officers with complements of experienced gun crews, spotters, and submarine observers with good night vision, are required, and would be competent to carry out these test operations."

III. PRESENT INVESTIGATION

10. Test Location. The selection of test locations for full scale studies of sky glow had to be based on several factors, such as availability of electric power, existence of telephone lines, proximity to bases for the seacraft and aircraft required, quarters for the troops, feasibility of blacking out the area, possibility of interference by glows from surrounding communities, and public cooperation and attitude toward inconveniences resulting from test activities.

a. Point Pleasant, New Jersey (Appendix A). (1) After weighing the above factors, the city of Point Pleasant, New Jersey, a summer resort community, located on the Atlantic Ocean, approximately 50 miles south of New York City, was chosen for the initial sky glow studies.

(2) Sea observations during the initial sky glow studies were made on a line having an azimuth of approximately 105° to the Point Pleasant test area.

(3) Land observations of sky glow brightness were conducted from the following locations in respect to source of sky glow:

5 miles west with azimuth of 261° (station 1)
10 miles west with azimuth of 284° (station 2)
15 miles west with azimuth of 285° (station 3)
5 miles north on shore line (station 4)
5 miles south on shore line (station 5)

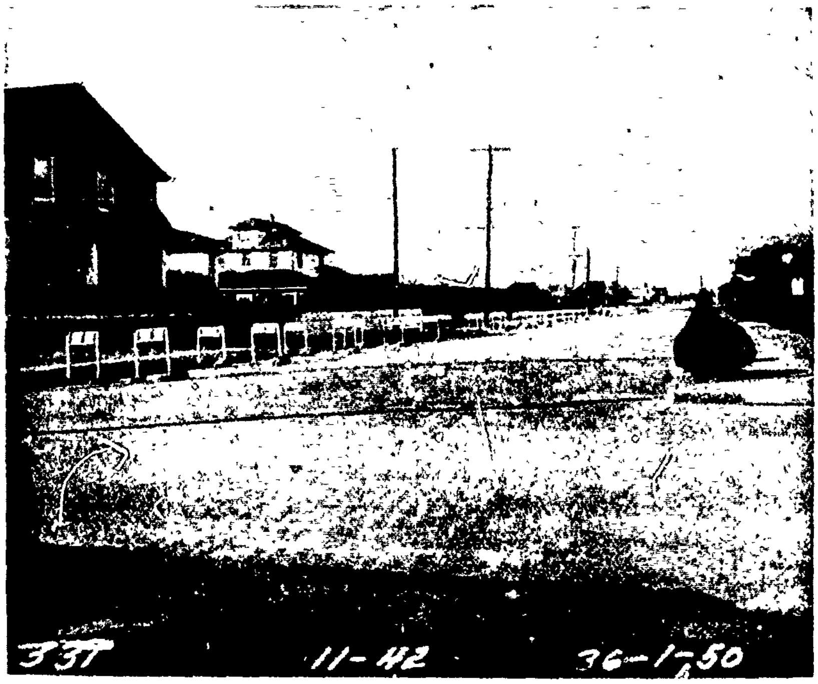


Fig. 1
A portion of the Point Pleasant test area.
Note type of streets and number of buildings.

(4) The beach front and Monmouth Hotel of Spring Lake, New Jersey, a shore community a few miles north of Point Pleasant, were used for the study of the effect of various automobile lighting, and window brightnesses, when visible from the sea.

b. Jacksonville Beach, Florida (Appendix A). (1) Since the studies at Point Pleasant, New Jersey, indicated the desirability of securing additional data and investigating other factors, Jacksonville Beach, Florida, was selected as the site of a second full scale field test. In addition to factors already mentioned as influencing choice of a location, this test area was selected in order to encounter less severe but more variable weather conditions with atmospheres of lower light transmission than those experienced at Point Pleasant, New Jersey. The test area at Jacksonville Beach, unlike Point Pleasant, New Jersey, had very few buildings. (See fig. 2)

This proved to be a slight disadvantage, since a built-up community causes glow to be apparent at heights which are more representative of sky glow over cities, whereas the absence of buildings at Jacksonville Beach permitted measurements of the glow very close to the ground. Also, buildings and trees serve to absorb and disperse a portion of the light, which effect was greater at Point Pleasant.

Fig. 2
A portion of the Jacksonville Beach test area.
Note type of street and number of buildings.

(2) Sea observations during the sky glow studies were made on a line having azimuth of 64° to the Jacksonville Beach test area.

(3) Land measurements of sky glow brightness were conducted from the following locations in respect to source of sky glow:

7 miles west on azimuth of 246° (station 1)
11-3/4 miles west on azimuth of 244° (station 2, figs. 3 and 4)
15-1/2 miles west on azimuth of 244° (station 3, fig. 5)
5 miles north on shore line (station 4)
5 miles south on shore line (station 5, figs. 6 and 7)

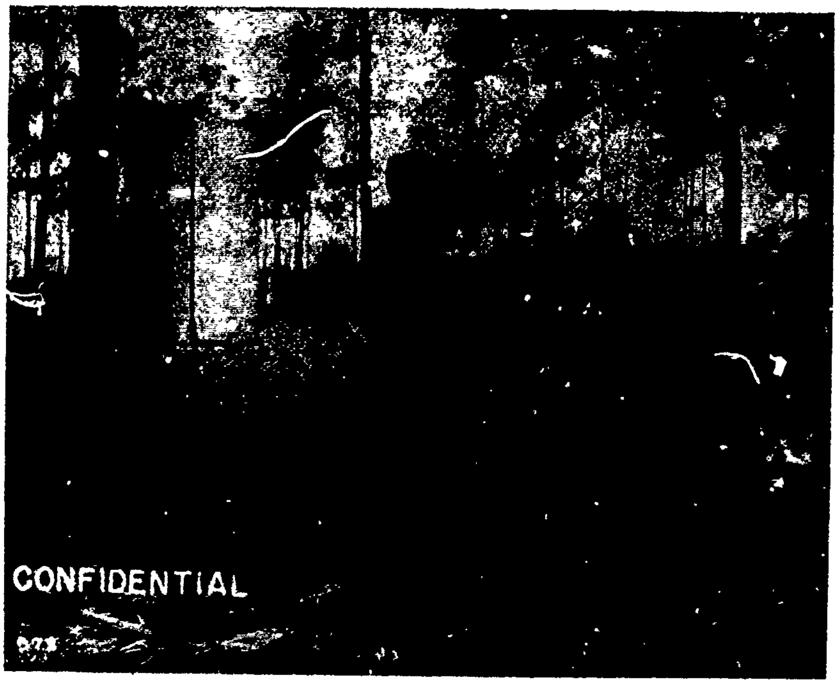


Fig. 3
Station 2 - 11-3/4 miles west of source of sky glow.
Note field telephone installation.
Jacksonville Beach Tests

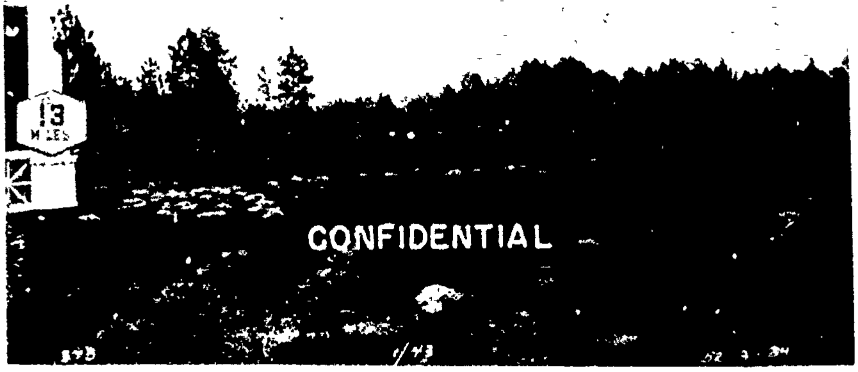


Fig. 4
Horizon at Station 2 looking east toward source of sky glow.
Jacksonville Beach tests

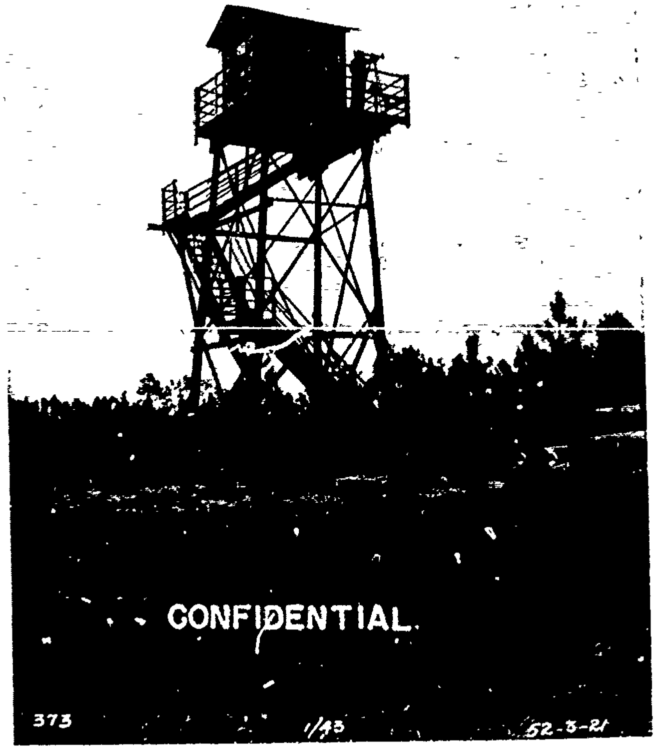


Fig. 5 -- Airplane spotter's tower used for Station 3, $15\frac{1}{2}$ miles west of source of sky glow. A similar tower on the beach at Atlantic Beach was utilized for Station 4.
Jacksonville Beach tests

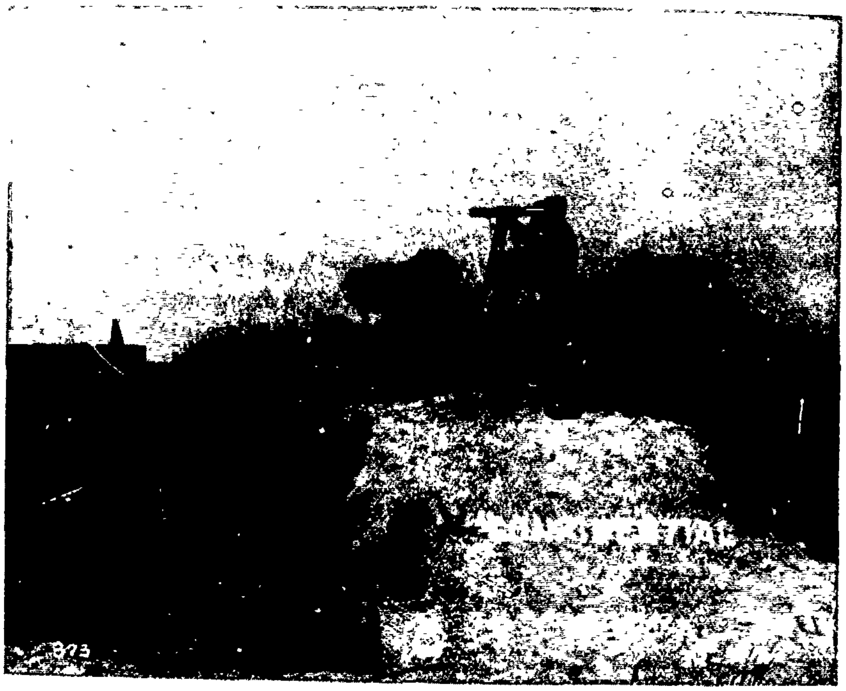


Fig. 6
Station 5 - 5 miles south of source of sky glow.
Jacksonville Beach Tests

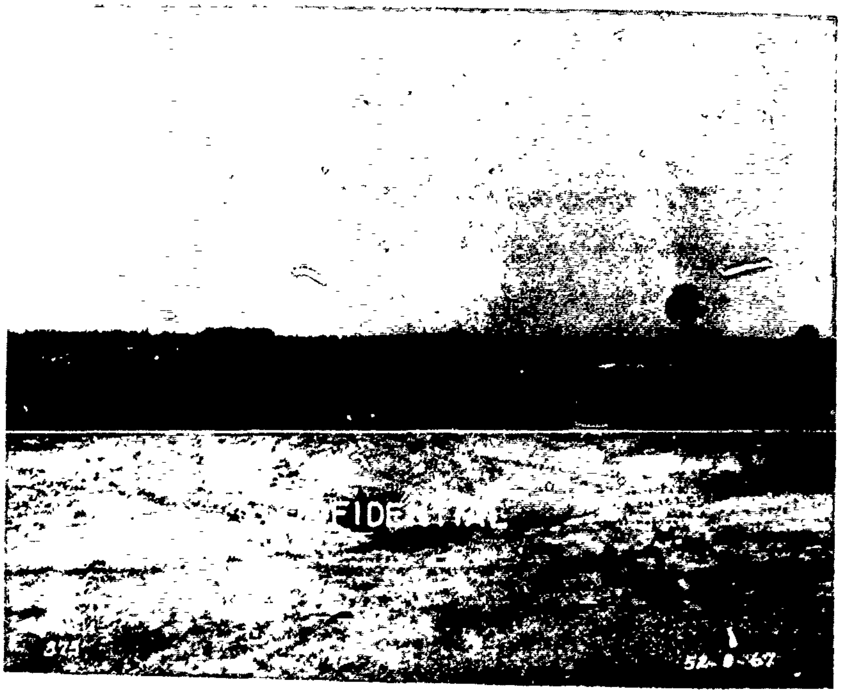


Fig. 7
Horizon at Station 5 - Looking north toward source of sky glow.
Jacksonville Beach Tests

(4) The beach front and Atlantic Hotel of Atlantic Beach, Florida (fig. 8), were utilized for study of automobile lighting and aids to navigation, and determination of maximum permissible brightnesses of vertical surfaces when visible from the sea.

Fig. 8
Atlantic Hotel and beach front at Atlantic Beach, Florida. Covered porch was equipped with approved indoor blackout lamps to test visibility of illumination from those sources.

(5) A one mile section of Atlantic Boulevard (Appendix A), which is perpendicular to the coast line, was used for study of sky glow produced by maximum night open highway traffic. The seaward end of this same street was utilized to study the effectiveness of baffles at the ends of streets open to the sea and to determine permissible non-hazardous illumination levels on horizontal surfaces.

c. Laboratory Tests. Laboratory facilities were utilized to conduct sky glow investigations on a reduced scale, to determine the amount of zonal light flux emitted by shielded sealed beam automobile headlamps and various types of street lighting luminaires, and to investigate the amount of light emitted from standard types of show windows.

11. Personnel. a. Captain Oscar P. Cleaver, the Engineer Board, was in charge of overall test activities for the Army. Other assigned Engineer Board personnel were Mr. Charles F. Cashell, director of test procedures, Captain Sylvester Guth (Jacksonville Beach only), 1st Lt. Robert O. Swain, 1st Lt. Robert F. Royster (Point Pleasant only), 2nd Lt. George Henderson (Jacksonville Beach only), Sergeant John R. Davis, Sergeant William Musiker, Sergeant Joseph L. Martin (Point Pleasant only), Cpl. Charles E. Longley (Point Pleasant only) Cpl. Ashby R. Hodges, Private Willard Cyr (Jacksonville Beach only), and photographers. Mr. George Crum (Point Pleasant only) and Mr. Hal P. Letcher (Jacksonville Beach only). A company from the 132nd Engineers, based at Fort Hancock, New York, commanded by Captain H. G. Slear, handled all tasks in connection with operation of the lighting units for the Point Pleasant test. At Jacksonville Beach, similar tasks were performed by a detachment from the Replacement Center, Fort Moultrie, South Carolina, under command of 1st Lt. Donald M. Ashton, Jr., 263rd Coast Artillery.

b. Lt. Commander E. A. Fintel, Eastern Sea Frontier, directed the activities at sea for the Navy. Representatives of the Bureau of Yards and Docks who assisted were Lt. Commander McRea Parker (Jacksonville Beach test only) and Lt. Robert L. Champion.

c. Coast Guard personnel present for tests of aids to navigation were directed by Captain F. P. Dillon, and Lt. Commander J. A. Ciccolella.

d. The following acted as observers and recorders of the test data:

Mr. Val Roper, Chairman, Motor Vehicle Lighting Committee, Illuminating Engineering Society, New York, New York.

Mr. George Baumgartner, photometrist assigned to the Engineer Board, General Electric Company, Nela Park, Cleveland, Ohio.

Mr. C. S. Woodside, Committee on Highway and Street Lighting, Illuminating Engineering Society, New York, New York.

Mr. William F. Little, photometrist assigned to the Engineer Board, Electrical Testing Laboratories, Inc., New York, New York.

Mr. Ray Teele, Bureau of Standards, Washington, D. C.

Lt. J. J. Fox, Second Service Command, New York, New York. (Point Pleasant only).

Mr. Edward S. Sproles, Department of Commerce, Weather Bureau, Atlanta, Georgia, Office. (Jacksonville Beach only).

12. Equipment. a. Lighting units.- (1) Sky glow was produced by light from sealed beam headlamps mounted in pairs in specially constructed stands. These stands consisted of two upright members bolted to a trough in which the lighting units were held at normal height of automobile headlamps. The troughs were so constructed that they could be rotated to elevate or depress the headlamp beams to any angle, and the light produced by the headlamps could be diffused by special screens and progressively dimmed by shielding. Figures 9 and 10 show details of the stands.

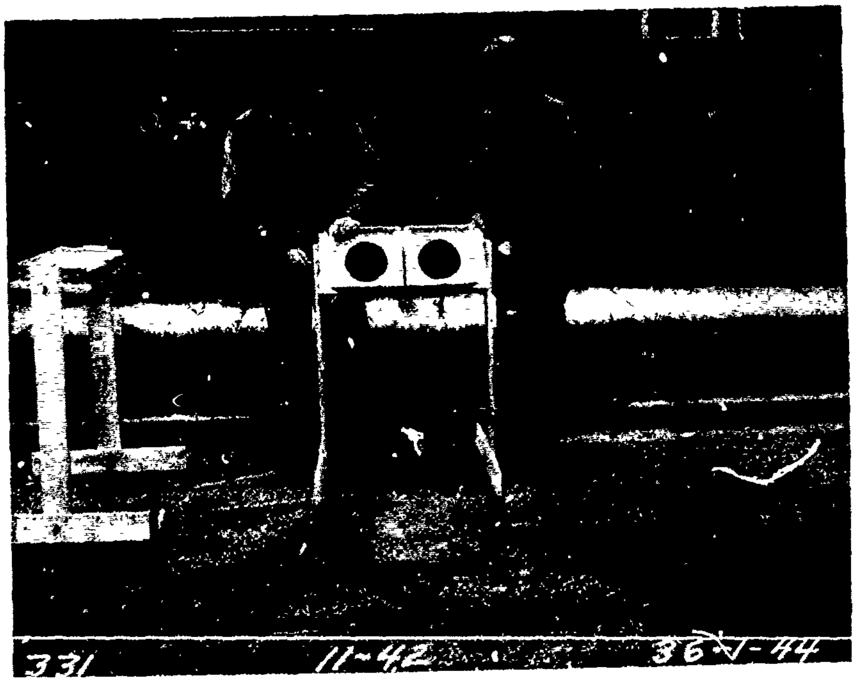


Fig. 9
Close-up of stands without lamps used at Point Pleasant, New Jers

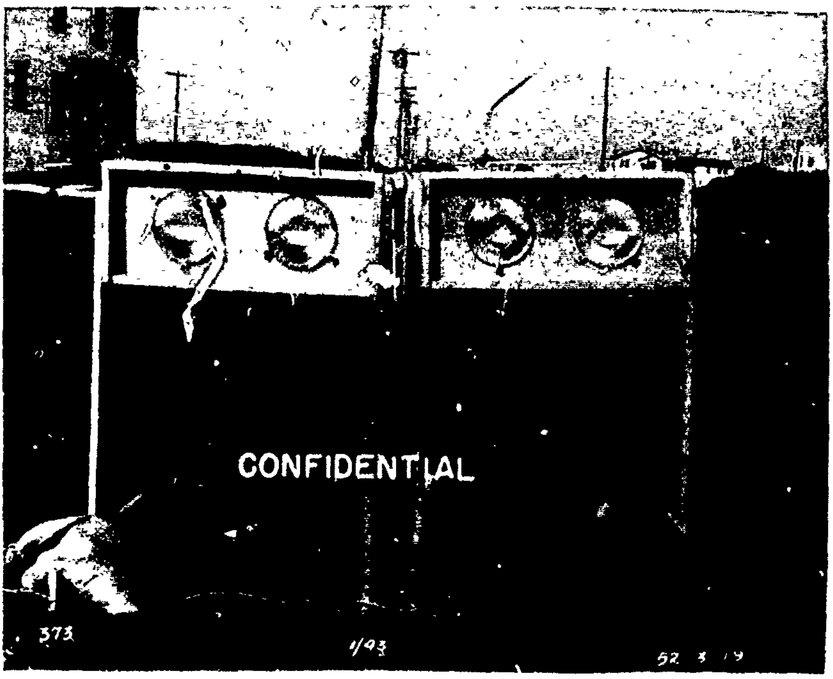


Fig. 10 Close-up of improved stands with lamps used at Jacksonville Beach, Florida

(2) At Point Pleasant, New Jersey, 1836 of the sealed beam headlamps in 918 stands were employed. At Jacksonville Beach, Florida, two test areas were used. Test Area 1 in Jacksonville Beach employed 2358 sealed beam headlamps in 1179 stands, while 792 headlamps in 396 stands were used to produce sky glow over Test Area 2, located near the shore $2\frac{1}{2}$ miles south of Test Area 1. (See Appendix A).

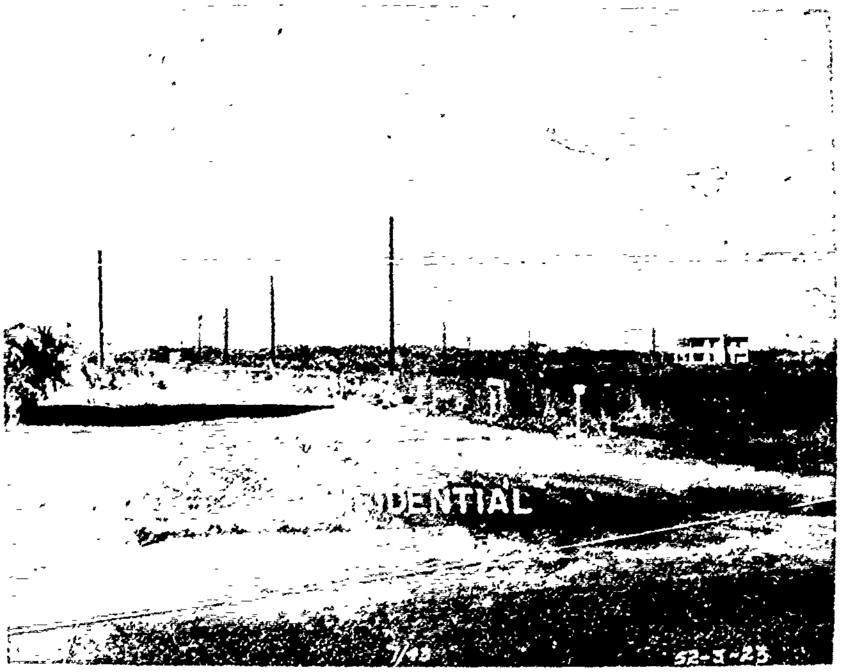


Fig. 11 Single row of lighting units on street at Jacksonville Beach.

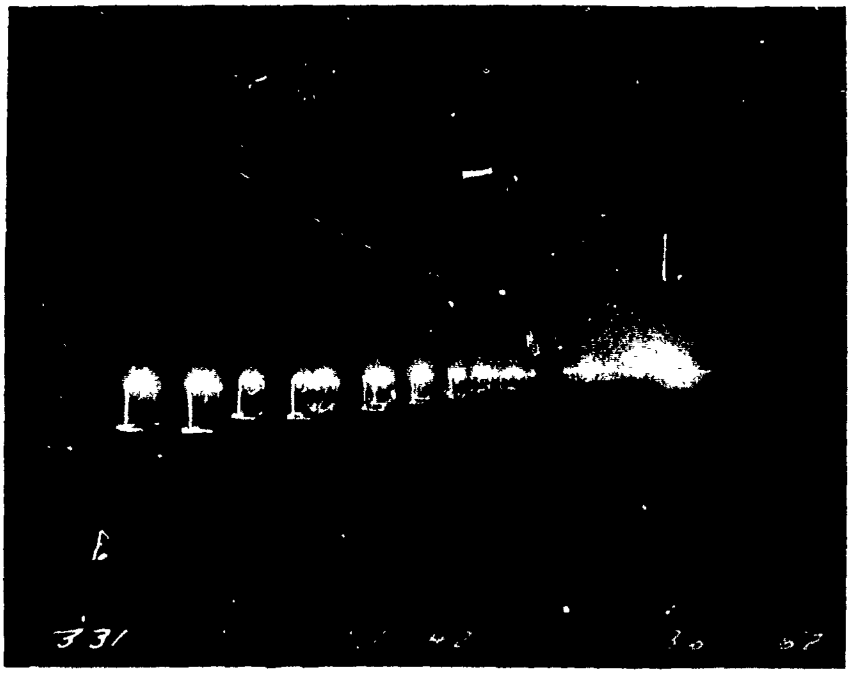


Fig. 12
Night view of lighting units at Point Pleasant.
Clear atmosphere does not delineate beam pattern.

Fig. 13
Night view of lighting units at Jacksonville Beach.
Slight mist in atmosphere delineates beam pattern.

(3) The lighting units were shielded by means of black cardboard set at appropriate numbers marked on the sides of the troughs. By this means, the lighting in the test area could be dimmed without color change from full intensity to zero in any desired steps.

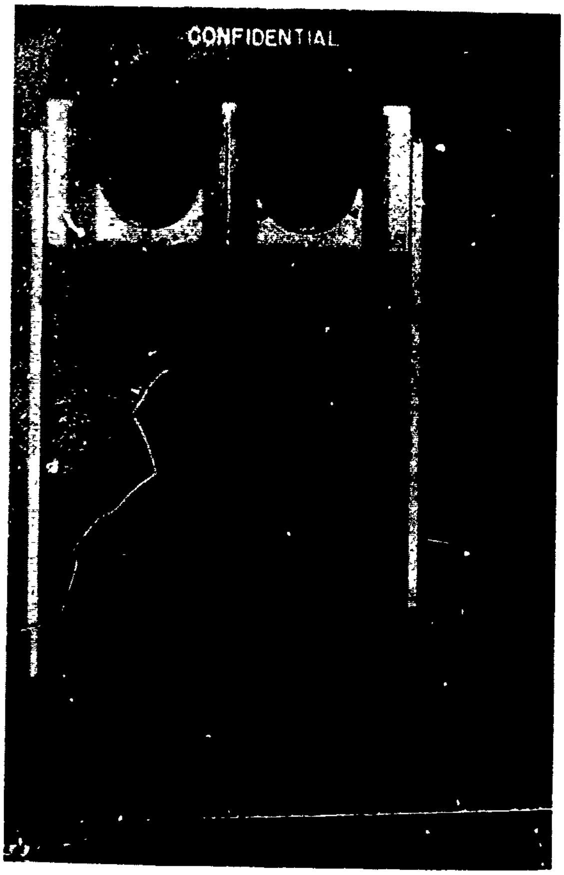


Fig. 14
Lighting unit shielded for
upper ½ of its diameter.
Point Pleasant, New Jersey

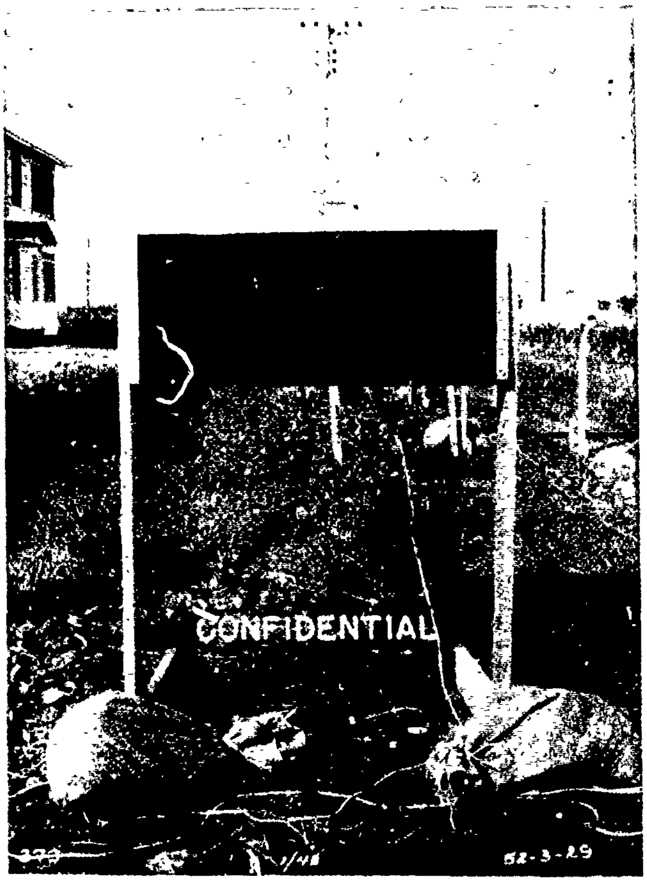


Fig. 15 -- Cardboard used to shield lighting units at Jacksonville Beach, Florida.

(4) The wiring harness of the lighting units, power lines, and switches for changing from driving (high) to passing (low) beams are illustrated in figure 16.

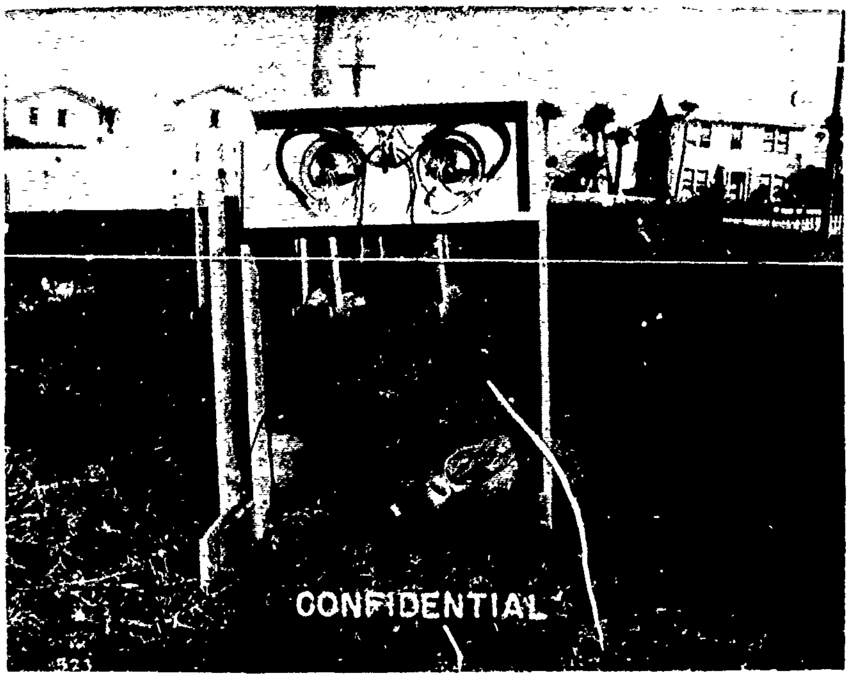


Fig. 16 -- Power leads, wiring harness, and headlamp switch.

(5) The angular elevation or depression of the light beams was changed at will by rotating the trough containing the lighting units. The angles were controlled by means of lines drawn on the uprights of the stands, designating the desired position. (Figs. 17 and 18). Tests on the relative amounts of sky glow produced with the beams elevated or depressed at various angles were conducted at Point Pleasant only.

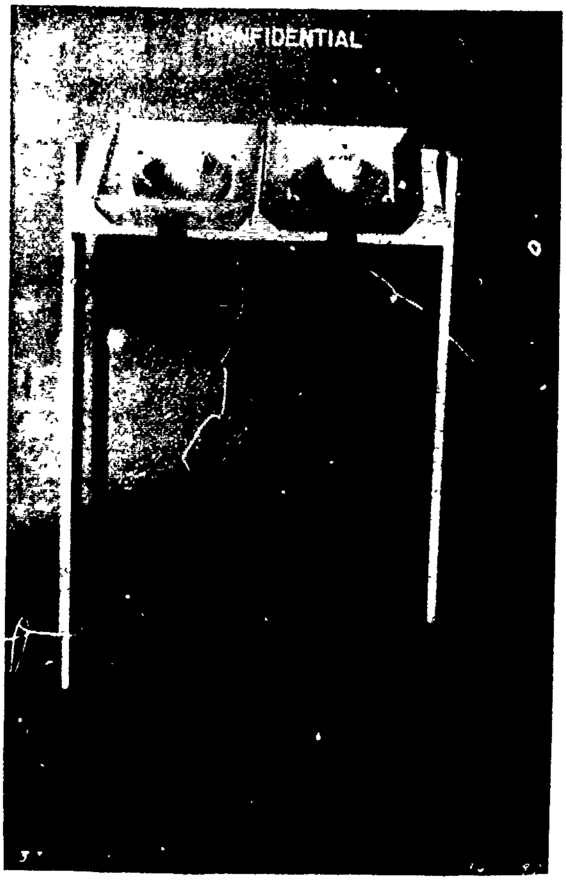


Fig. 17
Lighting units so arranged that beams are elevated 60 degrees above the horizontal.

Fig. 18 -- Lighting units so arranged that beams are depressed 45 degrees below horizontal.

b. Communications. (1) A 1/4-ton truck equipped for outdoor broadcasting was used to give directions to troops handling necessary changes in operation of lighting units (fig. 19).

(2) At Point Pleasant, telephonic communications were provided from Headquarters to two points in the test area; i.e., ground crew station and the radio truck. At Jacksonville Beach, the radio truck (figs. 20 and 21) was located at Test Headquarters, which was also the ground crew station, thereby eliminating the necessity for additional telephonic communication to those points.

(3) Two-way radio communication was maintained between Headquarters and the boats and aircraft by means of the mobile radio unit, furnished by the Lakehurst Naval Air Station for the Point Pleasant tests and by the U. S. Coast Guard Base at Charleston, South Carolina, for the Jacksonville Beach tests.

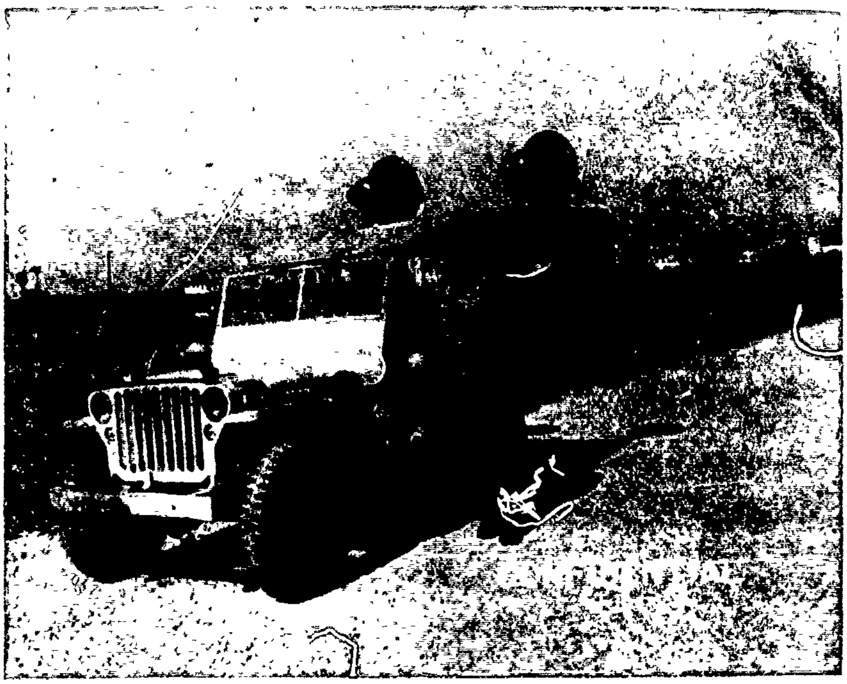


Fig. 19 -- Sound truck.

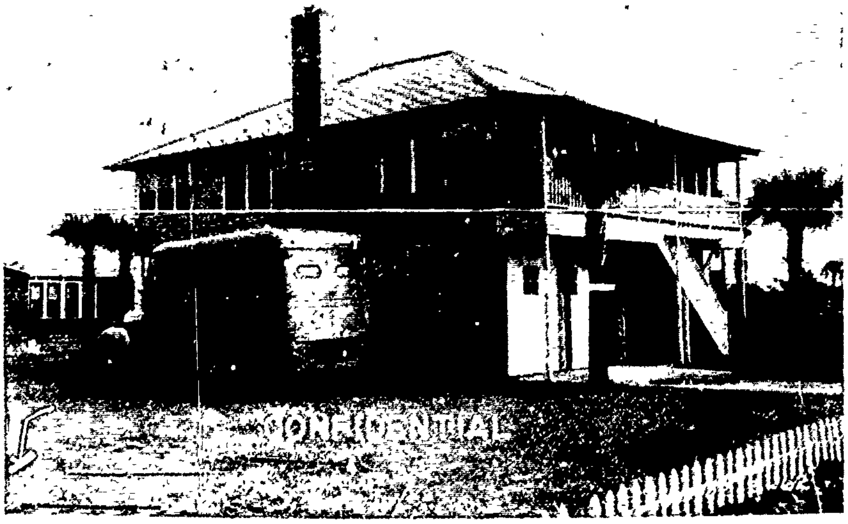


Fig. 20
Mobile radio unit and test headquarters,
Jacksonville Beach, Florida

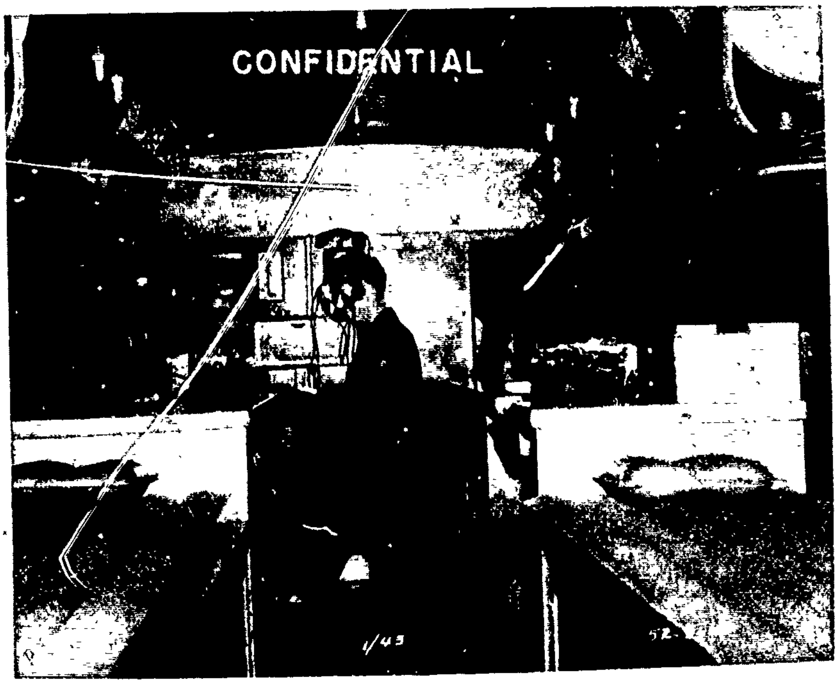


Fig. 21 -- Interior of mobile radio unit.

(4) All land stations were in telephonic communication with test headquarters at all times. In order to establish this service, wire covering approximately 12 miles was strung by the Signal Corps where telephone lines did not exist.

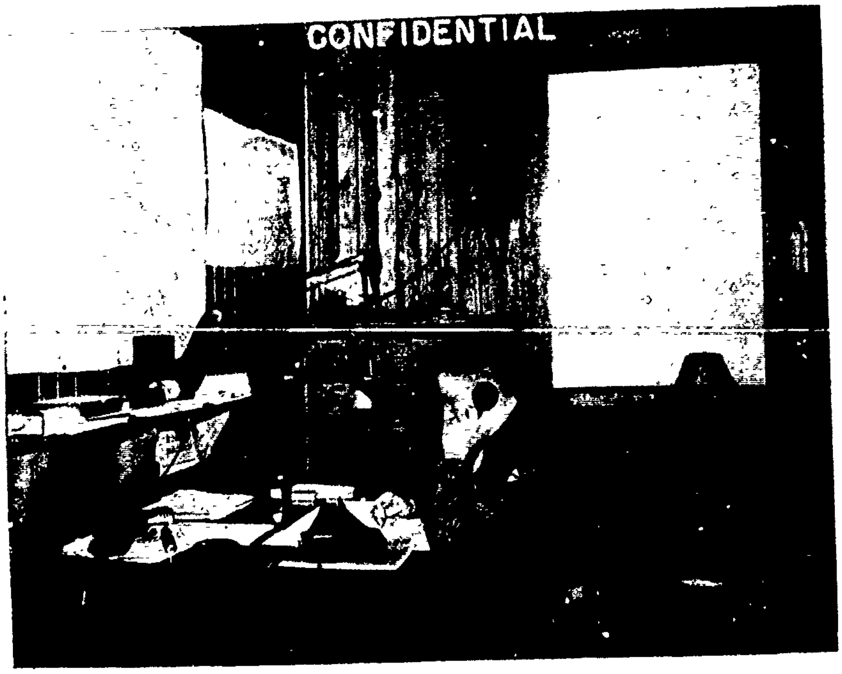


Fig. 22 -- Control room at test headquarters. Jacksonville Beach, Florida

c. Boats. At Point Pleasant, two army boats based at Sandy Hook were used for offshore observations -- the Dixonia, a converted yacht was used by the observation party; and the Samson, a sea-going tug, simulated a target boat by plying between the sky glow or sources of direct light and the offshore observers. Two coast guard boats, the Talapoosa, a C. G. cutter, and the Umpgua, a tug, based at Bayhead, Florida, were respectively employed for the same purposes during the Jacksonville Beach tests. Vessels used as target in both tests were approximately 165 feet in length.

d. Aircraft. Aircraft were furnished by the Lakehurst Naval Air Station (blimp) and the Jacksonville Naval Air Station (patrol bomber) for tests in their respective vicinities.

e. Brightness meters. Measurements of sky glow brightness were accomplished by means of Taylor "Model A" low brightness meters (figs. 23 and 24). This meter operates upon the principle of matching two illuminated fields - one, the test field to be measured, and the other, the comparison field which can be illuminated to known values which are read directly from the scale on the instrument. With experienced operators, a high degree of accuracy is possible over an entire range of brightnesses from 0.1 to 0.000005 footlamberts.

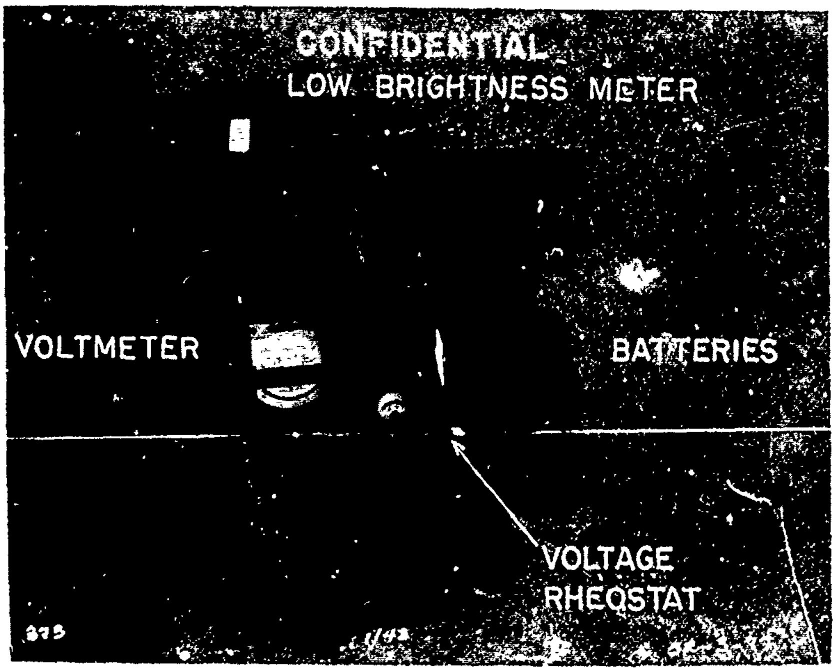


Fig. 23
Taylor "Model A" low brightness meter; and volt meter used to record sealed beam headlamp voltage.

Fig. 24 -- Taylor "Model A" low brightness meter and tripod.

f. <u>Atmospheric transmission equipment.</u> Atmospheric transmission was measured by means of a beach searchlight, test plates, and a Luckiesh-Taylor brightness meter. Hoods and baffles were used to shield test plate from light reflected from surroundings.

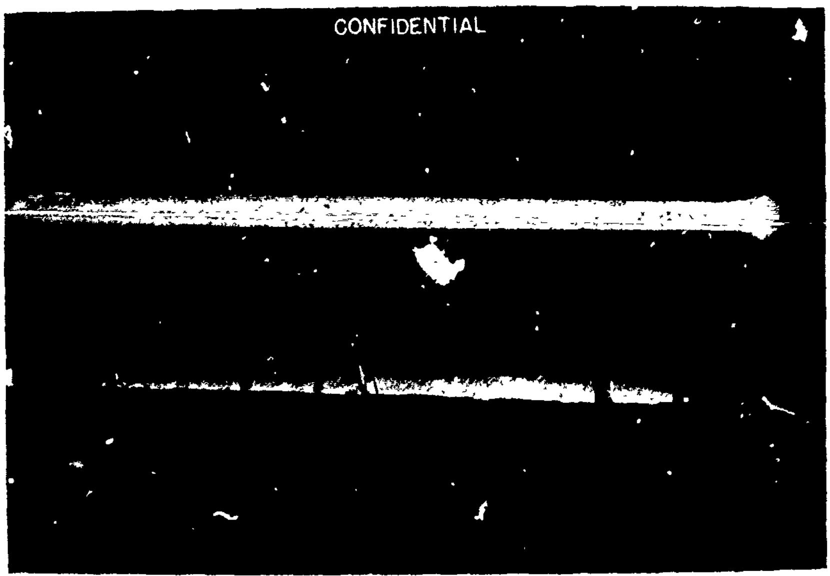


Fig. 25 -- Night view of beach searchlight.

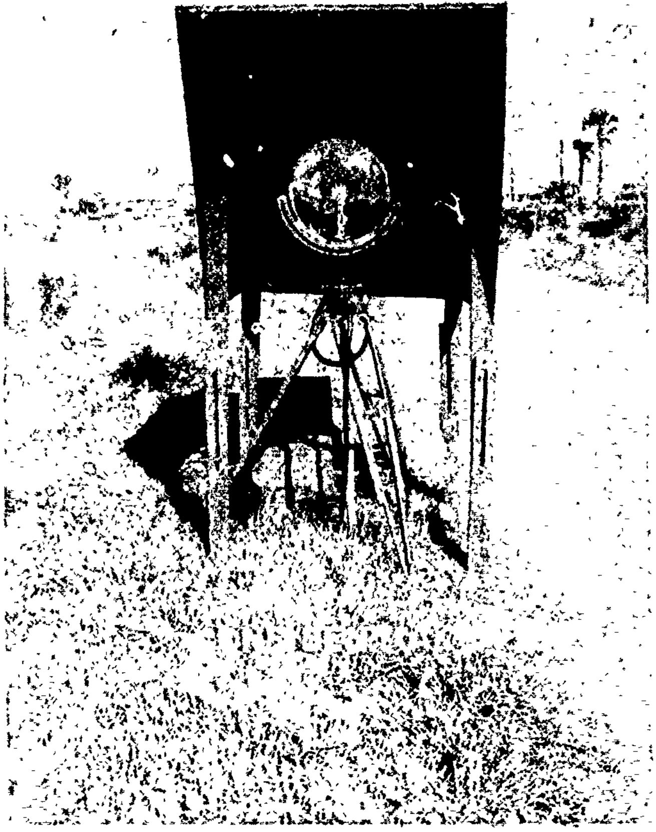


Fig. 26 -- Beach searchlight and shield.

Fig. 27 -- Booth, 1000 feet from searchlight, used to insure measurements in same portion of beam.

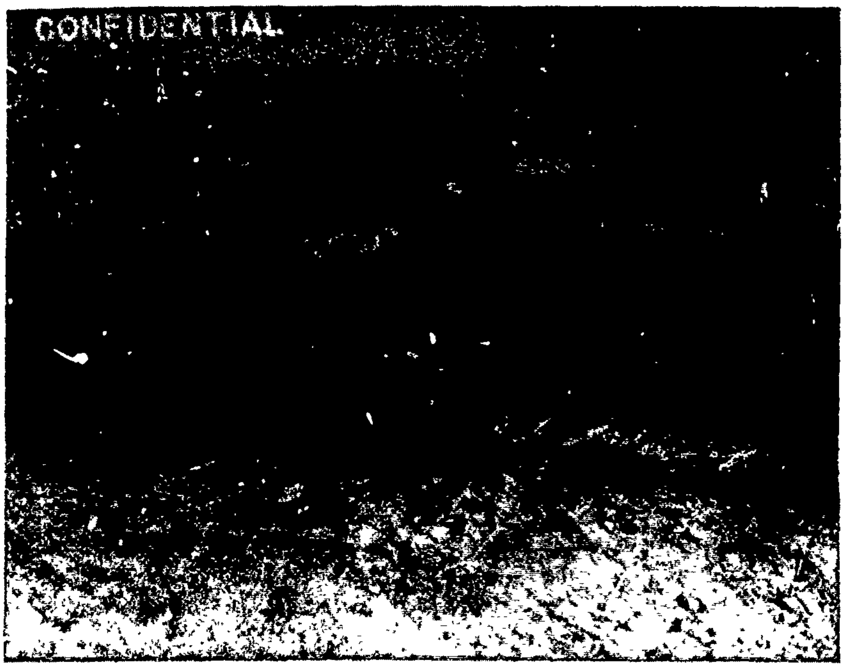


Fig. 28 --
Power supply for beach searchlight.

g. Weather equipment. A complete field unit for taking weather data was furnished by the Atlanta, Georgia, Office of the United States Weather Bureau. A view of the ceiling projector is shown below. (See Appendix D for record of weather data).

Fig. 29 --
Ceiling projector.

h. Window brightness equipment. For determination of maximum window brightnesses non-hazardous to ships at various distances from them, diffusing screens of tracing paper were attached to windows and brightness was produced by special light boxes so designed that various intensities were obtainable without color change in the lighting.

Fig. 30
Special light box used in window brightness test.

i. Automobile headlighting equipment. Various automobiles, including Fords, Chevrolets, Plymouths, several army vehicles, and a 35 passenger bus were used during Point Pleasant tests to determine hazard to shipping caused by direct light from a number of types and modifications of automobile lighting devices when visible from the sea. A special test car (fig. 31) equipped with all required lighting devices, and a navy bus, were employed at Jacksonville Beach.

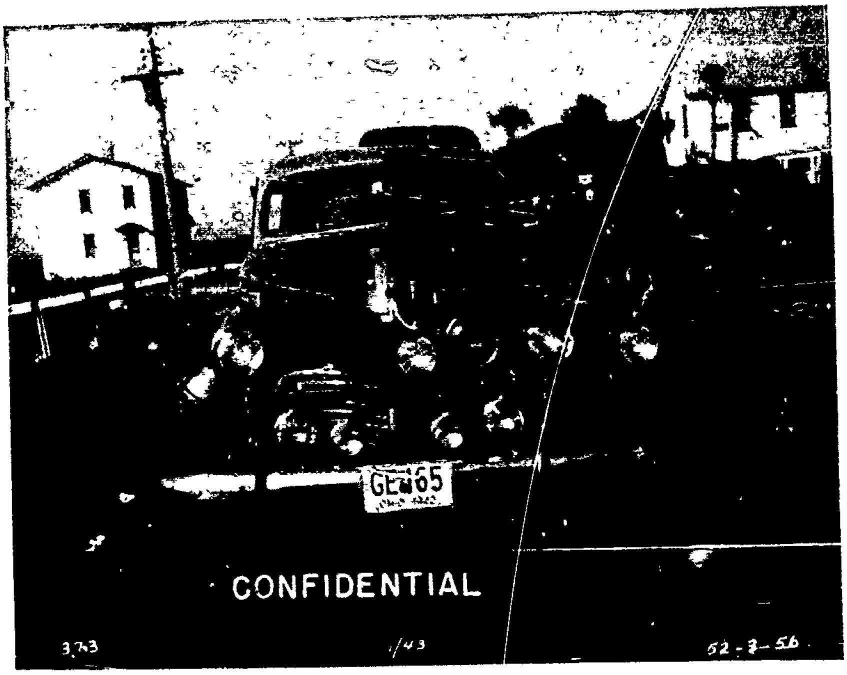


Fig. 31 -- Special test car and headlamps.

j. Minor aids to navigation. Aids to navigation emitting white, green, and red light and equipped with special switching arrangements to produce various flashing cycles and beam candlepowers are shown below in test position.

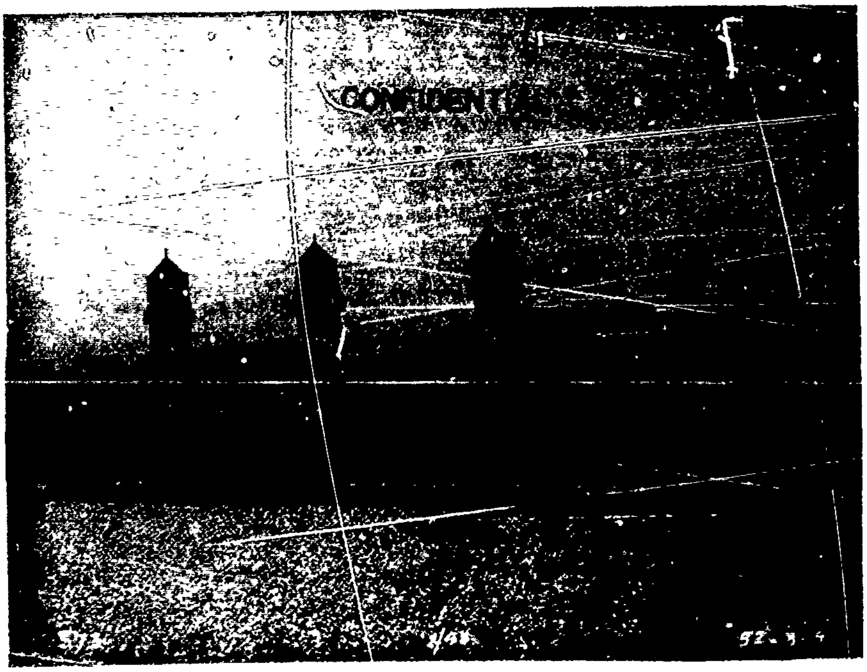


Fig. 32 -- Aids to Navigation.

k. Miscellaneous. Miscellaneous items of equipment used during the tests included motor vehicles, floodlamps, variacs for dimming light sources, and volt meters.

13. Test Procedures. Sample written test procedures selected from those used during both tests are given in Appendix B. To conserve space, the entire set of procedures is not included; however, method employed for each test is covered, since several tests were repeated during both periods. Although procedures as outlined were not strictly followed nor tests conducted in the order originally planned due to weather conditions and other circumstances, the procedures serve to indicate the thought, care, and planning back of the tests.

14. Moon Phase During Conduct of Tests. All tests were conducted during dark of the moon.

15. Test Data. In order to provide a chronological record of the test data for ready checking and reference, and to record significant data which were not required in analysis of a particular item, complete sky glow data as recorded each night are included in Appendix C. Nightly record of weather data taken at Jacksonville Beach is given in Appendix D. Data pertinent to each item under test are included with description of that particular item.

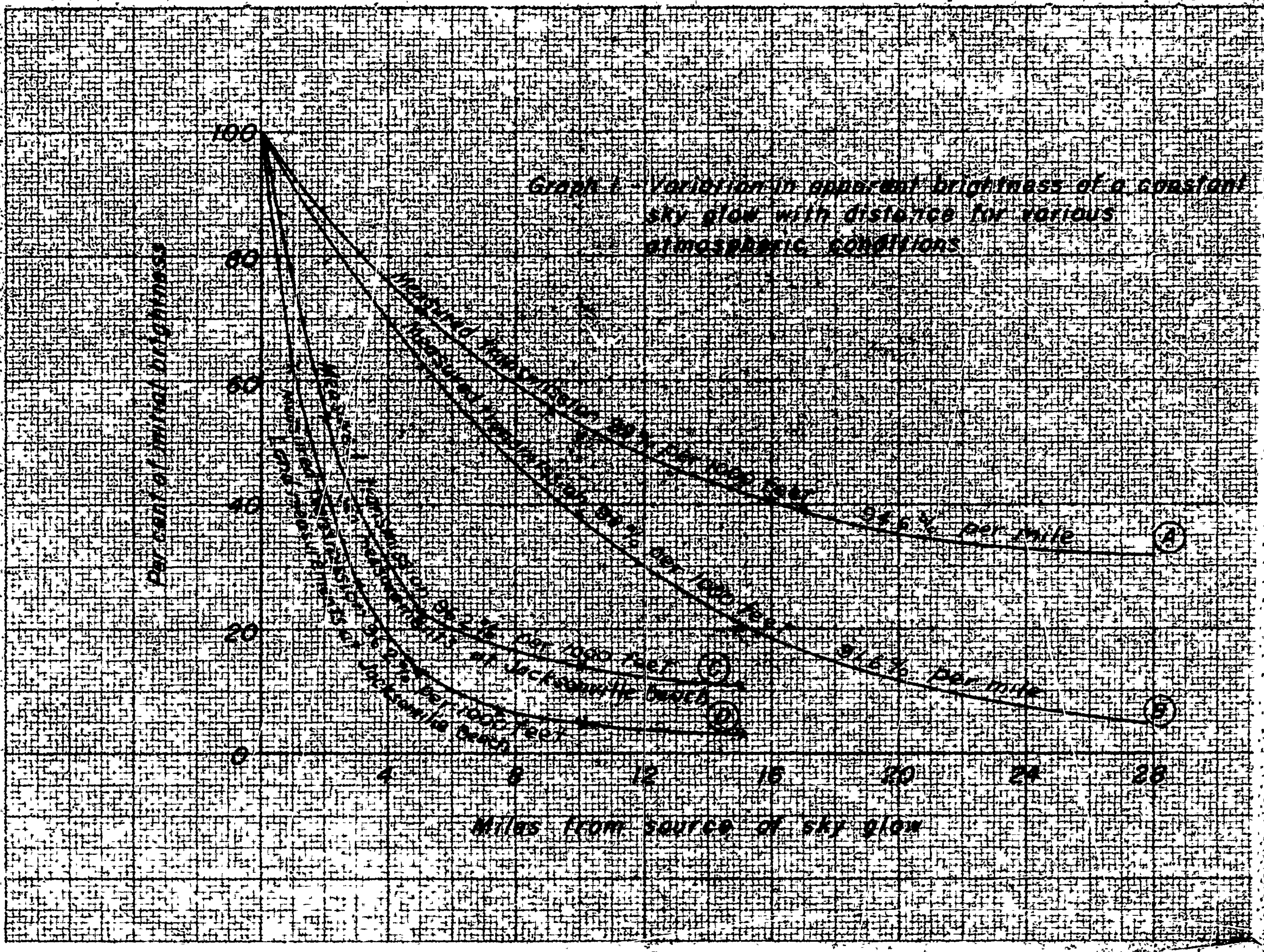
16. Fundamental Laws Governing Sky Glow. Three fundamental laws concerning artificial sky glow brightness, which are applicable under any given set of circumstances or conditions, were derived from the data taken. The pertinent data and curves expressing the laws are set forth in the following sub-paragraphs:

a. The variation in apparent brightness of a constant sky glow with distance for a constant atmospheric condition.- (1) During the course of the full scale field tests, measurements of sky glow produced by a constant light flux were made at various distances from the source of the light flux during periods when atmospheric transmission of light was quite constant throughout the entire region. Values obtained by these measurements are given in Table 1 and plotted in per cent on Graph 1. Graph 1 was developed in the following manner: First, value obtained at location nearest source of sky glow was considered as 100% and values obtained at locations farther from source of sky glow were plotted in per cent of shortest distance value. Curve thus obtained was projected back to zero distance or source of sky glow. Final curve, shown as Graph 1, was then calculated with value obtained at zero distance as 100%.

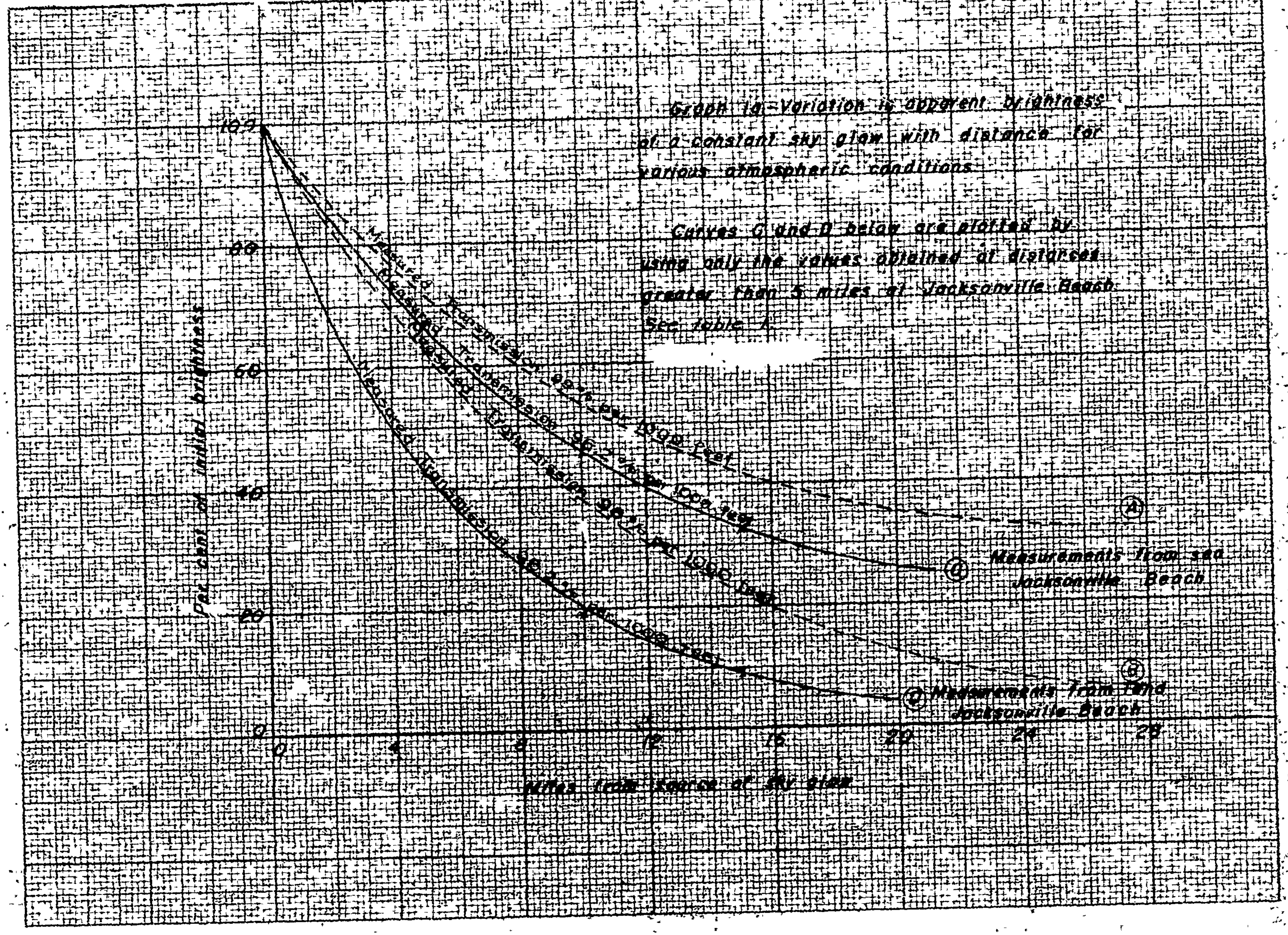
MEASURED ATMOSPHERIC TRANSMISSION PER 1000 FT.		99 %			99 %			98 %			962 %						
WEATHER		CLEAR			CLEAR			OVERCAST LOW			CLEAR						
MEASUREMENTS FROM		6½ MILES EAST	9 MILES EAST	17 MILES EAST	5 MILES WEST	10 MILES WEST	17 MILES EAST	5 MILES WEST	10 MILES WEST	15 MILES WEST	1 MILE SOUTH	2 MILES SOUTH	3 MILES SOUTH	5 MILES SOUTH	7½ MILES SOUTH	10 MILES SOUTH	15 MILES SOUTH
BRIGHTNESS MICRO-FOOTLAMBERTS	INLAND HORIZON	-	-	-	120.0	45.0	-	122.0	138.0	51.0	82.0	79.0	85.0	85.0	-	90.0	90.0
	ZENITH	-	-	-	120.0	102.0	156.0	79.0	84.0	84.0	125.0	95.0	90.0	95.0	95.0	100.0	80.0
	SEA HORIZON	-	-	-	-	-	-	-	-	-	75.0	75.0	82.0	70.0	-	-	-
	TEST AREA HORIZON	138.0	114.0	78.0	252.0	180.0	144.0	252.0	156.0	78.0	2300.0	1200.0	1020.0	450.0	230.0	180.0	100.0
PERCENT OF BRIGHTNESS MEASURED AT POINT CLOSEST TO TEST AREA		100.0	82.6	56.5	100.0	71.5	57.0	100.0	62.0	31.0	100	52	44.4	19.5	10.0	7.8	4.4
LOCATION AND DATE		POINT PLEASANT, N.J. NOVEMBER 16, 1942			POINT PLEASANT, N.J. NOVEMBER 16, 1942			POINT PLEASANT, N.J. NOVEMBER 12-13, 1942			JACKSONVILLE BEACH, FLORIDA JANUARY 15, 1943 - LAND MEASUREMENTS						

MEASURED ATMOSPHERIC TRANSMISSION PER 1000 FT.		96.2 %			
WEATHER		CLEAR			
MEASUREMENTS FROM		2 MILES EAST	5 MILES EAST	10 MILES EAST	15 MILES EAST
BRIGHTNESS MICRO-FOOTLAMBERTS	INLAND HORIZON	98.0	95.0	95.0	83.0
	ZENITH	100.0	150.0	140.0	135.0
	SEA HORIZON	84.0	84.0	81.0	87.0
	TEST AREA HORIZON	640.0	260.0	175.0	135.0
PERCENT OF BRIGHTNESS MEASURED AT POINT CLOSEST TO TEST AREA		100.0	40.6	27.3	21.0
LOCATION AND DATE		JACKSONVILLE BEACH, FLORIDA JAN. 15 1943 - SEA MEASUREMENTS			

TABLE I- SUMMARY OF DATA ON VARIATION IN APPARENT BRIGHTNESS OF A CONSTANT SKY GLOW WITH DISTANCE FOR VARIOUS ATMOSPHERIC CONDITIONS.



Graph 1 - Variation in apparent brightness of a constant sky glow with distance for various atmospheric conditions



Graph 1a - Variation in apparent brightness of a constant sky glow with distance for various atmospheric conditions

Curves C and D below are plotted by using only the values obtained at distances greater than 5 miles at Jacksonville Beach. See table 1.

(2) Curve A shown on Graph 1 includes readings made at Point Pleasant, New Jersey, from both the land and the sea. However, readings made at Jacksonville Beach, Florida, from the sea (Curve C) give higher values than those made simultaneously on land (Curve D). Since atmospheric transmission was measured over land, the apparent discrepancy between land and sea readings was due to higher transmission over the sea which may be explained as follows (see Appendix D): "During this series of tests (Jacksonville Beach) visibility was noticeably better over the sea than over land. Since there is always more wind over a water surface than over an adjacent land surface, the mixing of air is greater. However, the more important factor is the fact that water surfaces are not cooled by radiation as rapidly as land surfaces, and since the water temperatures here were higher than the cooled land surfaces, the temperature of the air over water did not drop low enough to cause fog." Hence, higher atmospheric transmissions of light than those measured over land were encountered over the sea during the Jacksonville Beach tests. The low, even temperatures prevalent at Point Pleasant did not produce that effect.

(3) Curves C and D of Graph 1 show a greater rate of decrease in brightness for values within 5 miles of the source of sky glow than for values at distances greater than 5 miles from the source of sky glow. Factors which caused this more rapid rate of decrease are not known but a "height of measurement" factor could have been the cause. That is, since extremely low horizons over the test area were obtainable from the sea and from land in a southerly direction, brightness may have varied with the height of horizon measured until after 5 miles the curvature of the earth and intervening obstructions caused measurements to be taken at such a height that all fell in a band of glow of uniform brightness. Hence, for measurements closer than 5 miles to source of sky glow two factors were affecting brightness of the glow - the height of the horizon and the distance from source - whereas the only factor active farther than 5 miles was distance from the source. Graph 1a has been plotted by the method described in sub-paragraph (1) above by using only the values obtained for 5 miles and more (Table 1). Curves A and B of Graph 1 have been replotted for reference. New Curves C and D have the same shape as Curves A and B. Curve C, however, falls between Curves A and B, since transmission over the water was somewhat higher than the transmission measured over land.

(4) Graph 1b shows the values of Graph 1a plotted on semi-logarithmic paper. The equation of Curves A, B, and D, and Curve C if transmission is taken as approximately 98.4 per cent

Fig. 33 -- Appearance of sky glow from 15 miles west of Point Pleasant, New Jersey. Light beams pointed vertically.

The above effect was produced by a double cloud layer, although brightness at test area horizon was so low that it was undiscernable. Clouds above light source with clear atmosphere beneath may cause unpredictably high brightnesses visible as a beacon for greater distances.

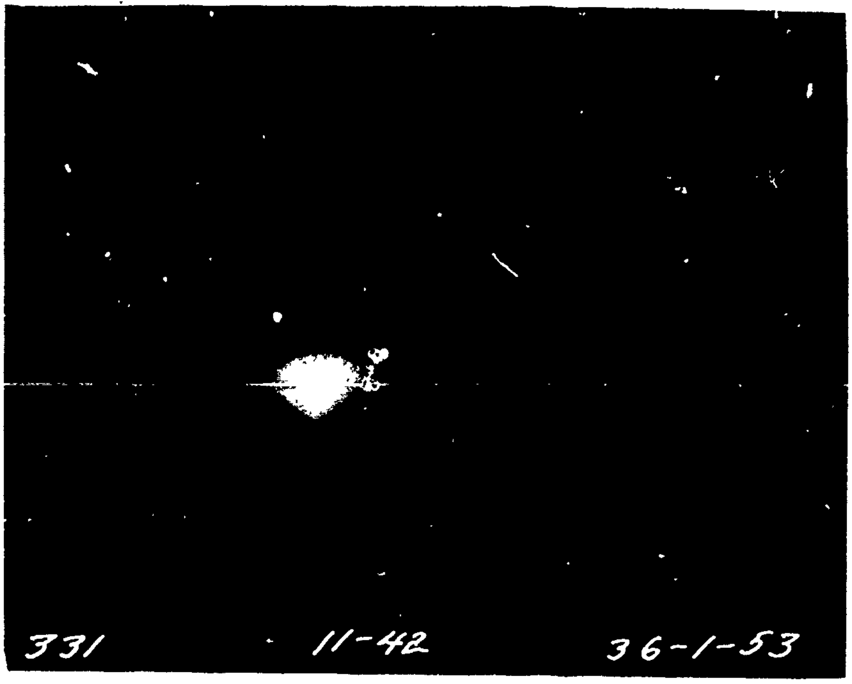


Fig. 34 -- Appearance of sky glow from 10 miles west of Point Pleasant, New Jersey. Light beams pointed vertically.

Note low brightness on test area horizon and extremely high brightness with wide spread on cloud. Compare with figure 33.

Fig. 35 -- Another sky glow effect from 10 miles west of Point Pleasant, New Jersey. Light beams pointed vertically. Cloud appears less dense than that of fig. 34 and some of the light flux penetrates through.

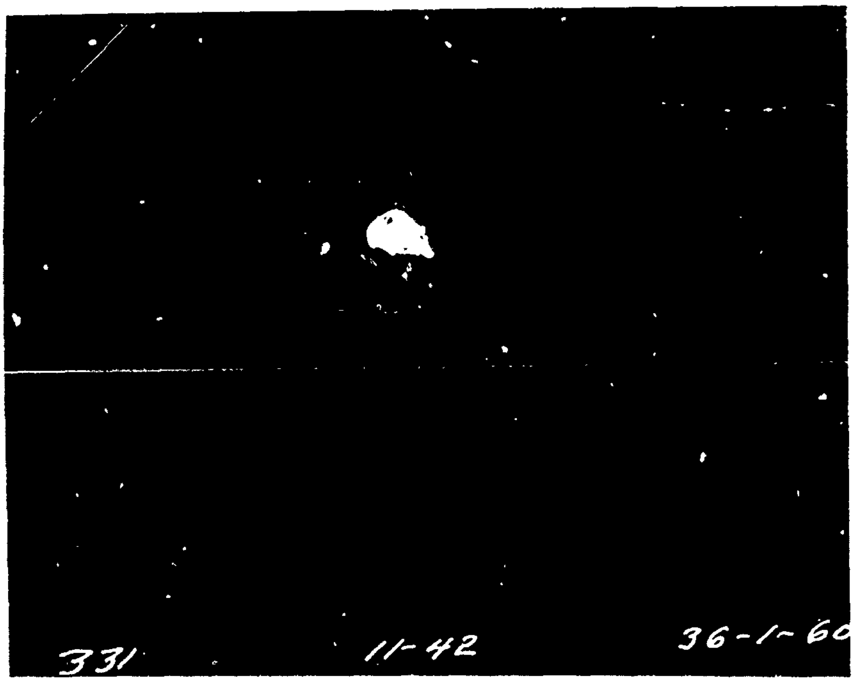
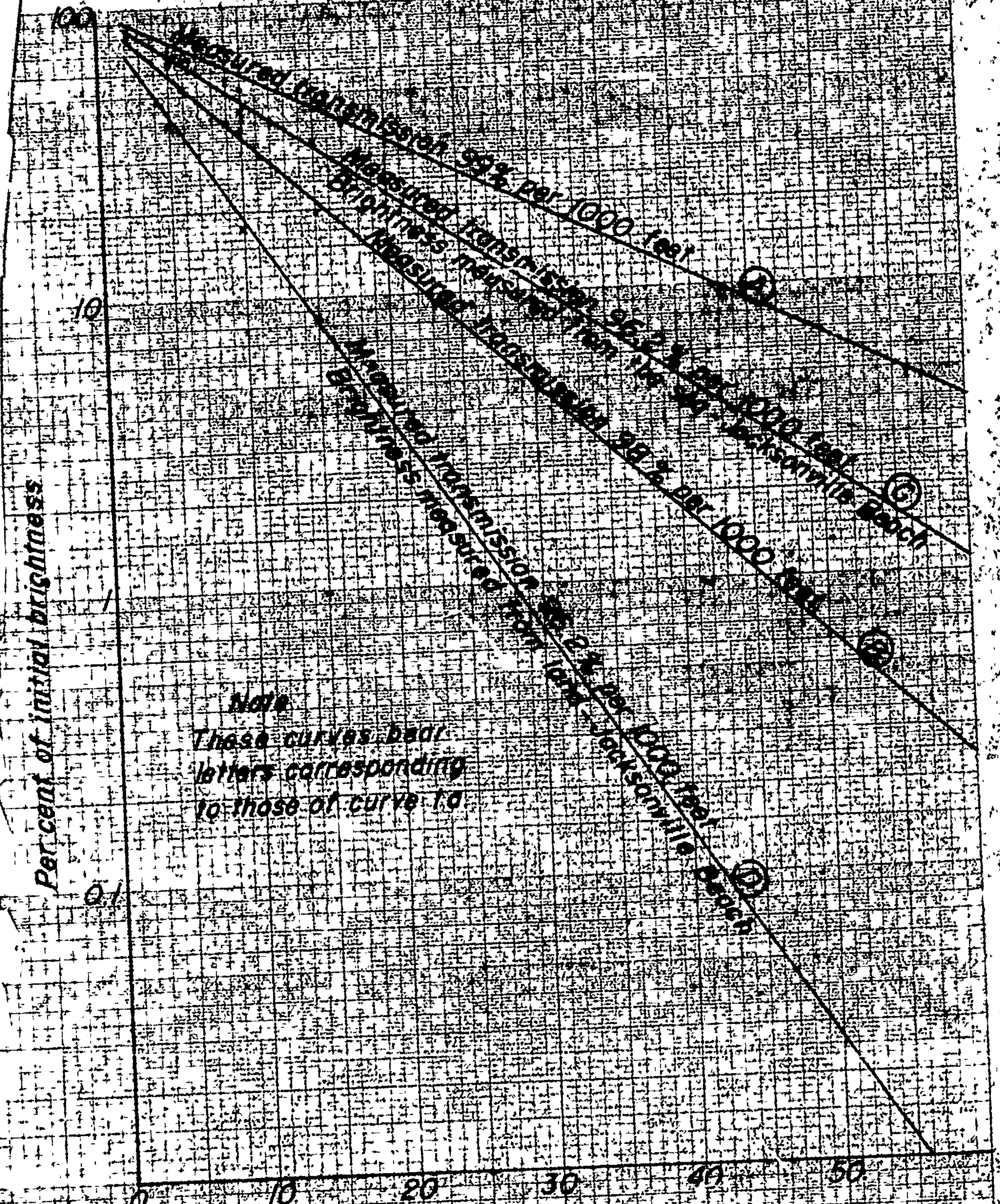


Fig. 36 -- In this view of sky glow from 10 miles west of Point Pleasant, New Jersey, cloud between camera and sky glow appears to obscure portion of sky glow above test area horizon. Light beams pointed vertically.

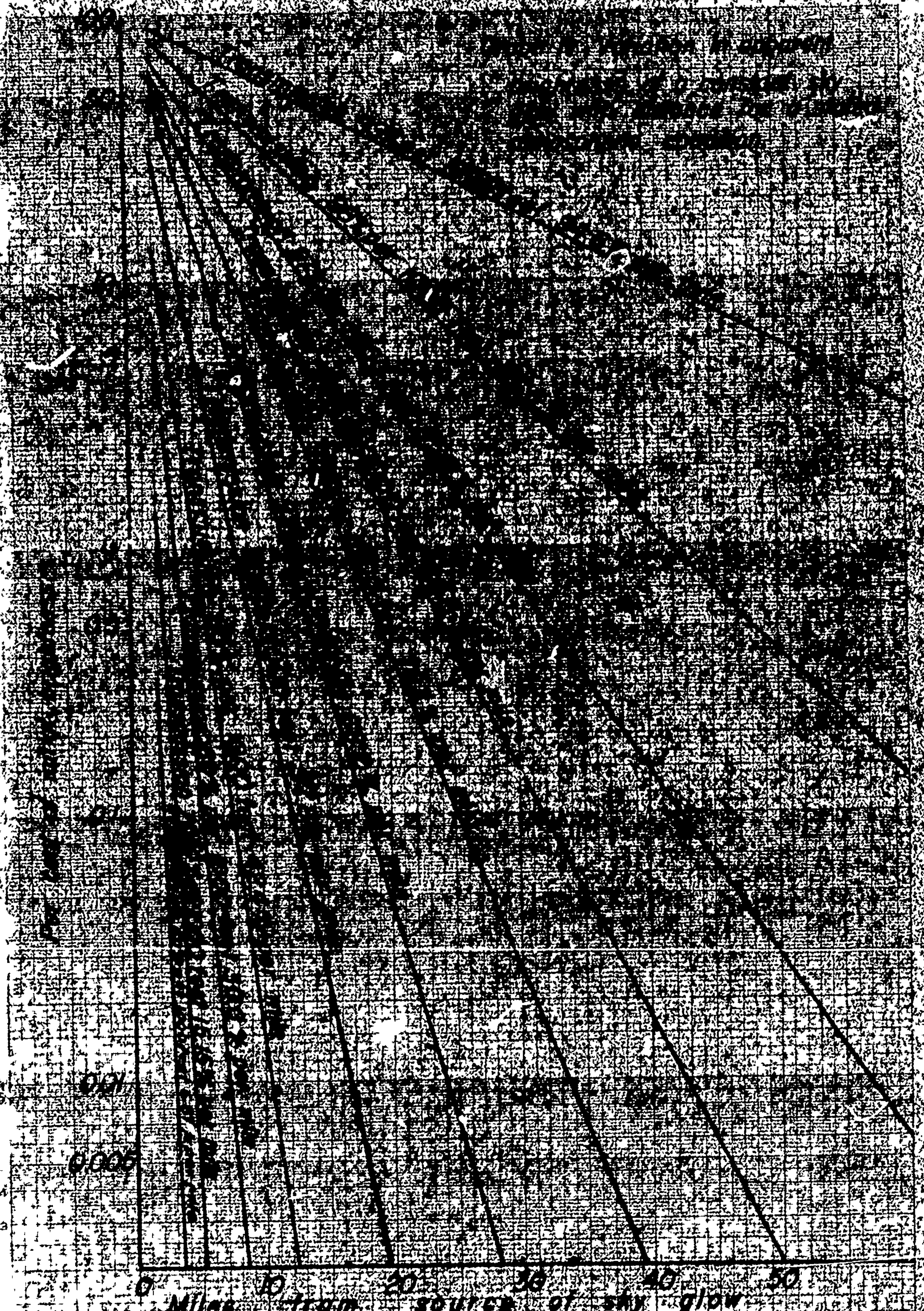
to account for the higher transmission over the sea, is $B_r = 100\ t^{5.28n}$, when B_r is residual sky glow brightness in per cent at stated distance from source of sky glow, t is atmospheric transmission in decimals per 1000 feet of atmosphere, and n is the number of miles from source of sky glow. This equation becomes $B_r = 100\ t^n$ when t (atmospheric transmission) is expressed in decimals per mile. Expressing both sides of the equation in decimals instead of per cent, it is shown that B_r (brightness residual at any point) varies directly as the nth power of the atmospheric transmission; $B_r = B_i t^n$ where B_i is brightness produced at source. Moreover, if brightness is measured at any distance from the source of light, the brightness which would be measured at any other distance may be computed by the same equation, provided the atmospheric transmission factor is known. Also, if sky glow brightness over a location is measured from two points, the distance between which is known, average atmospheric transmission may be computed by the above equation.

(5) By substituting values of t in the equation, $B_r = 100\ t^{5.28n}$, it was possible to plot the curves for any atmospheric transmission desired. Graph 1c shows a family of curves plotted on semi-logarithmic paper for 60 to 99 per cent atmospheric transmission per 1000 feet.

(6) It will be noticed that the foregoing curves and equations have been developed from actual total brightness (natural sky brightness plus artificial glow) measured at various distances from the source of artificial glow. Since natural horizon brightness is a constant for simultaneous measurements in the same direction regardless of distance from the source of artificial glow, it is seen that the values representing the artificial glow (i.e., total brightness measured minus natural horizon brightness) do not exactly follow the curves as given. Belief is held, however, that artificial glow does decrease with distance as illustrated by the curves and that a factor of decrease in glow as the height of horizon increases compensates for the constant horizon brightness. In other words, values obtained at 10 and 15 miles would have been somewhat higher in relationship to those obtained at 5 miles if the glow at the same distance above ground had been measured from all three locations.



Graph Ib - Variation in apparent brightness of a constant sky glow with distance for a stated atmospheric condition.


100
50
0.01
0.005
0
10
20
30
40
50
Miles from source of sky glow

b. The addition of sky glow brightnesses. (1) When brightness is measured on the axis of two sky glows separated by a considerable distance. (a) For this determination, the test area at Jacksonville Beach (hereinafter referred to as Test Area 1) and a second test area (hereinafter referred to as Test Area 2) located between Test Area 1 and observers' station 5 miles south thereof were used. A night view of the upward flux from the 792 lamps in Test Area 2 is shown below (fig. 37).

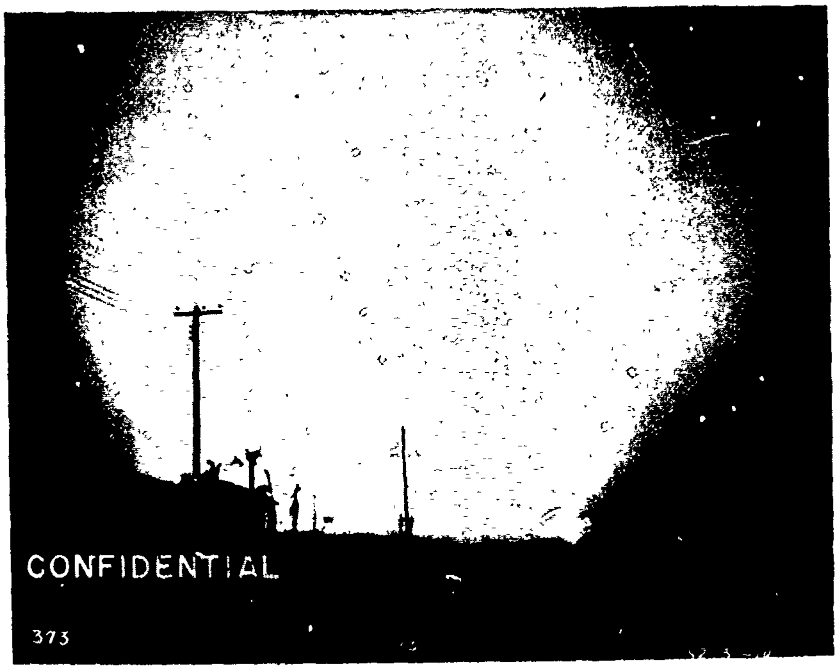


Fig. 37
Close-up night view of Test Area 2.
Note shape of glow and the spread of the light over adjacent unlighted areas.

(b) Sky glow measurements were made on the axis of the two test areas from 5 miles south of Test Area 1 (2.5 miles south of Test Area 2) and from two special stations north of Test Area 1 - one 4.4 miles north and the other 2.2 miles north. Arrangements for this part of the test are illustrated below:

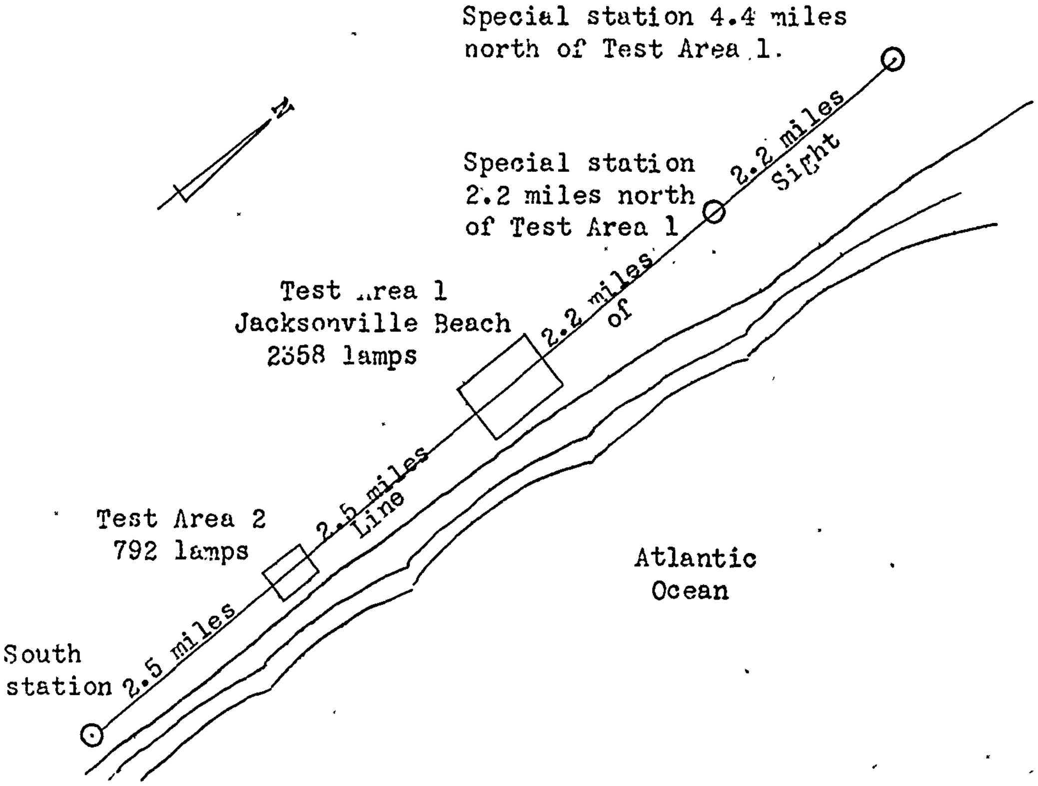


Fig. 38 -- Arrangements for determination of addition of sky glow brightnesses separated by a considerable distance when brightness is measured on their axis.

(c) The results obtained during the two nights of this test are set forth in Tables 2 and 2a. Data obtained proved that the residual brightness at point of measurement of each sky glow add directly; i.e., B_r (total brightness residual at point of measurement) equals B_1 (brightness residual from first sky glow) plus B_2 (brightness residual from second sky glow). Hence, from equation given in sub-paragraph a. above, apparent brightness measured through two sky glows is expressed as follows:

Data on addition of sky glow brightnesses - Jacksonville Beach, Florida

ITEM		MEASUREMENTS FROM STATION 4.4 MILES NORTH OF TEST AREA I						MEASUREMENTS FROM STATION 2.5 MILES SOUTH OF TEST AREA 2					
		AREAS PRODUCING GLOW						AREAS PRODUCING GLOW					
		~~TEST AREAS I AND 2~~	TEST AREA I	TEST AREAS I AND 2	TEST AREA 2	TEST AREAS I AND 2	TEST AREA I	~~TEST AREAS I AND 2~~	TEST AREA I	TEST AREAS I AND 2	TEST AREA 2	TEST AREAS I AND 2	TEST AREA I
BRIGHTNESS MICRO-FOOTLAMBERTS	INLAND HORIZON	~~55~~	-	-	55	55	55	~~105~~	85	85	90	95	100
	ZENITH	~~120~~	-	-	-	-	-	~~260~~	240	200	210	200	170
	SEA HORIZON	~~55~~	-	-	55	55	55	~~95~~	89	80	85	90	92
	TEST AREA HORIZON	~~290~~	330	390	70	390	340	~~4100~~	850	4700	6800	5000	-
	SKY GLOW-TEST AREA HORIZON MINUS INLAND HORIZON	235	275	335	15	335	285	3995	764	4615	6710	4905	-
ATMOSPHERIC TRANSMISSION PER 1000 FEET		86 % AT 12:36 A.M.			83 % AT 1:58 A.M.			86 % AT 12:36 AM.			83 % AT 1:58 A.M.		
WEATHER	TIME	12:40 A.M.			1:40 A.M.								
	CEILING (FEET)												
	SKY	CLEAR			CLEAR								
	VISIBILITY (MILES)	6			6								
	OBSTRUCTIONS TO VISION	HAZE			HAZE								
	TEMPERATURE AND DEW POINT	37/35			37/35								
	WIND DIRECTION AND VELOCITY	CALM			W 2								
	RELATIVE HUMIDITY	91			91								
	THERMOMETERS DRY	37			36								
	THERMOMETERS WET	36			35.7								

Summary

Eliminating first reading of combined glows (shown crossed out on above chart), which is much lower than subsequent readings, the results are as follows:

From north station, both readings of combined glows were 335 micro-footlamberts, while adding each of the values for Test Area 1 to the value of Test Area 2, 290 and 300 micro-footlamberts respectively are the values obtained for the combined glows.

From south station, reading of Test Area 2 through some trick of atmosphere was greater than either of the readings of the combined glows.

This test was repeated on the following night- see Table 2 d.

Table 2- The addition of brightnesses of two sky glows separated by a considerable distance when measured on a line through their axis.

Data on the addition of sky glow brightnesses — Jacksonville Beach, Florida

ITEM		Measurements from station 2.2 miles of Test Area 1							Measurements from station 2.5 miles south of Test Area 2						
		Areas producing glow							Areas producing glow						
		Test area 2	Test areas 1 and 2	Test area 1	~~Test areas 1 and 2~~	Test area 2	Test areas 1	Test areas 1 and 2	Test area 2	Test areas 1 and 2	Test area 1	~~Test areas 1 and 2~~	Test area 2	Test area 1	Test areas 1 and 2
Brightness micro-footlamberts	Dark reading – Lights at both areas extinguished	33	33	33	~~33~~	33	33	33	33	33	33	~~33~~	33	33	33
	Test area horizon	150	1200	1060	~~1230~~	143	820	900	360	1500	850	~~650~~	500	380	900
	Sky glow – Test area horizon minus dark reading	117	1167	1027	~~1197~~	110	787	867	327	1467	817	~~617~~	467	347	867
Atmospheric transmission per 1000 feet		77.4%	82.0%						77.4%	82.0%					

Weather				
	Time		4:15 am	5:00 am.
	Ceiling (feet)			20,000
	Sky		Scattered clouds	broken clouds
	Visibility (miles)		12	10
	Obstructions to vision			
	Relative humidity		91	96
	Temperature and dew point		46/44	48/46
	Wind direction and velocity		Calm	W 5
	Remarks		Clouds-N, W, and SE.	
	Thermometers	Dry	46.5	47.5
		Wet	45.2	47.0

Summary

Eliminating second reading of combined glows (shown crossed out on above chart) and considering each set of 3 readings before and after the crossed out one as a unit, the results are as follows

Test areas	From north station			From south station		
	Measured in combination	Measured individually and added	Per cent deviation	Measured in combination	Measured individually and added	Per cent deviation
First group of readings						
1 and 2	1167	1144	-2.0	1467	1144	-22.0
Second group of readings						
1 and 2	867	897	+3.5	867	814	- 6.0

Table 2a- The addition of brightnesses of two sky glows seperated by a considerable distance when measured on a line through their axis.

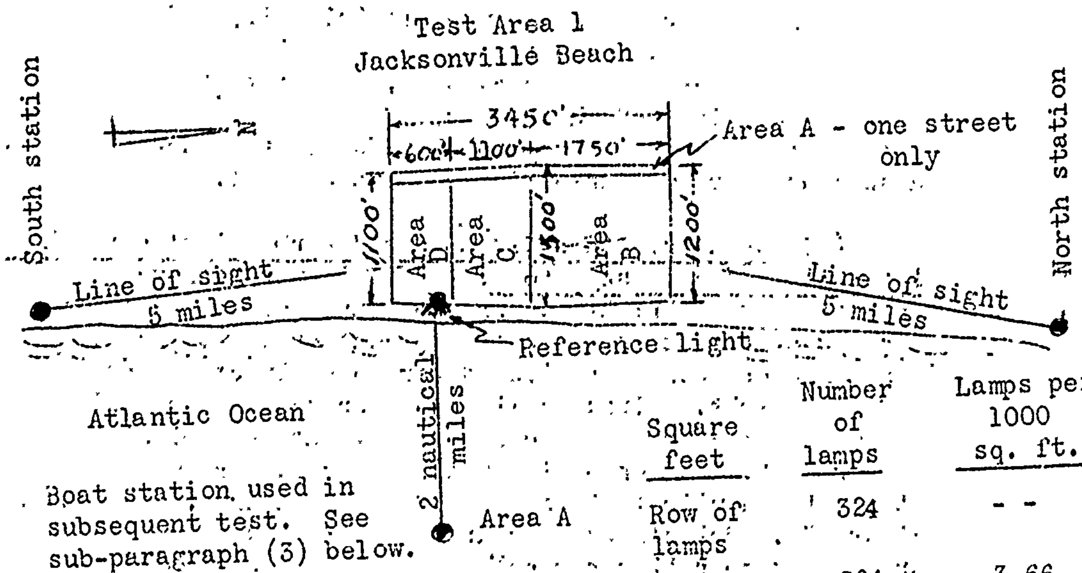
Let B_r = Apparent brightness viewed through both sky glows from any point.

B_1 = Apparent brightness of one sky glow at any point on axis of both between location of B_r and source of glow.

B_2 = Apparent brightness of second sky glow at any point on axis of both between location of B_r and source of glow.

Then $B_r = B_1 t^x + B_2 t^y$ when t is atmospheric transmission in decimals per unit distance, x is distance between locations of B_r and B_1 divided by unit distance, and y is distance between locations of B_r and B_2 divided by unit distance.

(2) When brightness is measured on the axis of two or more adjacent sky glows. (a) Test Area 1 (Jacksonville Beach) was divided into four sub-areas for this study. Each sub-area could be turned on and off independently of the other sub-area. Extent of these areas, number of lamps in each, and locations from which sky glow brightness was measured are illustrated below:



Boat station used in subsequent test. See sub-paragraph (3) below.

	Square feet	Number of lamps	Lamps per 1000 sq. ft.
Area A	Row of lamps	324	- -
Area B	2,362,500	864	3.66
Area C	1,320,000	522	3.95
Area D	890,000	648	7.28
Totals	4,572,500	2358	5.15

Fig. 39 -- Arrangements for determination of **addition of** adjacent sky glow brightnesses when brightness is measured on their axis.

(b) Tests were conducted on three separate nights by measuring brightness produced by each area separately and brightness produced by all possible combinations of Areas B, C, and D. Results obtained on first night of these tests are given in Table 3. Variable weather conditions were encountered on this night and data obtained are of no value in revealing the additive factor of adjacent sky glows. The table does serve, however, to demonstrate the erratic and unpredictable brightnesses which will be encountered under fluctuating conditions of sky, weather, and atmosphere. (Measurements of Area A are not included in this section for they were not considered significant. They may be found in Appendix C.)

(c) Data recorded on subsequent nights of same test are set forth in Tables 3a and 3b. Table 3a gives the data obtained when undiffused light was used and Table 3b when diffused light was used. Although weather conditions varied to a small extent, they were much more stable than those prevailing the night of the first test. The data show that, as in the case of sky glows separated by distance, the residual brightnesses of adjacent sky glows are directly additive when brightness is viewed through both glows. Values obtained when the glow over two or more areas was measured in combination are not exactly the same as the values obtained when the glow over each area was measured individually and added together. However, the deviation between the two values is generally small enough to support above conclusion, except that for values listed in last two lines of the summary of Table 3b. The discrepancies between these values were probably due to the increase in brightness caused by fog during latter part of test.

(3) When brightness is measured perpendicular to the axis of laterally adjacent sky glows. (a) Tests were conducted to determine the effect that brightness from one area of upward light had transversely on brightness over an adjacent or nearby area. Such transverse factors were established for both direct upward beams and diffused light. Diffused light was produced by covering the lighting units with tracing cloth having light transmission factor of 43 per cent. Measurements of the sky glow were made from a location at sea two nautical miles east of the test area, as illustrated in Figure 39. Brightness over Area D (fig. 39) was measured whenever Area D was operating regardless of other areas operating at the same time. Brightness of each area when operating alone was also obtained. Hence, the calculation of the effect which brightnesses from Areas C and B had transversely on brightness produced by Area D alone was possible. Table 4 gives the values obtained when vertical beams of light were used and Table 4a the values for diffused light.

Data on addition of sky glow brightnesses - Jacksonville Beach tests

	ITEM	Measurements from north station							Measurements from south station						
		Areas producing glow							Areas producing glow						
		B	C	D	BC	BD	CD	BCD	B	C	D	BC	BD	CD	BCD
Brightness - micro-footlamberts	Inland horizon	17	19	15	16	14	17	45	9	13	10	10.5	8	11	8
	Zenith	45	55	55	45	40	60	55	27	40	19	12.5	17	27	40
	Sea horizon	14	12	16	16	15	16	17	9	13	11	8.5	8	10	14
	Test area horizon	340	100	90	350	700	555	500	138	50	400	75	75	230	260
	Sky glow - Test area horizon minus inland horizon	323	81	75	334	686	538	455	129	37	390	64.5	67	219	252
Brightness of overcast as measured from test area - micro - footlamberts		2000	6000	24,000	75,000	B 35,000 D 50,000	80,000	—							
Weather	Time	4:10 a.m.		3:00 a.m	4:10 a.m.		3:00 a.m.	2:15 a.m.							
	Ceiling (feet)	450		550	450		550	450							
	Sky	Overcast		Overcast	Overcast		Overcast	Overcast							
	Visibility (miles)	3		6	3		6	4							
	Obstructions to vision	Haze - Light rain		Haze	Haze - Light rain		Haze	Haze Light rain							
	Temperature - dew point	49/49		51/51	49/49		51/51	51/50							
	Wind velocity - direction	N 10		N 8	N 10		N 8	N 8							
	Relative humidity %	98		100	98		100	98							
	Remarks	Overcast ragged		—	Beam fading gradually										
	Thermometers Dry	49.0		50.7	49.0		50.7	50.8							
	Thermometers Wet	48.8		50.7	48.0		50.7	50.5							
Atmospheric transmission per 1000 feet		89.9% at 3:05 am.													

The above tabulation cannot show the additive effect of adjacent sky glows due to rapidly changing weather conditions. It is included in this report only as part of the data taken and as a matter of academic interest to demonstrate the erratic and unpredictable brightnesses which will be obtained under fluctuating conditions of sky, weather, and atmosphere. This test was repeated twice more — see tables 3a and 3b.

Table 3 — The addition of brightnesses of two or more adjacent sky glows when measured on a line through their axis.

Data on addition of sky glow brightnesses – Jacksonville Beach tests

ITEM		Measurements from north station							Measurements from south station						
		Areas producing glow							Areas producing glow						
		B	C	D	BC	BD	CD	BCD	B	C	D	BC	BD	CD	BCD
Brightness micro-footlamberts	Inland horizon	65	65	60	60	60	55	55	98	110	110	102	120	106	95
	Zenith	110	110	110	110	120	120	130	165	148	150	—	145	160	150
	Sea horizon	70	75	60	60	60	60	55	94	95	101	96	94	100	91
	Test area horizon	170	120	140	240	290	210	350	285	250	300	360	440	520	650
	Sky glow - Test area horizon minus inland horizon	105	55	80	180	230	155	295	187	140	190	258	320	414	555
Atmospheric transmission per 1000 feet		87.5 % at 4:20 a.m.		81.5 % at 3:40 a.m.	87.5 % at 4:20 a.m.		81.5 % at 3:40 a.m.		87.5 % at 4:20 a.m.		81.5 % at 3:40 a.m.	87.5 % at 4:20 a.m.		81.5 % at 3:40 a.m.	
Weather	Time	4:30 a.m.		3:30 a.m.	4:30 a.m.		3:30 a.m.								
	Ceiling	None		None	None		None								
	Sky	Clear		Clear	Clear		Clear								
	Visibility (miles)	6		6	6		6								
	Obstructions to vision	Haze		Haze	Haze		Haze								
	Temperature-dew point	35/33		37/31	35/33		37/31								
	Wind direction-velocity	W2		W2	W2		W2								
	Relative humidity %	91		79	91		79								
	Thermometers Dry	35.2		37.3	35.2		37.3								
	Thermometers Wet	34.2		34.9	34.2		34.9								

Summary

Area combinations	From north station			From south station		
	Measured in combination	Measured individually and added	Per cent deviation	Measured in combination	Measured individually and added	Per cent deviation
BC	180	160	-11	258	327	+27
BD	230	185	-16	320	377	+18
CD	155	135	-13	414	330	-20
BCD	295	240	-18	555	517	-7

Table 3a – The addition of brightnesses of two or more adjacent sky glows when measured on a line through their axis.

Data on addition of sky glow brightnesses - Jacksonville Beach, Florida.

ITEM		Measurements from north station							Measurements from south station						
		Areas producing glow							Areas producing glow						
		B	C	D	BC	BD	CD	BCD	B	C	D	BC	BD	CD	BCD
Brightness micro-foot lamberts	Inland horizon	62	53	55	60	53	55	55	–	–	–	–	–	–	–
	Zenith	130	106	110	145	130	120	110	–	–	–	–	–	–	–
	Sea horizon	57	50	49	53	50	47	50	–	–	–	–	–	–	–
	Test area horizon	86	72	67	107	90	63	80	190	130	90	180	220	100	110
	Sky glow - Test area horizon minus inland horizon	24	19	12	47	37	8	25	128	77	35	120	167	45	55
	Sky glow on haze above test area horizon	–	–	90	–	–	95	100	130	53.	120	130	210	119	140
Atmospheric transmission per 1000 feet		74.6% at 318 a.m	77.4% at 4:05 a.m.	76.1% at 2:35 a.m	74.6 % at 3:18 a.m.		76.1% at 2:35 a.m.		74.6% at 3:18 a.m.	77.4 % at 4:05 a.m.	76.1 % at 2:35 a.m	74.6 % at 3:18 a.m.		76.1% at 2:35 a.m.	

ITEM			B	C	D	BC	BD	CD	BCD
Weather	Time		3:30 a.m.		2:40 a.m.	3:30 a.m.		2:40 a.m.	
	Ceiling		None		None	None		None	
	Sky		Clear		Clear	Clear		Clear	
	Visibility (miles)		12		12	12		12	
	Obstruction to vision		None		None	None		None	
	Temperature - dew point		45/43		45/42	45/43		45/42	
	Wind direction - velocity		Calm		NW2	Calm		NW2	
	Remarks		Slight haze aloft		Clouds S and E	slight haze aloft		Clouds S and E	
	Relative humidity %		93		89	93		89	
	Thermometers	Dry	45		45	45		45	
		Wet	44		43.5	44		43.5	

Summary

Area combinations	From north station			From south station		
	Measured in combination	Measured individually and added	Percent deviation	Measured in combination	Measured individually and added	Per cent deviation
BC	47	43	-8.5	120	205	+71
BD	37	36	-2.7	167	163	-2.5
CD	8	31	+290	45	112	+149
BCD	25	55	+120	55	240	+336

Table 3b - The addition of brightnesses of two or more adjacent sky glows when measured on a line through their axis.

Data on addition of sky glow brightnesses - Jacksonville Beach, Florida.

Item			Areas producing glow						
			D	DC	DB	DBC	BC	B	C
Sea Conditions			Flat calm	Flat calm	Flat calm	Flat calm	Flat calm	Flat calm	Flat calm
* Brightness micro-footlamberts	Inland horizon		78	90	78	130	125	125	95
	Zenith		230	250	230	148	150	150	270
	Sea horizon		68	78	68	87	115	115	115
	South end of test area horizon		620	850	700	700	940	620	680
	Sky glow - Test area horizon minus inland horizon		542	760	622	570	815	495	585
Sky glow spread in degrees	Lateral		5	7	-	12	12	9	-
	Vertical		45	60	45	30	80	60	-
Atmospheric transmission per 1000 feet			81.5 % at 3:40 a.m.	81.5 % at 3:40 a.m.	87.5 % at 4:20 a.m.	81.5 % at 3:40 a.m.	87.5 % at 4:20 a.m.	87.5 % at 4:20 a.m.	87.5 % at 4:20 a.m.
Weather	Time		3:30 a.m.	3:30 a.m.	4:30 a.m.	3:30 a.m.	4:30 a.m.	4:30 a.m.	4:30 a.m.
	Ceiling		None	None	None	None	None	None	None
	Sky		Clear	Clear	Clear	Clear	Clear	Clear	Clear
	Visibility (miles)		6	6	6	6	6	6	6
	Obstructions to vision		Haze	Haze	Haze	Haze	Haze	Haze	Haze
	Temperature and dew point		37/31	37/31	35/33	37/31	35/33	35/33	35/33
	Wind direction and velocity		W 2	W 2	W 2	W 2	W 2	W 2	W 2
	Relative humidity %		79	79	91	79	91	91	91
	Thermometers	Dry	37.3	37.3	35.2	37.3	35.2	35.2	35.2
		Wet	34.9	34.9	34.2	34.9	34.2	34.2	34.2

* Readings were taken at the south end of the illuminated area in each test.

Table 4 - Effect of one sky glow brightness on an adjacent sky glow brightness when brightness is measured perpendicular to their axis-upward beams of light.

(See next page for summary.)

Upward beams of light

GLOW MEASURED OVER AREA	AREAS OPERATED	GLOW IN MICRO-FOOTLAMBERTS	INCREASE OF GLOW ABOVE AREA MEASURED		AREA WHICH CAUSED INCREASE	INCREASE EXPRESSED IN PER CENT OF GLOW PRODUCED BY AREA WHICH CAUSED THE INCREASE	REMARKS
			MICRO-FOOTLAMBERTS	PER CENT			
D	D	542	—	—	—	—	—
D	DC	760	218	40.2	C	37.3	D and C are udjacent areas
D	DB	622	80	14.7	B	16.1	D is separated from B by 1100 feet
D	DCB	570	28	5.2	CB	—	These values are obviously low and should not be considered
C	C	585	—	—	—	—	—
C	CB	815	230	39.2	B	46.5	C and B are adjacent areas. Compare with percentage values obtained for DC above.
B	B	495	—	—	—	—	—

Summary- Table 4

Data on addition of sky glow brightnesses - Jacksonville Beach, Florida

Item			Areas producing glow						
			D	DC	DB	DBC	BC	B	C
Sea condition			Flat calm	Flat calm	Flat calm	Flat calm	Flat calm	Flat calm	Flat calm
Brightness * micro-foot-lamberts	Inland horizon		86	86	95	80	95	83	108
	Zenith		190	190	220	250	220	200	175
	Sea horizon		90	90	90	67	90	60	72
	Test area horizon		380	580	500	760	480	390	490
	Sky glow-Test area horizon minus inland horizon.		294	494	405	680	385	307	382
Height of brightest spot of sky glow in degrees			1/2	1/2	1/2	1/2	1/2	1/2	—
Sky glow spread in degrees	Laterally		8	10	12	12	10	10	—
	Vertically		5	5	4	5	4	3	—
Atmospheric transmission per 1000 feet			76.1% at 2:35 am.		74.6% at 3:18 am.	76.1% at 2:35 am.	74.6% at 3:18 a.m.		77.4% at 4:05 am.
Weather	Time		2:40 am.		3:30 am.	2:40 am.	3:30 a.m.		4:15 a.m.
	Sky		Clear		Clear	Clear	Clear		Scattered clouds
	Visibility (miles)		12		12	12	12		12
	Obstruction to vision		None		None	None	None		None
	Temperature-dew point		45/42		45/43	45/42	45/43		46/44
	Wind direction-velocity		N.W2		Calm	NW2	Calm		Calm
	Remarks		Clouds S and E		Slight haze aloft	Clouds S and E	Slight haze aloft		Clouds-N,W,& SE
	Relative humidity %		89		93	89	93		91
	Thermometers	Dry	45		45	45	45		46.5
		Wet	43.5		44	43.5	44		45.2

* Brightness over area D was recorded in all tests involving it; otherwise brightness over the area or areas used was recored

Table 4a-Effect of one sky glow brightness on an adjacent sky glow brightness when brightness is measured perpendicular to their axis.- diffused light.
(See next page for summary)

DIFFUSED LIGHT

GLOW MEASURED OVER AREA	AREAS OPERATED	GLOW IN MICRO-FOOT LAMBERTS	INCREASE OF GLOW ABOVE AREA MEASURED		AREA WHICH CAUSED INCREASE	INCREASE EXPRESSED IN PER CENT OF GLOW PRODUCED BY AREA WHICH CAUSED THE INCREASE	REMARKS
			MICRO-FOOT LAMBERTS	PER CENT			
D	D	294	-	-	-	-	-
D	DC	494	200	68.0	C	52.5	D AND C ARE ADJACENT AREAS
D	DB	405	111	37.8	B	36.2	D IS SEPARATED FROM B BY 1100 FEET
D	DCB	680	386	131.0	CB	-	
C	C	382	-	-	-	-	
C	CB	385	3	0.8	B	1.0	CB MEASUREMENT IS OBVIOUSLY LOW, SINCE IT IS APPROXIMATELY SAME AS C ALONE. COMPARE VALUES WITH DC ABOVE
B	B	307	-	-	-	-	

SUMMARY - TABLE 4A

(b) From these tables, it is seen that diffused light (the type normally causing glow over cities) increases the glow over a laterally adjacent or nearby area to a much larger extent than direct upward beams. However, atmospheric transmission was from 7 to 13 per cent lower on the night diffused light was used than on the night direct upward beams were used; hence, the greater refraction and reflection qualities of the atmosphere of lower transmission may have accounted for part of the higher increase factor by spilling more light over into the nearby area than would have occurred for atmospheres having higher transmissions. Another point of departure between the glows produced by direct beams and diffused light was the relative height of glow. At the point of measurement (2 nautical miles from glow), glow from direct beams subtended vertical angles from 30 to 80 degrees, while angles subtended by glow from diffused light ranged from 3 to 5 degrees. On the other hand, no significant difference in lateral spread between the two glows was apparent.

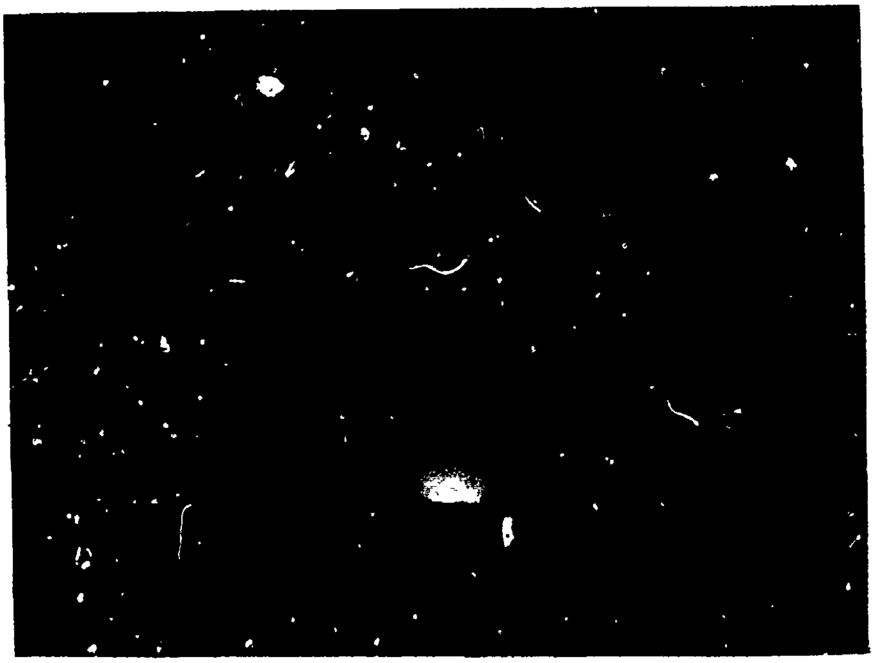


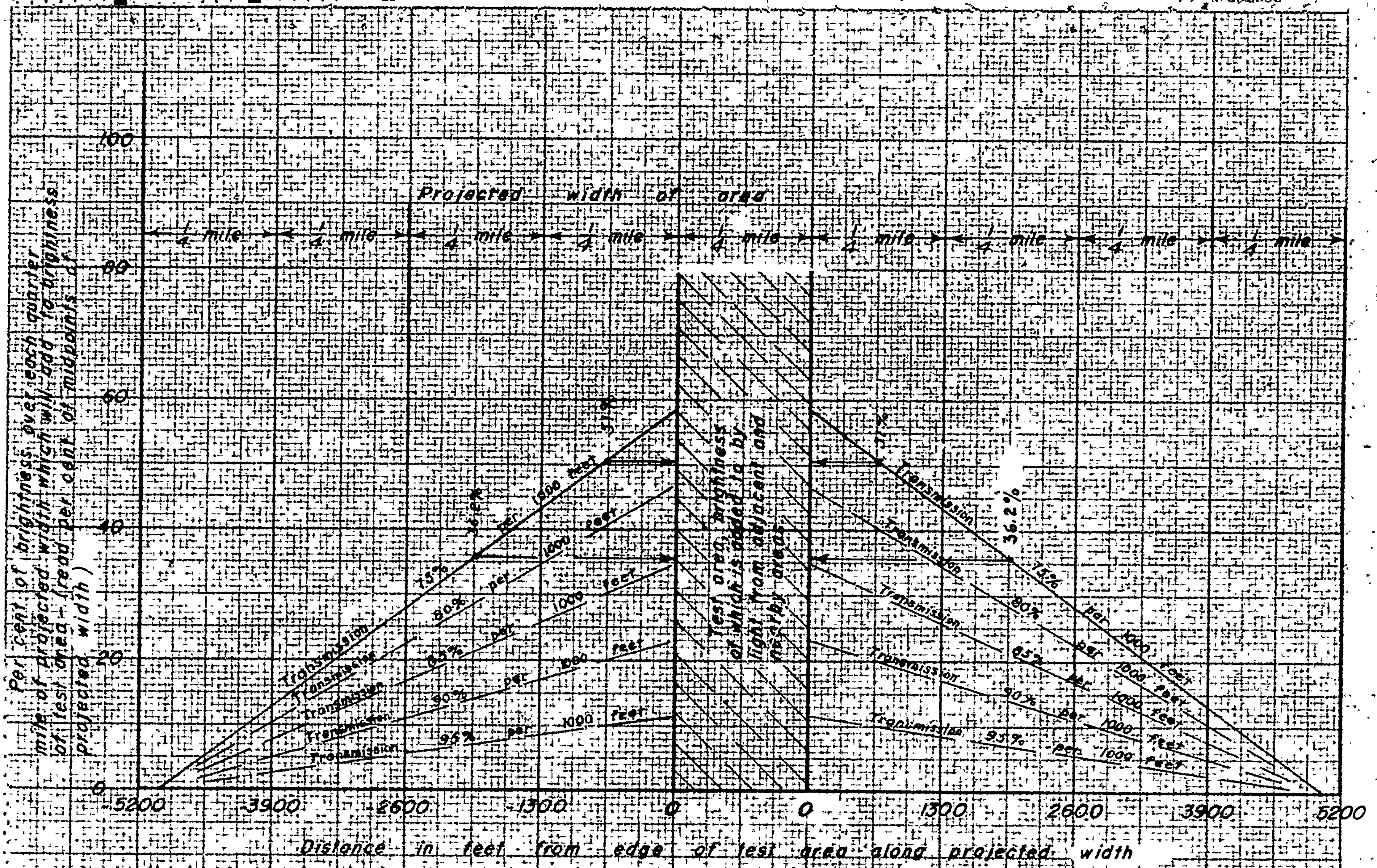
Fig. 40
Appearance of sky glow from 5 miles north of
Jacksonville Beach, Florida

Notice wide spread of sky glow which is approximately 6 times the width of the area containing the lighting units. Buildings and trees on right are clearly silhouetted.

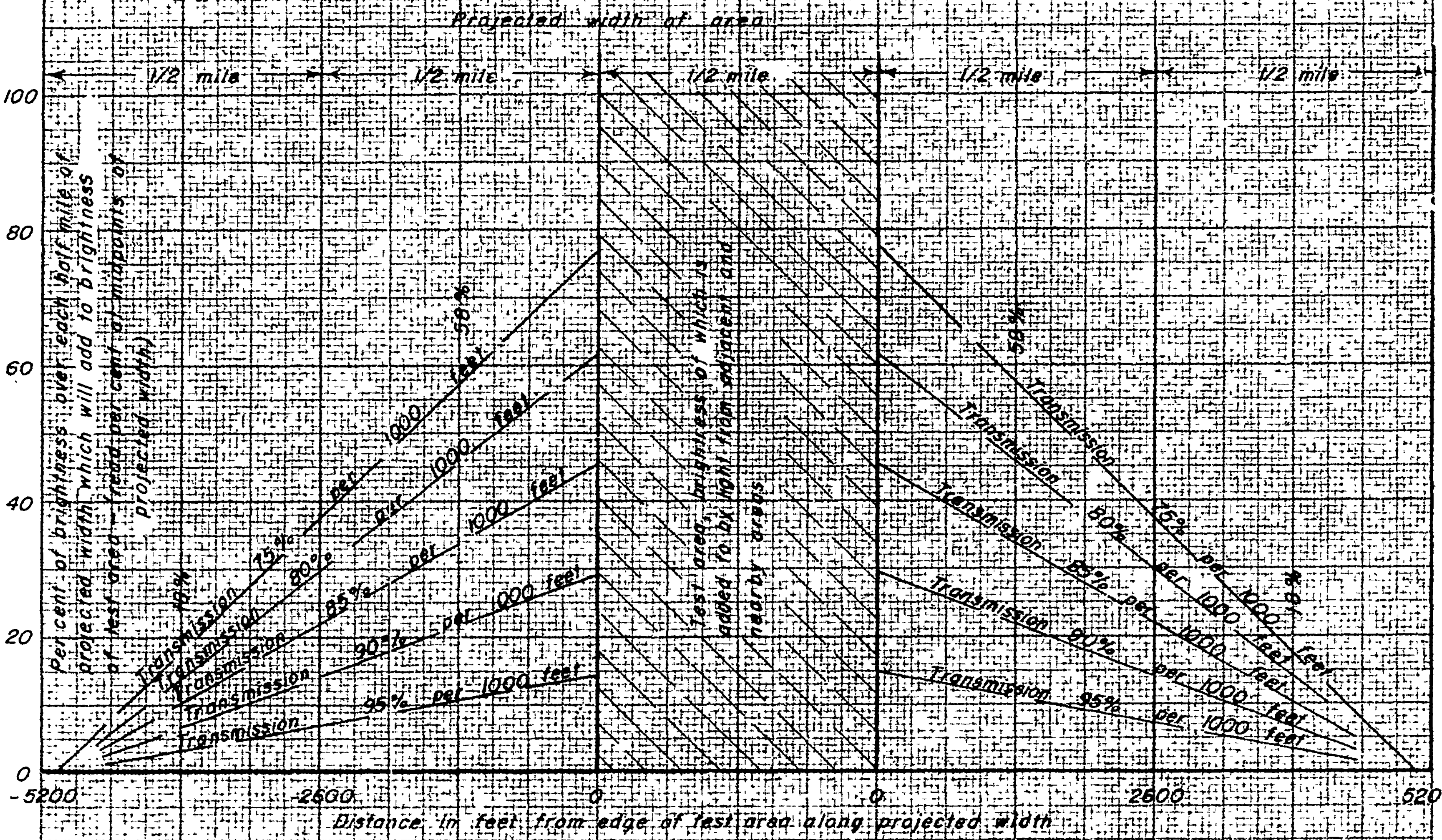
(c) Since glow above cities is almost wholly produced by diffused light, calculations which follow are based on the values of Table 4a. The percentages of glow from Areas C and B (52.5 and 36.2 per cent respectively) which increased brightness over Area D were used to develop Graph 2. On the assumption that under theoretical conditions of 100 per cent atmospheric transmission (as found in a vacuum) an area of light flux would cause no glow ove. an adjacent area, curves showing the additive factors of laterally adjacent and nearby sky glows, each of 1/4 mile of projected width, were plotted for atmospheres having light transmission factors from 75 to 95 per cent. Graph 2a shows the same information on the basis of increments of 1/2 mile of projected width, which gives a larger unit for computations. Graph 2a reveals that each one mile of projected width on each side of a 1/2 mile of projected width adds part of its glow to the brightness of glow over the 1/2 mile of projected width. (A straight line relationship is shown on the graph. Although information which would reveal the exact nature of the curve was not determined, the straight line relationship for the atmospheric transmissions shown is believed true for all practical purposes.)

(d) The extremely high brightnesses recorded over cities become understandable in view of the build-up of brightness caused by the addition of brightnesses from areas of light flux in line (sub-par. (2) above) and the increase in brightness over one area produced by adjacent and nearby areas along the projected width adding part of their brightness to it. This build-up of brightness is illustrated by Graph 2b. It has been assumed for the curve that each area of unit depth and width produces equal brightness. When a number of areas of the unit depth occur in line, the values from the curve must be multiplied by the number of areas in line. In sub-paragraph c below, a method is developed for computation of sky glow brightness to be expected at any distance from the source of a known amount and distribution of light for any atmospheric condition.

c. Amount of sky glow produced by a unit light flux of known distribution in a given area. (1) Tabulation of data. Since the light flux produced by the sealed beam headlamps used in the full scale tests was known (total lumen output of the lamps was obtained by measuring the lumen output of one sealed beam headlamp when unshielded and when shielded one-quarter, one-half, and three-quarters and multiplying by number of lamps operating), computations of amount of sky glow produced by a unit light flux of known distribution in a given area are possible. Table 5 sets forth amount of sky glow from direct upward beams as recorded at a distance from the test area for various atmospheric conditions. Table 5a sets forth similar data for diffused light (obtained at Point Pleasant



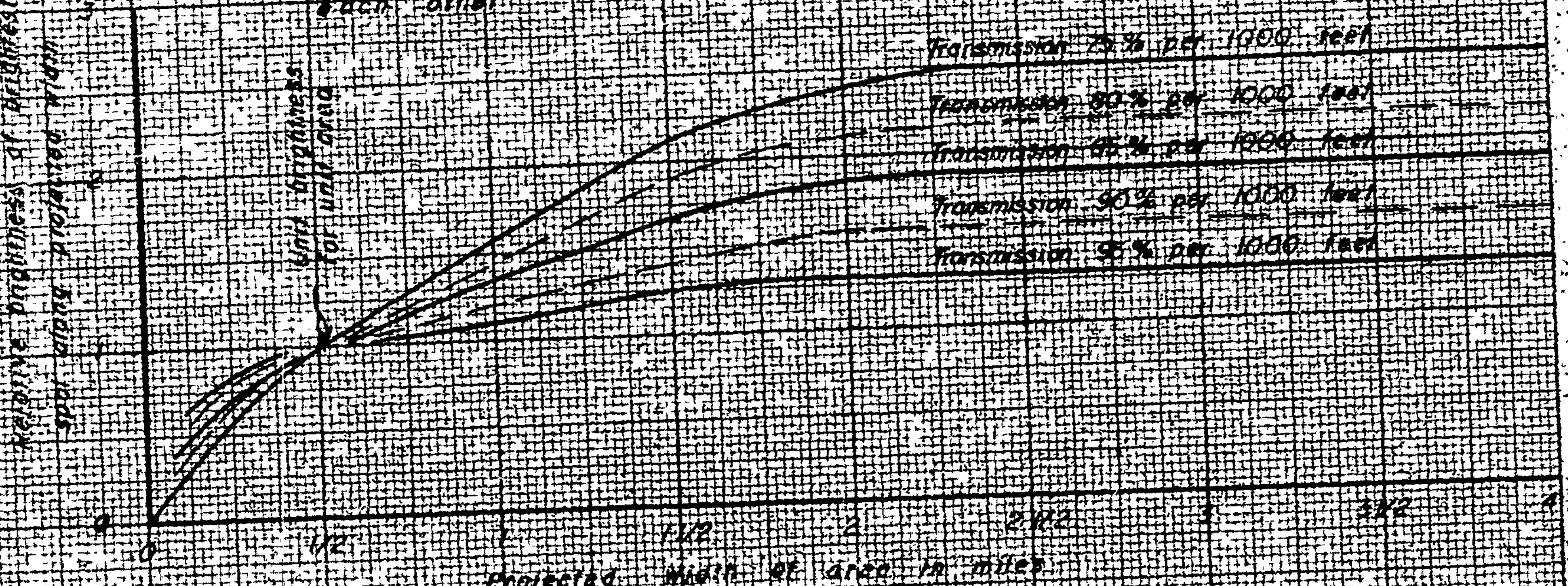
Graph 2 - The additive factors of sky glow brightness when brightness is measured perpendicular to the projected width of the areas producing the glow - diffused light



Graph 2 a - The additive factors of sky glow brightnesses when brightness is measured perpendicular to the projected width of the areas producing the glow-diffused light

Curve is based on areas, 1/2 mile in width, of unit depth, with each area producing equal brightness for the given atmospheric transmission (For computations involving areas producing unequal brightness, use figures of Curve 2a.)

Caution: Equal areas having same amount and distribution of light do not produce same brightness of sky glow for all atmospheric transmissions (see sub par 16c), therefore curves are not to be compared with each other



Graph 2b - Build up of sky glow brightness as projected width increases by covering the sealed beam headlamps with tracing paper having transmission of 50 per cent and at Jacksonville Beach, with tracing cloth having transmission of 43 per cent). Tables 5 and 5a also contain amount of sky glow which would have been apparent at point of measurement on the basis of 500,000 lumens in test area, together with brightness of sky glow at source of upward light calculated therefrom by solving the equation $B_i = \frac{B_r}{t^{5.28n}}$ (sub-par. 16a. above). These B_i values - initial brightness of sky glow or brightness at source of upward light - are plotted on Graph 3.

(2) Width of area factor.- In order to provide a unit area upon which to base calculations for any city, an area 1/2 mile by 1/2 mile has been arbitrarily selected, and the following method followed in converting values of Graph 3 to the basis of the selected unit. Since all but three of the measurements of sky glow from diffused light were made perpendicular to the short axis (1200 to 1500 feet) of the test area (approx. 1/4 mile by 1/2 mile), sky glow which would be produced by 500,000 lumens in each of two such adjacent areas, or by 1,000,000 lumens of diffused upward light in an area 1/2 mile by 1/2 mile, may be computed by applying additive factors for adjacent widths of 1/4 mile from Graph 2. These calculations are given below:

1	2	3	4
Atmospheric Transmission per 1000 feet	Sky glow for diffused light from Graph 3 (micro-footlamberts)	Width of area factor from Graph 2	Sky glow produced above an area 1/2 mile by 1/2 mile by 1,000,000 lumens of diffused light. (micro-footlamberts)
.95	1600	1.10	1760
.90	9000	1.20	10800
.85	49000	1.31	64200
.80	351000	1.41	495000
.75	1600000	1.51	2420000

Values in column 4 have been plotted on Graph 3a together with calculated values for areas wider than 1/2 mile on the basis that each area of 1/2 mile in width and 1/2 mile in depth has 1,000,000 lumens of diffused upward light. (Additive factors were obtained from Graph 2a).

(3) Equation for computation of glow at source for any condition.- The equation of the curve for the unit area (1/2 mile by 1/2 mile) of Graph 3a is $B_i = 10^{18.02-15.56\ t}$, where B_i is initial brightness of sky glow or brightness at source of light and t is atmospheric transmission per 1000 feet expressed in decimals. For any amount of diffused upward light in the unit area, the equation becomes $B_i = \frac{L\ 10^{18.02-15.56\ t}}{1{,}000{,}000}$ where L is the number of lumens of diffused upward light in the unit area. As width of area is increased by addition of unit areas the following equation may be used to compute

glow above long dimension of entire area:

$$B_i = \frac{10^{18.02-15.56t}\ (L + f_1L_1 + f_1L_2 + f_2L_3 + f_2L_4)}{1,000,000}$$

where L is the number of lumens of diffused upward light in the unit area above which sky glow brightness is being computed; L_1 and L_2 are the number of lumens in each laterally adjacent unit area; L_3 and L_4 are the number of lumens in the respective unit areas next adjacent; and f_1 is additive factor for adjacent areas and f_2 is additive factor for next adjacent areas, which correspond to the t (atmospheric transmission) for which calculations are made. This equation involves a total effective width of area of 2½ miles (see Graph 2a).

(4) Equation for computation of glow residual at any distance from source for any condition.- (a) By substituting value of B_i from the equation in sub-paragraph (3) above in the equation $B_r = B_i\ t^{5.28n}$ (sub-par. 16a), the sky glow residual for any atmospheric transmission at any distance from an area of unit depth may be computed, provided the amount of diffused upward light for each unit area along effective width of area is known. This equation is

$$B_r = \frac{10^{18.02-15.56t}\ (L + f_1L_1 + f_1L_2 + f_2L_3 + f_2L_4)\ t^{5.28n}}{1,000,000}$$

where B_r is apparent brightness of sky glow residual at any distance from source of upward light, t is atmospheric transmission in decimals per 1000 feet, and n is any distance from source of upward light expressed in miles. When n is zero, the equation reverts to the formula for computation of glow at source as given in sub-paragraph (3) above.

(b) The above equation is based on an area of unit depth. Since sky glow brightness residual at a given point from areas of upward light in line with the given point are directly additive (sub-par. 16b), depth factors must be added to the above equation as depth of area increases. The equation then becomes:

$$B_r = \frac{10^{18.02-15.56t}\ (L+f_1L_1+f_1L_2+f_2L_3+f_2L_4)\ t^{5.28n}}{1,000,000} \ldots$$

$$+ \frac{10^{18.02-15.56t}\ (L_A+f_1L_{1A}+f_1L_{2A}+f_2L_{3A}+f_2L_{4A})\ t^{5.28(n+\frac{A-1}{2})}}{1,000,000}$$

where A is the number of areas of unit depth (½ mile in depth) in line. If each unit area is assumed to have same

Measured atmospheric Transmission per 1000 feet		99%		98%		97%		96.2%	87%		86%	85.3%	83%	81%			78.3%		76%		71.2%	71.1%
Total lumens		236076	642600	642600		642600		872460	642600		872460	872460	872460	78948			106110		872460		872460	872460
Measured from		6 1/2 miles east	5 miles west	5 miles(c) west	5 miles south	5 miles west	5 miles north	5 miles south	5 miles(f) west	5 miles(f) south	5 miles south	5 miles south	5 miles north	5 miles east	5 miles west	5 miles south	5 miles north	5 miles west	5 miles north	5 miles south	5 miles south	5 miles south
Brightness micro-footlamberts	Inland horizon	-	120	122	48	132	186(d)	80	211	72	86	84	55	51	67	57	95	95	70	36	45	20
	Zenith	-	120	79	60	192	114	90	132	120	240	-	130	102	79	-	110	142	120	62	140	26
	Sea horizon	-	-	26(b)	-	-	-	70	-	-	89	73	55	57	-	-	55	55	60	50	62	85
	Test area horizon	138	252	252	300	240	278	440	356	340	850	530	350	153	175	162	180	102	600	750	155	110
	Sky glow - Test area horizon minus natural horizon	72(a)	132	226	252	(g) 200	(e) 206	360	(e) 284	268	764	446	295	102	108	105	85	47	530	714	110	90
	Sky glow produced at point of observation by 500,000 upward lumens — Actual	153	103	176	196	156	160	207	217	208	437	256	169	630	745	665	400	225	304	409	63	52
	Sky glow produced at point of observation by 500,000 upward lumens — Average	153	103	186		158		207	212		437	256	169	680			312		356		63	52
	Calculated brightness at source $Bi=Br/t^{5.28n}$	179		317		353		570	8400		23500	17000	23100	190100			199500		396500		495000	420000

(a) Dark reading (all lamps extinguished) was subtracted from 138 to obtain this value.

(b) This value was obtained from a location at sea and has been assumed to be correct for station 5 miles west.

(c) Figures in this column are averages of 5 readings.

(d) Read sky glow S.W. of station for inland horizon.

(e) Inland horizon of 72 measured from station 5 miles south was used to obtain this value.

(f) Figures in this column are averages of 3 readings.

(g) Sea horizon of 40 was assumed

Note: East and west readings were made perpendicular to long axis of test area; north and south readings, perpendicular to short axis.

Table 5 - Sky glow produced by direct upward beams of light in an area approximately 1200 ft. by 3500 ft. during various atmospheric transmissions

Measured Atmospheric Transmission per 1000 feet			98%			88.5 %			85 %		82%	80%	79.7%			76 %			72.8%	69%	66.1%
Total lumens			321300			375158			181000	45627	375158	181000.	45627			375158			375158	181000	375158
Measured from			5 miles west	5 miles south	5 miles north	5 miles south	5 miles north		5 miles south	5 miles south	5 miles south	5 miles south	7 miles west	5 miles south	5 miles north	7 miles west	5 miles south	5 miles north	5 miles south	5 miles south	5 miles south
Brightness micro-footlamberts	Inland horizon		114	-	50	75	-	75	72	75	59 (c)	80	85	75	75	85	59	55	120	72	80
	Zenith		108	54	54	110	130	120	126	150	-	150	150	115	110	160	175	150	154	150	160
	Sea horizon		-	-	-	85	65	60	71	70	-	76	75	80	60	90	49	55	71	70	80
	Test area horizon		210	246	282	530	550	450	330	103	850	610	150	140	130	112	125	100	750	500	540
	Sky glow - Test area horizon minus natural horizon		170 (a)	196 (b)	232	455	475	375	258	28	791	530	75	65	55	22	66	45	630	430	460
	Sky glow produced at point of observation by 500,000 lumens	Actual	265	305	361	605	635	500	710	308	1055	1460	825	710	600	30	88	60	840	1165	612
		Average	310			580			509		1055	1460	712			59			840	1185	612
	Calculated brightness at source $(B_i = B_r/t^{5.28n})$		530			14250			37150		203000	525000	288500			65600			3,665,000	21250000	34250000

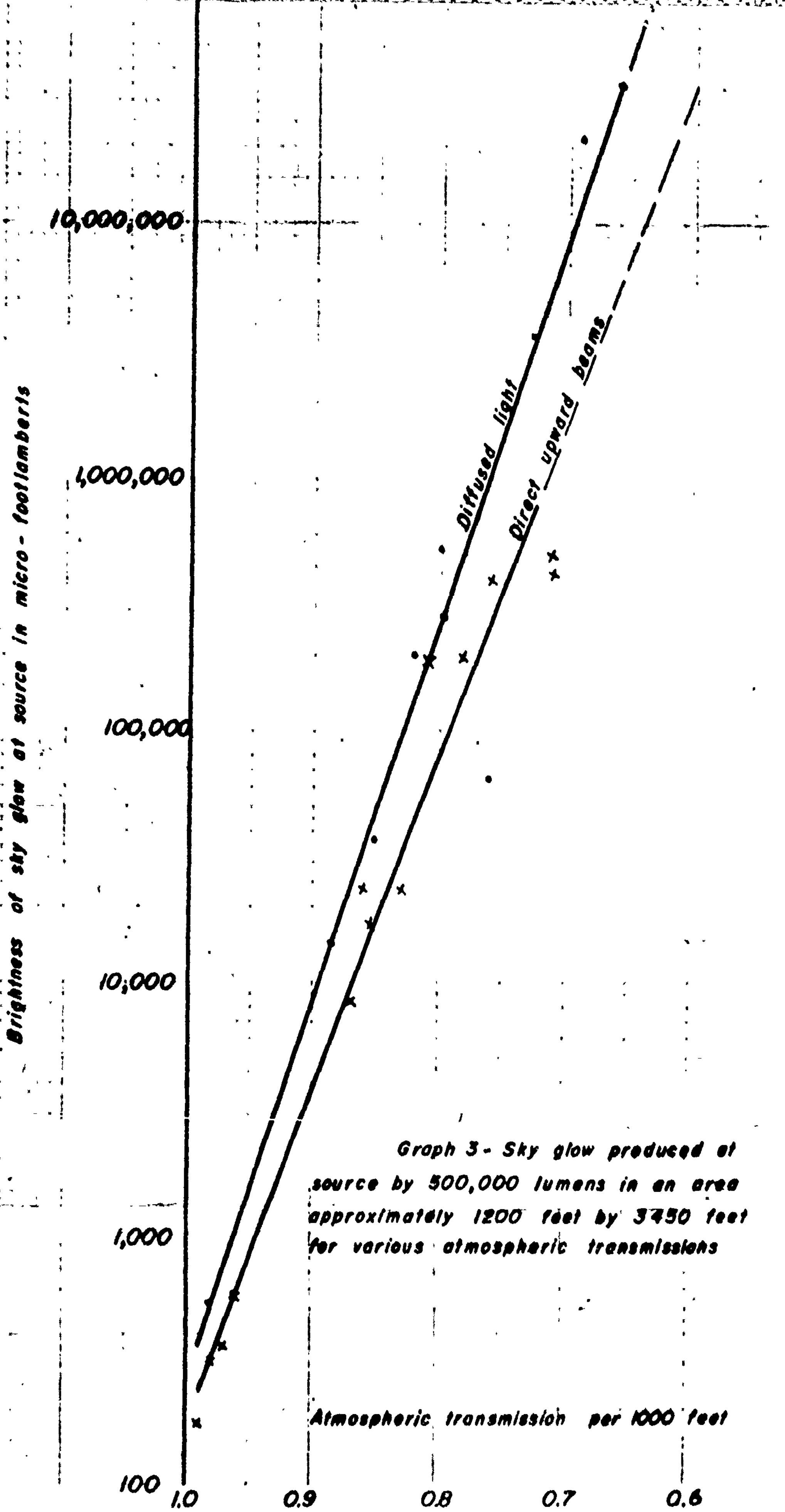
(a) Since sea horizon was not measured, an arbitrary value of 40 has been assumed

(b) Inland horizon from station 5 miles north was used.

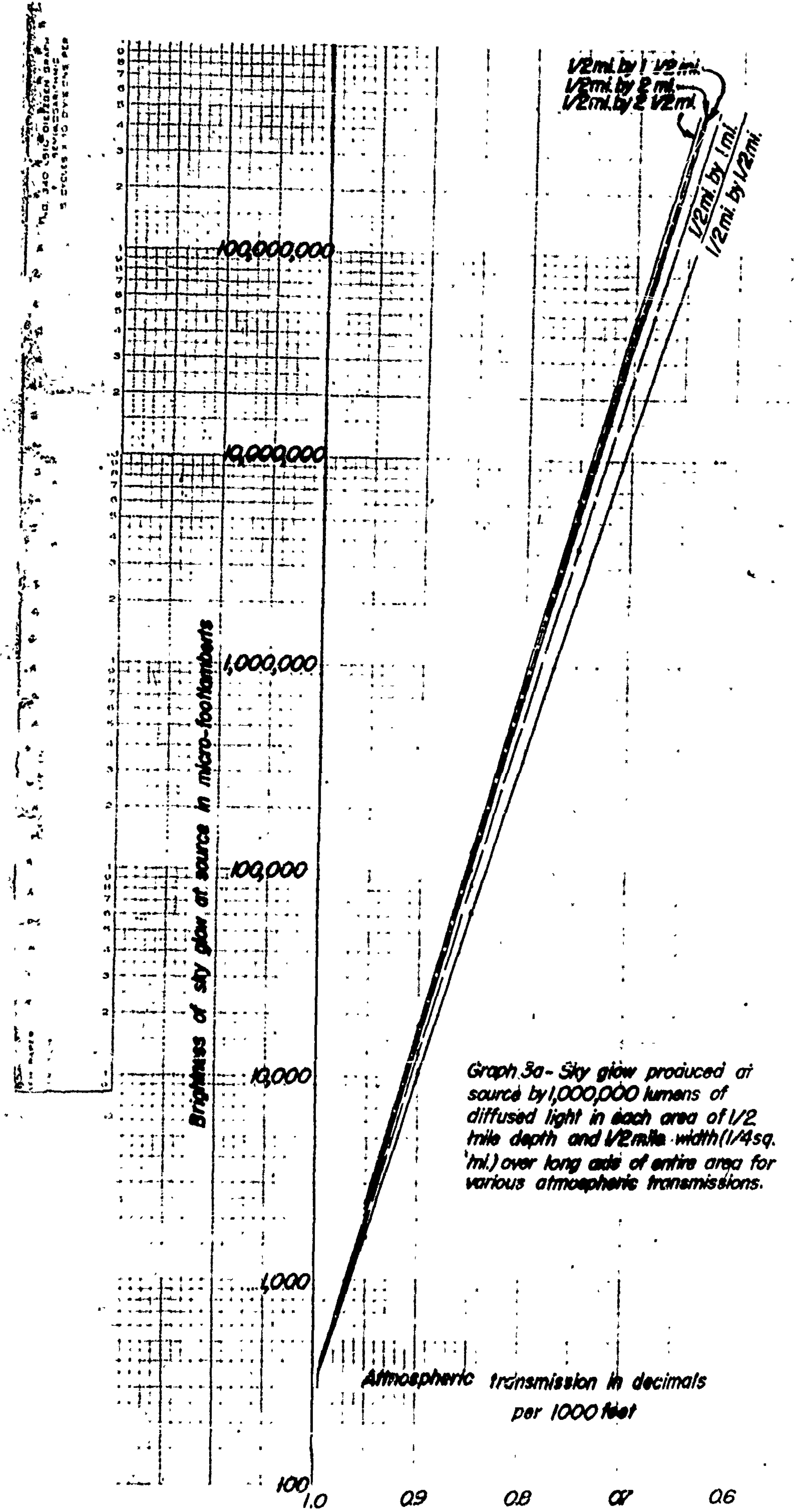
(c) This value was obtained from a reading taken earlier.

Note: East and west readings were made perpendicular to long axis of test area; north and south readings, perpendicular to short axis.

Table 5a – Sky glow produced by diffused light in an area approximately 1200 ft. by 3500 ft. during various atmospheric conditions.



Graph 3 - Sky glow produced at source by 500,000 lumens in an area approximately 1200 feet by 3450 feet for various atmospheric transmissions



Graph 3a - Sky glow produced at source by 1,000,000 lumens of diffused light in each area of 1/2 mile depth and 1/2 mile width (1/4 sq. mi.) over long axis of entire area for various atmospheric transmissions.

amount and distribution of light, reasonably accurate computations of sky glow produced at any distance from the nearest area may be made by the following formula:

$$B_r = \frac{10^{18.02-15.56t}\,(1+2f_1+2f_2)\ ALt^{5.28\,(n+\frac{A-1}{4})}}{1,000,000}$$

(5) <u>Relative amounts of sky glow produced at source of upward light by an area of unit depth.</u>- For rapid conversion of calculated or measured sky glow brightness at source of upward light for a certain atmospheric condition to the brightness which would be produced at source for any other atmospheric transmission, Graphs 3b, 3c, and 3d are presented. For example:

If effective width of area producing glow is 1½ miles and a brightness measurement at 5 miles away for an atmospheric transmission of 80 per cent per thousand feet is 60 micro-footlamberts, brightness of source may be computed by

$$B_i = \frac{B_r}{t^{5.28n}} = \frac{60}{.8^{26.4}} \text{ or } 21,800 \text{ micro-footlamberts.}$$

Therefore, for 90 per cent transmission per thousand feet, brightness at source can be obtained by multiplying 21,800 x .02 (from Graph 3d), equals 436 micro-footlamberts. Finally, brightness which would be produced by this new value at the location 5 miles away for 90 per cent transmission may be calculated by substituting 436 for B_i in the equation $B_r = B_i\ t^{5.28n}$, or B_r equals 27 micro-footlamberts, as compared to the value of 60 micro-footlamberts assumed for 80 per cent transmission per 1000 feet.

In this manner, sky glow for various atmospheric transmissions and at different distances from the source may be calculated and compared by means of the data given in the graphs described above.

(6) <u>Critical atmospheric transmissions for various distances from areas of various widths.</u>- (a) On Graph 3e are plotted solutions of the equation for computing the sky glow over the long dimension of areas of unit depth and multiples of unit width (sub-par. (3) above), which is residual for various atmospheric transmissions at various distances from the area. One million lumens of diffused upward light has been assumed in each unit area (½ mile by ½ mile). Graph 3e shows that two miles from the source of upward light highest brightness is produced at very low transmissions, since the curve ascends until moisture in the atmosphere reaches fog proportions. As the distance from the source of upward light increases, the critical transmission (one which gives highest brightness) becomes higher, until at distances of 8 miles and over the highest transmission occurring is the critical one, regardless of width or depth of area producing glow.

(b) Values of Graph 3e may be multiplied by $\frac{L}{1,000,000}$ (L = lumens of diffused upward light evenly distributed in the area) to obtain residual brightness for any amount of diffused upward light in an area of unit depth. If depth of area is greater than $\frac{1}{2}$ mile (the unit depth), values of Graph 3e may be multiplied by number of $\frac{1}{2}$ mile units in the depth of area to calculate roughly resulting sky glow brightness.

(c) Graph 3e may also be used to convert brightness measured under one set of conditions to the brightness which would result under another set of conditions. For example:

Assume, at five miles from an area over one and one-half miles in width, a residual brightness of 100 micro-footlamberts with atmospheric transmission of 80 per cent per 1000 feet, then brightness at the same location for 90 per cent transmission would be $100 \times \frac{990}{2250}$; brightness at 8 miles for 80 per cent transmission would be $100 \times \frac{66}{2250}$ and for 90 per cent transmission, $100 \times \frac{190}{2250}$.

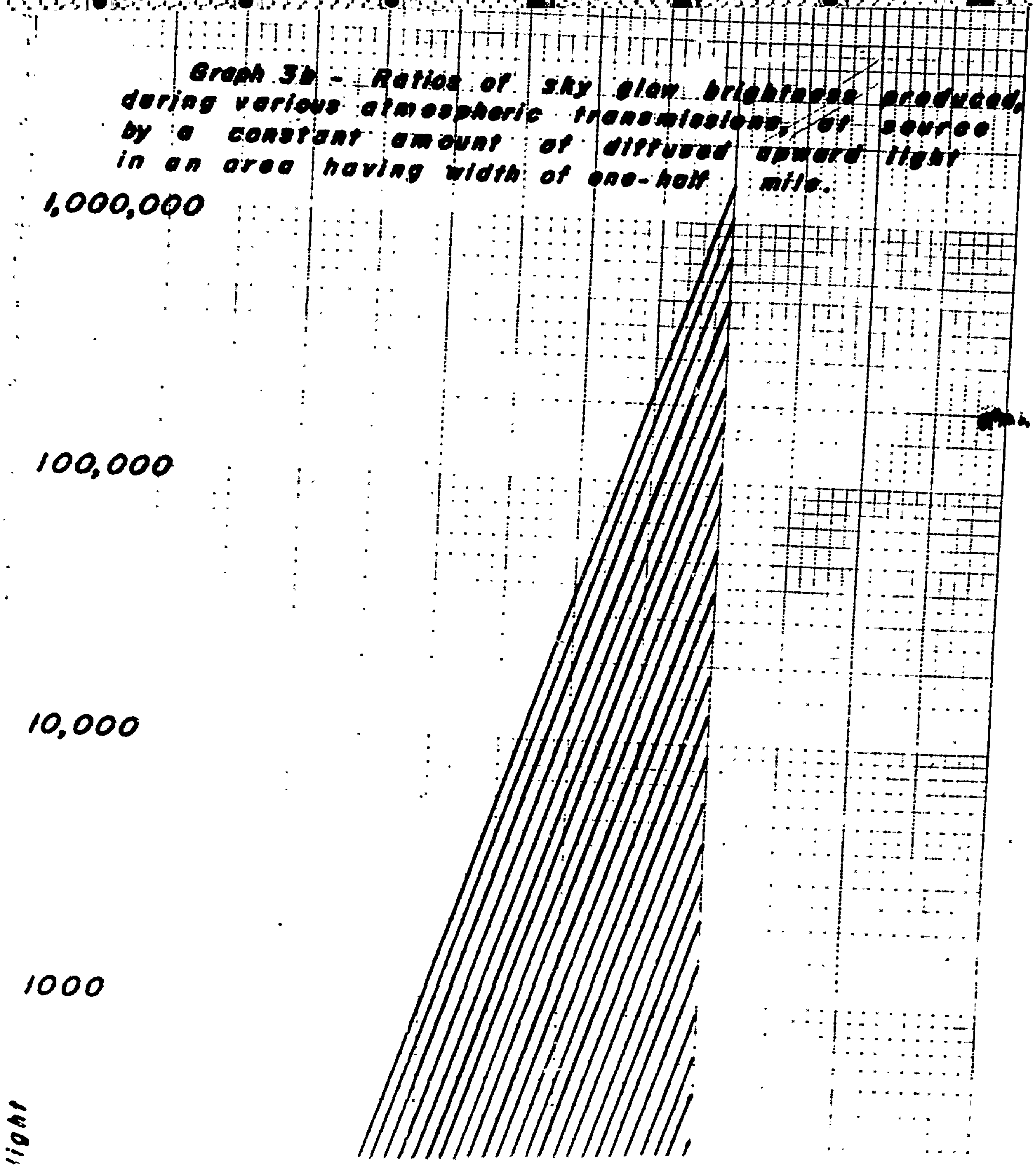
(d) Rough estimates of the amount of diffused upward light producing a sky glow brightness may be made from Graph 3e, provided approximate width and depth of effective area are known and it is assumed that the light is evenly distributed over the area. For example:

A sky glow brightness measurement made at a distance of 6 miles reads 100 micro-footlamberts and atmospheric transmission is 85 per cent per 1000 feet. The curve for 6 miles on Graph 3e reads 620 micro-footlamberts at 85 per cent transmission for an area with width of $1\frac{1}{2}$ or more miles. Then L (number of lumens of diffused upward light in each unit area, $\frac{1}{2}$ mile by $\frac{1}{2}$ mile, of the area under study) equals

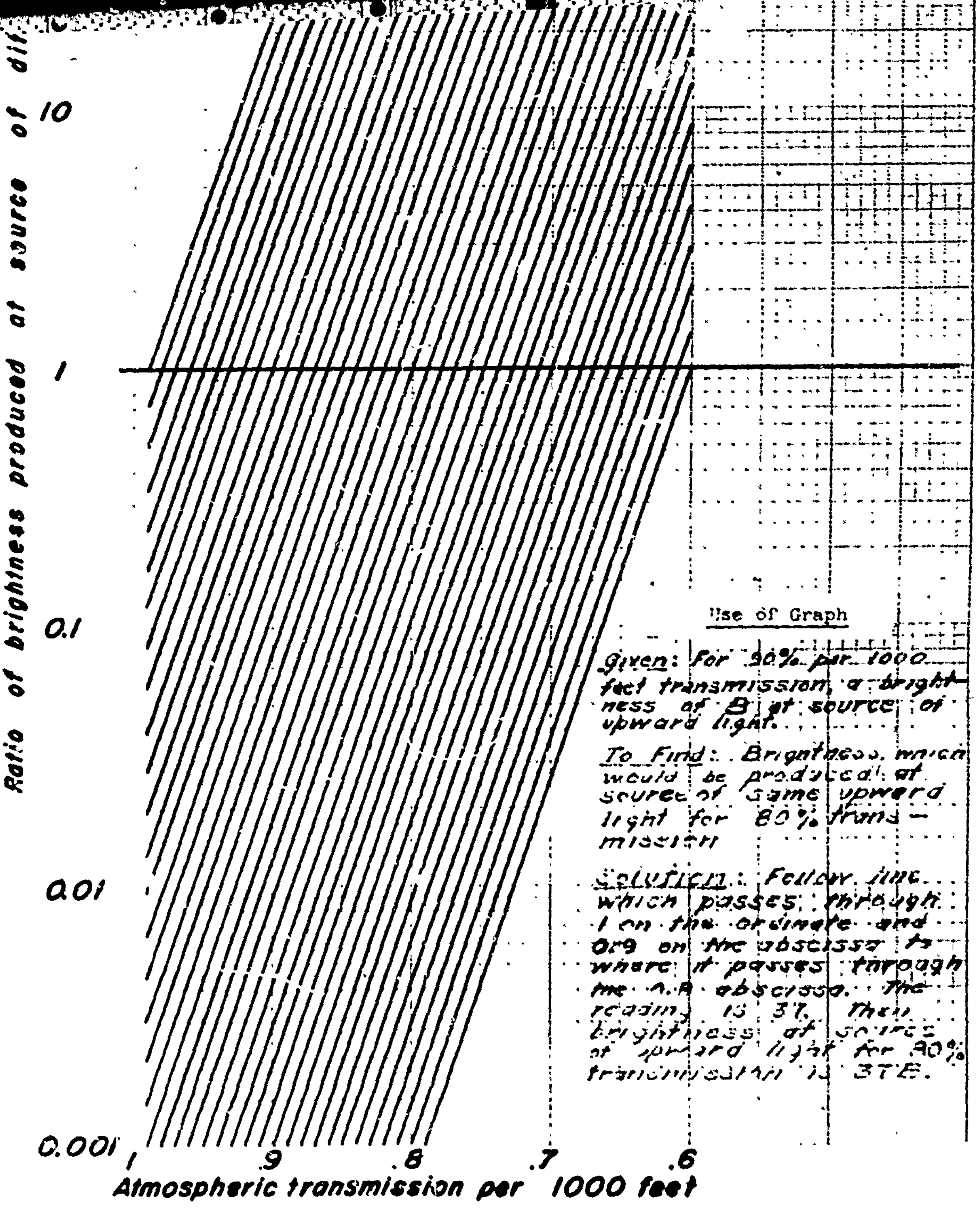
$\frac{100}{.620} \times 1,000,000 = 161,000$ lumens, provided the area is of unit depth.

17. Threshold Visibility Distances of Sky Glow Brightnesses. a. In an effort to obtain data by which to evaluate the "beacon effect" furnished aircraft by sky glow over cities and to establish the maximum distance which artificial glow can be detected during various atmospheric conditions, threshold visibility distances from the air for several sky glow brightnesses were obtained at Point Pleasant, New Jersey, and Jacksonville Beach, Florida. In all cases, the aircraft involved flew directly east from the test area and the observers recorded the maximum distance the artificial glow was barely perceptible.

1 of 2


Graph 3b - Ratios of sky glow brightness produced, during various atmospheric transmissions, at source by a constant amount of diffused upward light in an area having width of one-half mile.

2 of 2



Use of Graph

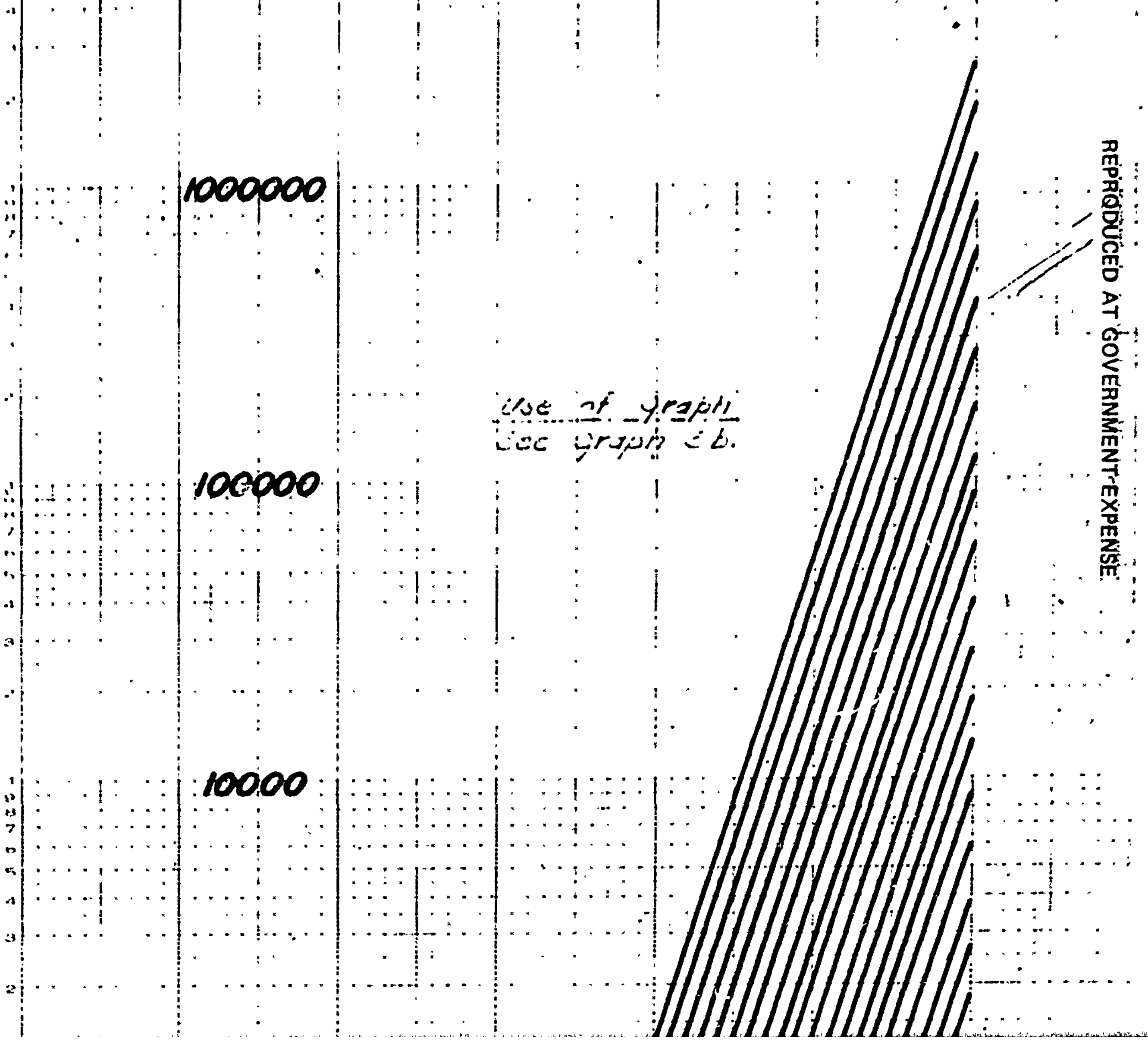
Given: For 90% per 1000 feet transmission, a brightness of B at source of upward light.

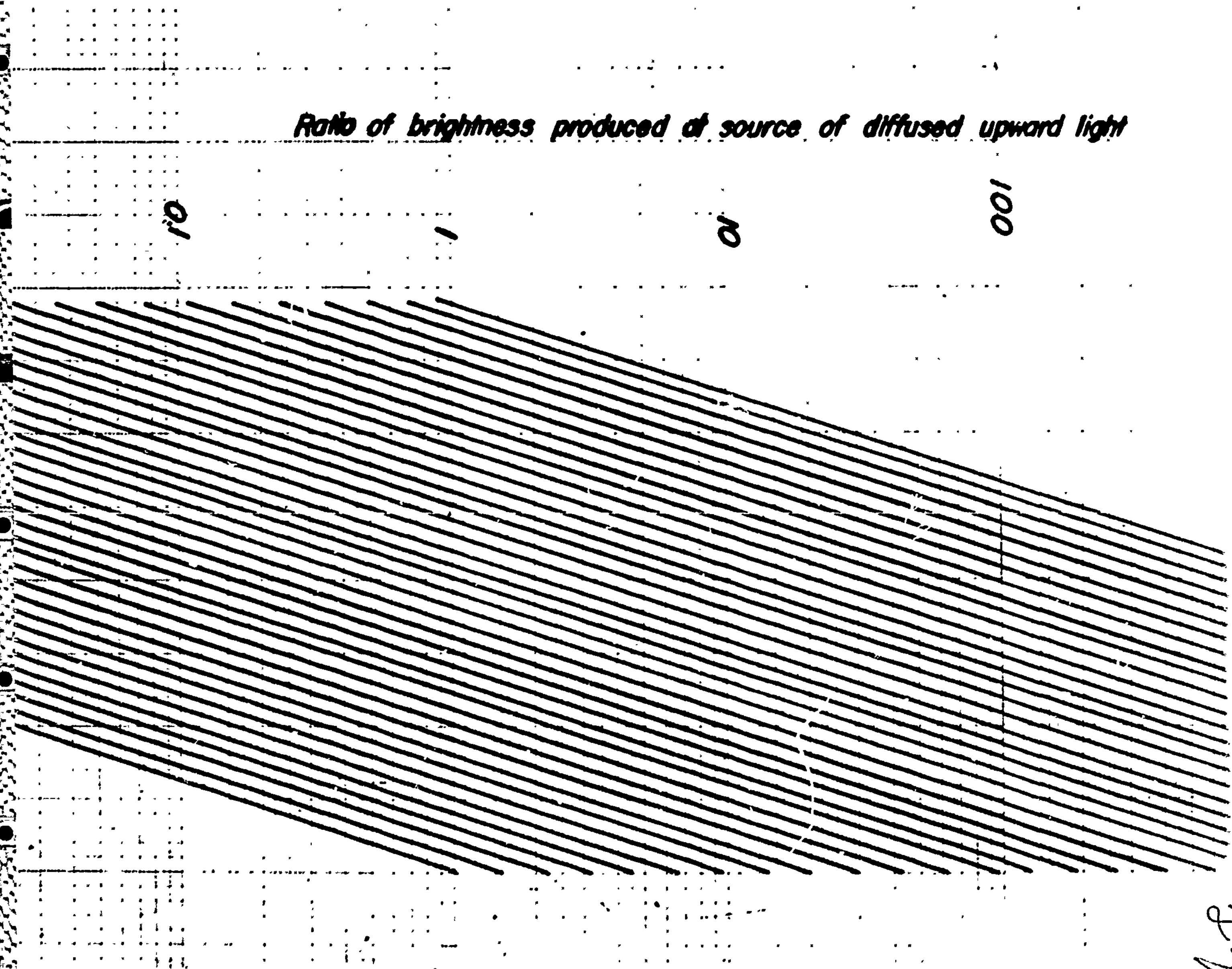
To Find: Brightness which would be produced at source of same upward light for 80% transmission

Solution: Follow line which passes through 1 on the ordinate and 0.9 on the abscissa to where it passes through the 0.8 abscissa. The reading is 37. Then brightness at source of upward light for 90% transmission is 37B.

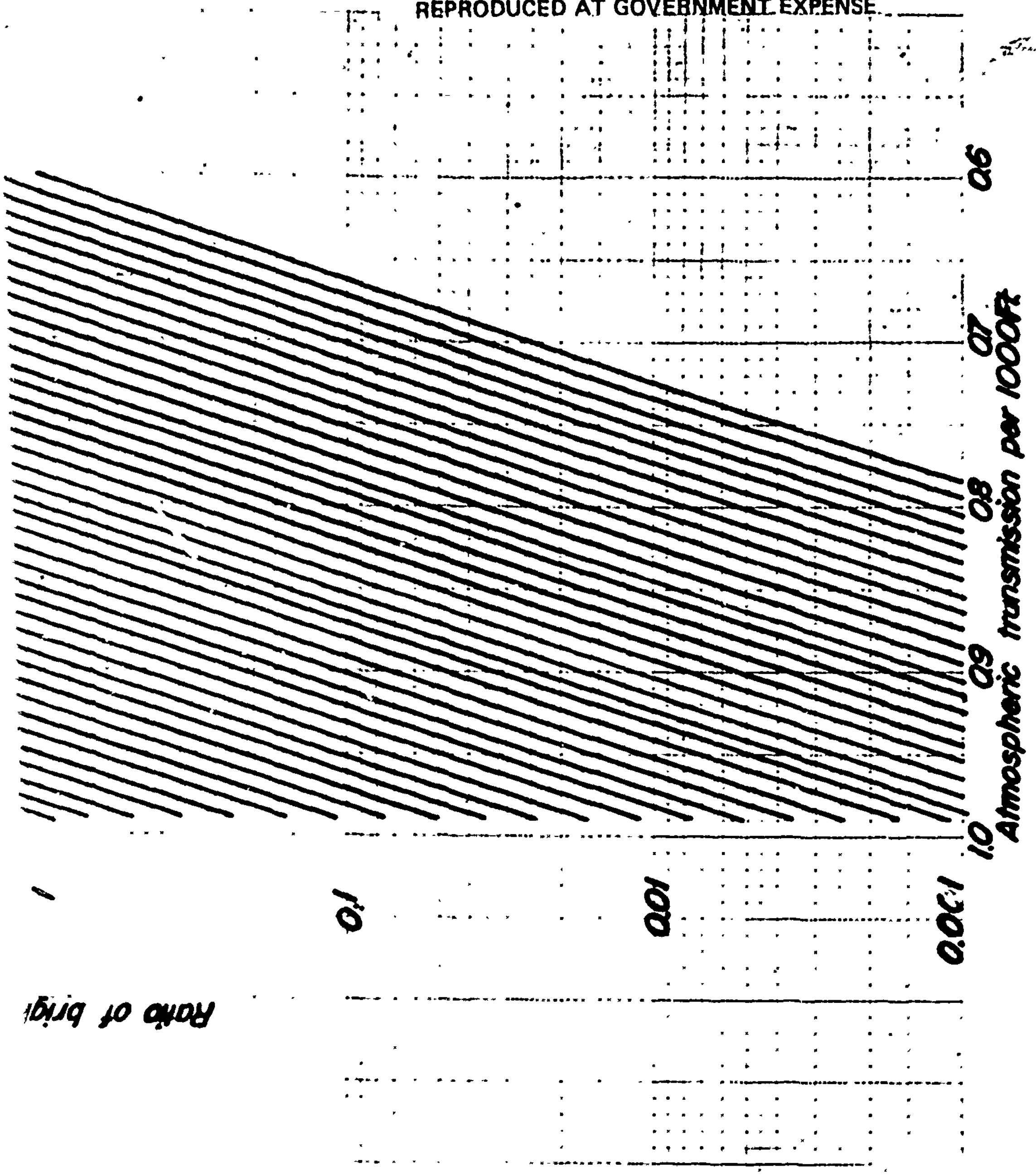
1 of 3

Graph 3c-Ratios of sky glow brightness produced, during various atmospheric transmissions, at source by a constant amount of diffused upward light in an area having width of one mile.



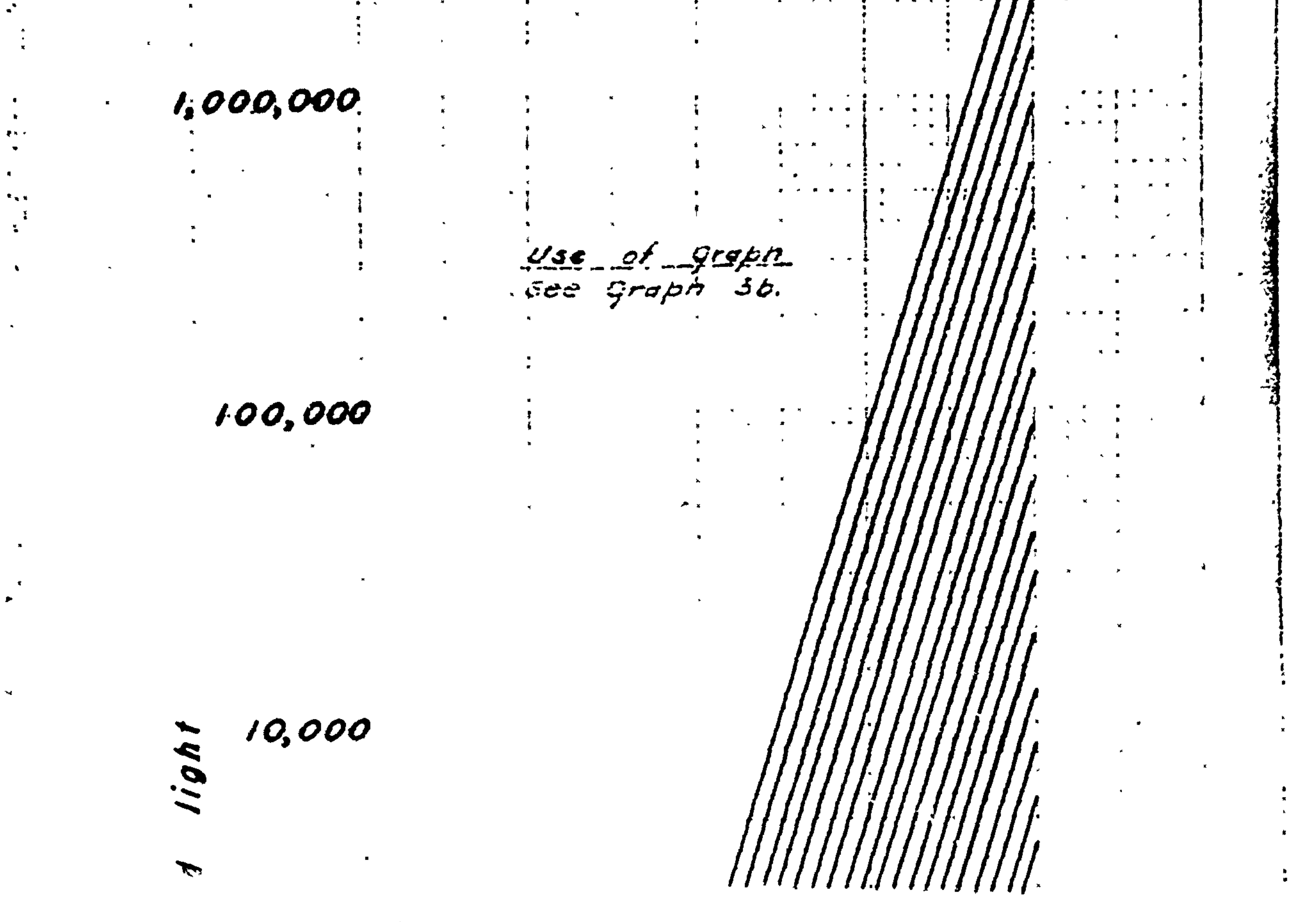

Ratio of brightness produced at source of diffused upward light
0.1
1
10
100

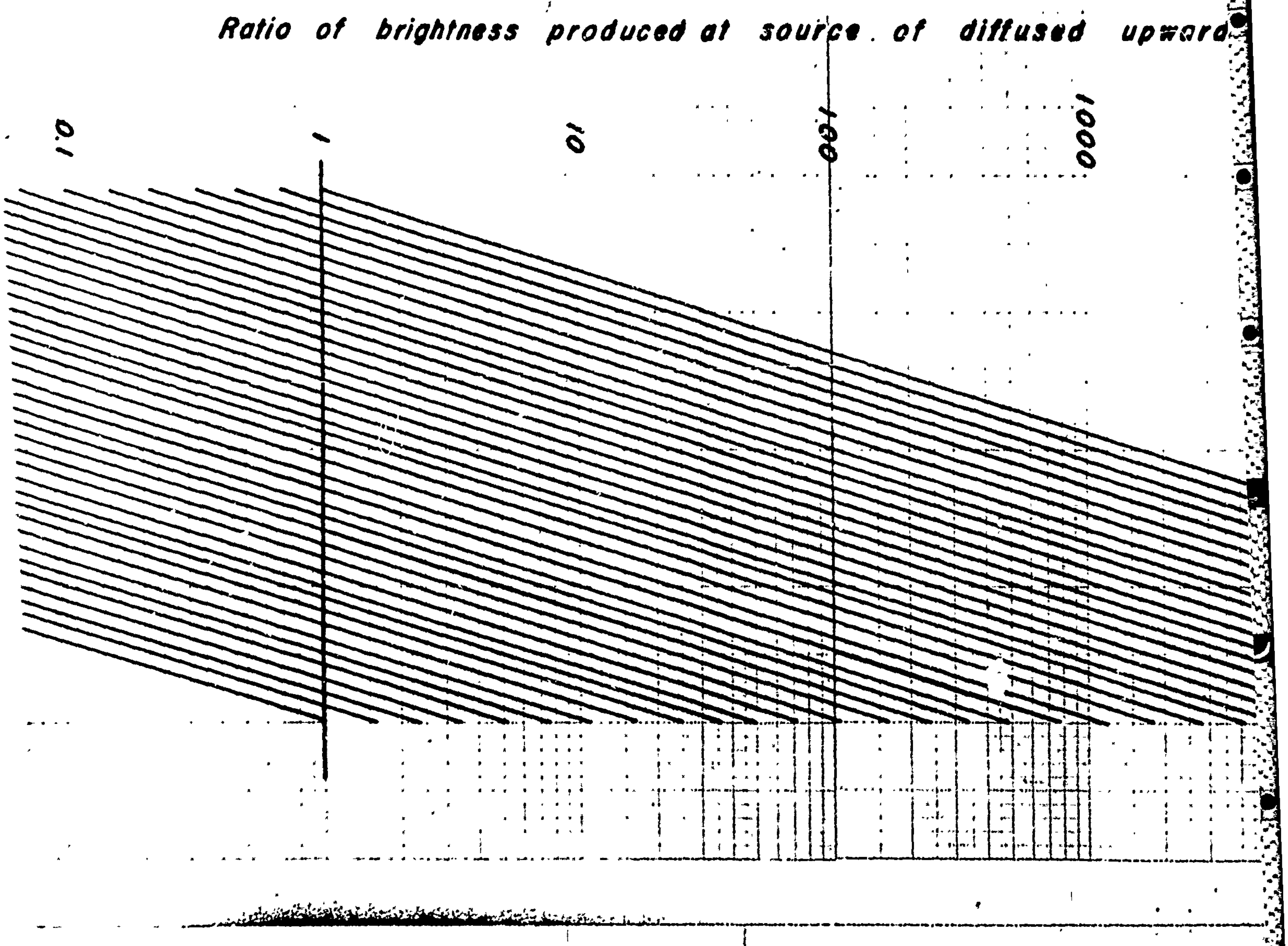
REPRODUCED AT GOVERNMENT EXPENSE



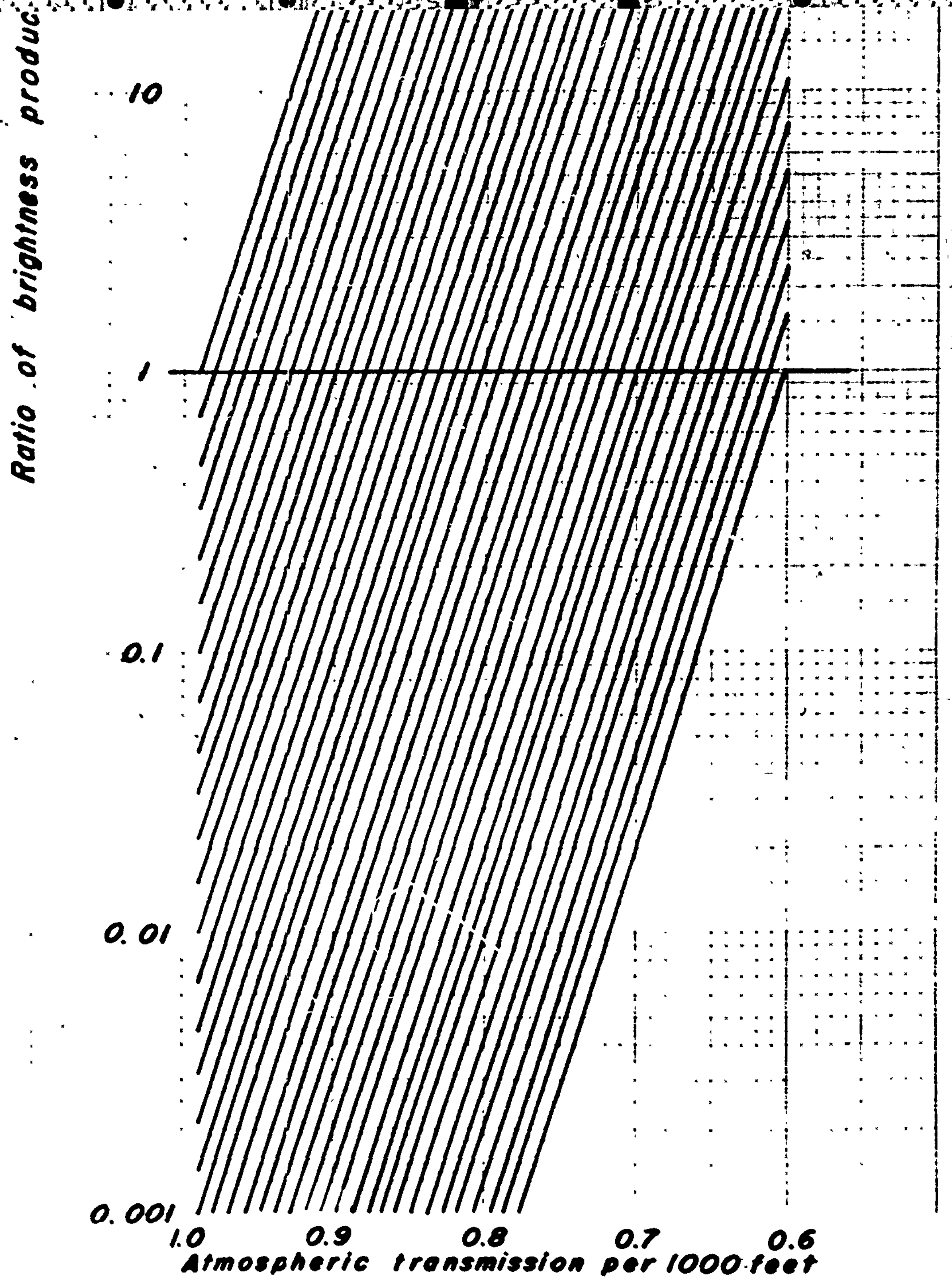
1 of 3

Graph 3a - Ratios of sky glow brightnesses produced, during various atmospheric transmissions, at source by a constant amount of diffused upward light in an area having width of one and one-half or more miles.

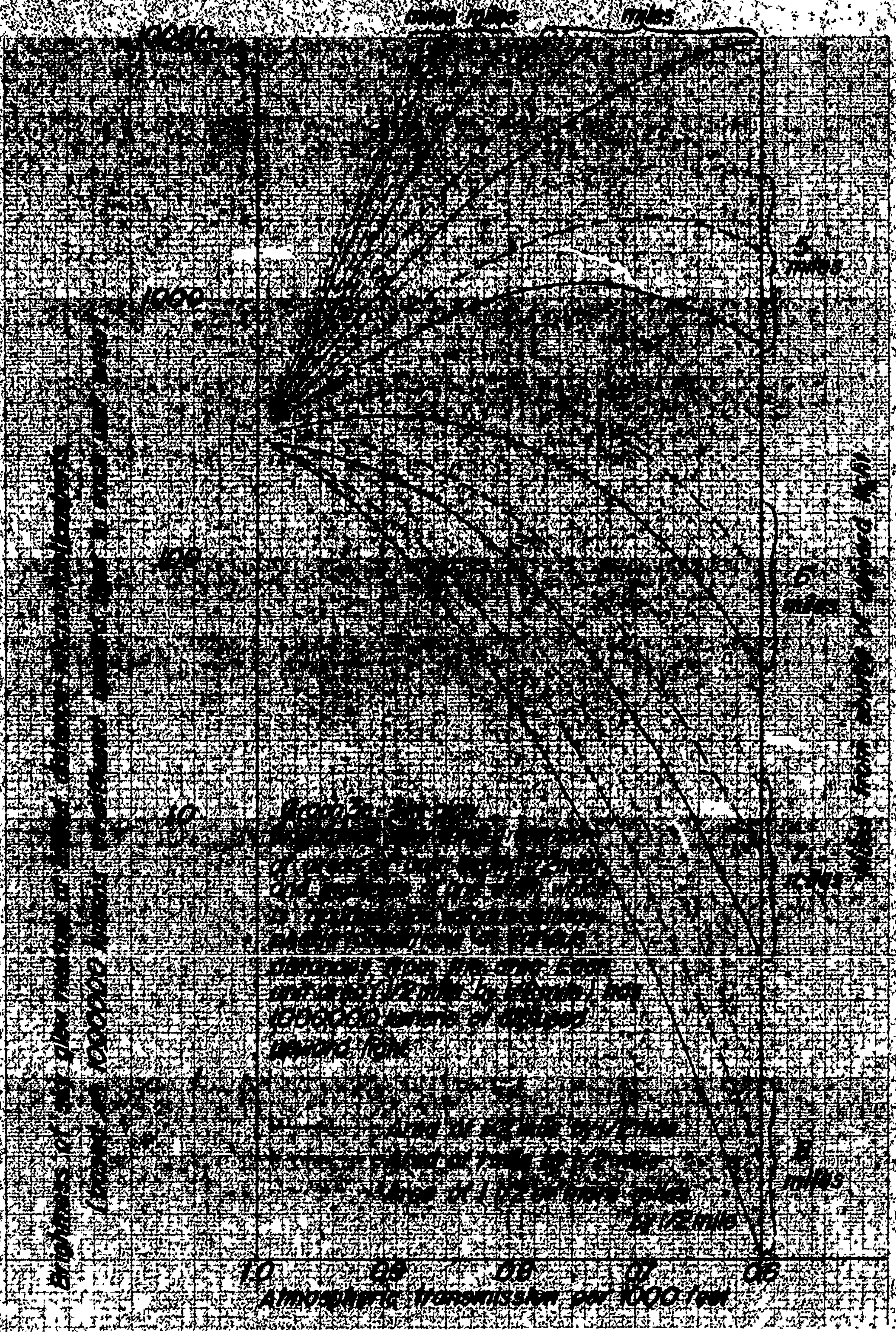



Ratio of brightness produced at source of diffused upward
0.1
1
10
100
1000

2 of 3


Ratio of brightness produc
10
1
0.1
0.01
0.001
1.0
0.9
0.8
0.7
0.6
Atmospheric transmission per 1000 feet

3 of 3


10000
1000
100
10
miles
5 miles
miles
miles
by 1/2 mile
1.0
0.9
0.8
0.7
0.6
Atmospheric transmission per 1000 feet

Simultaneously, brightness of the glow was recorded from various locations on land. Results obtained are set forth in Table 6. By subtracting the distance between test area and point of brightness measurement from the threshold visibility distance, values in Column 3 below are obtained. Values of Column 4 result from the multiplication of Column 2 by appropriate values from Graph 1c for atmospheric transmissions and distances listed in Columns 1 and 3 respectively.

Atmospheric transmission per 1000 feet.	Brightness measured 5 miles from test area (micro-footlamberts)	Threshold visibility distance (miles)	Computed Brightness residual at threshold visibility distance (micro-foot lamberts)
98	1423	43	12.09
98	398	38	5.97
98	249	33	6.22
98	165	23	12.87
85	530	29	0.00
85	430	25	0.00
85	258	12	0.00
85	28	6	0.15
81	96	6	0.14

Values of Column 4 represent the brightness contrast between the natural background brightness and the artificially created sky glow which was barely perceptible to dark-adapted air observers. These contrast values vary between zero and 12.87 micro-footlamberts. This variation can be caused by a number of factors; among them being faulty dark adaptation of the observers, roughness of the air, variations in clearness of the windows of the aircraft, and the greater difference in brightness required by the eye to distinguish a contrast as general level of illumination increases (natural horizon brightness was approximately 1½ to 2 times higher for atmospheres having light transmission factor of 98 per cent per 1000 feet than those having transmissions of 85 and 81 per cent). The curves of Graphs 4 and 4a have been developed from the data taken by use of Graph 1c with the assumption that, under the test conditions (dark, moonless night), 0.15 micro-footlamberts is the smallest difference in brightness of extremely low illumination levels which can be detected by dark adapted observers from aircraft for atmospheres having light transmission of 85 per cent or less per 1000 feet; and 6.0 micro-footlamberts under same conditions for atmospheres of 98 per cent or more per 1000 feet light transmission, with proportional increase between 0.15 and 6.0 micro-footlamberts for transmissions between 85 and 98 per cent per 1000 feet. Curves of Graph 4a reveal that on extremely clear nights relatively low sky glow brightnesses may be seen for great distances. In fact, sky glow brightnesses on the order of 1000 micro-footlamberts at the source of glow (brightnesses many times greater have been recorded over cities from locations several miles distant) can be detected for distances in excess of 90 miles during dark, moonless nights having an atmospheric transmission of 99 per cent per 1000 feet. This threshold visibility distance for equal brightness is reduced to 33 miles for 97 per cent transmission and is only 3 miles for 60 per cent transmission. It will be noted that the curves for low brightness values cross within 6 miles or less of the source of sky glow; which means that the same low initial brightness may be seen for greater distances under the lower light transmission. This effect is caused by the higher horizon brightness usually prevalent with atmospheres of high light transmission, due to less obscuration of starlight; and, therefore, the assumption that a greater difference between the artificial sky glow and natural horizon brightness is required for detection of the sky glow at high transmissions.

b. Since Graphs 3b, 3c, and 3d give the relative amount of sky glow brightness produced by a constant light flux for various atmospheric transmissions, it becomes possible to evaluate the sky glow brightness which would be produced over a city for any atmospheric condition from a brightness measurement made during a known atmospheric condition. Then, by use of Graph 4a, the maximum threshold visibility distance of sky glow produced by a particular city may be computed and its "beacon effect" evaluated. It must be borne in mind, however, that under conditions of clouds or overcast skies many times the expected brightness may be produced thereon; and, if extremely clear atmosphere exists below the clouds, threshold visibility distance will be somewhat increased. However, this increase in threshold visibility distance caused by higher brightness on clouds becomes progressively less as the atmosphere increases in density and is practically non-existent for an atmosphere having 60 per cent or less light transmission per 1000 feet.

18. Maximum Brightness of Background Which Will Not Render Ships Visible to Submarine Observers. a. Naval observers. Data on maximum brightness of background which is not sufficient to silhouette ships were taken at both the Point Pleasant, New Jersey, and the Jacksonville Beach, Florida, tests. Naval officers experienced in convoy duty and anti-submarine warfare acted as submarine observers. Night vision tests revealed that these observers possessed about average visual efficiency under low level illumination, but their experience and knowledge of the problem under investigation increased their over-all visual efficiency as observers for this test to far above the average of that of inexperienced persons.

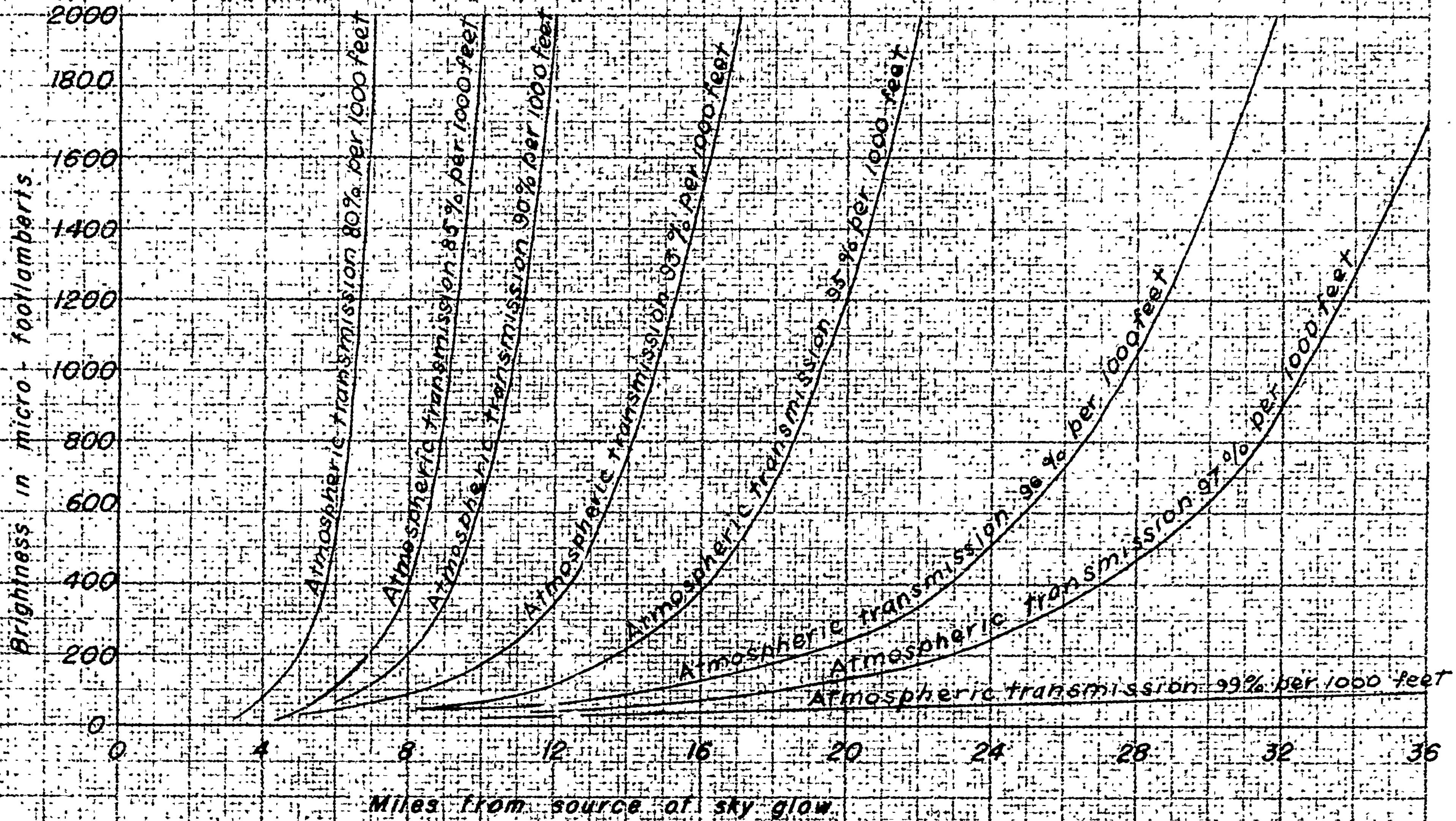
b. Procedure. Observations were made by the naval officers using night binoculars (7.5) from a boat stationed at pre-determined intervals - 500 yards to 6500 yards - from a target boat which plyed back and forth in front of the test area sky glow at 2, 5, and 17 nautical miles offshore. Observers were

Data on threshold visibility distances

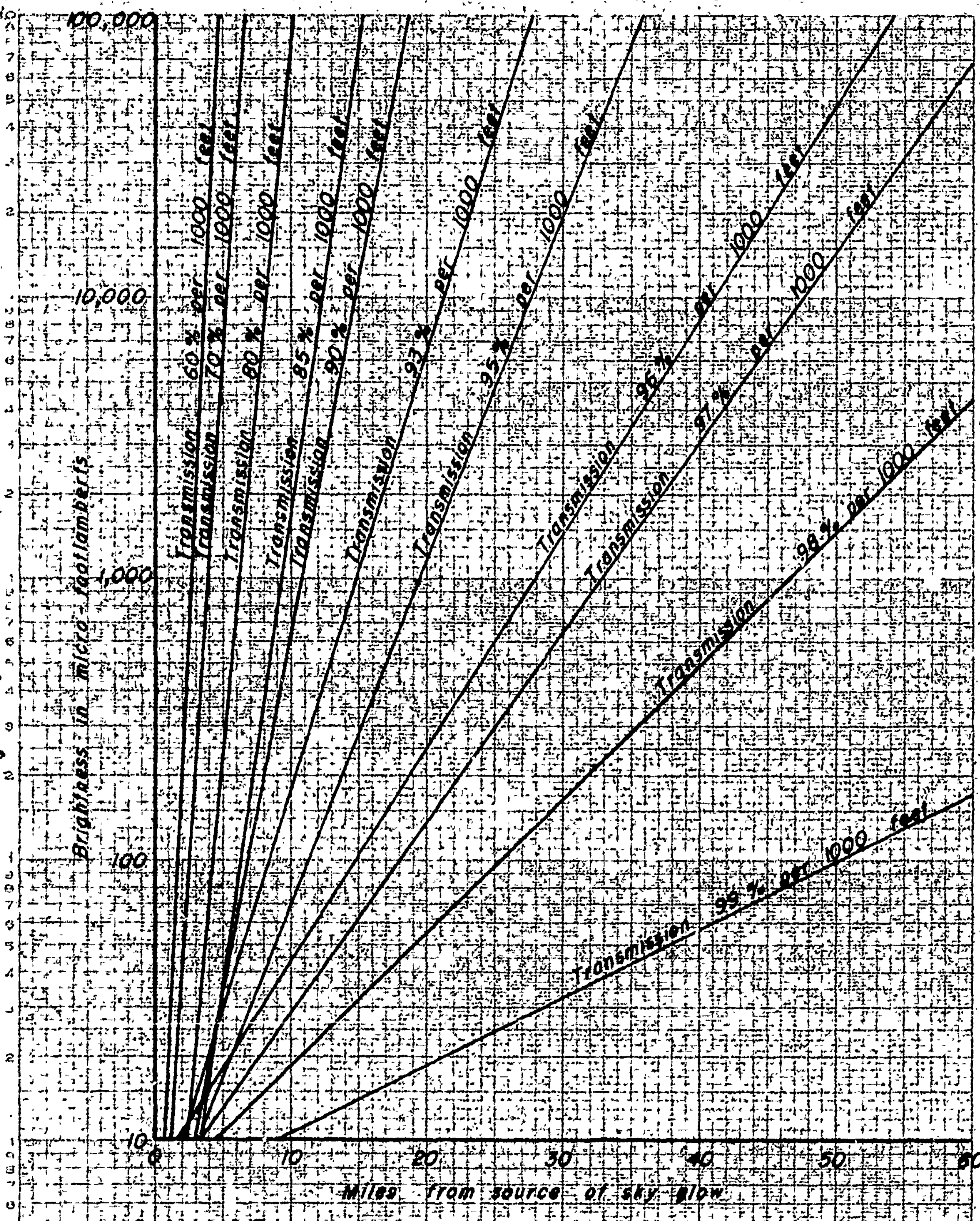
Atmospheric transmission per 1000 feet		98%			98%		85%	85%	85%	85%	81%		
Measured from		5 miles west	10 miles west	15 miles west	5 miles east	5 miles east, from air	5 miles south	5 miles south	5 miles south	5 miles south	5 miles east.	5 miles west	5 miles south
Brightness micro-foot lamberts	Inland horizon	122	138	51	95	(a) 220	80	72	72	75	—	67	—
	Zenith	79	84	84	135	200	150	150	126	150	—	79	—
	Sea horizon	—	—	—	84	—	76	70	71	70	—	—	—
	Test area horizon	252	156	78	260	300	610	500	330	103	153	175	162
	Cloud above test area	1545	536	300	—	—	—	—	—	—	—	—	—
	Sky glow-Test area minus natural horizon	1423	398	249	165	80	530	430	258	28	86	108	95
Threshold visibility distance from the air	Altitude	700 feet			1250 feet		2500 feet	2500 feet	2500 feet	2500 feet	700 feet		
	Distance	48 miles			28 miles		34 miles	30 miles	17 miles	11 miles	11 miles		
Location		Point Pleasant			Jacksonville Beach		Jacksonville Beach	Jacksonville Beach	Jacksonville Beach	Jacksonville Beach	Point Pleasant		
Weather		Overcast low			Clear		Clear				Overcast		

(a) This is not true inland horizon brightness.

Table 6- Threshold visibility distances from the air of several sky glow brightnesses during various atmospheric transmissions.



Graph 4 - Threshold visibility distances of sky glow brightness as affected by atmospheric transmission



Graph 4a - Threshold visibility distances of sky glow brightness as affected by atmospheric transmission stationed at heights above the water level representative of conditions normal to submarine construction. For the various predetermined intervals, variation in sky glow above test area was directed from the observation boat by the naval observers to such a brightness that type of seacraft (target boat), its course, and its speed could no longer be determined. All brightness readings were made from the observation boat by trained photometrists using Taylor "Model A" low brightness meters which were calibrated each night before test operations began.

c. Analysis of the data. The data recorded (see table 7) have been used in the development of the groups of curves on Graphs 5 and 5a. Since silhouetting effectiveness is a direct function of the total background brightness consisting of inland horizon brightness plus the artificially created brightness above the test area, the former values have not been eliminated for development of the curves. From these curves, it is possible to determine the maximum sky brightness residual at point of observation, from all sources, which is non-silhouetting for the various conditions investigated during the test, and to interpolate with reasonable accuracy for other conditions likely to be encountered in practice. The curves were developed in the following manner:

(1) Since the brightness of the background was measured at the point of observation, the values obtained were already corrected for distance and atmospheric transmission effects on apparent brightness of sky glow (Graph 1c). However, the small but definite "vision blurring" due to the light scattering effect of atmosphere, and the reductions in angular subtense of objects as the distance between an observer and an object is increased, combined to produce a curve with an ascending slope when maximum non-silhouetting brightness is plotted against distance between target and observation boats for a given atmospheric transmission. Therefore, slope of this curve, which is dependent upon atmospheric transmission and effect of distance upon the visual angle subtended by an object at the retina of the observer's eye, becomes greater with increase in density of atmosphere. The two factors may be logically considered as straight line functions with the "vision blurring effect" dependent upon both the atmospheric transmission and the distance between observers and target boat, while the effect of reduced visibility is directly proportional to the distance for any atmospheric condition.

(2) Analysis of the data recorded with the target boat offshore 2 nautical miles and with an atmospheric transmission of 85 per cent per 1000 feet indicates that the slope of the curve resulted from effect of those two factors and that it could be used as the basis for determining their effect at different atmospheric transmissions and with the target boat

at different distances offshore. For instance, the curve for 63 per cent atmospheric transmission with the target boat offshore 2 miles (Graph 5) was calculated as follows: Since the maximum non-silhouetting brightness was known by test to be 63.7 micro-footlamberts for 2000 yards between boats at 73 per cent transmission, 49.5 micro-footlamberts for 2000 yards at 85 per cent transmission, and 90 micro-footlamberts (average) at 4000 yards for 63 per cent transmission, a second point oncurve for 63 per cent transmission was determined by direct proportion, for the "visibility vs. distance" factor is a constant for any given distance from the target-boat; and, hence, the slope of the new curve will vary from that of the 85 per cent transmission curve only because of the influence of the greater "vision blurring effect" due to greater scattering of light by moisture and other particles in an atmosphere of 63 per cent transmission. As the target boat and the observers draw very close together (at distances less than 500 yards) both "visibility vs. distance" and atmospheric "vision blurring" effects will become less and less and will rapidly approach a constant value for all atmospheric transmissions, irrespective of the distance the target ship is offshore. Since it is logical to expect both of these effects to be at a minimum for very high transmissions (99 per cent and over per 1000 feet), the curve for this value was extended until it intersected the ordinate at approximately 30 micro-footlamberts and all curves were terminated at this point.

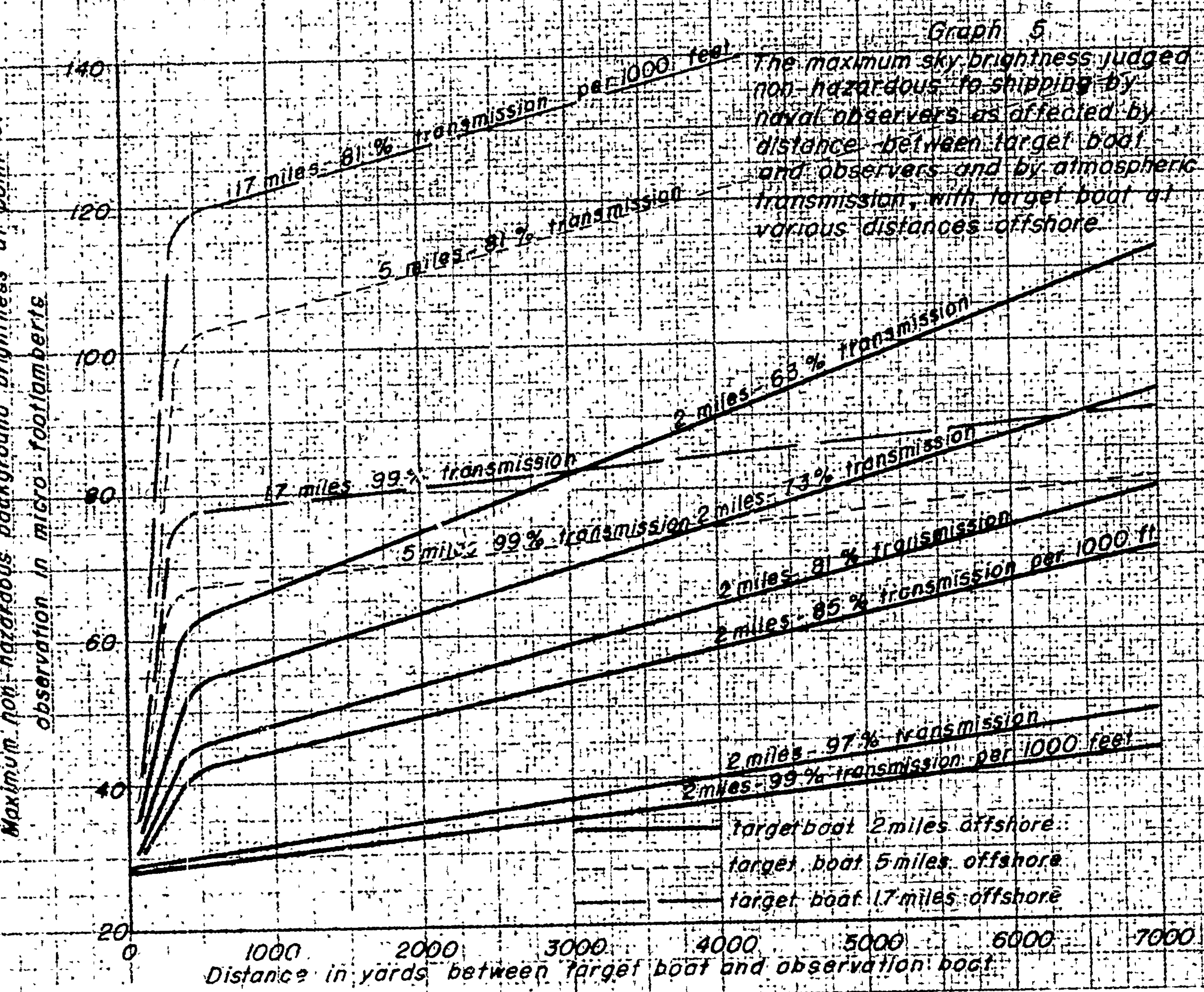
(3) Curves for the target boat at 5 and 17 miles offshore were plotted using the same method described in sub-paragraph (2) above; that is, variations in non-silhouetting brightness due to distance of target boat offshore were established by actual test data, and other points on the respective curves were calculated using the curve for target boat at 2 miles offshore and 85 per centtransmission as the basis for determining the "visibility vs. distance" and "vision blurring" effect for various distances between target boat and observation boat and for different atmospheric transmissions.

(4) It should be noted that the distance of the target boat from the shore influences to an appreciable extent the maximum non-silhouetting brightness for a given distance between target and submarine. Since the shore outline with its broken dark horizon of buildings, trees, and other objects is readily visible from two miles offshore, while at greater distances the curvature of the earth and the "vision blurring" effect of the atmosphere tend to create a more or less uniform dark horizon, it is reasonable to assume that the irregular shore line provides reference points which render the determination of a ship's type, course, and speed easier than against a uniform dark horizon. Hence, less background

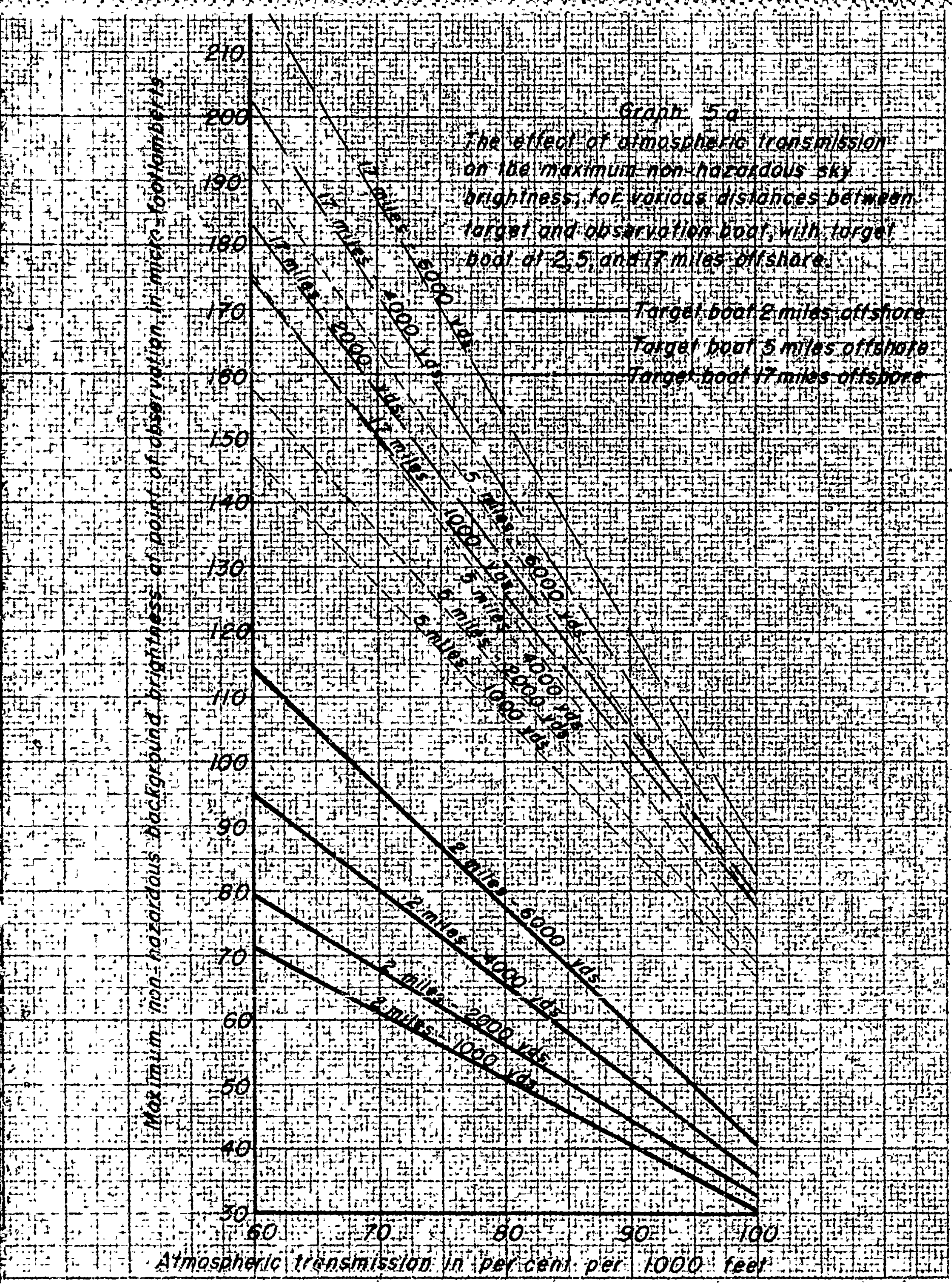
Naval observer	Distance between target boat and shore (source of sky glow) in nautical miles	Distance between target boat and observation boat in yards	Brightness of background (natural brightness plus artificial glow) in microfootlamberts measured from observation boat.	Atmospheric transmission in percent per 1000 feet	Conditions which would affect visibility	
					Weather	Sea
Lt. Commander E.A. Fintel	17	500	78	99	Appears slightly hazy at test area	Average swell
	6 1/2	1000	69	99	Appears slightly hazy at test area.	Average swell
	5	1000	66	99	Clear overhead Appears to be light mist toward horizon.	Average Swell
	5	2000	111	81	Slight overcast	Smooth, with long roll. Some phosphoresence
	2	1000	45	81	Starlight clear	Smooth
	2	2000	63.7	73	Clear	No record
	2	4000	97	63	Sky was clear. Haze over land.	Sea was rough enough to prevent water brightness aiding silhouette effect
Lt. C.G. Winstead	2	4000	84	63	High, thin overcast Haze over land.	No record.
	2	6500	(a) 69	35	High, thin overcast Haze over land	No record

(a) Average of 78 micro-foot lamberts which was just enough to silhouette target boat and 60 micro-foot lamberts which did not silhouette target boat.

Table 7- The maximum background brightness judged non-hazardous to shipping by naval observers during atmospheres having various light transmissions factors.



Graph 5
The maximum sky brightness judged non-hazardous to shipping by naval observers as affected by distance between target boat and observers and by atmospheric transmission, with target boat at various distances offshore



Graph 5-a

The effect of atmospheric transmission on the maximum non-hazardous sky brightness, for various distances between target and observation boat, with target boat at 2, 5, and 17 miles offshore.

brightness is required to produce the same hazard to shipping close to shore. Data taken when seas were high near shore indicate that the natural roughness of the water surface at greater distances from shore may also be a factor. It is logical to assume that the above factors would cease to influence the results beyond a given distance of target boat from shore, and the test data taken at 2, 5, and 17 miles offshore confirms this assumption.

(5) The curves of Graph 5a were plotted from data taken from Graph 5 in order to show the effect of atmospheric transmission on the value of the maximum non-silhouetting brightness with the target boat at a constant distance from the shore and with constant distance between boats.

d. Use of graphs. From factors established by Graphs 5 and 5a, and by applying the law of decrease in apparent brightness of sky glow with distance from its source (Graph 1c), it is now possible to determine the range of permissible brightnesses above cities as affected by distance from shipping lanes and atmospheric conditions. An analysis of these values as compared with actual sky glow conditions over a city will indicate the extent of dimming necessary to provide maximum safety to shipping from enemy submarine action.

19. Variation in Amount of Sky Glow with Elevation or Depression of Light Beams.- a. Determination of the variation in amount of sky glow with elevation or depression of light beams was conducted at full scale at Point Pleasant, New Jersey, (see figs. 17 and 18, for method of controlling elevation of beams, and figs. 41 and 42 for sky glow effects obtained), and later checked at reduced scale in the laboratory. Values obtained from measurements at full scale are set forth in Table 8, and the values of that table for measurements from the location in direction of the light beams are plotted on Graph 6. Graph 6a gives a comparison between the data obtained during full scale tests and the laboratory tests conducted with a single lighting unit placed 25 feet in back of a baffle while measurements of sky glow produced for various elevations of the light beam were made from a location 75 feet in front of the baffle. Hence, it is shown that sky glow brightness, when viewed from a location in the direction the light beams are pointed, increases steadily as the light flux is directed from 180° to 105° above nadir, the increase being very rapid for angles of 150° to 105° above nadir; and decreases rapidly from 105° above nadir to angles below the horizontal. A further analysis of amount of glow produced by zones of light emission including values obtained when the beams are directed away from and transversely to the point

of measurement, based on 1,000,000 lumens per each zone of 30° or 60°, is given in sub-paragraph 5a. of Appendix E.

b. These two analyses reveal that the zone of light emission most productive of sky glow lies between 90° and 120° above nadir. Since the flux emitted at high angles above the horizontal is wasted for normal types of city lighting, any necessary reduction in sky glow from essential lighting must be accomplished, insofar as possible, by eliminating the light flux in those zones which are of no value to the purpose of the lighting, and by confining the flux to zones below the horizontal in such a manner that the effectiveness of the lighting is not unduly impaired.

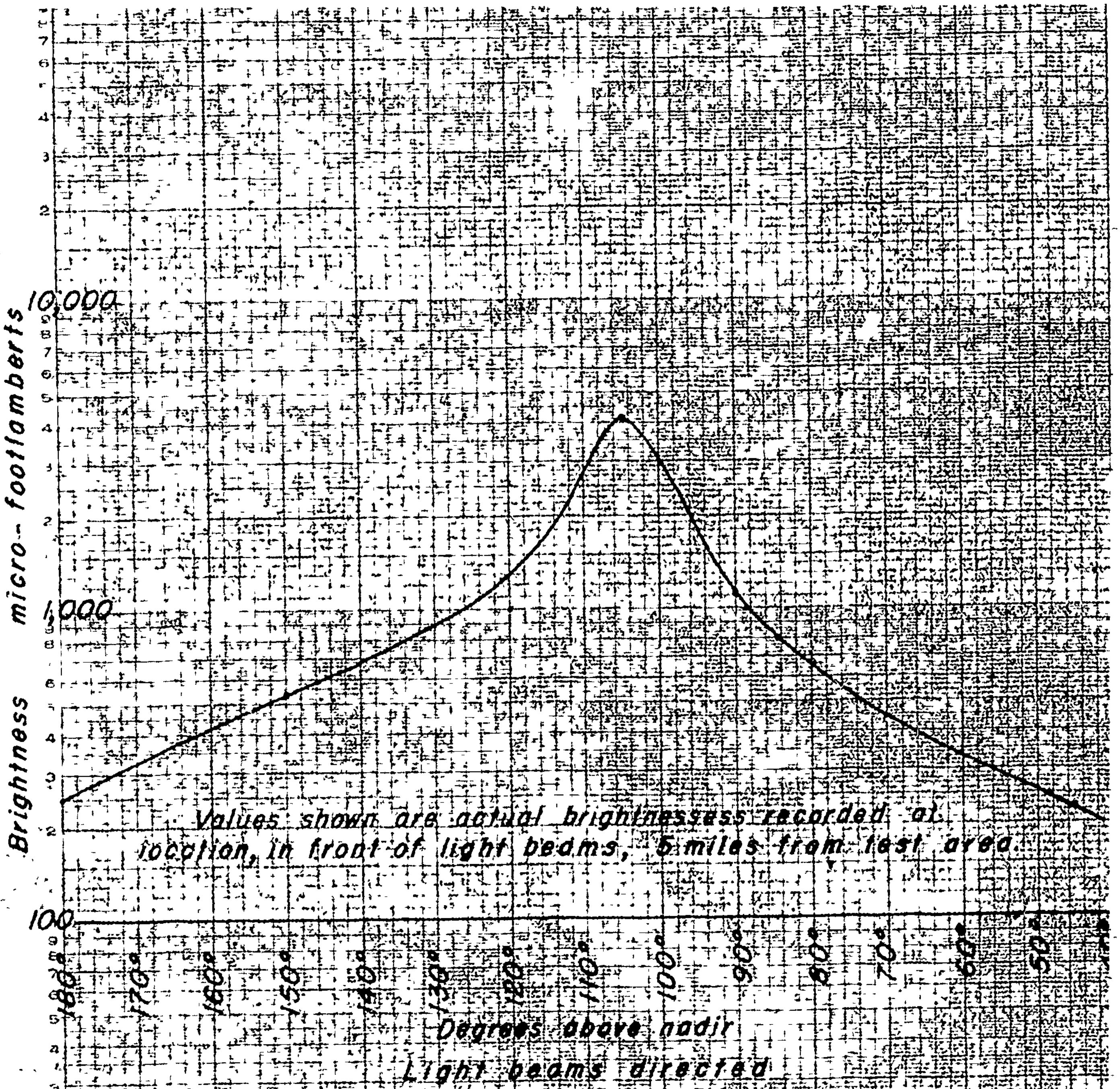
Fig. 41
Beams 60° above horizontal.
View from 5 miles west of test area. Beams were pointed south. Notice high brightness produced on cloud.

Sky glow was produced by 1836 sealed beam headlights with their beams directed above and below the horozontal at angles shown in chart below. For all angles below the vertical, lamp beams were directed toward the south.

Item		Measurements from station 5 miles north						Measurements from station 5 miles south						Measurements from station 5 miles west					
		Beams vertical	Beams 60° above horizontal	Beams 30° above horizontal	Beams 15° above horizontal	Beams horizontal	Beams 45° below horizontal	Beams vertical	Beams 60° above horizontal	Beams 30° above horizontal	Beams 15° above horizontal	Beams horizontal	Beams 45° below horizontal	Beams vertical	Beams 60° above horizontal	Beams 30° above horizontal	Beams 15° above horizontal	Beams horizontal	Beams 45° below horizontal
Brightness micro-footlamberts	Zenith	49	–	–	–	–	54	60	81	160	60	78	60	54	–	–	–	–	–
	Inland horizon	48	–	–	–	–	64	48	–	–	–	–	42	144	–	–	–	–	–
	Test area horizon	Not recorded	Not recorded	Not recorded	Not recorded	216	No perceptible glow	300	600	1020	4200	1140	270	210	Not recorded	Not recorded	150	96	78
	Sky glow- Test area horizon minus inland horizon.	–	–	–	–	152		252	552	972	4152	1092	228	(a) 150	–	–	(a) 90	(a) 36	(a) 18
	Brightness on cloud	557	1200	420	450	–		720	1200	810	–	–	–	1800	2100	360	–	–	–
Weather and sky conditions		Overcast high						Overcast low						Overcast low					
Atmospheric transmission		99 to 92 % per 1000 feet.																	
Remarks		Changing cloud formations above test area cause high, unpredictable brightnesses to bereflected from them.																	

(a) Since sea horizon was not recorded, a value of 60 micro-footlamberts was assumed and subtracted from test area horizon to obtain value given.

Table 8-Variation in amount of sky glow with elevation and depression of light beams.



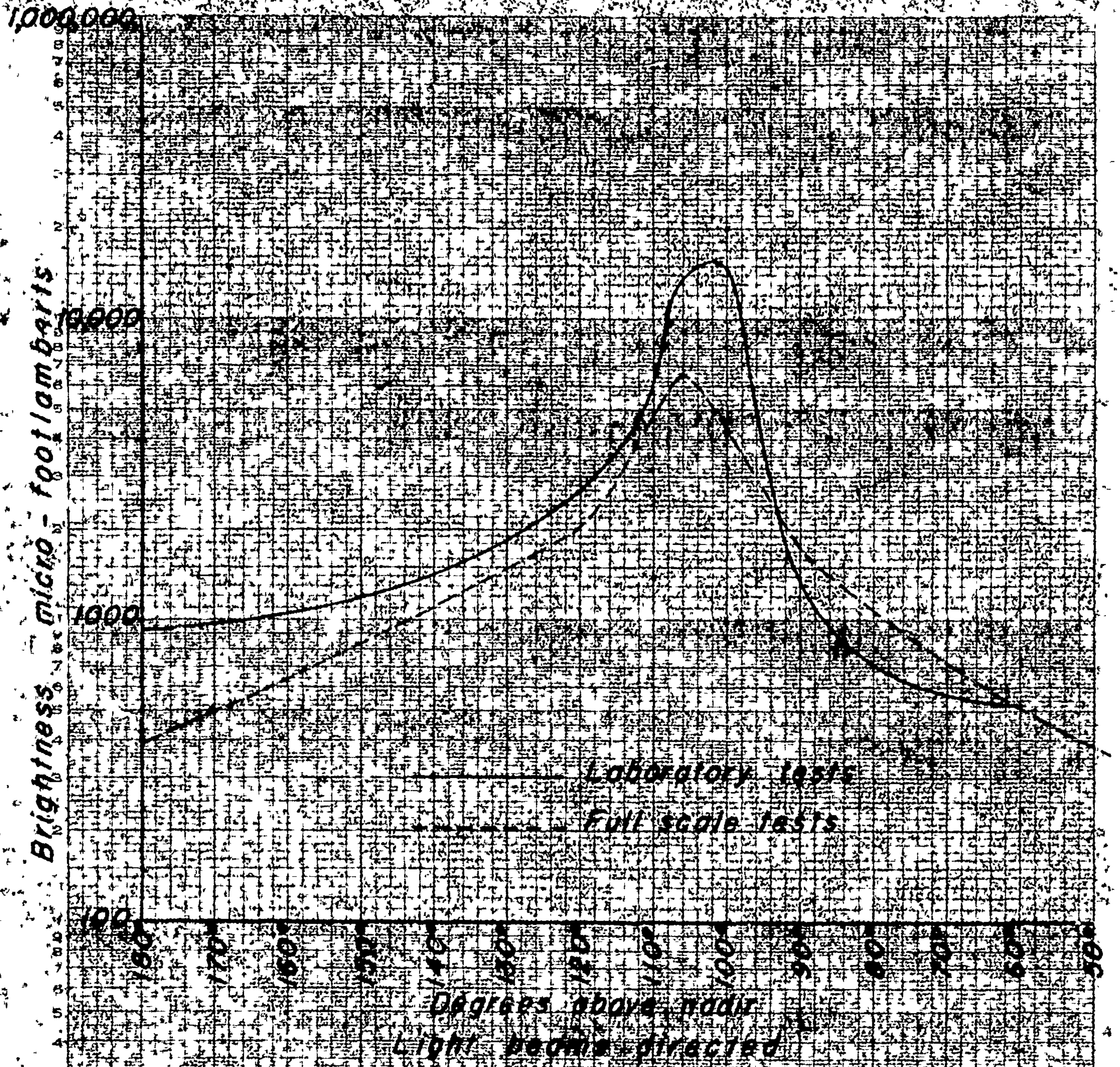
Values shown are actual brightnessess recorded at location, in front of light beams, 5 miles from test area.

Total lumens — 642,600

Atmospheric transmission — 92% per 1000 feet

Graph 6 - Variation in amount of sky glow with elevation and depression of light beams.

Full scale tests.



Above curves are based on sky glow produced 5 miles in front of light beams by 1,000,000 lumens. Differential between curves may be due in large measure to difference in atmospheric transmission.

Graph 60 - Comparison of results of full scale and laboratory tests on variation in amount of sky glow with elevation and depression of light beams.

Fig. 42
Beams 30° above horizontal.
View from 5 miles west of test area. Beams were pointed south. Notice high brightness produced on cloud.

20. Contribution to Sky Glow by Specific Types of Illumination and Reductions in Sky Glow Accomplished by Various Methods of Treatment. a. Vehicular headlamps.- (1) Test procedure. - For this study, the sealed beam headlamps used at Point Pleasant, New Jersey, and Jacksonville Beach, Florida, were positioned with lens face vertical to simulate automobiles on level ground (fig. 10) and at slight angles upward to simulate automobiles ascending grades. The units were switched to passing (low) or driving (high) beams, and shielded or hooded (figs. 14 and 43), as required. Sky glow measurements for the various conditions were made from locations 5 miles to the north and south, 5 and 7 miles west, and 2 nautical miles east of the test area. For procedure followed when actual vehicles were used to simulate maximum night coastal highway traffic, see sub-paragraph (5) below.

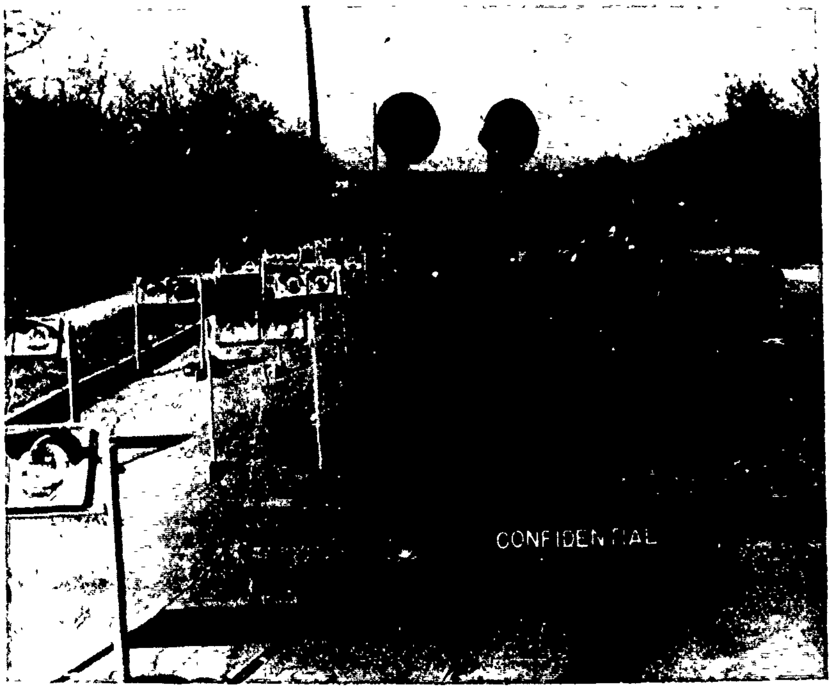


Fig. 43
Test lighting units equipped with 6 inch hoods are shown above. The 1/4-ton truck with loud speaker equipment was used to instruct ground crews in test procedure.

(2) The effect of up-grades.- Table 9 presents data taken at Point Pleasant, New Jersey, on the increase in sky glow which may result from upgrades (the same effect may be produced by improperly adjusted headlamps projecting their beams at angles above the horizontal). In front of the beams (measurements from 5 miles south of test area), the apparent sky glow may be increased as much as 3 times when vehicles ascend an upgrade of $2\frac{1}{2}$° (approximately 4% upgrade) and 4 times for upgrades of 5° (approximately 9% upgrade).

(3) The effect of various methods of shielding and hooding headlamps in reducing sky glow.- The comparative reductions in sky glow to be expected from various methods of shielding and hooding are given by Tables 9a and 9b and are presented graphically in Graphs 7, 7a, and 7b. Table 9c indicates the relative reductions accomplished by the various methods of shielding and hooding as measured from a location in front of the beams. These data represent

Glow produced by 1836 sealed beam headlamps pointed south and concentrated in an area approximately 1/5 square mile.
Point Pleasant, New Jersey.

Item		Beams horizontal						Beams tilted 2 1/2° upward						Beams tilted 5° upward											
		Measurements from						Measurements from						Measurements from						Measurements from					
		5 miles north		5 miles south		5 miles west		5 miles north		5 miles south		5 miles west		5 miles north		5 miles south		5 miles west		5 miles north		5 miles south		5 miles west	
Head light beam		Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving
Weather-sky conditions		Clear						Overcast						Clear						Clear					
Brightness micro-footlamberts	Inland horizon	93	84	54	60	168	144	(b) 318	72	54	72	-	-	108	108	84	60	108	114	78	72	66	72	156	180
	Zenith	75	78	90	-	138	180	84	210	120	120	270	134	90	120	108	120	126	120	84	84	90	-	132	168
	Sea horizon	69	66	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	75	78	-	-	-	-
	Test area horizon	204	342	1050	1500	174	180	360	258	(c) 450	3000	150	120	258	438	1620	4020	114	114	186	510	4200	5100	90	164
	Sky glow - test area horizon minus natural horizon	111	258	996	1440	(a) 105	(a) 114	306	186	396	2928	81	54	150	330	1536	3960	(a) 45	(a) 45	108	438	4134	5028	(a) 15	(a) 86
Atmospheric transmission per 1000 feet.		76%						97%						97%						76%					

(a) Since station 5 miles west did not record sea horizon, sea horizon readings of station 5 miles north were used to arrive at these values.

(b) Since this reading is obviously affected by glow from some source, inland horizon reading of station 5 miles south was used in computations.

(c) Reading is low due to cloud between test area and observer.

Table 9 - The effect of up grades on sky glow produced by sealed beam automobile headlamps.

Point Pleasant, N.J.
1942

Glow produced by 1836 sealed beam headlights faced toward the south with lens face vertical and concentrated in an area of approximately 1/5 square miles.

Condition of units		Lamps unshielded						Lamps shielded upper 1/4						Lamps shielded upper 1/2						Lamps shielded 3/4		6" horizontal hood			
Measurements from		5 miles north		5 miles south		5 miles west		5 miles north		5 miles south		5 miles west		5 miles north		5 miles south		5 miles west		5 miles south	5 miles west	5 miles south		5 miles west	
Headlight beams		passing	driving	passing	driving	passing	driving	passing	driving	passing	driving	passing	driving	passing	driving	passing	driving	passing	driving	passing	passing	passing	driving	passing	driving
Weather & sky conditions		Clear		Clear		Clear		Clear		Clear		Clear		Clear		Clear		Clear		Slight overcast		Clear		Clear	
Brightness Micro-foot lamberts	Inland horizon	93	84	54	60	168	144	96	104	60	84	114	192	120	90	84	84	240	162	54	66	60	840(c)	93	415(c)
	Zenith	75	78	90	-	128	180	90	60	-	90	138	168	72	66	-	90	168	180	-	72	84	240	84	183
	Sea horizon	69	66	-	-	69(b)	66(b)	90	69	-	-	90(b)	69(b)	75	72	-	-	no perceptible glow	72(b)	-	60(b)	-	-	-	-
	Test area horizon	204	342	1050	1500	174	180	126	192	540	900	156	180	102	102	322	660		168	210	48	240	900	69	402
	Sky glow-test area horizon minus Inland horizon for north & south & sea horizon for west	111	258	996	1440	105	114	30	88	480	816	66	111	0	12	238	576		94	156	0	180	60	0	0
Atmospheric transmission per 1000 ft.		76 %						76 %						76 %						81 %		97%			

(a) Since inland horizon was not obtained at the scuth station, value of north station was assumed.

(b) Sea horizon values for station 5 miles west are assumed values based on readings at other stations.

(c) These readings were taken while moon was still in sky. Moon set at 4:23 a.m.

Table 9a- Relative sky glow produced by passing ana driving beams and the effect on brightness thereof by various methods of shielding and hooding.

Jacksonville Beach, Florida

Glow produced by 2358 sealed beam headlights faced toward
the north, with lens face vertical, and concentrated in an
area of 4,572,500 square feet (approximately 0.16 square miles)

ITEM		Lamps unshielded						Lamps shielded for upper 1/2 of lens												Lamps shielded for lower 1/2 of lens					
		Measurements from						Measurements from						Measurements from						Measurements from					
		5 miles north		5 miles south		7 miles west		5 miles north		5 miles south		7 miles west		5 miles north		5 miles south		7 miles west		5 miles north		5 miles south		7 miles west	
Head light beam		Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving
Brightness micro-footlamberts	Inland horizon	70	80	82	98	65	85	70	80	79	78	83	88	70	70	52	38	Could not	detect any glow	70	70	21	24	Station	unoccupied
	Zenith	120	140	110	102	111	130	120	140	108	–	130	111	110	110	58	67			110	110	57	35		
	Sea horizon	60	80	50	60	66	78	70	80	52	55	75	72	60	60	28	25			60	60	29	22		
	Test area horizon	8500	15000	400	720	86	85	3000	5800	360	500	85	83	4000	10000	145	210			12000	20000	269	430		
	Sky glow – Test area horizon minus natural horizon	8430	14920	318	622	20	7	2930	5720	281	422	10	11	3930	9930	93	172			11930	19930	296	406		
Atmospheric transmission per 1000 feet		71%	90%	71%	90%	71%	90%	72.9%						78%						91.8%					

Table 9b – Relative sky glow produced by passing and driving beams of sealed beam headlamps, and the effect on brightness thereof by various methods of shielding.

Reduction in sky glow to following percentages resulting from use of passing beams - Driving beam sky glow taken as 100% in each case.

Headlamp treatment	Point Pleasant New Jersey		Jacksonville Beach, Florida			
	Sealed beam		Sealed beam		Standard[(b)]	
	Driving	Passing	Driving	Passing	Driving	Passing
Unshielded	100%	69%	100%	50%[(a)]	100%	18%[(c)] 29%[(d)]
Upper ½ shielded	100%	60%	–	–	–	–
Upper ½ shielded	100%	41%	100%	51%	100%	17%[(d)]
Lower ½ shielded	–	–	100%	59%	–	–
6 inch hood	100%	35%	–	–	–	–

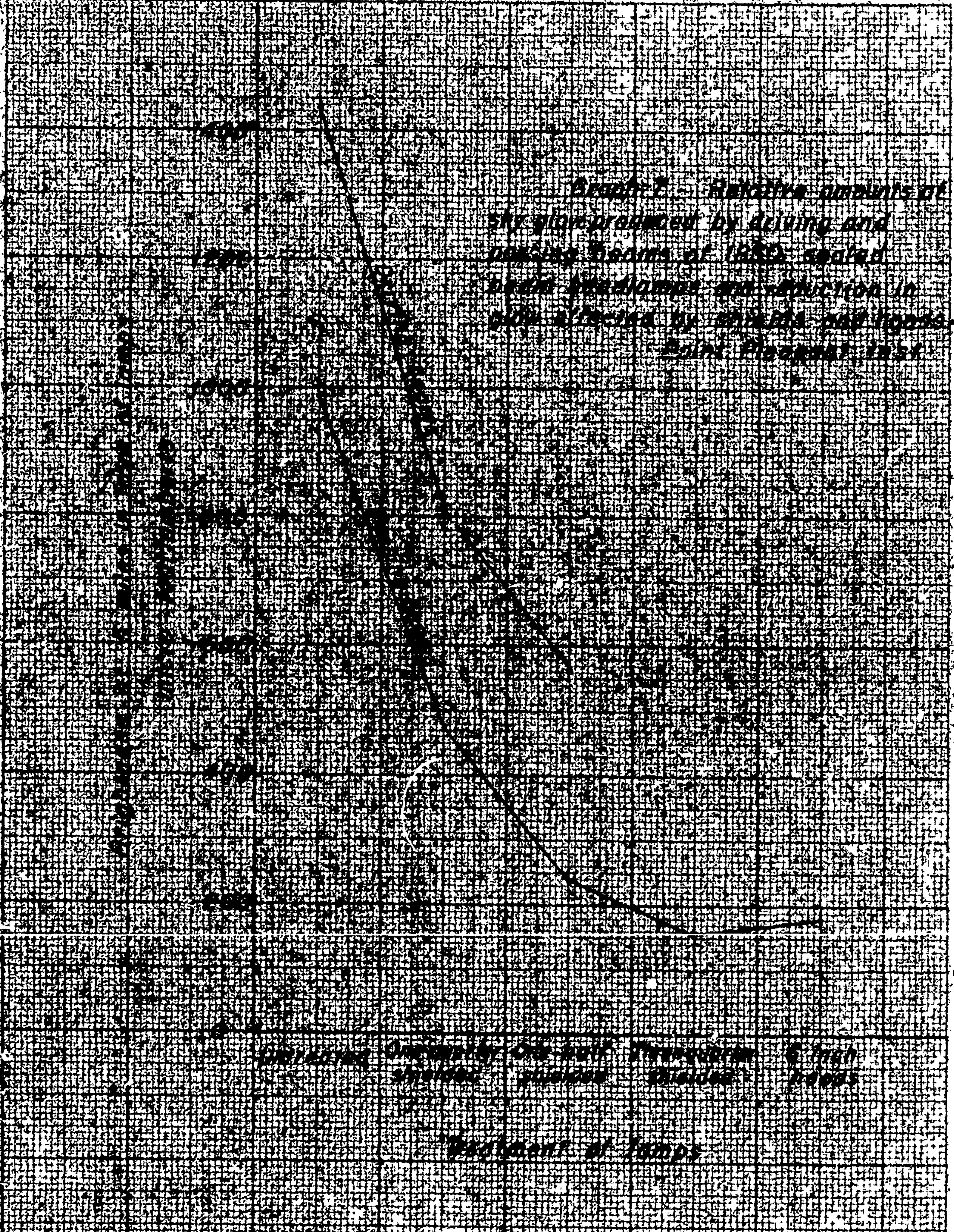
(a) Uncorrected for variation in atmospheric transmission. (b) See table 9e.
(c) Data taken from boat 2 nautical miles east. (d) Data taken from land 1.7 miles west.

Reduction in sky glow to following percentages effected by shielding and hooding driving and passing beams as compared to beams from untreated headlamps - Unshielded beam sky glow taken as 100% in each case.

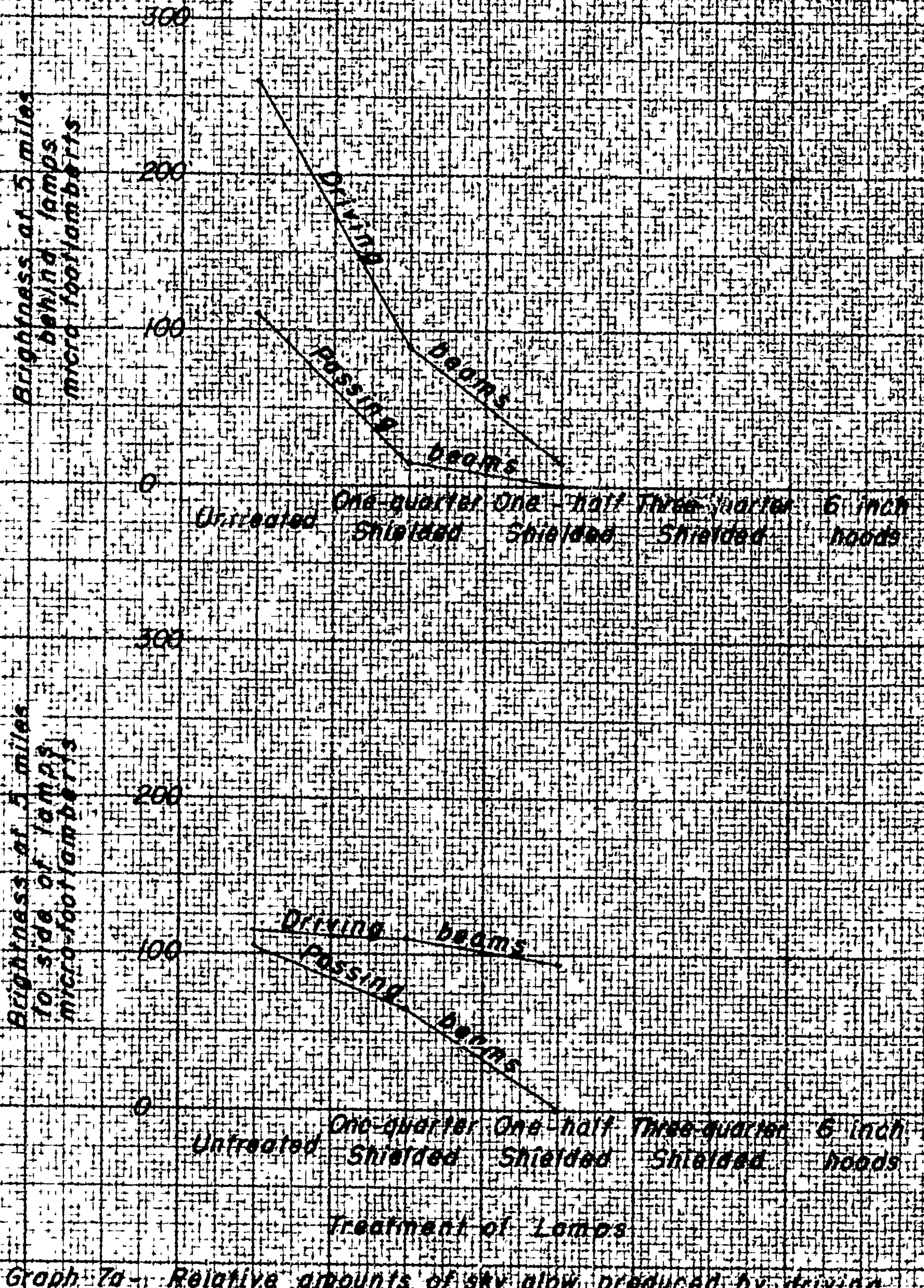
Headlight beam	Test location	Unshielded		Upper ¼ shielded	Upper ½ shielded		Upper ¾ shielded	Lower ½ shielded	6 inch hoods
		Sealed beam	Standard[(a)]	Sealed beam	Sealed beam	Standard[(a)]	Sealed beam	Sealed beam	Sealed beam
Driving	Point Pleasant	100 %	–	57 %	38 %	–	–	–	–
	Jacksonville Beach	100 %	100 %	–	40 %	24 % (b) 37 % (c)	–	133 % (d)	–
Passing	Point Pleasant	100 %	–	48 %	24 %	–	16 %		20 %
	Jacksonville Beach	100 %	100 %	–	39 %	29 % (b) 22 % (c)	–	159 % (d)	–

(a) See table 9e. (b) Data taken from boat 2 nautical miles east. (c) Data taken from land 1.7 miles west. (d) Values increased by reflected light from lower half of lens to upper hemisphere and by angle at which light is projected above the horizontal.

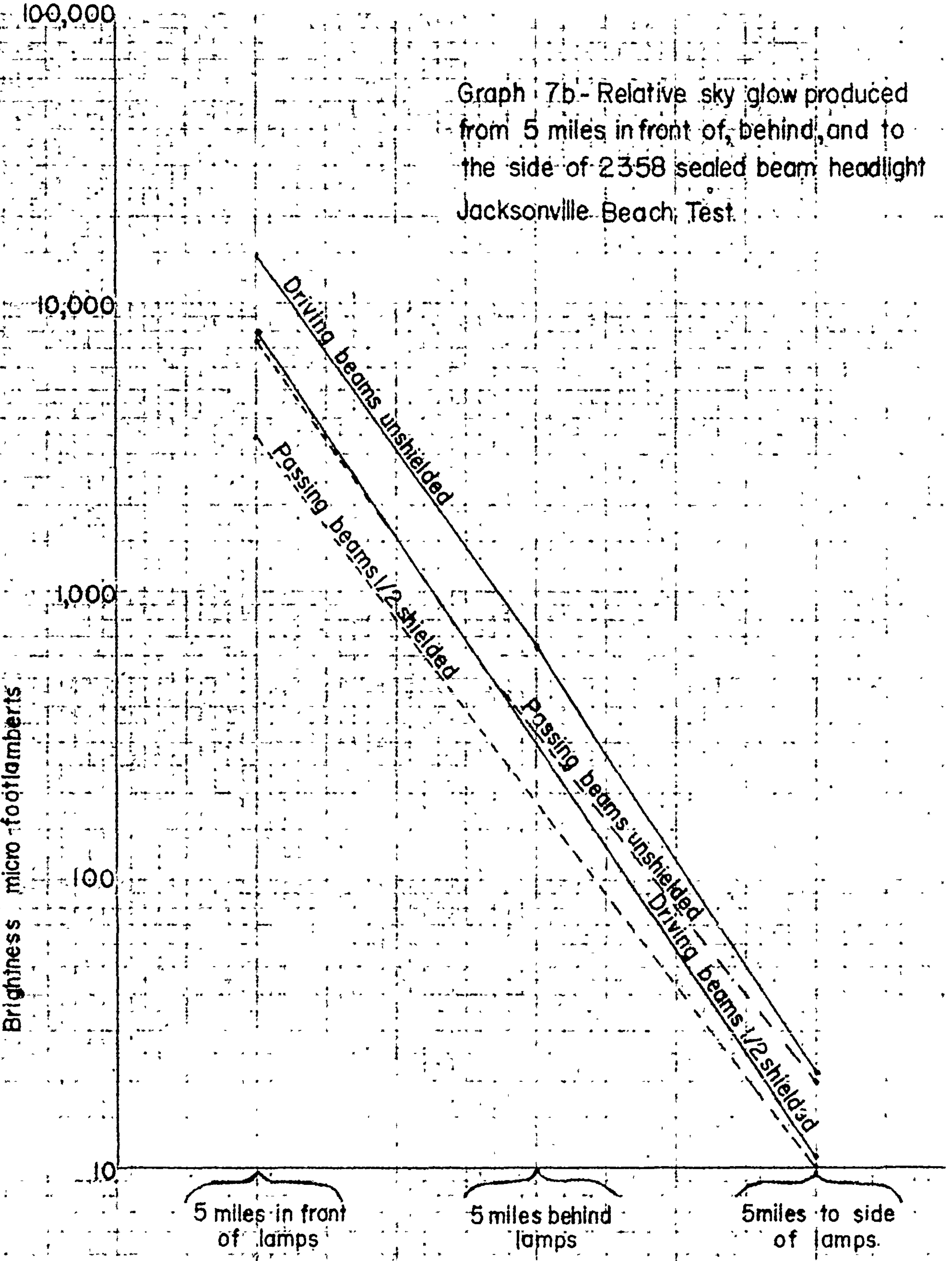
Table 9c -- Relative reductions by shields and hoods in sky glow produced by headlamps.



Graph 7. — Relative amounts of sky glow produced by driving and passing beams of 1950 sealed beam headlamps and reduction in glow afforded by shields and hoods. Point Pleasant, 1951



Graph 7a- Relative amounts of sky glow produced by driving and passing beams of 1836 Sealed beam headlamps and reduction in glow affected by shields and hoods - Point Pleasant tests.



Graph 7b - Relative sky glow produced from 5 miles in front of, behind, and to the side of 2358 sealed beam headlight Jacksonville Beach Test probable order of magnitude rather than exact ratios.

(a). Sky glow from headlamps directed toward the observer.- In Tables 9a and 9b and Graph 7, the effectiveness of upper shielding or hooding combined with passing beams for the reduction of sky glow is indicated. In comparison to unshielded passing beams, 1/2 shielding reduced sky glow approximately 75 per cent (60 per cent at the Jacksonville Beach, Florida, test due to different street surfaces from those at Point Pleasant, New Jersey). Six inch hoods were responsible for reductions of approximately 80 per cent (probably due to absorption of upward light reflected from horizontal prisms of the lower half of the lens) and 3/4 shielding reduced the glow approximately 84 per cent. These values represent the order of magnitude only since they may be expected to vary somewhat depending upon the reflection factors of roadways, the type of headlamps, and their beam patterns resulting from focus of lamp. While 3/4 shielding and 6 inch hoods reduce the light above the horizontal slightly more than 1/2 shielding, the greatly reduced road illumination from 3/4 shielding results in driving hazards which outweigh any advantage to be realized from the further small reductions in sky glow; likewise, the man hours and materials required to prepare, install, and maintain hoods does not recommend their use as a practical solution. The least desirable method was shown to be shielding the lower half of the lens (fig. 44), which resulted in redirecting a great amount of light above the horizontal, thereby increasing the sky glow as much as 60 per cent above unshielded conditions for the passing beam.

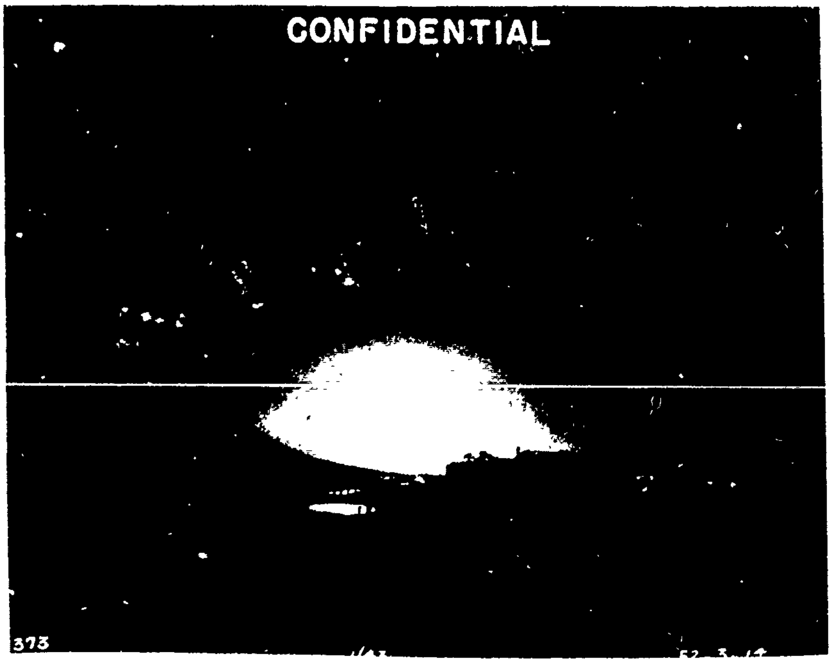


Fig. 44
Sky glow produced by 2358 sealed beam headlamps, positioned with lens face vertical, with the lower half of lens shielded in combination with driving beams, as viewed in front of lamps from 5 miles away. Note the shape of the glow and the angle above the horizontal at which the light appears to be directed.

This increase is due to internal secondary reflections, from the masked portion of the lens and the reflector, added to the normal upward light from the upper half of the lens. The angle at which the resulting light beam is projected into the atmosphere may further increase the apparent brightness, since tests showed that sky glow from a given amount of light flux will increase rapidly as the angle of projection above the horizontal increases from 0 degrees to 15 degrees when the beams are pointed in the direction of the observer (see Graph 6).

(b). Sky glow from headlamps directed transversely to and away from the line of sight of the observer.- Data in Tables 9a and 9b and Graphs 7a and 7b reveal that the sky glow produced by motor vehicle headlighting when beams are projected transversely to the line of sight of the observer or away from the point of observation is a very small per cent of the glow resulting when the beams are directed at the observer. Shielding the upper half of the lens further reduces the glow in the above directions. Such limiting directions of view infrequently occur; and, even in the case of one-way coastal highways leading away from the ocean, the glow resulting from unshielded passing beams, under certain atmospheric conditions and sufficiently heavy concentrations of traffic, could be hazardous to coastal shipping within two miles of the glow. Half shielding and passing beams, however, will in such cases greatly reduce the hazard and will remove it entirely for most coastal highways. (See sub-par. (5) below.)

(4) Sky glow produced by maximum concentrations of city traffic.- Table 9d presents data on sky glow resulting from arrangement of lighting units in the Jacksonville Beach test area to simulate actual maximum night vehicle concentrations to be expected in 1/5 square mile of the densest traffic section of cities above 200,000 population (App. C). Of the 804 sealed beam headlamps used, 222 lamps were pointed north, 170 east, 222 south, and 190 west. Measurements were made from 5 miles north, south, and west of the area, and from 2 nautical miles east. The brightness produced by unshielded lamps was found to be hazardous to shipping at five miles from source of glow for atmospheric transmissions ranging from 65 to 75 per cent. This brightness would have been approximately one-half less for an atmospheric transmission of 95 per cent per 1000 feet. Hence, the higher atmospheric transmissions, and the presence of buildings along the streets (not typical of the test area) to absorb some of the light from the lamps would somewhat reduce the sky glow, but it is unlikely that the reduction would be sufficient to render sky glow from this typical arrangement of automobiles in a city non-hazardous at 5 miles. The combination

Jacksonville Beach, Florida

Since prior investigations had shown that the probable maximum number of vehicles using headlights to be expected in the densest traffic section of one-fifth square mile of any city above 200,000 population is approximately 500, 804 sealed beam headlamps were used to simulate actual vehicular spacings and directions in the Jacksonville Beach test area. 222 lamps were pointed north; 222, south; 170, east; and 190, west. Measurements of sky brightness produced were made from locations 5 miles north and south, 7 west, and 2 nautical miles east of test area. Results are tabulated below:

Measurements from		5 miles north				5 miles south				7 miles west				2 nautical miles east			
Treatment of lamps		Unshielded		Upper half shielded		Unshielded		Upper half shielded		Unshielded		Upper half shielded		Unshielded		Upper half shielded	
Headlight beam		Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving	Passing	Driving
Brightness micro-footlamberts	Inland horizon	11	12	16	16	10	10	16	9					–	–	–	–
	Zenith	65	45	32	45	24	24	47	36	Because	of	high horizon		85	–	–	–
	Sea horizon	27	10	17	11	12	14	16	9	measured	from this	posi-		50	31	50	34
	Test area horizon	105	125	70	75	1440	570	40	180	tion,	low clouds	prevented		4300	5400	1700	3000
	Sky glow - Test area horizon minus natural horizon	93	113	54	59	1430	560	24	171	the glow.	observation	of	any	4250	5369	1650	2966
Atmospheric transmission per 1000 feet		76.3%	68.9%	93.5%	73.0%	76.3%	68.9%	93.5%	73.0%					76.3%	68.9%	93.5%	75%

Notes: Because of extremely variable weather and atmospheric conditions, especially changing height of overcast, above readings are somewhat erratic and irregular. From station 5 miles south, with lamps unshielded, the passing beam gave approximately 3 times the brightness produced by the driving beam, whereas, in all former readings of driving versus passing beam, the driving beam produced higher brightness.

The absence of buildings in the test area and the absence of obstacles to vision between test area and stations 5 miles south and 2 miles east permitted the observation of extremely low horizons; hence very high readings were recorded. Readings from station 5 miles north are considered more representative of glow above a city.

Table 9d - Sky glow produced by maximum night concentration of city traffic.

of half shielding with passing beams, even for the high brightness range of the lower transmissions, reduced the sky glow measured from north and south stations (direction of maximum concentrations of lamps) to values within the range which naval observers in other tests indicated were non-hazardous to shipping. However, for large cities, the values obtained must be increased by factors established for the addition of sky glow brightnesses from areas in line (sub-par. 16b(2)) and from areas alongside (sub-par. 16b(3)). It is apparent that under certain conditions, automobiles using half shielded headlamps on passing beams in large cities within 5 miles of shipping lanes may produce glows hazardous to shipping during the early evening hours only, which are the hours of maximum light traffic. As the distance of the city from the shipping lane increases, atmospheric absorption of light rapidly reduces brightness apparent at the shipping lanes, and the hazard to shipping is thereby decreased. The concentration of automobiles investigated here was typical of conditions before gasoline consumption was greatly restricted; and it is probable that for distances over 5 miles from the shipping lanes, present city traffic employing half shielding and passing beams would provide a safe margin before the sky glow produced from those light sources only would become hazardous at any atmospheric transmission typical of average weather conditions in coastal areas.

(5) Sky glow produced by typical concentrations of motor vehicles on coastal highways. (a) In this test, automobiles of various makes with standard headlighting (only a few with sealed beam lamps) were arranged to simulate maximum traffic per mile on main coastal highways (App. G). Beginning at approximately 1 mile from shore line, 35 automobiles were spaced 150 feet apart with lamps pointing toward the sea, and in the adjacent lane 15 were spaced 350 feet apart and directed away from the sea. A four lane concrete highway (reflection factor 24 per cent) which ran on a line perpendicular to the coast line over relatively flat terrain was used. Direct light from the headlamps was obscured from observers by buildings, trees, and a baffle at the shore end of the highway. Data recorded at observation stations 2 miles south, 1.7 miles west, and 2 nautical miles east are given in Table 9e.

(b) The glow produced by unshielded headlamps (driving and passing beams) was in the hazardous range when observed both from the direction of the sea and from the station on the highway. The station at side of beams recorded non-hazardous glow. Half shielding in combination with passing beams reduced the glow to a range considered non-hazardous for the atmospheric transmission (81 per cent per 1000 feet) encountered during the test. While these 2 mile values for half shielding may be expected to increase with lower atmospheric transmissions and decrease with higher transmissions (for distances greater than 2 miles the values will be less for all transmissions), the fluctuation within the range of transmissions typical of coastal areas should never be sufficient to increase the sky glow to hazardous levels for maximum motor vehicle concentrations on coastal highways.

b. Street Lighting.- (1) Computation of sky glow.- The contribution to sky glow above a city by street lighting depends upon the types of luminaires, the wattage of the lamps, the reflection factor of the streets, the color, height and arrangement of nearby buildings, and the illumination on the street. Standard practice based on traffic flow is given in the table[1] below:

Street Classification	Traffic flow basis of street classification Maximum night hour traffic flow in both directions	Lamp Lumens	Mounting height of luminaire in feet	Spacing measured along middle line of street in feet
Very light traffic	Under 150	1000	15	90-110 staggered
		2500	20-22	130-170 "
		4000	25-30	200-250 center
Light traffic	150-500	2500	16-18	100-120 staggered
		4000	20-25	130-170 "
		6000	22-25	130-170 "
Medium traffic	500-1200	6000	20-25	100-120 staggered
		10000	22-27	130-170 "
		15000	25-30	130-170 "
Heavy traffic	1200-2400	10000	24-28	100-150 opposite
		10000	24-28	75-90 staggered
		10000	24-28	150-180 opposite
Very heavy traffic	2400-4000	15000	25-30	100-150 opposite
Heaviest traffic	Over 4000	15000	25-30	100 opposite

The wide variations from this practice found in most cities, and the lack of uniformity in practice between cities, make impossible the conduct of full scale tests to obtain data representative of amount of sky glow produced by normal city street lighting. However, fundamental data recorded at both the Point Pleasant and the Jacksonville Beach tests, when applied to street lighting of a city where actual conditions can be ascertained by survey, makes possible a reasonably accurate computation of the sky glow by substituting total

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[1] Street lighting standards of the Illuminating Engineering Society.

Jacksonville Beach, Florida

target boat 2 nautical miles offshore
observation boat 1000 yards farther

Condition of units		no shields						upper 1/2 shielded					
		driving beam			passing beam			driving beam			passing beam		
Measured from		1.7 miles west	2 miles south	boat	1.7 miles west	2 miles south	boat	1.7 miles west	2 miles south	boat	1.7 miles west	2 miles south	boat
Brightness micro-foot-lamberts	inland horizon	–	65	70	–	55	55	–	57	50	–	52	70
	zenith	170	110	110	175	120	100	180	125	110	180	130	110
	sea horizon	98	63	–	90	58	55	80	55	50	85	45	46
	test area horizon	1600	64	260	520	55	90	650	44	95	180	44	80
	Sky glow - test area horizon minus natural horizon	1502	0	190	430	0	35	570	0	45	95	0	10
Atmospheric transmission		82 % per 1000 feet											

Traffic surveys revealed that maximum night traffic on coastal highways was approximately 50 vehicles per mile -35 in one direction and 15 in the other. 50 automobiles were positioned on a mile of east-west highway which leads directly to the sea to simulate actual traffic, 35 facing the sea and 15 facing inland. Sky glow produced was then measured, as indicated in table, in line with the headlight-beams from a location at sea and from 1.7 miles west, also on a line perpendicular to the headlight beams at a location 2 miles south.

Table 9e- Sky glow produced by maximum night traffic on coastal highways.

emitted lumens above and below the horizontal from the street lighting luminaires in service, multiplied by proper maintenance and reflection factors, for L in the equation given in sub-paragraph 16c(4) as follows:

$$B_r = \frac{10^{18.02-15.56t} \, (1+f_1+f_1+f_2+f_2) \, AMP \, (L_a+RL_b) \, t^{5.28(n+\frac{A-1}{4})}}{1,000,000}$$

B_r - Sky glow from street lighting residual at any point

f_1, f_2 - additive factors for laterally adjacent and next laterally adjacent areas of unit width

A - number of areas of unit depth in line with point for which residual sky glow brightness is computed

M - Maintenance allowance - estimated lumen output of luminaires in per cent of lumen output with lamps and luminaires new and clean. A value of 80% may be a reasonable estimate in most municipalities.

P - Percentage of upward light from the luminaires and reflected from the street surfaces not absorbed by trees or buildings. This must be determined by actual conditions in the area under consideration

L_a - lumens which would be emitted above the horizontal by new, clean luminaires

L_b - lumens which would be emitted below the horizontal by new, clean luminaires

R - average reflection factor of the pavements

t - atmospheric transmission per 1000 feet

n - number of miles from area under consideration

The above equation is based on a reasonably even distribution of luminaires throughout the area for which glow is computed. If the luminaires are unevenly distributed, the equation must be broken into its component divisions of unit areas, as set forth in sub-paragraph 16c(4)(b), for more accurate computations.

(2) Types of luminaires.- A survey of luminaires in use by cities revealed that, in general, street lighting luminaires are divided into three distinct classifications: diffusing, redirective, and open reflector types. The generated lamp lumens emitted above and below the horizontal varies with each type as shown in the table below:

	Lumen, in per cent of lamp lumens		
	Diffusing luminaires	Redirective luminaires	Open reflector luminaires
Above the horizontal	35	7	5
Below the horizontal	35	53	75
Total	70	60	80

Since the angle at which the generated lamp lumens are emitted is an important factor in determining the brightness of the resultant glow, the above table should be used in establishing the values for substitution in the equation of sub-paragraph (1) above, when exact photometric characteristics of the luminaire are not known.

(3) Reflectance of street surface and surrounding buildings. Light directed toward roadway by luminaires will normally undergo many reflections before becoming a part of the sky glow over a city. Reflection factors of roadways and buildings may vary from 5% to 30%, and measurements should be made whenever possible to determine the proper values for substitution in the equation of sub-paragraph (1) in the interest of accuracy of results. Surveys indicate that, for average city conditions in business districts, less than 10% of the light incident on the street becomes effective in creating sky glow.

(4) Reduction in downward light accompanying restrictions in upward light.- Since dimout of street lighting usually requires shielding of luminaires to absorb light above the horizontal together with a reduction of lamp wattage, resultant hazard and retarded movement of essential traffic must be weighed in relation to the primary purpose of the light reduction. Visibility is essential to safety; and, at very low levels on roadways, visibility may become so poor that total blackout would be no more hazardous to traffic movement. As a basis for analysis, three degrees of reduction in upward light from luminaires are assumed: (a) Not more than 10% of lamp lumens above the horizontal, (b) not more than 3% of the lumens above the horizontal, and (c) practically no light above the horizontal. The per cent reductions in downward light which will accompany the above restrictions on upward light are set forth in the table below:

Estimated Reductions in Downward Light
Accompanying Restrictions in Upward Light

Per cent reduction in downward light by zones below the horizontal

Type of Luminaire	Restriction (a)		Restriction (b)		Restriction (c)	
	0-30°	30-90°	0-30°	30-90°	0-30°	30-90°
Diffusing	20	0	40	5	65	10
Redirective	0	0	10	0	75	0
Open reflector	0	0	5	0	20	0

Estimates based upon investigation of actual installations (see Appendix E) indicate that overall street lighting effectiveness with the above restrictions would be (a) 90-95 per cent normal (b) 70-90 per cent normal, and (c) 25-50 per cent normal. The figures given in the above table represent order of magnitude rather than exact values, and data based upon analysis of local conditions should be used whenever possible in study of reduced visibility accompanying proposed reductions in amount and distribution of street lighting.

c. Lighted show windows. (1) Test procedure.- A model show window of average size and proportions, wired for both fluorescent and filament lamps in standard reflecting equipment, was used. Measurements were made to determine the lumens emitted by various zones of the trim (background included) using typical reflection factors for merchandise and backgrounds. The effect of awnings, and dimout curtains was also studied. (See Appendix F for additional details.)

(2) Results. Graph 8 presents the approximate distribution of lumens emitted by both filament and fluorescent lighted show windows of the average store or service establishment in angular zones above and below the horizontal (zones for degrees 0 to 40 above nadir are not included). In the 0 to 40 degree zone above nadir estimation is difficult since, in the typical window, the emitted light is a mixture of light direct from the overhead unlouvered equipments and reflected from the merchandise and backgrounds. Ordinarily, the lighting units are so positioned near the top of the glass that direct light from the lamps and reflectors is incident upon the glass at a high angle. Much is reflected internally, the remainder causes a peak in illumination within a few feet of the building line. When either incandescent or fluorescent lighting is used, the lumens in the 0 - 40 degree zone vary between 1200 to 2000. Hence, total lumens emitted above and below the horizontal by average incandescent and fluorescent

lighted show windows with and without awnings and with and without typical cloth mesh dimout curtains are as follows:

Lumens emitted from an average show window

Incandescent Lighted

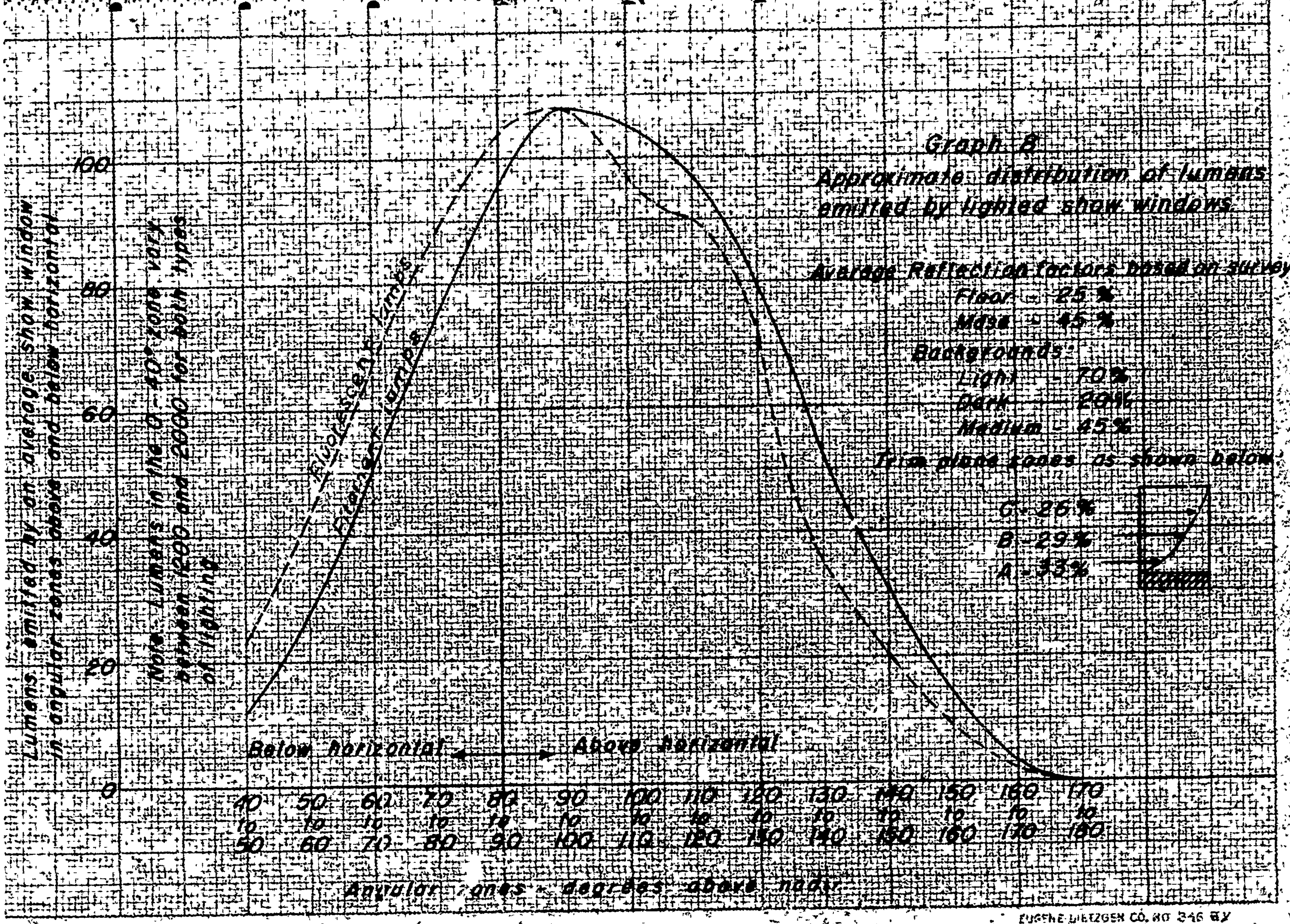
	No Awning		Awning	
	No curtain	Curtain	No curtain	Curtain
Below Horizontal	1462 to 2262	150 to 220	1462 to 2262	150 to 220
Above Horizontal	489	120	190	50

Fluorescent Lighted

	No Awning		Awning	
	No curtain	Curtain	No curtain	Curtain
Below Horizontal	1525 to 2325	165 to 235	1525 to 2325	165 to 235
Above Horizontal	431	105	140	35

With no dimout treatment or awnings for the window, the total light emitted upward is less than 500 lumens, about equivalent to total output of a 40-watt filament lamp. With a lowered awning, the total light emitted upward ranges from 140 to 190 lumens, the lower figure representing the output of a 15-watt filament lamp. With dimout curtain only, the total light emitted upward is not more than 120 lumens, or less than the total output of a 15-watt filament lamp. With both curtain and awning, the light emitted upward is about equivalent to the total output of a 6-watt filament lamp. All of the lumens emerging below horizontal, in the typical case, must undergo one or more reflections at relatively low reflection factors before reaching the upper air; and a considerable part of all upward light is intercepted by buildings and trees which generally have low reflection factors. It is logical to assume that less than 1/2 of the lumens incident on the sidewalk would reach the upper air without secondary reflections. Dimout curtains on show windows are very effective in reducing light emitted upward as well asthe relatively large numbers of lumens emitted below the horizontal.

(3) Sky glow calculations. By applying reflection factors of surroundings as determined by measurement of actual conditions to values of Graph 8 and above tables, total lumens reaching the upper atmosphere from the average show window can be appoximated. The sky glow resulting from the window may then be calculated by substitution of the proper values in general formula given in sub-paragraph 16c.(4)(b). Total sky glow from show windows will therefore depend upon their concentration in a given area. Data are available (see Appendix F) on the average



Graph B

Approximate distribution of lumens emitted by lighted show windows.

number of display windows in cities of various populations. However, general computations of sky glow should be based on local surveys where possible, since population alone is no true index of the concentration of lighted show windows in a given area.

d. Other types of lighting. The foregoing sub-paragraphs have dealt with analysis of sky glow produced by three specific types of lighting. Sky glow contribution by any type of lighting may be computed by the general formula given in sub-paragraph 16c.(4)(b) if the lighting is diffused, or by variation in sky glow according to zones of emitted lumens for different directions of viewing if the light is not diffused, as given in Graph 6 and Appendix E. For the latter method, variation at source of sky glow with atmospheric transmission may be taken from the direct beams curve of Graph 3.

21. Light Sources and Illuminated Surfaces Visible from the Sea. In addition to reduction or elimination of sky glow, coastal dimout is concerned with lights which may be directly visible from the sea, including light sources themselves, the glow which may be produced around lighting fixtures under certain conditions, and the brightness of illuminated surfaces. Such light may be effective for great distances in aiding submarines to locate and identify ships. To obtain data on this phase of the dimout problem, various tests were conducted with specific light sources and illuminated surfaces, including automobile and bus lighting, traffic signals, minor aids to navigation, small and large vertical surfaces, and large horizontal surfaces. Experienced naval officers were stationed at 1000 yards from the target boat which plied back and forth in front of the light source or illuminated surface at distances of 2 nautical miles and 5 nautical miles. These officers judged the hazard to shipping caused by each type of lighting tested, and when possible, directed reduction in illumination to non-hazardous levels. All such observations were made during the dark of the moon.

a. Automobile and bus lighting. (1) Eight automobiles with various types of head and tail lighting and a 35 passenger bus with normal interior illumination were used at Point Pleasant, New Jersey, for determination of hazard to shipping effected by motor vehicle lighting. Naval observers with the unaided eye and with night binoculars (7.5) determined which lights constituted a hazard to shipping at a distance of 5 nautical miles. Table 10 sets forth the results obtained. The zenith, sea horizon, and inland horizon brightnesses recorded during test were respectively 220, 90, and 110 micro-footlamberts. This table reveals that all exterior lighting of motor vehicles, including half-shielded headlamps, 250 beam candlepower headlamps, and tail lamps, when pointed seaward constitute a hazard to shipping, if observers use night binoculars. The standard blackout driving light when pointed seaward was declared hazardous because it was improperly aimed, which projected the beam horizontally rather than 1 degree below the horizontal.

(2) With vehicles moving parallel to the coast line; i.e., with the vehicles moving on a path perpendicular to the line of sight of the sea observers, half-shielded headlamps on both driving and passing beams, 250 beam candlepower headlamps, blackout headlamps, parking lights, and tail lamps proved to be non-hazardous when sea observers with night glasses were stationed 5 nautical miles offshore. However, under actual conditions, this arrangement between the moving vehicle and the sea observers is never maintained for an appreciable time. Even when a road is exactly parallel to the coast, sea observers have a zone of maneuver of 180 degrees within which they can so position themselves that their line of sight is not perpendicular to the path of either one or the other direction of traffic. Curved roads, inlets of the sea, and similar features, of course, always establish a number of points from which vehicle lighting will be directed seaward.

(3) The normal interior illumination of 2.56 horizontal footcandles at top of seat arms of the 35 passenger bus used in the study proved barely satisfactory when viewed with night glasses from 5 nautical miles at sea. This illumination must be considerably reduced when the viewing distance is decreased to 2 nautical miles.

(4) Table 10a presents data similar to the above which were obtained with the target boat 2 nautical miles from the light sources and the naval observers 1000 yards farther. A special test car (fig. 31) equipped with various types of headlights so arranged that any desired voltage could be obtained and a Navy bus (on left under windows, fig. 45) were used in this test.

(5) With the target boat 2 nautical miles away, all lighting tested, with the exception of the American standard blackout headlamp, was in the judgement of the experienced naval observers hazardous to shipping, both while the light was pointed directly seaward and while the vehicles were moving parallel to the coast line (perpendicular to the line of sight of observers). Parking lights and tail lamps were not observed during this series of tests; however, they had been declared hazardous from 5 nautical miles when they were pointed directly seaward, and it can be assumed, in view of the one volt permitted on sealed beam headlamps, that they are hazardous when moving parallel to the sea with target boat 2 nautical miles away. It can therefore be con-

Target boat 5 nautical miles offshore
Spring Lake, New Jersey, November 17, 1942
Street lights were extinguished during test.
Atmospheric transmission not determined, slight haze.
Zenith-220 micro-footlamberts, sea horizon-90 micro-footlamberts;
Inland horizon-110 micro-footlamberts.

Observation		Driving beams		Passing beams		One-half shielded headlamps:				250 b.c.p. headlamps		Parking lights		Tail lights		Blackout driving lamp aimed upward	Blackout driving lamp properly aimed		Bus with normal interior illumination (d)
						Driving beams		Passing beams											
		Pointed seaward	Moving parallel to sea	Pointed seaward	Moving parallel to sea	Pointed seaward	Moving parallel to sea	Pointed seaward	Moving parallel to sea	Pointed seaward	Moving parallel to sea	Pointed seaward	Moving parallel to seu	Pointed seaward	Movining parallel to sea	Pointed seaward	Moving parallel to sea.	Pointed seaward	Stationary
Unaided eye	Hazardous	✓		✓		✓		✓		✓									
	Non-hazardous		✓		✓		✓		✓		✓	✓	✓	✓	✓	(b) ✓	✓	✓	✓
Night glasses	Hazardous	✓	✓	✓	(a) ✓	✓		✓		✓		✓		✓		✓	(c) ✓		
	Non-hazardous						✓		✓		✓		✓		✓			✓	Barely satisfactory
Type of Automobile		1941 Plymouth		1942 Plymouth		1939 Ford				---		1942 Chevrolet–		1942 Ford		---	---		---

(a) Passing beams while moving parallel to the sea are hazardous only when flux to right of vehicle illuminates objects which can be observed from the sea.

(b) This blackout driving lamp was aimed too high and beam passed over observers.

(c) This blackout driving lamp proved to be aimed higher than 1 degree below the horizontal.

(d) Horizontal foot candles at top of seat arms in center of bus - 2.56

Table 10- Hazard rating of motor vehicle lighting with target boat 5 nautical miles therefrom.

Target boat 2 nautical miles offshore
Atlantic Beach, Florida
Area blacked out
Zenith-135 micro-footlamberts; sea horizon-55 micro-footlamberts; Inland horizon-66 micro-footlamberts.

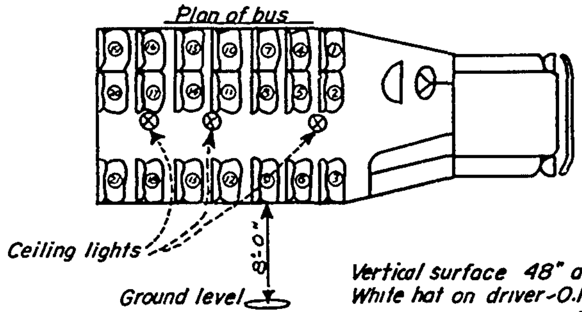
Observation		Driving beams		Passing beams		Headlights 1/2 shielded				250 b.c.p. headlamps		Blackout driving lamp properly aimed		Bus with normal interior illumination
						Driving beams		Passing beams						
		Pointed seaward	Moving parallel to sea	Pointed seaward	Moving parallel to sea	Pointed seaward	Moving parallel to sea	Pointed seaward	Moving parallel to sea	Pointed seaward	Moving parallel to sea	Pointed seaward	Moving parallel to sea	Stationary
Night binoculars	Hazardous	✓ⓐ	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓ⓒ
	Non-hazardous											✓ⓑ	✓	

ⓐ When voltage on sealed beam headlights was reduced to one volt, they were declared non-hazardous when pointed directly at naval observers. Such voltage, of course, produces no useful light.

ⓑ This is a border-line case. As long as the vehicle is moving, the blackout lamp is non-hazardous. If vehicle is stationary, there is some question whether or not the lamp would be hazardous.

ⓒ When interior illumination of bus was reduced to non-hazardous levels the values below were obtained.

Position	Height above floor	Footcandles 45° plane
①	36"	0.16
②	36"	0.38
③	36"	0.15
⑧	36"	0.034
⑳	36"	0.02



Vertical surface 48" above floor-maximum 0.15 f.c.
White hat on driver-0.1 f.c.
Bottom step-0.044 f.c.
Ground level, 8'-0" from bus-0.008 f.c.

Table 10a–Hazard rating of motor vehicle lighting with target boat 2 nautical miles therefrom.

cluded that any type of normal exterior vehicle lighting must be extinguished when vehicles move on roads or streets which permit direct viewing from 2 nautical miles or less at sea, and any exterior lighting which is non-hazardous to shipping, with the exception of blackout headlamps, is of no driving value, except as markers.

(6) The illumination level permitted in the bus when the target boat was 2 nautical miles therefrom is considerably less than that permitted when the target boat was at a distance of 5 nautical miles. The illumination as measured inside the bus on a 45° plane 36 inches above the floor varied for different points of the interior from 0.02 footcandles to 0.38 footcandles (approximately the illumination provided by full moonlight to 19 times the illumination provided by full moonlight). This level of illumination is sufficient to provide safety of movement within the bus.

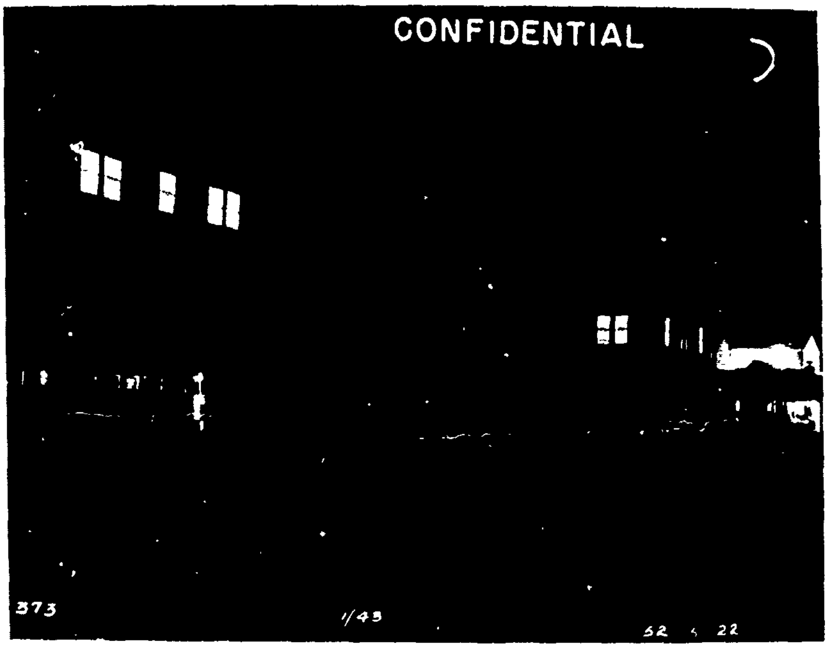


Fig. 45
View of bus in position for test of interior illumination. Windows above bus and to the right were used to determine maximum permissible window brightness when target boat is 2 nautical miles from them.

b. Traffic signals. (1) Voltage on a standard three color light traffic signal employing 60 watt 120 volt lamps and center suspended at approximately 14 feet above road level (this was approximately 24 feet above sea level) was reduced at the direction of naval observers from 2 nautical miles away until the signal was no longer considered hazardous. A voltage of 32 volts was found to be non-hazardous but signal indications were poor on all but dark, moonless nights.

(2) When the yellow traffic signal lens (selected because of its higher light transmission factor) was fitted with a louver consisting of 6 vanes, each 6 inches in length, spaced evenly along lens diameter and bent downward at an angle of 7 degrees, the operating voltage which produced non-hazardous brightness was found to be 42 volts. The combination of louvers and 42 volts on the lamps produces color indications adequate under full moonlight for the control of traffic at distances between 10 to 300 feet from the signal (distance specified for all light and atmospheric conditions except dense fog by the Manual on Uniform Traffic Control Devices for Street and Highways). Such indications, however, are not adequate as signals during daylight.

(3) The above data provide a basis for the treatment of traffic signals which are directly visible from the sea. On the other hand, no modification of traffic signals is required from the standpoint of reduction of sky glow (i.e., in areas not directly visible from the sea). The amount of light above the horizontal from a traffic signal employing 60 watt, 120 volt lamps is approximately as indicated below:

Color of lens	Lumens above the horizontal
Green	7.4
Red	18.3
Yellow	28.8

A portion of this light is absorbed by trees and buildings. Therefore, upward light from the number of traffic signal lamps operating simultaneously in a city is insignificant. For example: On the basis of city squares 300 feet by 300 feet, with every intersection controlled by standard three light traffic signals, one for each direction of traffic movement, approximately 256 lamps would be operating simultaneously for a major part of the traffic cycle in an area 1/2 mile by 1/2 mile (384 traffic signal lamps for a small portion of the signal cycle). The above figures will have to be raised by an appropriate factor for cities which employ more than one signal face per direction of traffic movement.

c. Street and highway lights. Throughout the offshore observations, the naval observers complained that shaded street lights on shore were definitely hazardous to shipping at distances of nearly 4 nautical miles. They were declared non-hazardous at greater distances. The street lights observed were of two types - (1) a lamp, without globe, operated base down and shaded by a deep conical shield, and (2) normal street lighting luminaires with the globe made opaque with paint except for a vertical slit on the side away from the ocean and incased in a cylindrical shield, having an opening in juxtaposition to the slit (some light, however, was projected through the top and bottom of the hood). Since the light source, bulb, and diffusing globe when used were shielded in both instances from direct viewing from the sea, the hazardous light or glow detected by the naval observers was produced by a "halo" effect around the shields. Because of this halo effect, these methods of shielding street and highway lights from sea observation do not eliminate hazard to shipping within 4 nautical miles of them. Further, such shielding permits only small splotches of light on the roadway surface within their immediate vicinity with very dark areas between, thereby creating conditions particularly unfavorable for safe traffic movement. However, the fact that these shielded lights did not constitute a hazard to shipping at distances greater than 4 nautical miles suggests that many street and highway lights which are farther than 4 nautical miles from shipping lanes may be modified by less restrictive shields to eliminate hazard to shipping and yet retain a reasonable measure of their usefulness, provided that large vertical surfaces visible from the sea are not illuminated to hazardous levels (see sub-par. e(2) below). Methods of providing non-hazardous illumination on ground areas within 4 nautical miles of shipping lanes are given in paragraph 22.

d. Minor aids to navigation. (1) Tests of the possible assistance in locating and attacking ships given to enemy submarines by minor aids to navigation were conducted in cooperation with the Aids to Navigation Section, Headquarters, United States Coast Guard. The test apparatus consisted of the following:

(a) Three 200 mm 3rd District type waterproof buoy lanterns with pressed glass lenses - one clear, one type C red shade, and one type C green shade.

(b) Power source consisting of twelve cells Willard DH5-1, 500 ampere hour, low discharge cells connected in two parallel banks of six cells each tapped for both 12 and 6 volt supply.

(c) Ten Wallace and Tiernan, type FU-639, 6-10 volt, single contact flasher mechanisms, with cams cut to give the following flashing characteristics:

Cycle	On	Off	On	Off
Sec.	Sec.	Sec.	Sec.	Sec.
10.0	1.0	9.0		
10.0	5.0	5.0		
10.0	0.5	9.5		
5.0	1.0	4.0		
5.0	0.2	4.8		
4.0	0.4	3.6		
4.0	0.2	0.6	0.2	3.0
3.0	0.2	2.8		
3.0	0.3	2.7		
1.0	0.3	0.7		

(d) Three Wallace and Tiernan, 6-15 volt, Type FU-1297, four-lamp lamp changers.

(e) Supply of S-11, C-8 filament, prefocus base lamps of following sizes:

6.2 V - 0.25 A
6.2 V - 0.70 A
12.0 V - 0.55 A
12.0 V - 1.35 A
12.0 V - 3.05 A

(2) The above apparatus was installed on the east parapet of the roof of the Atlantic Beach Hotel (see figs. 8, 32, and 46) at a focal plane height of 29 feet $8\frac{1}{2}$ inches above high water and connected to facilitate rapid changes in candlepower, color, and flashing characteristics.

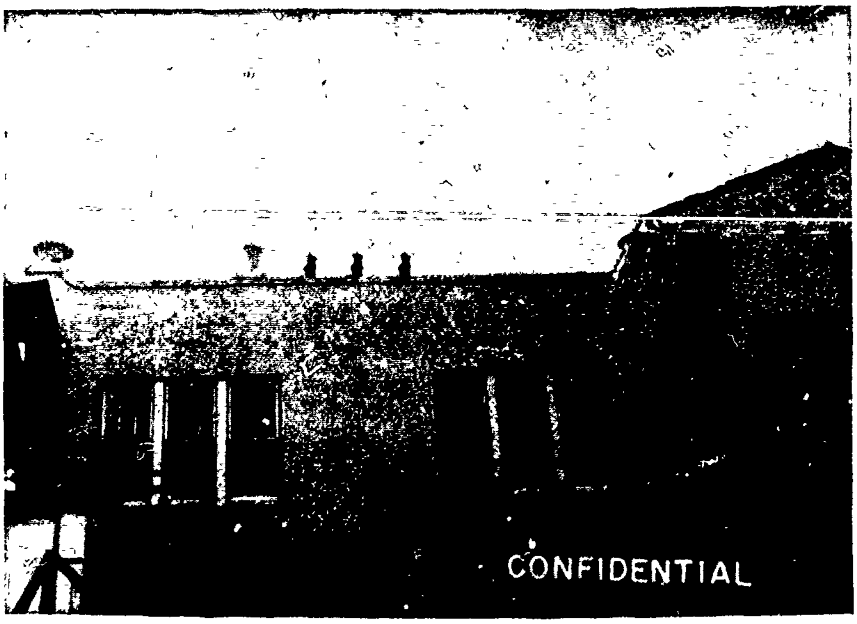


Fig. 46 -- Minor aids to navigation installed on parapet of Atlantic Beach Hotel. View from seaward side.

(3) Preliminary observations on land by naval observer eliminated further test of a number of the flashing and intensity characteristics because of obvious aid which would be given to submarines in detecting ships. On the following night, observations were made from the sea with the target boat 2000 yards from the shore and the naval observers using night binoculars (7.5) 1000 yards farther. During the observations, atmospheric transmission of light per 1000 feet varied between 87.3 and 91.3 per cent. The sky was clear throughout duration of test, visibility was 12 miles, wind was from the northwest with a velocity between 6 and 12 miles per hour, and relative humidity varied between 68 and 73 per cent. Sky and inland horizon brightnesses recorded from the sea at beginning of test were respectively 150 and 40 micro-footlamberts. Table 11 lists the observations on hazard rating of minor aids to navigation of various color, intensity, and flashing cycles in respect to possible aid provided enemy submarines in locating coastal shipping. Conclusions reached by the naval observers as result of this test are as follows:

(a) Maximum permissible candlepowers for flashing or fixed minor aids to navigation, on the basis of eliminating possible assistance afforded enemy submarines in locating coastal shipping at night, for the colors listed are:

Red	165
Clear	90
Green	30

(b) Flashing lights give less assistance to submarines than fixed lights.

(c) The degree of possible assistance given by minor aids to navigation to submarines in locating and attacking ships decreases as the eclipse period increases and as the length of flash decreases. For maximum freedom of ships from detection by submarines, the eclipse period is theoretically infinite and the length of flash zero, practically they should be the maximum and the least respectively that can be used to attain the required functions of illuminated minor navigational aids.

e. Non-hazardous brightnesses of vertical surfaces. (1) Small surfaces.- The maximum brightnesses of small vertical surfaces incapable of providing aid to submarines in locating and attaching their prospective targets were determined by means of illuminated windows. The windows were covered with diffusing screens and illuminated from the interior of the rooms by special light boxes so designed that various intensities could be obtained without color change in the lighting. (See Fig. 47 for typical arrangements). Naval observers directed reduction in window

Fig. 47
Typical arrangements, showing diffusing screen on window and special light box, for test of maximum permissible brightness of small vertical surfaces visible from the sea.

brightness until levels non-hazardous to shipping were obtained. Ten consecutive windows on the third floor of the Monmouth Hotel at Spring Lake, New Jersey, were used with the target boat 5 nautical miles therefrom; results are set forth in Table 12. (Also, see figs. 48 and 49). Further tests conducted with target boat 2 nautical miles from 9 windows, including 3 double windows, of the second floor of the Atlantic Beach Hotel, Atlantic Beach, Florida, (see fig. 45) resulted in determination of maximum permissible brightness for that distance when the naval observers used night binoculars. Comparative figures when night binoculars are used for the observations for the two distances and conditions are listed below:

	Target boat 2 nautical miles from windows	Target boat 5 nautical miles from windows
Maximum permissible brightness	.009 footlambert	.05 footlambert
Number of windows	9 (6 single, 3 double)	7 single
Size of windows		
Single	36 inches by 60 inches	32 inches by 42 inches
Double	72 inches by 60 inches	
Atmospheric transmission per 1000 feet	80 to 84.7 per cent	81 per cent

Target boat 2000 yards from the aids to navigation with observation boat 500 to 1000 yards farther. All observations made with aid of night binoculars (7.5)

	Color	Clear					Red			Green				
	Intensity (a)	1050 c.p.	553 c.p.	90 c.p.	43 c.p.	43 c.p.	165 c.p.	165 c.p.	165 c.p.	165	83	30	30	30
	Flashing Characteristics	Steady	Steady	Steady	Steady	On .3 sec. Off 2.7 sec.	Steady	On .5 sec. Off 9.5 sec.	On .4 sec. Off 3.6 sec.	Steady	Steady	Steady	On .5 sec. Off 9.5 sec.	On .4 sec. Off 3.6 sec.
Hazard	Hazardous	✓	✓							✓	✓	✓		
	Non-hazardous			✓	✓	✓	✓	✓	✓				✓	✓
	Remarks of naval observers	Halo was pronounced. Silhouette was fair.	Very little silhouetting or halo.	White need not be reduced.	None	No halo, no glow. Short dark period does not contribute to non-hazardous rating	No halo or silhouette	If such a period could be used, it would be less of an aid to submarines than a shorter period	Submarine could estimate length of prospective target quite closely	Slight halo and silhouette	Still a trifle green halo	Getting to threshold	Saw nothing. No halo. Period of darkness is max. for confusion of submarine	Short dark period does not contribute to non-hazardous rating

(a) Candlepowers have been corrected for voltage drop.

Table II-Hazard rating from the standpoint of revealing ships to submarines of minor aids to navigation with various colors, intensities, and flashing characteristics.

(2) Large surfaces.- The east walls of the bath house of the Atlantic Beach Hotel, as shown in figure 50, were illuminated by floodlamps, and the resulting brightness was reduced at the direction of naval observers until it was declared non-hazardous to shipping at a distance of 2 nautical miles from it.

Fig. 48 -- A stage in the reduction of window brightness, Spring Lake, New Jersey.

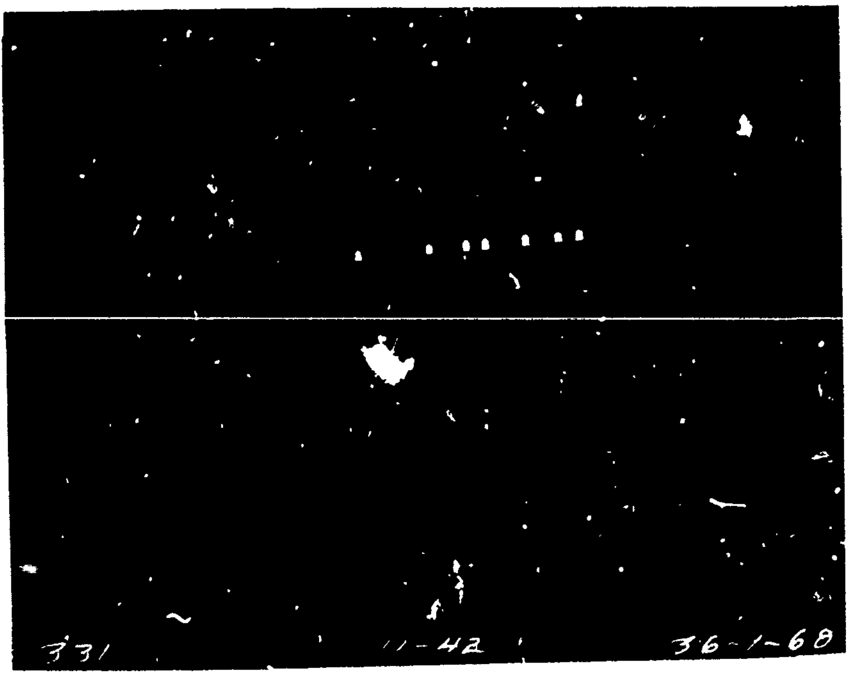


Fig. 49 -- Brightness of these windows (0.123 footlamberts) was declared non-hazardous to shipping at distances of not less than 5 nautical miles when naval observers used unaided eyes. A brightness of 0.05 footlamberts was declared permissible when observers employed night binoculars.

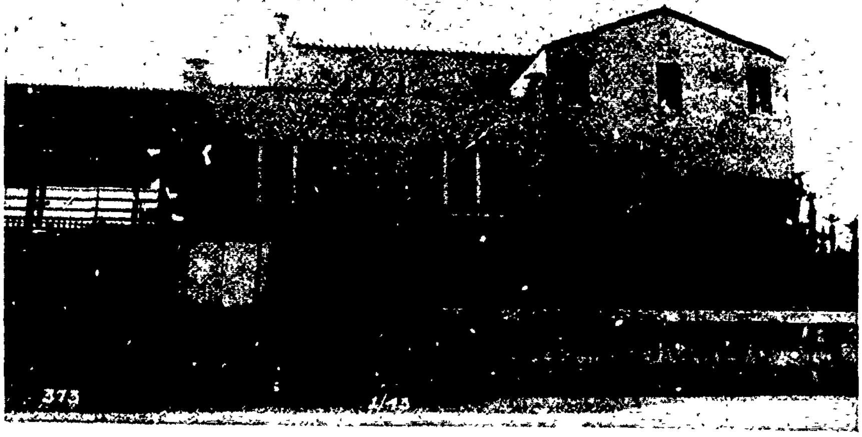


Fig. 50
East walls of bath house of Atlantic Beach Hotel. White stucco with reflection factor of 54 per cent - Jacksonville Beach tests.

The wall in the foreground shown by Figure 50, was 16 feet high by 36 feet wide, while the one with the inverted "V" roof was 25 feet high at the sides by 31 feet wide, or a total area of 1200 square feet; both were of white stucco with a reflection factor of 54%. The brightness of this wall declared non-hazardous to shipping was .0006 footlambert as compared with the .009 footlambert obtained for the windows. Hence, maximum permissible brightnesses of vertical surfaces decrease as the illuminated area increases. However, the permissible brightnesses of vertical surfaces greater than 15 square feet are so low that they approach blackout levels.

f. Use of approved indoor blackout lamps. War Department approved indoor blackout lamps or units used to furnish a low level of illumination either outdoors or indoors do not produce a hazard to shipping at distances of 2 nautical miles or more. When ten consecutive rooms of the third floor of the Monmouth Hotel at Spring Lake, New Jersey, were equipped in the proper manner with approved indoor blackout lamps, the illumination provided was not even detected when viewed 5 nautical miles

Target boat 5 nautical miles from windows

Size of windows: 32 inches by 42 inches

Atmospheric transmission: 81% per 1000 feet

Window number [(a)]		1	2	3	4	5	6	7	8	9	10	Average
Non-hazordous brightness (footlamberts)	Unaided eye	.15	out	out	.057	.108	.109	out	16	.078	.20	.123
	Night binoculars	.054	out	out	.041	.072	.044	out	.05	.042	.048	.050

(a) Windows are numbered from south to north.

Table 12-Maximum permissible brightnesses of small vertical surfaces with target boat 5 nautical miles therefrom

therefrom. During the Jacksonville Beach tests, a wooden porch, 115 feet long and 25 feet wide (see fig. 8), of the Atlantic Beach Hotel, was equipped with 8 indoor blackout lamps on 12 foot centers, and mounted at 8 feet 3 inches above floor level. The porch overlapped the white wall (reflection factor 54 per cent) of the building for 40 feet. The orange light from the lamps produced a wall brightness of 500 micro-footlamberts. From 2 nautical miles away, the light provided by the eight lamps, including the wall brightness, was not even detected. Hence, on porches, in yards, in corridors or rooms having windows visible from the sea, and similar places, a low level of illumination sufficient to permit safe, comfortable movement without creating a hazard to shipping at distances of 2 nautical miles or more therefrom may be obtained by use of War Department approved indoor blackout lamps.

22. Illumination of Ground Areas in Locations Visible from the Sea. a. For study of permissible levels of illumination on roadways and other ground surfaces in areas visible from the sea, and the utility of such illumination for traffic movement, a section of Atlantic Boulevard in Atlantic Beach, Florida, (App. A) was selected. This roadway is perpendicular to the shore line. Its surface is part red brick with reflection factor of 16.8 per cent and part concrete with reflection factor of 24 per cent. The seaward end was equipped with a 10 foot high, whitewashed baffle having a reflection factor of 80 per cent. Three 150 watt PAR 38 bulb floodlamps in deep hoods were installed on existing poles at a height of 18 feet above ground. These lamps were spaced 420 to 450 feet apart, directed to avoid illuminating vertical surfaces insofar as practicable, and so connected that illumination on the roadway surface could be varied at will. A perspective sketch of the arrangements is given by Figure 51. Naval observers stationed 1000 yards farther at sea than a target boat which was 2 nautical miles from the test area directed adjustment of the various combinations of illumination possible to non-hazardous levels for the atmospheric transmission conditions prevailing (82.7% per 1000 feet). After permissible illumination had been established, citizens of the community cooperated by furnishing and driving their private cars, and commenting on traffic safety and operating conditions when vehicles do not use any lighting.

b. First, the baffle alone was illuminated on the land side by means of floodlamps until the glow produced around the baffle was no longer hazardous from the ship silhouette standpoint. This brightness as recorded from the observers' boat was 55 micro-footlamberts; inland horizon brightness was 42 micro-footlamberts; and zenith brightness was 95 micro-footlamberts. Brightness of baffle on land side under above conditions was 6.7 footlamberts at vertical center line, and 3.7 and 2.4 footlamberts fifteen feet to right and left of center line respectively.

Driving tests conducted without any vehicular lighting revealed that the illuminated baffle finely silhouetted objects and persons up to considerable distances from the baffle when directly in the line between approaching cars and the baffle, but persons and vehicles moving into the roadway from sidewalks and cross streets were not noticeable until in line with the baffle. The sudden appearance of such persons or vehicles from darkness at the side of the road was extremely dangerous. Driving away from the baffle was, of course, similar to driving without any illumination except the natural brightness inherent in dark, moonless nights, and was very hazardous. Pedestrians had great difficulty in detecting vehicles approaching the baffle. Such a system of lighting proved inadequate for driving even at very low speeds and was adjudged totally impractical.

c. Next, the three floodlamps were turned on and the lighting of both the baffle and roadway was adjusted until brightness of the test area was termed non-hazardous by the naval observers. This brightness as recorded from the observers' boat was 46 micro-footlamberts while inland horizon brightness was 42 micro-footlamberts. Brightness of land side of baffle was 0.35 footlambert at the vertical center line and 0.35 and 0.15 footlambert 15 feet to the right and left thereof respectively. Brightnesses of the roadway surface were as follows:

Roadway Brightnesses in Footlamberts

Distance from mounting pole along center line of light pattern	Lamp No. 1 (nearest ocean)	Lamp No. 2 (second from ocean)	Lamp No. 3 (farthest from ocean)
15 feet	.05	.005	.002
30 feet	.02	.002	- -
45 feet	.008	- -	- -
60 feet	.003	- -	- -
Roadway surface	Red brick	Concrete	Concrete
Reflection factor	16.8%	24%	24%

The above illumination on the street (a maximum of approximately .3 footcandle on the brick pavement) proved adequate for driving at low speeds (12 to 15 miles per hour) with light traffic, and is just below the recommended average value for medium traffic (500 to 1200 vehicles per hour). However, the recommended value of illumination from street lighting alone is predicated on the continued use of headlights; nevertheless, such illumination when headlights are not used is adequate for

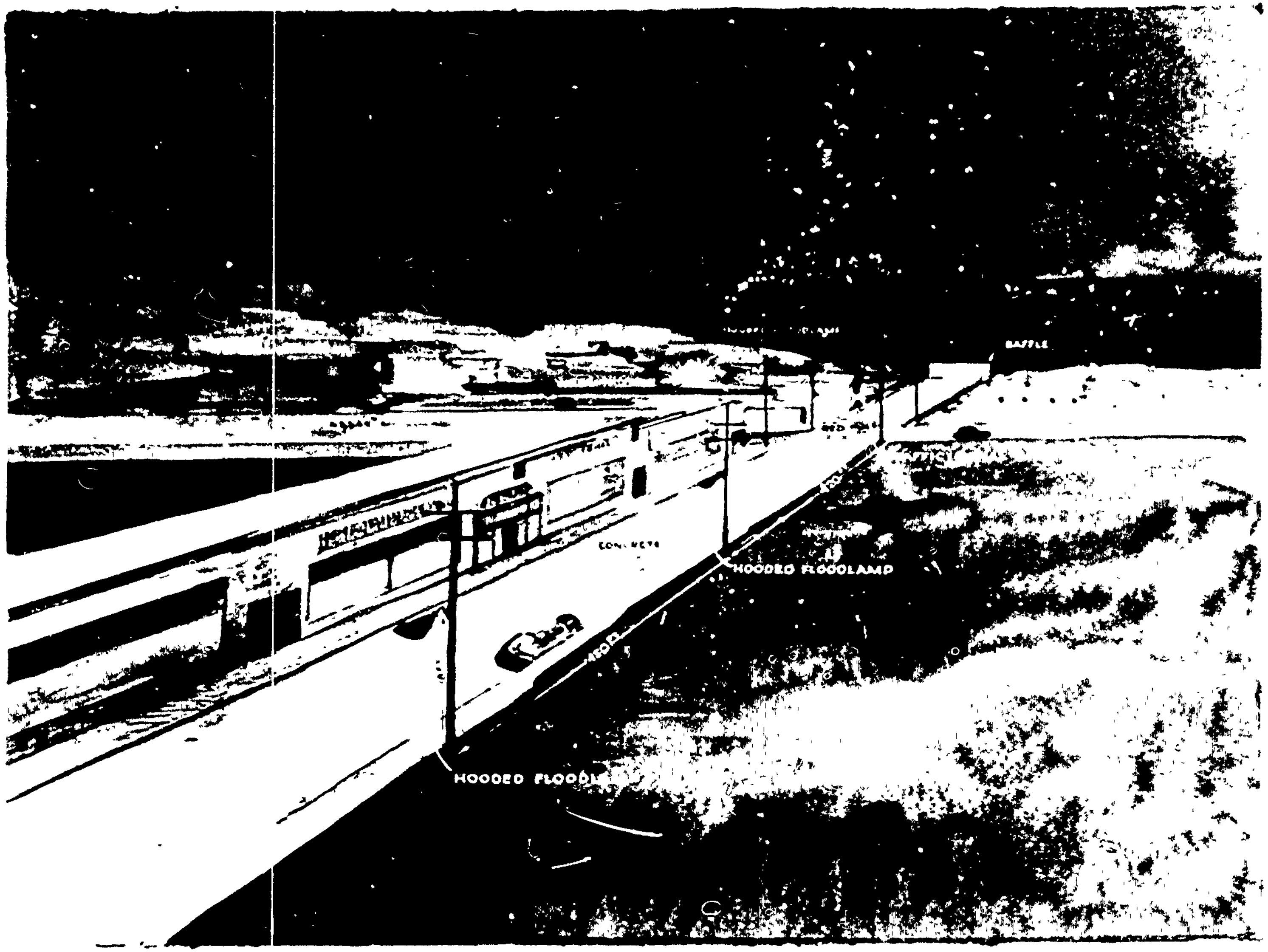


FIG 51
ARRANGEMENT OF FLOODLAMPS AND BAFFLE FOR
SPECIAL STREET LIGHTING TEST
JACKSONVILLE BEACH, FLORIDA

light traffic at low speeds when careful attention is paid to personal safety by both drivers and pedestrians. The illuminated baffle provided little additional aid to drivers except for those approaching it, and such illumination is not considered of practical value.

d. After completion of driving tests for the combination of illuminated baffle and street lighting, the baffle was removed and the street lighting increased until the naval observers indicated that maximum allowable from ship silhouette standpoint had been reached. Brightness of the test area then measured from the observers' boat was 45 micro-footlamberts, while inland horizon brightness was 30 micro-footlamberts. Brightnesses recorded on the roadway surface were as follows:

Distance from mounting pole along center line of light pattern	Roadway Brightnesses in Footlamberts		
	Lamp No. 1 (nearest ocean)	Lamp No. 2 (second from ocean)	Lamp No. 3 (farthest from ocean)
15 feet	.07	.01	.01
30 feet	.05	.05	.05
45 feet	.01	.02	.02
60 feet	.005	- -	- -
75 feet	.002	- -	- -
Roadway surface	Red brick	Concrete	Concrete
Reflection factor	16.8%	24%	24%

This provided a maximum illumination on the roadway surface of .4 footcandle which is the recommended average for street lighting (when headlights are also used) for streets subject to medium traffic. This illumination was judged adequate for safe operation of motor vehicles in light traffic at speeds up to 15 miles per hour, provided intensive use is made of traffic control markings and drivers and pedestrians practice reasonable caution.

e. The principle criticisms of the experimental street lighting concerned the glare from the floodlamps and the non-uniformity of the light pattern on the roadway surface which left dark spots between the lamps. Since glare and non-uniformity of light can be eliminated by a properly designed system, little significance is attached to the criticisms.

f. When a system of dimout street lighting is installed on sections of roadways visible from the sea, care must be exercised to prevent hazardous glow or "halo" effects which may be produced under certain conditions (see sub-par. 21c). Full utilization should be made of natural shielding provided by trees, buildings, and other growth and structures.

23. Summary of Results. a. Fundamental laws controlling sky glow.- Fundamental relationships between amount and distribution of light, atmosphere, and resultant sky glow, as established by this report, permit accurate calculations of sky glow brightness which, under any conditions of atmosphere, would be residual in any direction and at any distance from the source of upward light. These relationships are expressed as follows:

(1) Sky glow resulting from a lighted area is a function of concentration of the lighting units, the amount and distribution of the light, and the prevailing atmospheric transmission (sub-par. 16c and par. 19). Sky glow produced at source of diffused upward light is computed for unit areas (1/2 mile by 1/2 mile) by the following equation (sub-par. 16c(3):

$$B_i = \frac{L\ 10^{18.02-15.56\ t}}{1,000,000}$$

(2) For diffused light, width of area operative in causing build-up of sky glow brightness at the center of the width is $2\frac{1}{2}$ miles, i.e., lighted areas to a distance of one mile each side of an area of $\frac{1}{2}$ mile in width add part of their brightness to the brightness produced by the upward light in the area of $\frac{1}{2}$ mile width alone. These additive factors vary inversely as the atmospheric transmission. (sub-par. 16b(3)(c). The equation for computation of sky glow at source over the long dimension of an area $\frac{1}{2}$ mile in depth and more than $\frac{1}{2}$ mile in width is as follows (sub-par. 16c(3):

$$B_i = \frac{10^{18.02-15.56t}\ (1+f_1L_1+f_1L_2+f_2L_3+f_2L_4)}{1,000,000}$$

(3) Artificial sky glow brightness residual at all distances from source of upward light varies directly with the nth power of the atmospheric transmission. This relationship is expressed by the equation, $B_r = B_i\ t^n$; B_r is apparent brightness at any location, B_i is apparent brightness at any other location in line with the B_r location and source of upward light, t is atmospheric transmission per unit distance, and n is the distance between B_r and B_i divided by unit distance (sub-par. 16a).

(4) Residual brightnesses of two or more sky glows at any location from which they can be viewed in line are directly additive (sub-pars. 16b(1) and 16b(2). For two sky glows, this relationship is expressed by:

$$B_r = B_1 t^x + B_2 t^y$$

(5) Computations of the apparent sky glow brightness which would be residual under any conditions at any distance from the area or areas of diffused upward light may be made by solving the equation developed by substituting the B_i values of equation given in sub-paragraph (2) above for B_i of the equation in sub-paragraph (3) above or for B_1 and B_2 of the equation in sub-paragraph (4) above. On the basis of unit areas (selected as $\frac{1}{2}$ mile by $\frac{1}{2}$ mile) having same amount and distribution of light, recurring in line, the equation becomes (sub-par. 16c(4):

$$B_r = 10^{18.02-15.56t} (1+f_1+f_1+f_2+f_2) ALt^{5.28(n+\frac{A-1}{4})}$$

when t is expressed in decimals per 1000 feet, A is number of unit areas in depth of area, and n is number of miles from first unit area.

b. *Threshold visibility distances of sky glow brightnesses.* The distances artificial sky glow can be detected from aircraft under various conditions are established. On extremely clear nights, relatively low sky glow brightnesses may be seen for considerable distances. In fact, sky glow brightnesses on the order of 1000 micro-footlamberts at the source of glow (greater brightnesses have been recorded over cities from locations several miles distant) can be detected for distances in excess of 90 miles during dark, moonless nights having an atmospheric transmission of 99 per cent per 1000 feet. Conversely, extremely high brightnesses are detectable for only short distances with denser atmospheres. A brightness of 1000 micro-footlamberts can be seen for 33 miles for 97 per cent transmission per 1000 feet and for only 3 miles for 60 per cent per 1000 feet and at the latter transmission, relatively large increases in brightness do not significantly increase the visibility distance (par. 17).

c. *The effect of clouds on sky glow produced by a constant light flux.* Extremely high and unpredictable brightnesses may be reflected from clouds or overcast skies (figs. 33, 34, 35, 41, and 42). If very clear atmosphere prevails beneath the clouds, such brightnesses may be reflected in the water and produce a light path at near and far distances from shore against which ships may be silhouetted. However, cloud formations are transitory and constantly changing which reduces the hazard which they may cause due to the short duration or changing position of the light pattern.

d. *Maximum background brightness which will not render ships by silhouette to submarine observers.* Background brightnesses of low magnitude are capable of silhouetting ships. The magnitude of maximum background brightnesses which will not reveal passing ships to submarines varies with three factors:

(1) inversely as the atmospheric transmission, (2) directly as the distance between the submarine and its prospective target, and (3) directly as the distance of shipping lanes from shore. The latter factor is no longer operative when distance from shore is such that the irregularity of the shore horizon cannot be distinguished. Maximum non-hazardous brightness of background with the target boat 2 miles offshore ranges from 30 micro-footlamberts for an atmospheric transmission of 99 per cent per 1000 feet and 1000 yards between submarine and target to 105 micro-footlamberts for atmospheric transmission of 63 per cent per 1000 feet and 6000 yards between submarine and target; with the target boat 5 miles offshore, the maximum non-hazardous brightnesses become 79 micro-footlamberts and 184 micro-footlamberts respectively. (Par. 18).

e. Contributions to sky glow by specific light sources. (1) Vehicular headlamps. Motor vehicle headlighting is a factor in producing sky glow above cities, and in maximum night concentrations typical in cities above 200,000 population may alone produce sufficient glow with favorable atmospheric conditions to increase significantly background brightness at distances of 28 miles or less from source of glow. Night concentrations of traffic on main coastal highways may produce sky glow in front of and behind the line of traffic hazardous to shipping at distances of 8 miles away. Driving (high) beams on the average for both standard and sealed beam headlamps, produce approximately 2 times the glow from passing (low) beams. Shielding and hooding headlamps substantially reduce sky glow; the reductions from unshielded passing beams are approximately 67 per cent for half shielding; 84 per cent for three-quarter shielding, and 80 per cent for six inch hoods. Half shielding headlamps with use of passing beams provides the most economical and practical method of reducing sky glow to non-hazardous levels with maintenance of adequate road illumination for safe driving at reduced speeds (sub-par. 20a).

(2) Street lighting. The contribution to sky glow above a city by street lighting depends upon the types of luminaires in service, the wattage of the lamps, the illumination maintained on the streets, the reflection factor of the streets, and the color, height, and arrangement of nearby buildings. Although conduct of tests to evaluate this contribution from a representative city is impractical due to wide variance in practice between cities, such contribution is no doubt considerable, and a method based on local surveys is provided for its computation. With present types of luminaires, light emitted above the horizontal cannot be eliminated or greatly reduced by practical shields without accompanying reductions in downward light for those

angles near the horizontal needed for even distribution of street illumination between luminaires and, hence, adverse effects on safety and speed of movement of street traffic (sub-par. 20b.).

(3) Lighted show windows. Fluorescent lighted windows will on the average emit slightly less light above the horizontal and slightly more below the horizontal than those with filament lamps, the values being as follows:

Lumens emitted from an average show window

	Incandescent lighted	Fluorescent lighted
Below horizontal	1462 to 2262	1525 to 2325
Above horizontal	489	431
Total	1951 to 2751	1956 to 2756

Dimout curtains and/or awnings greatly reduce the amount of light which reaches the upper air - as much as 90 per cent when both dimout curtains and awnings are used. Surveys of actual number of lighted show windows and reflection and absorption factors prevailing in an area are needed for computation of sky glow from show windows in that area. These computations can then be made by substituting total lumens reaching the upper atmosphere from show windows in equations previously given. (Sub-par. 20c.).

f. Light sources and illuminated surfaces visible from the sea. Light sources, the "halo" glow which may be produced around lighting fixtures, and illuminated surfaces may be effective for great distances in aiding submarines to locate and identify ships. Therefore, the distance of shipping lanes from shore is an important factor in treatment of light sources, and in establishing permissible brightnesses of illuminated surfaces.

(1) Vehicular lighting. At distances of two miles or less to shipping lanes, all automobile lighting, with exception of the approved blackout headlamp and a low level of interior illumination (0.38 footcandles on a 45 degree plane) constitutes a hazard to shipping regardless of whether the vehicles are moving parallel or perpendicular to the coast line. With the exception of the approved blackout headlight, all types of headlighting, including parking lights and 250 beam candlepower headlamps, are equally hazardous when viewed directly from 2 and 5 miles offshore. However, at distances of 5 miles or greater, half shielding with passing beams and normal tail lighting are non-hazardous when the vehicle is moving parallel to the shore line with the lamps visible from the side only. Normal interior illumination of test bus (2.56 horizontal footcandles) is also non-hazardous at a distance of 5 miles. Baffles erected at the

end of streets open to the ocean are not totally effective in reducing the hazard of automobile lighting approaching the baffles directly. Headlighting on cars approaching within 300 feet of the baffle create a sky glow due to light reflected from its surface and the roadway which is judged hazardous by naval observers 2 miles offshore. For maximum effectiveness, baffles should be so constructed that the direct light from approaching cars would be obstructed at all angles and positions visible from the ocean, and its surface should be painted a matte black to absorb the light falling upon it. Even properly constructed baffles, however, cannot eliminate the hazardous sky glow from untreated headlamps produced in the atmosphere in front of heavy concentrations of traffic on highways approaching the ocean. (Sub-par. 20a(5) and par. 22).

(2) Street and highway lights. When less than 4 nautical miles to shipping lanes, street and highway lights require careful treatment to eliminate hazard to shipping. Generally, extinguishment of such lights is indicated. However, on essential streets and highways which approach the shore directly, a special lighting system, which confines the illumination to the street area, by means of hooded floodlights, directed away from the sea and mounted at least 20 feet above street level, makes possible safe driving without headlighting at reduced speeds. With proper spacing between floodlights and by utilizing the natural shielding provided by buildings and trees, such a system of lighting was judged safe by naval observers from offshore and by drivers on land when illumination levels on the roadway did not exceed 0.4 footcandle. This special lighting should be confined to coastal streets and highways from which headlights are directly visible at sea; but is not needed in those instances where headlights are only momentarily revealed by curves and upgrades with long-time intervals between succeeding cars (maximum night volumes in both directions not in excess of 200 vehicles per hour.) At distances greater than 5 miles f. shipping lanes, street lights need only be shielded from all points at sea, provided large vertical surfaces visible from the sea are not illuminated to hazardous levels. (Sub-par. 21c. and 21e.)

(3) Traffic signals. Traffic signals not visible from the sea do not produce sufficient sky glow to justify special dimming methods. When directly visible from the sea, they are hazardous and dimming is required. Reducing lamp voltage until non-hazardous brightness is accomplished results in unsatisfactory signal indications at required distances from the unit. Combinations of reduced voltage (42 volts for 60 watt 120 volt lamps) and special louvers (6 inch - 7 degree louver) are safe at two miles offshore and also provide effective signals for night operations, but not for day time use. (Sub-par. 21b).

(4) Minor aids to navigation. The degree of possible assistance by minor aids to navigation given to submarines in locating and attacking ships decreases as the eclipse period increases and as length of flash decreases. For maximum freedom of ships from detection by submarines, the eclipse period should be the maximum and the flash period the minimum that can be used to attain the required functions of illuminated minor aids to navigation. (Sub-par. 21d.).

(5) Illuminated vertical surfaces. Maximum permissible brightness of vertical surfaces varies with their size and their distance from shipping lanes. Brightnesses permissible on vertical surfaces within two miles of shipping lanes are generally of no practical usefulness. (Sub-par. 21e.).

(6) Indoor blackout lamps. War Department approved indoor blackout lamps used either indoors or outdoors provide a low level of illumination without causing a hazard to shipping. (Sub-par. 21f.).

IV. DISCUSSION

24. Sky Glow as a Brightness Background for Silhouetting Ships. a.- Non-silhouetting background brightnesses.- (1) Criteria for determination.- (a) The criteria applied by naval observers in judging whether or not a background brightness was hazardous to shipping differentiated between threshold visibility of a ship as a distinguishable but unrecognizable object against sky and water brightness and supra-threshold visibility which was just sufficient for dark-adapted eyes aided by night binoculars (7.5) to determine the type, speed, and course of the intended victim of an attack. The justification for such criteria probably lies in the fact that a submarine commander must have certain information upon which to hazard an attack with reasonable assurance of its successful prosecution. Nevertheless, the factor of threshold visibility cannot be entirely ignored, since the ability of a submarine observer to detect distant objects decreases the chances a ship has to escape attack, for, once it is located, the submarine can close in until visibility is sufficient to reveal the details necessary to hazard an attack. On the other hand, the practice of enemy submarines of lying offshore from sources of sky glow at distances sufficiently close to shipping lanes to determine the required details of passing ships, and the restricted field of vision resulting from use of night binoculars, suggests that threshold visibility and the factor of a chance encounter are of relatively less importance than a background of sufficient brightness to reveal required details. Therefore, ability to judge type of ship, and its speed and course as it passes before a lighted background, was the major criterion for establishing maximum non-hazardous brightness of background.

(b) Experience in submarine warfare and convoy duty, visual efficiency at night, and the state of dark adaptation of the eyes of the observers would affect the accuracy with which this criteria could be applied in obtaining data during tests. The fact that a high degree of accuracy was attained is evidenced by consistency of data taken for similar conditions but at different test locations, and by duplication of results with different naval observers.

(2) Range of, and factors influencing, non-hazardous brightnesses.- Test results revealed that non-hazardous brightness of background is not a single value but ranges from zero to a maximum of approximately 220 micro-footlamberts (Graphs 5 and 5a), depending upon three variables: distance of shipping lanes from shore, atmospheric transmission, and distance between the prospective target and the submarine. Therefore, in evaluating the hazardousness of a lighted background or in establishing

permissible limits of artificial sky glow, these three factors must be given due consideration in their relationship to prevailing conditions.

(a) Distance of shipping lanes offshore.- With all other variables constant, the farther the shipping lanes are from the shore line, the higher is the non-hazardous background brightness. This condition is probably due to differences in shore horizon outline resulting from the curvature of the earth and the lessened ability of the eye to differentiate detail at greater distances. These factors progressively obscure the definiteness of the shore horizon outline and thereby eliminate the high and low points and uneven brightnesses which may serve as references by which an observer can more easily determine speed and course of ship. At distances at which the curvature of the earth and visual limitations of the eye obscure definiteness of shore horizon, the required background brightnesses were more than 100 per cent greater than those for locations closer inshore, for the same atmospheric conditions and distance between target boat and observer. It is to be expected that increase in distance offshore becomes less and less an influencing factor on non-hazardous background brightness as distance from shore results in a uniform shore horizon. Evidence of this deduction is presented by Graph 5a which reveals the much greater differential in non-hazardous brightnesses between 2 miles and 5 miles offshore as compared to the differences recorded between 5 miles and 17 miles offshore, with all other conditions remaining identical. Roughness of the sea, which may increase with distance from shore, particularly off a lee shore, also was apparently a factor contributing to higher non-hazardous brightnesses recorded at greater distances from shore, since observers reported great difficulty in the application of criteria under rough sea conditions. Since maximum non-hazardous brightness of background may increase over 100 per cent with distance from shore, the position of shipping lanes with respect to shore should be considered in establishing practical limits of artificial sky glow, for amount of light which may be used at source of glow also increases with increase in permissible sky glow brightness residual at shipping lanes.

(b) Atmospheric transmission.- Graph 5a shows the wide variation in non-hazardous brightness resulting from changes in atmospheric transmission in the range common to coastal areas of the United States. With all other conditions the same, the higher non-silhouetting brightness at the lower atmospheric transmission apparently was due to the "vision-blurring" effect of particles of matter and water vapor in the air, thereby making necessary higher background brightness for visual definition required by the hazardous criteria. This assumption is given further weight by the fact that the slope of the curve becomes much greater as the distance between the observer and the target boat increases. This increase in slope may be logically considered as due entirely to "blurring effect" of the atmosphere since the variation in visual acuity is affected only by the distance between target boat and observation boat which is a constant for each curve of Graph 5a.

Atmospheric transmission is an important factor in selection of maximum non-hazardous brightness value or range in still another way by its influence on residual sky glow resulting at stated distances from a unit quantity of upward light. On Graph 3e, the atmospheric transmission at which residual sky glow will be the greatest for a given unit quantity of upward light at various distances from the source of glow is shown. Comparison of this graph with Graph 5a, reveals that the higher non-hazardous background brightness at lower transmissions means that the upward light at the source must be proportionally less when within 6 miles or less of shipping lanes and can be proportionally greater when more than 6 miles from shipping lanes. This reversal in amount of light at the source results from the fact that residual brightness from a unit quantity of light increases with decrease in atmospheric transmission at a rate many times greater than non-hazardous background brightness for distances less than 6 miles from the source of upward light and decreases with decrease in atmospheric transmission for distances greater than 6 miles. The critical transmission at 5 miles from the source of glow is approximately 70 per cent per 1000 feet and at greater distances its value increases with distance until beyond 6 miles the highest transmission possible produces the highest value of residual sky glow per unit of upward light.

Therefore, the range of atmospheric transmission values normal for a locality or region not only plays an important part in the selection of a suitable non-hazardous brightness value at the shipping lanes, but also influences the extent to which various types of lighting responsible for the upward light will have to be dimmed in order not to exceed this value for the most critical atmospheric conditions likely to be encountered.

(c) Distance between Target Boat and Submarine.- As distance between the eye of the observer and the object to be seen increases, visual acuity decreases because of decrease in the visual angle subtended by the object at the retina of the eye; and higher background brightnesses are required for discernment either by direct light or by silhouette. Graph 5 shows the relative magnitude of this factor on non-hazardous background brightness by curves drawn for 99 per cent transmission, since the "vision blurring" effect can be considered negligible at this transmission. As the distance between target boat and submarine decreases to less than 500 yards, the curves for any distance offshore and for all atmospheric transmissions would logically approach a common, low value, since "blurring" and "visibility-distance" effect no longer influence the value of background brightness required to reveal the boat by silhouette. It is unlikely, however, that submarines would normally approach that close to their target; and naval observers considered that from 2000 to 4000 yards were the critical torpedoing distances to be considered in the determination of non-hazardous background brightness for any given atmospheric condition or distance of shipping lanes offshore.

b. Effect on silhouetting hazard resulting from reduction of artificial sky glow.- (1) Since silhouetting effectiveness is a direct function of the total background brightness consisting of natural horizon brightness plus artificial sky glow, complete elimination of hazard to shipping directly attributable to background brightness can only be accomplished on the darkest of nights. Nevertheless, degree of hazard undoubtedly is progressively reduced as background brightness decreases to levels which make it more difficult for enemy observers to obtain the information upon which to base an attack. Therefore, greater safety to shipping can be provided by eliminating or reducing artificial sky glow on those moonless nights which have natural horizon brightnesses within or close to the non-silhouetting range. Conversely, significant increase in safety is not obtained even by complete elimination of artificial sky glow on moonlit nights when natural background brightness is substantially higher than the non-silhouetting range and artificial sky glow is a very small part of total brightness.

(2) Approximations of horizon brightness, based on available data, which appear to hold within reasonable limits under representative conditions of cloud and atmosphere are set forth in the following table:

Moon phase	Moon position	Clouds[(a)]	Order of Magnitude of brightness of sky near horizon microfootlamberts
Full	Near zenith	None	2,500
		Light	5,000
		Heavy	2,000
Full	Near horizon	None	1,500
		Light	2,000
		Heavy	500
Fine crescent	Near horizon	None	200
		Light	300
		Heavy	50

(a) Values apply to fairly clear atmosphere under conditions of no clouds or light clouds, and moderately hazy atmosphere under conditions of heavy clouds.

The following table lists unaffected horizon brightnesses recorded during test for moonless nights:

Atmospheric transmission in per cent per 1000 feet	Horizon brightness					
	Average		Minimum		Maximum	
	Sea	Inland	Sea	Inland	Sea	Inland
95-100	119	100	81	42	150	186
90-95	73	93	60	42	80	210
85-90	72	87	8	8	125	180
80-85	81	93	32	52	110	140
75-80	67	89	48	50	110	120
70-75	68	82	42	45	100	102
65-70	70	70	57	60	80	84

Anaylsis of test data indicates that natural horizon brightness unaffected by any artificial glow ranged from a low of 8 micro-footlamberts to a maximum of 210 micro-footlamberts for the moonless nights of the test period. These data are indicative of the fact that artificial sky glow can measurably contribute to shipping hazard offshore only on moonless nights, since moonlit nights, regardless of the moon phase, are invariably higher than maximum values of the non-hazardous range for all weather conditions. In addition, on moonlit nights a further aid to submarine is given by the reflection of the moon in the water creating a light path against which a ship is also clearly revealed by silhouette. The value or logic of dimout on nights when natural brightness far exceeds the non-hazardous range is therefore questionable, although many practical problems would probably be introduced by a dimout scheduled to conform with the phases of the moon.

25. Hours of the Year Reduction in Sky Glow is Effective.- The total hours of the year when moon phases and weather conditions are such that artificial sky glow can be expected to contribute measurably to shipping hazard offshore may have a marked bearing on policy concerning, and overall effectiveness of, dimout in relationship to detrimental results to land activities. An analysis of such natural conditions for the latitude of New England as typical of the maximum number of dark hours encountered along the Eastern Coast revealed the following:

Analysis of Dark and Daylight Hours Based on Non-hazard Horizon Brightness (New England Latitude)

Period of day	Total hours	Percentage of total hours	Percentage of dark hours	No. of hours per year natural horizon brightness is within or close to non-hazardous range
Daylight hours	4457	51.0	- -	0
Twilight hours	1274	14.5	- -	0
Moonlight hours	1500	17.1	49.5	0
Starlight hours	1529	17.4	50.5	1529
Total	8760	100.0	100.0	

The percentage of the dark hours when reduction or elimination of artificial sky glow may be expected to be beneficial as a means of passive defense is approximately 50. This percentage is the maximum to be expected on the Eastern Coast and will be reduced with latitude and with the prevalence of fog and rain which would obscure all artificial sky glow and considerably reduce natural horizon brightness.

26. Ship Sinkings Versus Hours of the Night and Phases of the Moon.- The confidential nature of information on the significant hours of night and the condition of the moon at which sinkings have occurred in the past makes it impossible to draw conclusions concerning the relative importance of natural sky glow (at sunset or dawn, and on moonlight nights) as compared with artificial sky glow as an aid to torpedoing. In view of the number of hours when artificial sky glow might possibly be an aid to the enemy and the man hours, materials, and disturbance to civilian activities necessary to reduce sky glow above a city to non-hazardous levels, it is essential that a complete analysis of this phase of the dimout problem be made by naval authorities before the maximum sky brightness or range of brightnesses upon which dimout regulations will be based is selected.

27. Reduction in Lighting Required of Certain Large Coastal Cities to meet Background Brightness Requirements.- As a basis for approaching the problem of retardation of transportation and land activities of all kinds which is bound to accompany reduction in essential light, the extent which large coastal cities would have to eliminate sky glow, and therefore reduce upward light to meet certain brightness requirements is presented. In the following table is set forth reported sky glow brightnesses observed during early months of 1941 over Boston, New York, and Providence:

City	1940 Population	Brightness recorded (micro-footlamberts)	Distance from city at which brightness measurement was made (miles)
Boston, Mass.	770,816	1200	9
Boston, Mass.	770,816	300	25
New York, N. Y.	7,454,995	4200	13
New York, N. Y.	7,454,995	615	20
Providence, R. I.	253,504	1300	8
Providence, R. I.	253,504	330	20

Atmospheric transmission was not recorded when the above brightnesses were obtained. However, based upon the assumption that the two brightnesses for each city were measured under nearly same atmospheric conditions, atmospheric transmission may then be computed. These computed transmissions are: for Boston, 98.5 per cent per 1000 feet; for New York 95,per cent per 1000 feet; and for Providence, 98 per cent per 1000 feet. In the table below are listed residual sky glow brightnesses computed for an assumed distance from center of each city, which approximates locations where submarine action against coastal shipping may possibly be effective:

City	Assumed distance from center of city (miles)	Computed residual brightness at shipping lanes (micro-footlamberts)
Boston	20	470
New York	20	615
Providence	32	90

These residual sky glows for Boston and New York far exceed non-hazardous brightness range for any condition of atmosphere and relative location of boats. In the case of Providence, the residual sky glow is within the non-hazardous range. These are significant values in that they are indicative of the extent to which coastal cities must reduce their upward light in order to conform to non-hazardous requirements. For example:

If permissible residual brightness from artificial glow at the shipping lanes is set at (a) 30 micro-footlamberts, (b) 100 micro-footlamberts, or (c) 200 micro-footlamberts, the reductions in lighting required of each city for each assumed standard are as follows:

	Per cent reduction in upward light required for residual sky glow brightness at assumed position of shipping lanes of:		
	30 micro-footlamberts	100 micro-footlamberts	200 micro-footlamberts
Boston	93.5	78.7	57.5
New York	95.2	83.8	67.5
Providence	66.7	0	0

28. Need to Weigh Retardation of War Effort on Land Resulting From Reduced Lighting Against Losses at Sea Resulting from Uncontrolled Lighting.- a. General.- There is evidence that present dimout practices are retarding certain phases of the war effort. Many industrial establishments, especially those employing outdoor processes, provide a source of sky glow, great reduction or elimination of which may result in lessened efficiency or serious curtailment of their operations. Highway transportation becomes slower and more hazardous with reduced street and vehicle lighting. Besides disruption of land activities resulting in losses to the war effort, problems of lowered morale and increase of crime are involved in reduction of lighting. On the other hand, it is obvious from past experience that safety of coastal shipping is endangered by normal use of lighting for conduct of land activities. This suggests the need for a comparative analysis of losses both on land and sea under normal lighting and dimout conditions in order to arrive at dimout regulations providing the proper balance.

b. Losses at sea.- Data on sea losses attributable to sky glow or exposed lights are not presently available and only scant information has been found upon which to evaluate losses on shore.

c. Lessened production.- No quantitative information is available concerning the effect on production of dimout measures taken by industrial plants, ship yards, and outdoor industries.

d. Highway transportation.- In principle, the overland transfer of persons and materiel important to prosecution of the war can hardly be regarded as a movement of lesser importance than a similar transfer of war personnel and goods at sea. The war value per unit of transportation, either by land or sea, varies with carrying capacity, importance of load or cargo, nature of mission, speed of travel, and similar factors. Numerous studies have been and are being made to determine the effect of dimout lighting on the traffic accident rate. The data thus far collected show a wide range of conditions existing. In some cities, night traffic is heavier and more concentrated than before the war, and night accidents have increased and day accidents have decreased; while, in other cities within the dimout zone, both day and night accidents have decreased.

e. Conclusion.- Therefore, before specifying the basic light values for future dimout practices, the full implications of land and sea losses, having regard for manpower, materials, production, facilitation of movement, and the general well-being of the population should be ascertained and evaluated.

29. Types of Dimout Programs.- Dimout programs, which provide various compromises between the requirements for safety of coastal shipping and the needs of war activities ashore, are outlined below:

a. Continuous dimout. (1) In this program of light control, extinguishment of all non-essential lighting and the restriction of all essential lighting, such as street lighting, would be required to the extent that resultant artificial sky glow would never exceed a value determined as permissible, whatever the phase of the moon, the length of dawn or dusk, or the weather conditions. Analysis of data (sub-par. 31f(2) indicates that a practical program can be devised to meet the fundamental requirements for protection to shipping by dividing the coastal area into zones extending inland from the coast and establishing maximum permissible sky glow values for each zone, based upon favorable atmospheric conditions and distance of zone from shipping lanes. However, the range of non-hazardous background brightness values at the shipping lanes is so low that required lighting restrictions would vary from total blackout at the coast to elimination of non-essential lighting only in the zones farthest from the sea. A program of this type would be relatively easy to administer; transition from dimout to blackout would be simplified; the public would be psychologically conditioned for living under blackout conditions if the military situation made this necessary; savings in electric energy and electric lamps would result; and, regardless of atmospheric changes, natural horizon brightness and other factors affecting the brightness of sky glow, artificial lighting on shore would not increase hazard to shipping. The continual dimout program is the basic idea back of present day attempts to dim coastal areas.

(2) A modified continuous dimout program, based upon a careful analysis of the situation on land and at sea by competent naval and army personnel, may offer the best compromise between conflicting requirements at sea and ashore. The

first step in the preparation of such a program would be to establish a brightness value from artificial lighting as a permissible residual every night at shipping lanes, based upon reasonable safety of shipping and the needs of war activities ashore, with proper consideration for such influencing factors as distance of shipping lanes offshore and prevailing atmospheric conditions. Once the basic permissible value is established, lighting restrictions in the various dimout zones could be adjusted to meet the new background brightness requirements. The modified form of continuous dimout might be best applied to coastal areas, where shipbuilding and other essential war industries are concentrated.

b. Dimout program based on variations in natural horizon brightnesses. During moonlight, and at dawn and dusk, the average normal horizon brightness (sub-par. 24b) is sufficiently high that drastic reductions in essential lighting would have little or no significant effect on ship visibility. It is not illogical, therefore, to take cognizance of this situation by restricting lighting to the extent required for maximum protection to shipping only during the dark of the moon, and by relaxing or removing all restrictions during periods of moonlight, twilight, and dawn. For approximately one-half of the so-called dark hours (par. 25), it would be necessary to extinguish, reduce, or treat such essential lighting as street and highway lighting, industrial protective lighting, ship yard and war plant lighting, and building windows. During moonlight periods, it is likely that essential lighting would be permitted to remain undiminished. Non-essential lighting would be subject to partial or complete extinguishment. If carefully planned and executed, this type of dimout could provide the required safety at sea during those periods when artificial sky glow is significant. However, it has many disadvantages: it would be complicated to plan and enforce on a local basis; dimout equipment required to shield or mask during dark period could not be easily adjusted or removed for the moonlight periods; lag in compliance by public from one period to the other might seriously endanger shipping during the dark period;

and benefits to war activities ashore may fail to materialize to the extent anticipated, since lighting for continuation of ground activities is more needed during the same dark period when dimout restrictions are required for safety of shipping.

c. Dimout program based on enemy submarine activity. Dimouts, as in the case of blackouts, might be limited only to periods when enemy activity was an acute menace. During such periods, dimout restrictions could be imposed in the severity required, and could be ordered on moonlight nights if appropriate. Notification could be through organized Army and OCD channels, and might come with little warning as in the case of an air raid; but generally the presence of enemy ships offshore would be known several hours in advance of the alarm. Such alarm would remain in force for the period required. Since this program anticipates more drastic restrictions than are feasible for continual dimouts, regular blackout equipment and discipline could be employed thereby accustoming the public to living under greatly restricted lighting for many hours or even days. At periods of no enemy activity, lighting as usual would be maintained, thereby providing adequate visibility for the efficient conduct of the war effort ashore. The effectiveness of this type of dimout will depend upon the efficiency of the warning and enforcement organizations and the thoroughness of public preparation and training for quick compliance. Public inconvenience and interference with essential war activity would reach a maximum only during alert periods. Other disadvantages are similar to those in sub-paragraph b. above. The adoption of this plan should be considered only if coastal areas have active warden organizations, available channels of notification to wardens and the public, and adequate street lighting switching facilities.

30. Importance of Establishing Basic Dimout Program. The selection of the most effective dimout technique to meet the war requirements at sea and ashore, modification of equipment to provide adequate light control, and establishment of inland limits of the dimout zone are all directly dependent upon the selection of the value of background brightness which can be permitted without seriously endangering vital coastal shipping.

Therefore, basic policy, including determination of an appropriate increment of artificial sky glow, based upon a careful study by competent naval and military authorities of the available statistics on losses ashore as compared to those at sea, upon evaluation of the factors affecting non-hazardous range of background brightnesses discussed in preceding paragraphs, and consideration of natural and tactical conditions, should be established. This policy will then become the foundation upon which a logical dimout program can be constructed in order to provide a practical solution based on the relative requirements and benefits on land and at sea.

31. Establishment of Inland Limits of Dimout Zone.- a. General.- Determination of inland limits of the dimout zone must necessarily depend on permissible artificial sky glow brightness residual at shipping lanes (as established by basic policy), the distances of shipping lanes from shore, the generated sky glow brightnesses above cities of various sizes and the distances such brightnesses are effective in creating a lighted background sufficient to silhouette ships, and the possibility that glows from two or more communities in line with the same location at sea will add to produce a resultant hazardous brightness.

b. Permissible artificial sky glow.- Since basic policy decisions have not as yet been made, it is necessary, in order to analyze the problem, to assume certain brightnesses as permissible increments from artificial sky glow residual at shipping lanes. Three such increments have been assumed: 30 micro-footlamberts, 100 micro-footlamberts, and 200 micro-footlamberts. These brightnesses lie near the lower and upper limits and the middle of the non-hazardous background brightness range. However, only the first two when added to natural horizon brightnesses normally prevailing on moonless nights will result in a total brightness still within the non-hazardous range, and these resultant brightnesses will be near the upper limits of that range.

c. Shipping lane distance from shore.- The distance of shipping lanes from shore affects distance inland to which dimout regulations must be applied in that the inland distance may be decreased in the same proportion that the offshore shipping lane distance is increased. However, varying the inland limits of the dimout zone in conformance with distance of shipping lanes offshore in different regions seems impractical and unwarranted even if the necessary information concerning location of shipping lanes were available. Therefore, for this discussion, a uniform distance offshore of 5 miles has been assumed.

d. Generated sky glow brightnesses above cities.- Quantitative measurements on magnitude of sky glow brightness above cities are very meager. In the majority of cases, those which are available lack complementary information, such as atmospheric transmission, upon which to base necessary computations. Also, no estimates or surveys of total upward light from any city, upon which calculations of sky glow may be based, are available. The following table lists some of the more significant brightnesses which have been recorded over cities:

City	1940 Population	Brightness recorded (micro-footlamberts)	Distance from city measurement was made - miles	Weather report
		Under normal lighting conditions		
Albany, New York	130,577	540	13	--
Schenectady, N.Y.	87,549	850	12	--
Providence, R.I.	253,504	330	20	--
Providence, R.I.	253,504	1300	8	--
Jersey City, N.J.	301,173	4000	10	High heavy overcast. Intermittent rain.
Jersey City, N.J.	301,173	4600	12½	Clear - Humid
		Under partial dimout restrictions		
New York, N.Y.	7,454,995	4200	13	High, heavy overcast. Intermittent rain.
New York, N.Y.	7,454,995	615	20	--
Boston, Mass.	770,816	1200	9	--
Boston, Mass.	770,816	300	25	--

Figures for the cities are in most cases maxima obtained by a series of readings covering several nights; therefore, for this analysis, it is assumed that measurements were made under optimum conditions for production of glow at the point of measurement. The most favorable atmospheric transmission for maximum residual brightness at distances of 8 miles or more from source of upward light is the highest which occurs or for practical use, 99 per cent per 1000 feet. Two brightness readings are shown for different distances for the cities of Providence, New York, and Boston. On the assumption that these measurements were taken under nearly optimum conditions, they may be used to compute actual transmission necessary to result in the per cent brightness drop for the increase in distance. These computed transmissions are: Providence readings, 98 per cent per 1000 feet; New York, 95 per cent per 1000 feet; and Boston, 98.5 per cent per 1000 feet. The following table presents distances from each city at which residual brightnesses of 30, 100, and 200 micro-footlamberts (from assumption in sub-paragraph b above) would result as computed on the basis of optimum transmission.

City	1940 Population	Distance in miles for residual brightness of 30	100	200
		micro-footlamberts		
Albany, N. Y.	130,577	66	43	31
Schenectady, N.Y.	85,549	75	50	34
Providence, R.I.	253,504	70	47	35
Jersey City, N.J.	301,173	99	82	65
New York, N.Y.	7,454,995	87	67	55
Boston, Mass.	770,816	72	49	37

The above table reveals that, when shipping lanes are 5 miles offshore, the dimout zone should probably extend 61 to 94 miles inland for a permissible brightness increment of 30 micro-footlamberts, 38 to 77 miles inland for 100 micro-footlamberts, and 26 to 60 miles inland for 200 micro-footlamberts, provided cities large enough to produce hazardous glows for those distances exist in the region. However, these distances are somewhat theoretical, since true atmospheric transmission at time brightness was recorded is unknown, and the distances would be increased if the transmissions were lower than those assumed. On the other hand, the distances may be reduced considerably in regions where transmissions of 99 per cent per 1000 feet do not occur or occur infrequently.

e. Aggregate of glows from two or more communities.- Glow residual at a location at sea from two or more glow producing areas in line with the sea location is the sum of the residual glows from each area. Where such conditions exist, therefore, the inland limits of the dimout zone must be extended to include the second glow producing area; and the total permissible increment of brightness from artificial glow must be divided between the glow producing areas.

f. Method.- (1) Final determination of inland limits of dimout zone should be based on survey of glow producing communities in coastal areas and actual brightness measurements made under known atmospheric conditions. Normally, however, it appears that control of lighting for dimout purposes need not be extended beyond 35 to 75 miles inland, depending on the residual brightness from artificial glow selected as permissible at shipping lanes.

(2) The table below provides a method for determining whether sky glow above a city or other installation will produce a residual brightness 5 miles offshore greater than the assumed allowable residuals of 30, 100, and 200 micro-footlamberts. Sky glow

when measured under the stated conditions, of less than the values set forth in the table require no reductions; but those that are greater must be reduced to the listed values.

> Sky glow brightness over and above natural horizon brightness shall not exceed the values listed in the following table, when measured at a distance of 5 miles from the glow producing area (city or town limits, or edge of other installations) on a clear, moonless night having stars clearly visible.

Zone	Distance from shore in miles	Maximum permissible sky glow brightness increments above natural horizon For residual brightness at shipping lanes of 30 micro-footlambert	100 micro-footlambert	200 micro-footlambert
1	0- 5	3(a)	10(a)	20(a)
2	5-10	39	130	260
3	10-15	50	170	340
4	15-20	68	220	440
5	20-25	90	300	600
6	25-30	120	390	780
7	30-35	160	520	1040
8	35-45	270	900	1800
9	45-55	480	1570	3140
10	55-65	800	2660	5320
11	65-75	1440	4730	9560

(a) These values are for atmospheric transmissions of light 99 per cent per 1000 feet. During transmissions which give highest brightness of glow at 5 miles from the source of upward light, ten times the given brightness will be produced. (See Graphs 3a and 3c).

32. Dimout Restrictions Based on Classification of Types of Lighting in Relationship to their Importance to the War Effort.- a. General.- Modern lighting may be divided into two rather broad classifications based upon primary functions performed in the interest of the war effort: (1) Essential lighting which is necessary for efficient and accelerated war production with minimum loss of materials and man hours, for facility and safety of traffic movement, and for maintenance of essential civilian services and morale; and (2) Non-essential lighting, which is used for amusement, decoration, and advertising purposes only. The first step in the reduction of sky glow, therefore, should be the extinguishment or modification of

non-essential lighting, to be followed by restrictions of essential lighting, only if necessary in order to meet basic background brightness requirements at the shipping lanes.

b. Representative types of essential lighting.-

Highway and street
Industrial interiors
Outdoor industrial
Outdoor protective
Ship yard
Railroad yard
Outdoor home lighting for safety and property protection
Vehicle lighting
Night constructions
Station platform
Airport and airway
Water navigation
Traffic and railroad signals
Exit and safety lighting

c. Representative types of non-essential lighting.-

Outdoor Advertising.- Lighted signs, display boards, billboards, poster boards, and spectacular displays of all types.

Ornamental Building Lighting.- Decorative floodlighting, outline lighting, facade lighting of all types.

Marquee decorative lighting
Show and display windows
Amusement and sports lighting
Decorative service station and parking space lighting
Pyrotechnic displays
Unshielded building windows of high brightness

33. Relative Brightness Increments Contributed to Sky Glow by Various Types of Lighting.- a. Seattle, Washington.- Based on survey of local conditions, Seattle, Washington, reports the following:

Inventory of Skyward Light

Classification	Net effective skyward light in 1000's of lumens	Per cent of total skyward light analyzed
Lighted bulletin and poster boards	350	1.5
Medium and small sized neon signs	2240	9.7
Theater marquee and miscellaneous lamps	270	1.2
Gasoline service stations and parking lots	3930	17.0
Building floodlighting	1032	4.5
Roof and building top signs	350	1.5
Theater and other large signs	2950	12.9
Sub-total	11,122	48.3
Street lighting		
Ornamental luminaires without reflectors	9386	41.0
Ornamental luminaires with refractors	99	0.4
Overhead, radial, dome, and lantern	2362	10.3
Sub-total	11,847	51.7
Total	22,969	100

The above table reveals that outdoor lighting for commercial purposes, generally of a type which is considered non-essential and which can be almost wholly eliminated or drastically reduced with little adverse effect on the war effort, produces approximately the same upward light as street lighting, and, inferentially, the same increment of sky glow above Seattle. Contributions to upward light from vehicles, building windows, and industrial and defense project floodlighting were not analyzed.

b. Los Angeles, California.- Similar surveys in Los Angeles indicated that outdoor advertising signs were responsible for 58 per cent of the sky glow while street lighting was responsible for 33 per cent. Together they account for 91 per cent of sky glow; the remainder is produced by other types of lighting.

c. Taunton, Massachusetts.- A "step" dimout of Taunton, Massachusetts, during which particular types of lighting were extinguished progressively and resultant decreases in sky glow recorded, returned the following:

Lighting extinguished in sequence	Sky glow decreased to (Average for readings made 8 miles east and 8 miles west of Taunton)	Per cent of sky glow contributed	
Outdoor signs, theater marquees and floodlights	87%	13	
Show windows (awnings raised)	82%	5	
Street lighting	29%	53	
Ornamental street lighting			25
Pendant type street lighting			24
Radial wave type street lighting			4
Automobiles	19%	10	
Indoor lights except defense industries	8%	11	
Defense plants	0%	8	

d. Calculated increments.- Sky glow produced by various types of lighting in the central business district of average cities of different population groups may be computed by equations developed from the test data, provided reasonably accurate estimates are available on the number and character of each type of lighting. Such calculations, and the assumptions upon which they were based, are contained in Appendix H. Listed below are calculated sky glow brightnesses from street lighting, automobiles, and show windows which would be residual, during an atmosphere having light transmission of 99 per cent per 1000 feet, at a distance of 5 miles from the central business district of an average city of the 200,000 to 300,000 population class and of an average city of the 500,000 population class:

Calculated increments of sky glow residual at 5 miles

Type of lighting	Above an average city of 200,000 to 300,000 population micro-footlamberts	Per cent	Above an average city of 500,000 population micro-footlamberts	Per cent
Street lighting (a)	206	26	502	40
Automobile headlamps (b)	194	25	262	21
Show windows	382	49	482	39
Total	782	100	1246	100

(a) Based on use of diffusing luminaires. Calculated sky glow values become 92 and 186 micro-footlamberts respectively when redirective luminaires employing same wattage lamps are used.

(b) Based on use of passing beams.

e. Weighed averages.- From the limited amount of data available and the calculated values, per cent contribution to sky glow from various types of lighting in the average city is estimated to be:

Classification	Per cent contribution to sky glow
Commercial lighting	38
Street lighting	33
Automobiles	15
Indoor lights except defense industries	8
Defense plants	6

The weighed contributions shown above will vary considerably with the character and size of cities; however, as a practical average they are believed to be fairly representative.

f. Conclusions.- (1) Generally, commercial outdoor lighting, including lighted show windows, and street lighting are the principal producers of sky glow. Together, they on the average are probably responsible for more than three-fourths of the glow above cities.

(2) Commercial outdoor lighting is on the average as large a contributor to sky glow as street lighting.

(3) In many cases, necessary reductions in sky glow can be accomplished solely by elimination or drastic reduction in so-called non-essential lighting. The possible reductions range from approximately 18 to 58 per cent, depending on the type of city, with an average reduction of approximately 40 per cent.

(4) Contribution to sky glow by street lighting will probably range from 30 to 50 per cent, with an average contribution of 36 per cent.

(5) Treatment of types of lighting other than commercial outdoor lighting and street lighting will result in relatively small decreases in sky glow above cities.

34. Factors to be Considered in Determining Proper Dimout Treatment for Various Types of Lighting.- a. General.- Normally, the relative necessity of the various types of lighting to the war effort, essential civilian activities, or maintenance of safety should be the prime consideration in priority of dimming required by dimout regulations. On that basis, first reductions in sky glow should be accomplished by reducing non-essential lighting even to the point of complete elimination, if necessary.

Further essential reductions in sky glow then must be consummated by proper treatment of remaining lighting in accordance with the degree of contribution to the national security. On the other hand, much can be done in reducing upward light from even the most essential types of lighting without destroying their usefulness to any significant extent.

b. Headlamps of motor vehicles.- (1) In comparison with certain other types of lighting, sky glow contributed by headlighting for automobiles is small; yet it may add measurably to degree of hazardousness of background brightness. Fortunately, headlamps may be so treated (except while on roads visible from the sea where they must be extinguished) that upward light is considerably reduced without undue impairment of their primary function, and without use of large quantities of critical materials and man-hours. Results of tests revealed that sky glow from passing beams is approximately 50 per cent of that from driving beams. The sky glow from passing beams in reduced by various methods of shielding and hooding as follows (percentages listed are probable order of magnitude rather than exact figures, due to focus of headlamps and properties of pavement surfaces):

	Treatment of headlamps			
	Upper one-quarter shielded	Upper one-half shielded	Upper three-quarters shielded	Six inch hoods
Per cent reduction in sky glow based on untreated passing beams as 100 per cent	52	69	84	80

While three-fourth shielding and six inch hoods reduce the upward light about 80 per cent, 11 to 15 per cent more than half-shielding, the inherent disadvantages of those methods outweigh that advantage. Greatly reduced road illumination, hazardous for use for driving even at low speeds, results from three-quarter shielding; and the man hours and materials required to prepare, install, and maintain hoods does not recommend their use as a practical solution. Since vehicular headlamps are necessary for continuance of street traffic and highway transportation at night and their contribution to sky glow is a small increment of total city sky glow, the method selected for their dimout treatment should obtain greatest gains in reduction of sky glow commensurate with provision of adequate road illumination. One-half shielding meets these specifications; while other methods of dimming, such as reduction to 250 beam candlepower or use of more restrictive shields, although effective in alleviating hazardous levels of sky glow, result in unsafe driving conditions. This fact is substantiated by comparisons of accident data from various cities where half shielded headlamps with those where parking lights or similar low illumination headlighting have been in use.

(2) Sky glow from vehicular headlamps on passing beams is approximately 15 per cent of total generated sky glow over cities. The requirement of one-half shielding with use of passing beams at all times will reduce that value to approximately 5 per cent (the reduction may be greater than indicated since many persons use driving beams for city driving). Quantitative reductions would be approximately as follows (see sub-par. 33 d):

	Reductions in sky glow effected by half shielding (passing beams) Average city	
	200,00 to 300,000 population (micro-footlamberts)	500,000 population (micro-footlamberts)
Sky glow from vehicle headlamps residual at 5 miles for 99 per cent transmission per 1000 feet	194 to 60	262 to 81

(3) The sky glow produced by the headlamps of open highway traffic, in front of and behind the line of traffic, is considerably less than that produced by the heavy night concentrations of city traffic. Headlamps being practically the only source of sky glow on such roads, adequate control of light, except in areas visible from the sea, is provided by half-shielding and use of passing beams. (For test results, see sub-par. 20 a (5)).

c. Street lighting.- (1) Street lighting is one of the major contributors to sky glow -- its contribution is on the order of 30 to 50 per cent (probable average: 33 per cent) and is also a type of lighting upon which depends, in large measure, continued night circulation with safety and dispatch of essential traffic, including the movement of production workers and the distribution of materiel. Regardless of its importance, however, street lighting must be controlled for adequate dimout whenever visible from the sea or when elimination or treatment of other types of lighting of lesser priority fails to reduce sky glow to acceptable limits. Methods of accomplishing required reductions in sky glow from street lighting should be based on maintenance of minimum street illumination required for reasonable safety with maximum elimination of light reaching the upper atmosphere.

(2) Street lighting luminaires presently in service are, in general, of three distinct types -- diffusing, re-directive, and open reflector -- possessing light output and distribution properties as shown below:

	Lumens in per cent of lamp lumens		
	Diffusing luminaires	Redirective luminaires	Open reflector luminaires
Below the horizontal	35	53	75
Above the Horizontal	35	7	5
Total	70	60	80

Assuming that only 50 per cent of all upward light reaches the upper atmosphere, due to absorption by trees and buildings, and that the pavements have an average reflectivity of 15 per cent, the ratios of contribution to sky glow for upward and downward light, and the per cent of lamp lumens effective in producing sky glow, from each type of luminaire are as follows:

	Light from luminaire	Diffusing luminaire	Redirective luminaire	Open reflector luminaire
Ratio of contribution to sky glow	Below the horizontal	1	1	1
	Above the horizontal	6.67	0.88	0.45
Per cent of lamp lumens effective in producing sky glow		20.1	7.5	8.1

The above tables show that, when lamps of same lumen output are used, and ignoring such factors as glare and proper distribution of light on the road, which are important considerations in a street lighting system, highest average street illumination is obtained from luminaires in the following order, - open reflector, redirective, and diffusing, due to their relative efficiency and light distribution; also that only small differences exist in contribution to sky glow by redirective and open reflector type luminaires, while diffusing luminaires contribute approximately 2.6 times more upward light than the others. The values in the second table are subject to variations due to different reflection properties of various types of pavements and the variations in absorption of upward light encountered in actual installations.

(3) Restrictions on upward light will substantially reduce sky glow, especially in the case of diffusing luminaires. However, such restrictions are usually unavoidably accompanied by reductions in downward light, particularly in the 0 to 30 degree zone below horizontal which is needed for even distribution of street

illumination between luminaires. The following table gives estimated per cent reductions in downward light accompanying these restrictions in upward light:

Estimated per cent reductions in downward light accompanying restrictions in upward light from luminaires to not more than:

	10% of lamp lumens above horizontal		3% of lamp lumens above horizontal		0% of lamp lumens above horizontal	
Type of luminaire	0-30°	30-90°	0-30°	30-90°	0-30°	30-90°
Diffusing	20	0	40	5	65	10
Redirective	0	0	10	0	75	0
Open reflector	0	0	5	0	20	0

The fundamental purpose of street lighting is to produce the illumination requisite for good visibility at night and, through good visibility, to promote safer use of streets. Experience in traffic safety and speed of movement as affected by illumination indicate that serious consequences in that connection can be expected to result from the above reductions in downward light. As a cause of accidents, poor visibility ranks with mechanical failure and driver and pedestrian carelessness. However, it is not the intent of this report to make a quantitative analysis of night accidents in relationship to street lighting, but only to point out the major factors which have to be considered in determining proper dimming methods.

(4) Based on certain assumptions, sky glow brightnesses produced by business districts of average cities of various sizes may be calculated by equations and graphs developed in this report. The assumptions used for the following analysis are:

400 feet between streets
60 foot width of street including sidewalks
Total of 13 streets in an area 1/2 mile by 1/2 mile
33,800 lineal feet of streets
Reflection factor of pavements - 15%
50% of upward lumens from luminaires reach upper atmosphere
50% of light reflected from pavements reach upper atmosphere

Traffic classification of streets in cities:

25000 to 50000 population - Light traffic
100000 to 300000 population - Medium traffic
500000 and over population - Heavy traffic

Standard street lighting practice as contained in sub-paragraph 20b(1)

Calculated sky glow values for the various sized cities are set forth below (calculations are contained in Appendix H):

Population size of city	Assumed size of business district in miles	Lamp lumens per luminaire	Number of luminaires per one-quarter square mile of business district	Sky glow in micro-footlamberts from street lighting residual at 5 miles for atmospheric transmission of 99 per cent per 1000 feet — For use of Diffusing luminaires	For use of Redirective luminaires
25,000 to 50,000	½x½	6,000	210	81.4	30.2
100,000 to 300,000	½x1	10,000	252	246	91.5
500,000	1x1	15,000	252	502	186
1,000,000	1½x1	15,000	252	628	233

The values of the above table should be compared with those in sub-paragraph 2Cf(2), where total artificial sky glow from all sources residual at 5 miles for conformance to background requirements for the assumed conditions is set forth.

(5) In many cases, particularly in cities only short distances from shipping lanes, adequate dimout may require not only restrictions in light emitted above the horizontal from luminaires but limitations on amount of light reflected upward and therefore limitations on the illumination permitted on the streets. Table contained in sub-paragraph 31f sets forth maximum permissible artificial sky glow above cities in accordance with their distance from shore in order to meet certain assumed background brightness requirements. Assuming that street lighting should be permitted to account for one-half of those brightnesses, the total permissible upward lumens from street lighting may be computed by use of Graph 3e. These upward lumen values are listed below (computations are contained in Appendix H).

Maximum permissible upward lumens from street lighting per unit area of 1/2 mile by 1/2 mile based on a total lighted area of 2-1/2 miles by 2-1/2 miles and shipping lanes at a distance of 5 miles offshore.

Zone	Distance from shore in miles	Maximum permissible upward lumens for total residual brightnesses at shipping lanes of:		
		30 micro-footlamberts (a)	100 micro-footlamberts (a)	200 micro-footlamberts (a)
1	0- 5	900	3000	6000
2	5-10	11700	39000	78000
3	10-15	15000	51000	102000
4	15-20	20200	66000	132000
5	20-25	27000	90000	180000
6	25-30	36000	116400	232800
7	30-35	47000	156000	312000
8	35-45	81000	270000	540000
9	45-55	144000	470000	940000
10	55-65	239400	798000	1596000
11	65-75	432000	1434000	2868000

(a) The permissible upward lumens from street lighting are based on one-half of these values, since that is the portion assumed to be permitted to street lighting.

Further, on the basis of the lumen values given in the above table, the maximum average illumination which can be permitted on the streets in order to conform with assumed background brightness requirements may be computed on the basis of one-half the permissible sky glow increment being allotted to street lighting; and the values thus obtained may be compared with recommended practice as a means of evaluating the utility of the permissible illumination. The following two tables respectively set forth permissible street illumination for various restrictions in upward light from two types of luminaires on the basis of (a) 50 per cent of light emitted above the horizontal from the luminaires and reflected from the pavements reaching the upper air and (b) 50 per cent of light emitted above the horizontal from the luminaires and 20 per cent of light reflected from the pavements reaching the upper air. (For calculations, see Appendix H) The assumptions of 50 per cent and 20 per cent, respectively, of reflected light reaching the upper air will probably bracket the true condition; the former applying to street surfaces having diffuse reflection and the latter to street surfaces, well-worn or wet, having specular reflection.

Based on 50 per cent of light emitted above horizontal and reflected from pavements reaching the upper atmosphere (15 per cent reflection factor of pavements).

Maximum permissible average street illumination (foot-candles) with following restrictions in upward light from luminaires:

Zone	Distance from shore in miles	10% of lamp lumens up Diffusing luminaires	7% of lamp lumens up Redirective luminaires	3% of lamp lumens up Diffusing luminaires	3% of lamp lumens up Redirective luminaires	0% of lamp lumens up Either luminaire
		For artificial sky glow brightness residual at shipping lanes of 30 micro-footlamberts[a]				
1	0- 5	.002	.003	.0037	.0044	.0059
2	5-10	.027	.040	.049	.056	.077
3	10-15	.034	.053	.063	.072	.098
4	15-20	.046	.070	.084	.096	.132
5	20-25	.061	.095	.113	.128	.176
6	25-30	.082	.126	.150	.174	.236
7	30-35	.106	.164	.196	.224	.308
8	35-45	.183	.284	.338	.387	.531
9	45-55	.325	.504	.600	.685	.945
10	55-65	.541	.842	1.000	1.140	1.560
11	65-75	.976	1.510	1.810	2.110	2.835
		For artificial sky glow brightness residual at shipping lanes of 100 micro-footlamberts[a]				
1	0- 5	.0068	.0105	.0125	.0141	.0195
2	5-10	.088	.136	.162	.184	.253
3	10-15	.114	.178	.208	.240	.326
4	15-20	.152	.230	.280	.311	.434
5	20-25	.204	.314	.374	.423	.586

Zone	Distance from shore in miles	10% of lamp lumens up Diffusing luminaires	7% of lamp lumens up Redirective luminaires	3% of lamp lumens up Diffusing luminaires	3% of lamp lumens up Redirective luminaires	0% of lam lumens u Either luminair
For artificial sky glow brightness residual at shipping lanes of 100 micro-footlamberts (a) (cont.)						
6	25-30	.272	.372	.500	.548	.780
7	30-35	.352	.564	.650	.735	1.015
8	35-45	.610	.944	1.125	1.270	1.750
9	45-55	1.085	1.645	2.00	2.220	3.120
10	55-65	2.180	2.780	3.33	3.760	5.170
11	65-75	3.260	5.000	6.00	6.750	9.350
For artificial sky glow brightness residual at shipping lanes of 200 micro-footlamberts (a)						
1	0-5	.0135	.0209	.0249	.0282	.039
2	5-10	.177	.272	.324	.367	.506
3	10-15	.227	.356	.416	.480	.652
4	15-20	.304	.460	.560	.622	.868
5	20-25	.407	.628	.748	.846	1.172
6	25-30	.544	.744	1.000	1.096	1.560
7	30-35	.704	1.092	1.300	1.470	2.030
8	35-45	1.220	1.888	2.250	2.540	3.500
9	45-55	2.170	3.290	4.000	4.440	6.240
10	55-65	4.360	5.560	6.660	7.520	10.340
11	65-75	6.520	10.000	12.000	13.500	18.700

Based on 50 per cent of light emitted above the horizontal from luminaires and 20 per cent of light reflected from the pavements reaching the upper air (15 per cent reflection factor of pavements).

For artificial sky glow brightness residual at shipping lanes of 30 micro-footlamberts (a)						
1	0-5	.0026	.0046	.006	.0076	.0146
2	5-10	.033	.060	.079	.099	.190
3	10-15	.043	.077	.101	.127	.244
4	15-20	.058	.103	.136	.170	.328
5	20-25	.077	.138	.182	.228	.440
6	25-30	.103	.184	.243	.304	.585
7	30-35	.133	.239	.317	.396	.764
8	35-45	.231	.415	.547	.685	1.315
9	45-55	.411	.735	.973	1.215	2.340
10	55-65	.684	1.230	1.620	2.020	3.890
11	65-75	1.235	2.205	2.920	3.730	7.020

<table>
<tr><th>Zone</th><th>Distance from shore in miles</th><th>10% of lamp lumens up Diffusing luminaires</th><th>7% of lamp lumens up Redirective luminaires</th><th colspan="2">3% of lamp lumens up</th><th>0% of lamp lumens up Either luminaire</th></tr>
<tr><th></th><th></th><th></th><th></th><th>Diffusing luminaires</th><th>Redirective luminaires</th><th></th></tr>
<tr><td colspan="7">For artificial sky glow brightness residual at shipping lanes of 100 micro-footlamberts[(a)]</td></tr>
<tr><td>1</td><td>0- 5</td><td>.0086</td><td>.0154</td><td>.0202</td><td>.025</td><td>.0487</td></tr>
<tr><td>2</td><td>5-10</td><td>.112</td><td>.199</td><td>.263</td><td>.325</td><td>.633</td></tr>
<tr><td>3</td><td>10-15</td><td>.143</td><td>.261</td><td>.337</td><td>.425</td><td>.815</td></tr>
<tr><td>4</td><td>15-20</td><td>.192</td><td>.338</td><td>.454</td><td>.550</td><td>1.085</td></tr>
<tr><td>5</td><td>20-25</td><td>.257</td><td>.460</td><td>.606</td><td>.750</td><td>1.465</td></tr>
<tr><td>6</td><td>25-30</td><td>.343</td><td>.545</td><td>.810</td><td>.970</td><td>1.950</td></tr>
<tr><td>7</td><td>30-35</td><td>.445</td><td>.800</td><td>1.055</td><td>1.300</td><td>2.540</td></tr>
<tr><td>8</td><td>35-45</td><td>.770</td><td>1.380</td><td>1.825</td><td>2.250</td><td>4.380</td></tr>
<tr><td>9</td><td>45-55</td><td>1.370</td><td>2.410</td><td>3.240</td><td>3.920</td><td>7.800</td></tr>
<tr><td>10</td><td>55-65</td><td>2.275</td><td>4.080</td><td>5.400</td><td>6.650</td><td>12.940</td></tr>
<tr><td>11</td><td>65-75</td><td>4.120</td><td>7.340</td><td>9.740</td><td>11.950</td><td>23.400</td></tr>
<tr><td colspan="7">For artificial sky glow brightness residual at shipping lanes of 200 micro-footlamberts[(a)]</td></tr>
<tr><td>1</td><td>0- 5</td><td>.0171</td><td>.0342</td><td>.0404</td><td>.0808</td><td>.0974</td></tr>
<tr><td>2</td><td>5-10</td><td>.223</td><td>.446</td><td>.526</td><td>1.032</td><td>1.266</td></tr>
<tr><td>3</td><td>10-15</td><td>.236</td><td>.572</td><td>.674</td><td>1.348</td><td>1.630</td></tr>
<tr><td>4</td><td>15-20</td><td>.384</td><td>.768</td><td>.908</td><td>1.816</td><td>2.170</td></tr>
<tr><td>5</td><td>20-25</td><td>.514</td><td>1.028</td><td>1.212</td><td>2.424</td><td>2.930</td></tr>
<tr><td>6</td><td>25-30</td><td>.686</td><td>1.372</td><td>1.620</td><td>3.240</td><td>3.900</td></tr>
<tr><td>7</td><td>30-35</td><td>.890</td><td>1.780</td><td>2.110</td><td>4.220</td><td>5.080</td></tr>
<tr><td>8</td><td>35-45</td><td>1.540</td><td>3.080</td><td>3.650</td><td>7.300</td><td>8.760</td></tr>
<tr><td>9</td><td>45-55</td><td>2.740</td><td>5.480</td><td>6.480</td><td>12.960</td><td>15.600</td></tr>
<tr><td>10</td><td>55-65</td><td>4.550</td><td>9.100</td><td>10.800</td><td>21.600</td><td>25.880</td></tr>
<tr><td>11</td><td>65-75</td><td>8.240</td><td>16.480</td><td>19.480</td><td>38.960</td><td>46.800</td></tr>
</table>

(a) One-half of this brightness is assumed to be allotted to street lighting.

The values of the above tables are subject to variation due to differences in reflectivity of street surfaces and variations in other conditions found in practice. They may be increased somewhat when the glow producing area is less than 25 miles in depth or width, but must be decreased if glow producing area is greater than 25 miles in depth. Compare them with recommended practice given below:

Footcandles -- Illumination for Safety[1]

Street Classification	Volume of vehicular traffic maximum night hour both directions	Illumination on street between curbs	
		Average	Minimum
Very light traffic	Under 150	0.1	0.02
Light traffic	150-500	0.2	0.05
Medium traffic	500-1200	0.4	0.1
Heavy traffic	1200-2400	0.8	0.2
Very heavy traffic	2400-4000	1.2	0.3
Heaviest traffic	Over 4000	1.5	0.4

Depending on brightness of background requirements, the above tables may be compared to reveal the following relationships:

(a) Zones where a virtual blackout is necessary, and zones where a useful measure of street illumination may be maintained over a considerable area.

(b) Permissible upper limits of street illumination in relationship to distance from shore.

(c) The degree of shielding of luminaires necessary to permit the use of reasonable street illumination. Since restrictive shields are likely to disturb the required distribution of light on the street, a balance must be struck between the shielding technique employed and use of lower average illumination with proper distribution.

(d) Zones where street lighting requires little or no treatment. In zones where permissible street illumination as given in the above tables exceeds the recommended practice, an analysis of the street lighting system should be made to determine necessary restrictions in upward light, if such is required.

(6) For permissible illumination on individual streets and roads in areas visible from the sea, see sub-paragraph 22 C. This higher level of illumination may also be employed at hazardous locations in the zones close to the shore, provided average street illumination in the area does not exceed the permissible values.

d. Traffic signals.- (1) Standards for traffic signals have long been established, both as to conditions which warrant their use and photometric requirements. Visibility requirements as set forth in the War Emergency edition of the "Manual on Uniform Traffic Control Devices for Streets and Highways" are: "Each lens, reflector, and visor shall be of such design as to render the lens, when illuminated, clearly visible to traffic controlled by that signal face at all distances from 10 to 300 feet, under all light and atmospheric conditions except dense fog". Any

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[1] See practice recommended by the Illuminating Engineering Society.

lowering of these standards by dimout treatment will have an adverse effect on traffic safety, as has been demonstrated in those communities where traffic signal lenses have been made opaque except for a small cross. A greater importance is attached to proper operation of warranted traffic signals during the war because of the vital need for expediting the movement of war workers and materials, including truck and mass carrier traffic, conserving war transportation facilities, and reducing loss of man-hours in war industries. Nevertheless, the possible contribution to sky glow by traffic signals must be investigated before decision as to proper treatment can be reached.

(2) In sub-paragraph 21b(3) is set forth data on output of light from traffic signals above the horizontal. Lumen output below the horizontal is approximately as follows: green lens, 15.3; red lens, 37.8; and yellow lens, 51.8. On the basis of city squares approximately 300 feet by 300 feet forming 64 intersections in an area 1/2 mile by 1/2 mile, with every intersection controlled by standard three light traffic signals having yellow overlap on green only, one signal face for each direction of traffic, 384 lamps would be operating simultaneously for a small portion of the signal cycle, or 128 each with red, green, and yellow lenses. Then, total lumens emitted, on the basis of 60 watt, 120 volt lamps, would be as follows:

	Lumens per area ½ mile by ½ mile
Above the horizontal	6976
Below the horizontal	13427.2

With reflection factor of 15 per cent for pavements, total lumens reaching upper atmosphere from an area ½ mile by ½ mile are as follows:

(a) On the basis of 50 per cent of light emitted from the signal above the horizontal and 20 per cent reflected from the pavements,

Total lumens = 6976 x .50 + 13427 x .15 x .50 = 4495

(b) On the basis of 50 per cent of light emitted from the signal above the horizontal and reflected from the pavements,

Total lumens = 6976 x .50 + 13427 x .15 x .20 = 3891

Calculated sky glow at a distance of 5 miles for 99 per cent transmission per 1000 feet by use of Graph 3c for the above lumen values are 1.44 and 1.25 micro-footlamberts respectively. Hence, sky glow produced by traffic signals is negligible even during the short period when the yellow indication is operating, and traffic signals should be retained at their full efficiency, except where visible from the sea (see sub-paragraph 21b).

e. Show windows. - Lighted show windows and outdoor advertising signs are major contributors to sky glow. Together with other commercial lighting their contribution is on the probable order of 38 per cent. A number of dimout treatments have been proposed for show windows, such as limitations on wattage per lineal foot of window, maximum permissible footcandles at the glass surface of the window, and use of dimout curtains composed of a fabric mesh. These methods substantially reduce the light which escapes to the outside. On the other hand, their use would create difficult problems of enforcement and control, involve re-wiring and use of critical materials, and would require production facilities and manpower which could be devoted to war production. Since this type of lighting is non-essential, dimout regulations should require extinguishment of show windows and other commercial lighting as the first requisite in effecting required reductions in sky glow.

f. Building windows. (1) Wide variation in the size of windows, their present shading equipment, their distance from surrounding buildings, and interior illumination, complicate the task of estimating the relative amount of sky glow contributed by these sources. However, sky glow produced by building windows may be considerable for certain types of installations such as concentrations of large office buildings as found in downtown business areas and modern industrial plants.

(2) Reductions in upward light from windows can be accomplished by masking with opaque material, shades, awnings, venetian blinds, newspaper, and other materials, and/or by dimming or shielding interior illumination. Tests on a typical office window revealed that the reductions in upward light resulting from various methods of masking are of the following order of magnitude:

Treatment of Building Windows
Order of Magnitude of Reduction in Upward Light in Per Cent

	Type of Shielding					
Treatment	Opaque	Light colored shades	Newspaper 1 thickness	Newspaper 2 thicknesses	Venetian Blinds Angled to ground	Venetian Blinds Angled to sky
Upper 3/4	88	70-75	70-75	85-90	56	52
Lower 3/4	75					
Upper 1/2	60	45-50	50-55	60-62		
Lower 1/2	40					
Total Window Surface		80-85	80-85	95-97	64	59

(3) From the table above, shielding upper portion of building windows is shown to be more effective in reducing sky glow for lighting installations which provide diffused interior illumination. While opaqueness of the shielded portion gives maximum effectiveness, nevertheless blinds of standard design with transmission factors not exceeding 25 per cent, newspaper, and venetian blinds all reduce upward light appreciably and at the same time their use further simplifies the problem of day lighting in a building.

g. Outdoor Floodlighting. (1) Outdoor industrial floodlighting is classified as essential to the war effort since it provides illumination for outdoor production of war equipment and for plant protection against sabotage. Dimout restrictions should, therefore, eliminate all non-essential lighting in the vicinity of the outdoor industrial floodlighting, and all upward light from the luminaires, before reductions are made in the illumination at the point of work. In general, equipping the lighting units with hoods and louvers which confine the illumination to the working plane and eliminates direct upward light will reduce sky glow sufficiently, provided illumination levels on the working plane are kept to a minimum consistent with the requirements of the seeing task.

(2) The sky glow resulting from outdoor floodlighting (industrial, parking space, service stations, etc.) depends upon the dimensions and reflection factor of the area illuminated, the level of illumination provided, the wattage and type of luminaire installed, the number of luminaires employed, and the atmospheric conditions encountered. If hoods and louvers are used to eliminate the direct upward light, the controlling factors for a given atmospheric condition become the average illumination on the working plane, the reflection factor of its surface, and the area illuminated. Standards of footcandle levels for outdoor floodlighting are given below:

Outdoor Industrial....................	10 to 50	footcandles
Service Stations......................	5 to 10	"
Parking Spaces........................	0.5 to 1	"
Piers.................................	1 to 5	"
Railroad Yards........................	0.1 to 0.2	"
Protective Lighting...................	0.2 to 0.5	"

Average reflection factors of various surfaces are shown below:

Green foliage and Grass	2% to 5%
Earth - Dark	0.5% to 2%
Earth - Light	2% to 15%
Concrete	15% to 50%

For a given area and atmospheric condition, the sky glow produced by outdoor floodlighting can be calculated using the graphs and equations of this report. For example, one mile of modern protective floodlighting, illuminating a strip, 300 feet in width, to a level of 0.34 footcandles, with the units shielded to prevent direct upward light, will produce a sky glow of 25 micro-footlamberts over the long dimension and 211 micro-footlamberts over the short dimension, when viewed from a distance of five miles with an atmospheric transmission of 99 per cent. (See Appendix H for calculations.) It is evident from this example that relatively low levels of illumination on the large areas to which this type of lighting is usually applied may produce enough upward light to make this source of sky glow hazardous to shipping.

35. Light Control Techniques for Shore Areas. - Light control methods adopted for shore areas should meet insofar as possible the requirements of ship safety and minimum interference with normal ground activities.

a. Vehicular lighting. - (1) On highways where vehicle lighting is not visible from the sea, half masked headlamps with use of passing beams appear to provide adequate reduction in sky glow with maintenance of reasonable road illumination for driving at reduced speeds. However, on highways where direct viewing from the sea is possible, all vehicle lighting, except a low level of interior illumination and exterior blackout lighting, must be extinguished unless obstructions to viewing from the sea are installed.

(2) In cities, situated within 5 miles or less of shipping lanes, where vehicle concentrations are sufficient to produce hazardous background brightness of glow even with half-shielded headlamps, further restrictions may be necessary depending on the permissible background brightness established by basic dimout policy.

b. Traffic circulation plans. - In coastal areas, traffic authorities should review the traffic circulation system and divert night traffic, wherever practicable, to streets and highways which are obscured from the sea.

c. Use of baffles. - Baffles may be erected at any location where direct offshore visibility of vehicle lighting is possible. Such baffles permit use of relatively short stretches of highways which are normally exposed to the sea by vehicles employing half-shielded headlamps on passing beams without hazard to shipping, provided the baffles are sufficiently high and wide to obscure headlights completely from any angle at sea. The inland side of baffles should be painted a matte black to absorb incident light from headlamps.

Where traffic in both directions does not exceed 200 vehicles in the maximum night hour, and the time each vehicle at average prevailing speeds is exposed to view from the sea does not exceed 2 to 3 seconds, baffles are unnecessary, if such exposed locations do not occur in rapid sequence (there should be at least 5 minutes driving time between such locations).

d. Aids to traffic movement.- (1) Markings.- White markings should be employed extensively on roadways where normal headlamps must be extinguished. (Where blackout headlamps are used or in areas where half-masked headlamps are permitted, reflectorized markings are recommended.) White paint should be used to mark center lines, lane lines, guide lines, crosswalk and limit lines, and vertical and sloping faces of curbs or of any obstacles in or near the roadway. Similar treatment should be given sidewalk obstacles for guidance and protection of pedestrians; and pedestrians should be urged to wear an article of white clothing.

(2) Illuminated signs.- On roads exposed to view from the sea, illuminated signs may be used to guide, safeguard, or regulate traffic, provided the light source and reflector are obscured from the sea and the illuminated surface, if facing any location at sea, cannot be detected for distances in excess of 4000 feet by dark-adapted observers on a clear, moonless night.

(3) Traffic signals.- When night operation of traffic signals visible from the sea is warranted, such signals should provide adequate signal indications for all distances from 10 to 300 feet from the signal during all operating periods. Such signals shall not be visible for distances in excess of 4000 feet when viewed by dark-adapted observers on a clear, moonless night. With 60 watt, 120 volt traffic signal lamps, these requirements can be met by attaching 7 degree louvers, with 6 inch parallel vanes spaced one inch apart, to each roundel and operating the lamps at 42 volts during night hours and at rated voltage during other periods. Although the prohibition of use of headlamps on roads visible from the sea will result in reduced speeds and traffic volumes and on that basis lessened need for operation of traffic signals, the increase in hazard because of dark surroundings may warrant continued night operation. Final determination of which traffic signals visible from the sea are to remain operative during the dark hours must be based to a large extent on the knowledge and experience of the local traffic authority and trends which will become apparent after initiation of dimout.

(4) Street and highway lighting.- A special roadway lighting system to aid driving without headlights may be installed on those streets which approach the sea directly. This system employs small floodlights in deep hoods to confine the light to the roadway without spill on adjacent buildings and trees. The units

must be directed away from the sea and mounted sufficiently high to minimize glare. They should be so located that full advantage is taken of any existing obstructions to direct viewing from the sea. Spacing and wattage of the lamps should be such that no less than 0.1 and no greater than 0.4 footcandle is provided on the roadway. In cities within the 0 to 5 mile coastal zone, where average street lighting levels may have to be much less than the above values in order to reduce sky glow sufficiently, the above level of illumination may be maintained at points of heavy pedestrian movement, hazardous locations, focal points of the traffic flow, and similar locations.

e. Building openings.- If normal illumination is maintained within interiors, all openings on the sides visible from the sea must be made light-tight. Windows on the side of the building away from the sea require no treatment unless in sufficient concentrations to produce hazardous glow, and such windows may be used for required ventilation. In rooms where all openings must be light-tight, ventilation equipment may be necessary. War Department approved indoor blackout lamps or units may be employed to provide a low level of interior illumination without any obscuration. These lamps or units should not be spaced less than 5 feet apart in any direction.

f. Yard and porch lighting.- A low level of illumination may be provided in yards, on porches, and similar features by use of War Department approved indoor blackout lamps or units, spaced not less than 5 feet apart in any direction. No shielding is required.

g. Protective lighting and outdoor production lighting.- To eliminate hazard to shipping caused by direct viewing of such lighting, the lighting must be extinguished or drastically modified. The final solution will probably represent a compromise between blackout for maximum safety of shipping and sufficient light for undiminished production of war materials. However, the system of illuminating horizontal surfaces as set forth in sub-paragraph 31d(4) above may be employed without hazard to shipping, provided area illuminated is not large enough to reflect a total light flux sufficient to produce hazardous sky glow. In any event, light sources should be encased in deep hoods to prevent escape of light above the horizontal, and directed away from the sea and downward. Shields should be employed on the seaward side as a precautionary measure against hazardous "halo" effects which may be produced around the openings of the hoods. Focusing of the lighting units should direct the light away from vertical surfaces insofar as practicable.

h. Minor aids to navigation.- Aids to navigation are essential for guiding ships safely along the coasts, yet they undoubtedly serve to aid enemy submarines in detecting ships and determining their type, speed, and course preliminary to pressing home an attack. Candlepower limits of aids to navigation are determined by signal strength required to afford proper guidance to ships, although some reductions could probably be made in the interest of diminishing the submarine hazard. Any treatment proposed for aids to navigation should balance their necessity as guides against losses by submarine action to which they may contribute.

i. Airway beacons and obstruction lights.- Airway beacons and obstruction lights must be maintained to guide night air traffic, including night air patrols of coastal sea lanes. However, several methods may be appropriate to minimize probable assistance afforded submarines in detecting ships:

(1) Using flashing or rotating signals.

(2) Eliminating light in the zones at and near the horizontal.

(3) Shielding units in direction of the sea.

V. CONCLUSIONS

36. Need for Establishment of Basic Dimout Policy.- The drastic curtailment of all lighting necessary for considerable distances inland in order to eliminate completely artificial sky glow apparent at shipping lanes, although effective for 50 per cent or less of the dark hours, may result in waste and loss of life on land detrimental to the overall war effort. Since the overall war effort is dependent not only on safety of shipping off the coasts but on maintenance of production, transportation, and other essential activities on land, a basic dimout policy which strikes the proper balance needs be established. This policy should express the combined Army-Navy dimout requirements as determined by evaluation of all factors bearing on the war endeavor and should establish the following:

a. Maximum amount of artificial sky glow brightness apparent at shipping lanes or at a stated distance offshore to be permitted.

b. Distance inland from coast to be included in the dimout zone.

c. Whether dimout should be enforced every night or whether selective programs based on lunar and atmospheric conditions or submarine activity should be executed.

37. Effect on Hazard to Ships of Reduction in Artificial Sky Glow.- The minimum amount of background brightness necessary to silhouette a ship, when the eye is aided by night binoculars, varies through a range of 30 to 280 micro-foot-lamberts, depending on atmospheric factors and relative positions of the observer and the silhouetted ship. Natural horizon brightnesses prevailing on moonless nights are within that range but are generally nearer the lower limit; and the range is exceeded for all other lunar phases except during conditions of fog, rain or snow. Elimination of all artificial sky glow therefore will reduce the silhouetting effect of the background to that inherent in natural horizon brightness and in many instances will completely remove the hazard to shipping. Reduction of artificial sky glow does not materially reduce the hazard to shipping on clear, moonlit nights. However, on moonless nights, the closer total background brightness approaches natural horizon brightness, the less are the chances for observers on a submarine to detect passing ships and gain the knowledge required to hazard an attack.

38. Fundamental Sky Glow Data.- a. Relationships.- (1) The apparent brightness of sky glow decreases with distance from the source of upward light in the same ratio as the atmospheric

transmission raised to the nth power, where n is the distance from source of upward light divided by the unit distance for which atmospheric transmission is expressed.

(2) Total apparent brightness from two or more sky glows at any location from which they can be viewed in line is the sum obtained by direct addition of brightness residual from each sky glow.

(3) Total width of lighted area effective in producing sky glow at central line of the width is 2½ miles; i.e., areas to width of one mile to each side of an area 1/2 mile in width, add part of their generated sky glow brightness to the latter. The amount of brightness added increases as the atmospheric transmission decreases.

(4) The amount of sky glow produced over a given area is a function of the amount, concentration, and distribution of light in the area, and the atmospheric transmission. On the basis of diffused light evenly distributed in an area of 1/2 mile by 1/2 mile, the resulting sky glow may be computed by the following equation:

$$B_i = \frac{L\ 10^{18.02-15.56t}}{1,000,000},$$

where B_i is resulting sky glow at source of upward light, L is the number of lumens of upward diffused light, and t is atmospheric transmission in decimals per 1000 feet.

b. Adequacy of data.- Fundamental data set forth herein are considered adequate for evaluation of amount of sky glow produced by any type, amount, and distribution of lighting; for delineation of inland limits of the dimout zone and the amount of light control necessary in each division thereof; and for preparation of dimout regulations after basic policy has been established. However, specific lighting installations, and problems arising from local conditions, must be investigated in order to design proper dimout treatment in conformity with fundamental data and the purpose of the lighting.

39. Contribution to Sky Glow by Specific Types of Illumination.- From available data, per cent contribution to sky glow from various types of lighting in the average city is estimated to be:

Classification	Per Cent Contribution to Sky Glow
Commercial lighting	38
Street lighting	33
Automobiles	15
Indoor lights except defense industries	8
Defense plants	6

These contributions will vary considerably with the character and size of cities; however, as a practical average they are fairly representative.

40. Inland Limits of the Dimout Zone.- The extent of the zone requiring dimout treatment depends on sky glow brightness permissible at shipping lanes as established by basic policy, but for most restrictive sky glow limitations it will probably extend inland as far as 80 miles from the shipping lanes. Necessary control of light will become less severe as the distance from the coast increases, and will vary from virtual blackout in shore areas to small reductions in non-essential lighting near the inland limits of the dimout zone.

41. Lighting Control in Shore Areas.- a. As the distance of shipping lanes from light source or illuminated vertical surface exposed to the sea increases, the candlepower or brightness limits non-hazardous to shipping also increases. However, relatively large increases in distance do not significantly increase non-hazardous values. Permissible candlepower limits of unshielded sources were too low to be utilized for illumination purposes and non-hazardous brightnesses of illuminated vertical surfaces approached blackout limits. Hence, for safety to shipping, all shore lights should be rendered invisible from any location at sea.

b. When shipping lanes are within 5 miles or less of shore installations, a relatively small amount of light escaping to the upper atmosphere will produce a sky glow of sufficient brightness during optimum conditions to silhouette ships. In an area of 1/2 mile by 1/2 mile, the minimum amount of upward lumens of diffused light which will produce a sky glow brightness when viewed from 5 miles away, of 30 micro-footlamberts is 900, of 100 micro-footlamberts is 3000, and of 200 micro-footlamberts is 6000. These amounts of light are so small that virtual blackout is preferable.

42. Priority of Treatment of Lighting for Reduction of Sky Glow.- a. Lighting should be divided into two rather broad classifications based upon primary functions performed in furtherance of the war effort.

b. Dimout should be accomplished insofar as possible by reduction or elimination of lighting considered non-essential. Data indicates that elimination of non-essential lighting will reduce artificial sky glow on the order of 18 to 58 per cent with an average reduction of 40 per cent.

c. After elimination of non-essential lighting, further required reductions in sky glow must be accomplished by treatment of essential lighting. Many types of essential lighting may be modified without too seriously restricting illumination therefrom; and such modifications should be made first. In general, dimout treatment applied to essential lighting should effect necessary reductions in sky glow with maintenance of reasonable seeing efficiency, insofar as possible.

43. Dimout Treatment of Specific Types of Lighting.- a. Motor vehicle lighting.- (1) Motor vehicle headlighting is a factor in producing sky glow above cities, and in maximum night concentrations in cities above 200,000 population may alone produce sufficient glow with favorable atmospheric conditions to increase significantly the silhouette hazard at distances of 28 miles or less from source of glow.

(2) With peak concentrations of traffic on main coastal highways, sky glow brightness produced in front of and behind the lines of traffic may increase significantly the silhouette hazard at distances of 8 miles or less from source of glow.

(3) Driving beams of sealed beam headlamps produce approximately 1.7 times more sky glow than passing beams. Shielding of upper half of headlamps using passing beams reduces sky glow approximately 70 per cent below the unshielded value. This method of dimming results in adequate reduction of sky glow for nearly all situations. It also retains a reasonable amount of road illumination, is non-glaring to drivers in approaching cars, requires no critical materials, and is easy to accomplish. While greater reductions in sky glow can be obtained by other methods of shielding -- making upper three-quarters of lens opaque or applying hoods or masks with various size slits -- or by use of 250 beam candlepower headlamps, such methods are either impractical or result in unsafe driving conditions.

(4) On roads visible from the sea, all vehicle lighting must be extinguished except War Department approved blackout vehicle lighting and a low level of interior illumination.

b. Street lighting.- (1) Street lighting, one of the most essential types of lighting, is a major contributor to sky glow. This contribution is on the order of 33 per cent. Large reductions in upward light from present luminaires cannot be accomplished by practical shields without resultant reduction in downward light in those angles near the horizontal needed for even distribution of street illumination between luminaires. With present luminaires, the reduction in downward light which will accompany restriction in upward light is as follows:

Estimated Reductions in Downward Light Accompanying Restrictions in Upward Light

Per cent reduction in downward light by zones below the horizontal

Type of Luminaire	Not more than 10% of lamp lumens above the horizontal		Not more than 3% of lamp lumens above the horizontal		Practically no light above the horizontal	
	0-30°	30-90°	0-30°	30-90°	0-30°	30-90°
Diffusing	20	0	40	5	65	10
Redirective	0	0	10	0	75	0
Open reflector	0	0	5	0	20	0

(2) In divisions of the dimout zone where street lighting must be treated to effect reductions in sky glow, the amount of light above the horizontal from the luminaires must be restricted and maximum street illumination values specified in order to meet dimout requirements.

(3) In areas visible from the sea the restrictive shields necessary to render present street and highway lights non-hazardous to shipping so reduce lighting efficiency that the solution appears to be extinguishment of the lights. However, a specially designed street lighting system giving specified illumination values may be useful on essential streets and highways which approach the shore directly, in order to maintain the movement of vehicles without use of headlamps.

c. Traffic Signals.- (1) Traffic signals do not appreciably contribute to sky glow and no modification is needed where direct viewing from the sea is impossible.

(2) When visible from the sea, traffic signals must be extinguished during dark hours or so treated that (a) they are invisible to dark-adapted observers beyond 4000 feet on a clear, moonless night and (b) adequate signal indications are provided during all operating periods.

d. Lighted show windows.- (1) Lighted show windows in the numbers found in shopping and commercial districts contribute appreciably to sky glow. Together with other commercial lighting, they may contribute approximately 38 per cent of sky glow above cities. Total lumens emitted above and below the horizontal by an average incandescent and fluorescent lighted show window are as follows:

Lumens emitted from an average show window

Incandescent Lighted

	No Awning No Curtain	No Awning Curtain	Awning No Curtain	Awning Curtain
Below horizontal	1462 to 2262	150 to 220	1462 to 2262	150 to 220
Above horizontal	489	120	190	50

Fluorescent Lighted

	No Awning No Curtain	No Awning Curtain	Awning No Curtain	Awning Curtain
Below horizontal	1525 to 2325	165 to 235	1525 to 2325	165 to 235
Above horizontal	431	105	140	35

(2) Dimout curtains and/or awnings materially reduce upward light; however, since show windows are classed as non-essential to the war effort and methods of light control are complicated, enforcement is difficult, manufacture of dimout materials requires man-hours and use of production facilities, the most appropriate dimout treatment is extinguishment.

e. Building windows.- Building windows in certain instances may contribute appreciably to sky glow. Proper treatment of windows depends on the type and function of the structure. Reduction in upward light may be had either by masking the windows or dimming or shielding interior illumination in such a manner that light incident on the window is reduced. Making upward three-quarters of glass area opaque will reduce upward light approximately 88 per cent. While opaqueness of the shielded portion gives maximum effectiveness in reduction of sky glow, nevertheless, blinds of standard design with transmission factors not exceeding 25 per cent, newspapers and venetian blinds all reduce upward light appreciably.

f. Use of indoor blackout lamps.- In areas or installations visible from the sea, use of War Department approved indoor blackout lamps spaced not less than 5 feet in any direction and without shields either indoors or outdoors does not create a hazard to shipping.

g. Minor aids to navigation.- Present minor aids to navigation may provide definite assistance to submarines. Proper dimout treatment depends on the relative necessity for their maintenance as guides to shipping as balanced against losses from submarine action which may be attributable to them. Further study by the appropriate authorities is required to develop correct treatment; however, the following may be concluded from the test data:

(1) Flashing lights give less assistance to submarines than fixed lights.

(2) Degree of assistance provided submarines lessens as eclipse period increases and as length of flash decreases.

(3) Maximum permissible candlepowers for flashing or

fixed minor aids to navigation, on the basis of eliminating possible assistance rendered submarines, provided submarines cannot approach closer than two nautical miles to them, are as follows:

Red	165
Clear	90
Green	30

44. Problems Arising from Specific Types and Applications of Lighting.- Many specific types and applications of lighting will require detailed investigations in order to develop correct dimout treatment in conformity with basic policy, fundamental data set forth in this report, and required lighting utility. A committee empowered to carry out such studies and to settle problems that may arise should be formed.

VI DIMOUT REGULATIONS

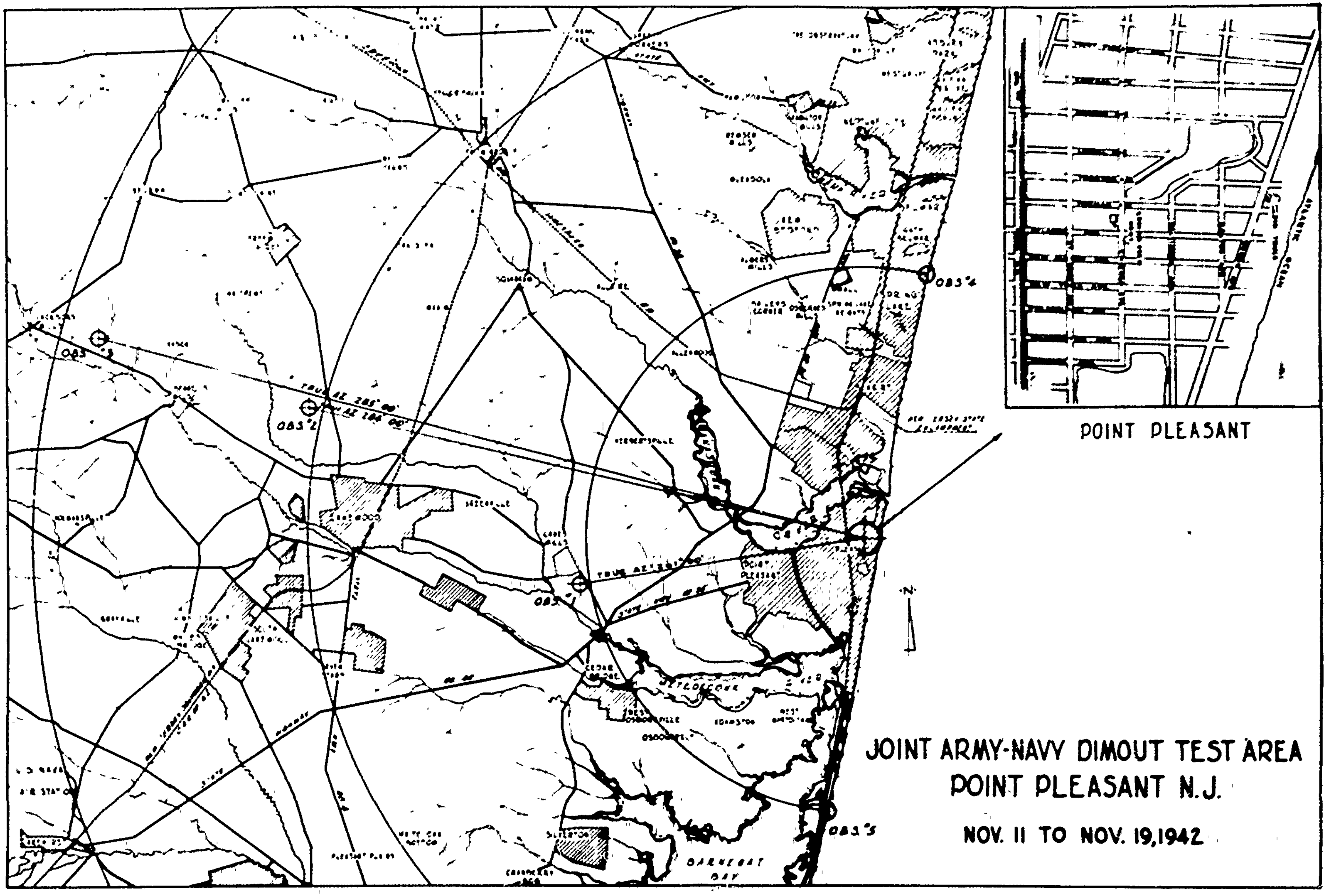
45. Interim Dimout Regulations. a. Application.- Dimout of coastal lighting is now in effect under regulations prepared by the various Defense Commands. Due to the necessity for quick action in combating the submarine menace to shipping, these regulations were hurriedly prepared without consultation between the Defense Commands, with the result that frequent revisions have been necessary. Much confusion on the part of the public has been created thereby. To correct this situation, final dimout regulations will be prepared to serve as models for future Defense Command regulations as soon as basic dimout policy has been established. In the meantime, however, interim dimout regulations are included to aid Defense Commands, by providing them with a means of judging by comparison the effectiveness of their present regulations, and to encourage revision of those regulations to achieve general uniformity of light control. The interim regulations should not be considered as final, and present Defense Command regulations should not be revised drastically pending the establishment of a basic dimout policy and the issuance of final dimout regulations. In those instances where Defense Command regulations deviate widely from interim regulations, the former should be adjusted to conform with the latter. On the other hand, where present regulations are comparable, further revisions should be postponed until final regulations are available in the interest of conservation of materials and manpower, and of preventing additional confusion on the part of the public.

b. Suggested interim dimout regulations.- Suggested interim dimout regulations for use as described in sub-paragraph a. above are contained in Appendix I.

46. Preparation of Final Regulations.- Final regulations based upon the investigations described in this report will depend upon the establishment of a basic dimout policy. Once established, the definition of divisions of the dimout zone, amount of light control necessary in each division, types of lighting which must be restricted, and the preparation of specifications for certain dimout lighting devices can be completed without further delay. The final regulations will specify the type and extent of light control necessary to solve all ordinary dimout problems. Unusual dimout situations will require individual study to determine the most appropriate methods of meeting war requirements on land and at sea.

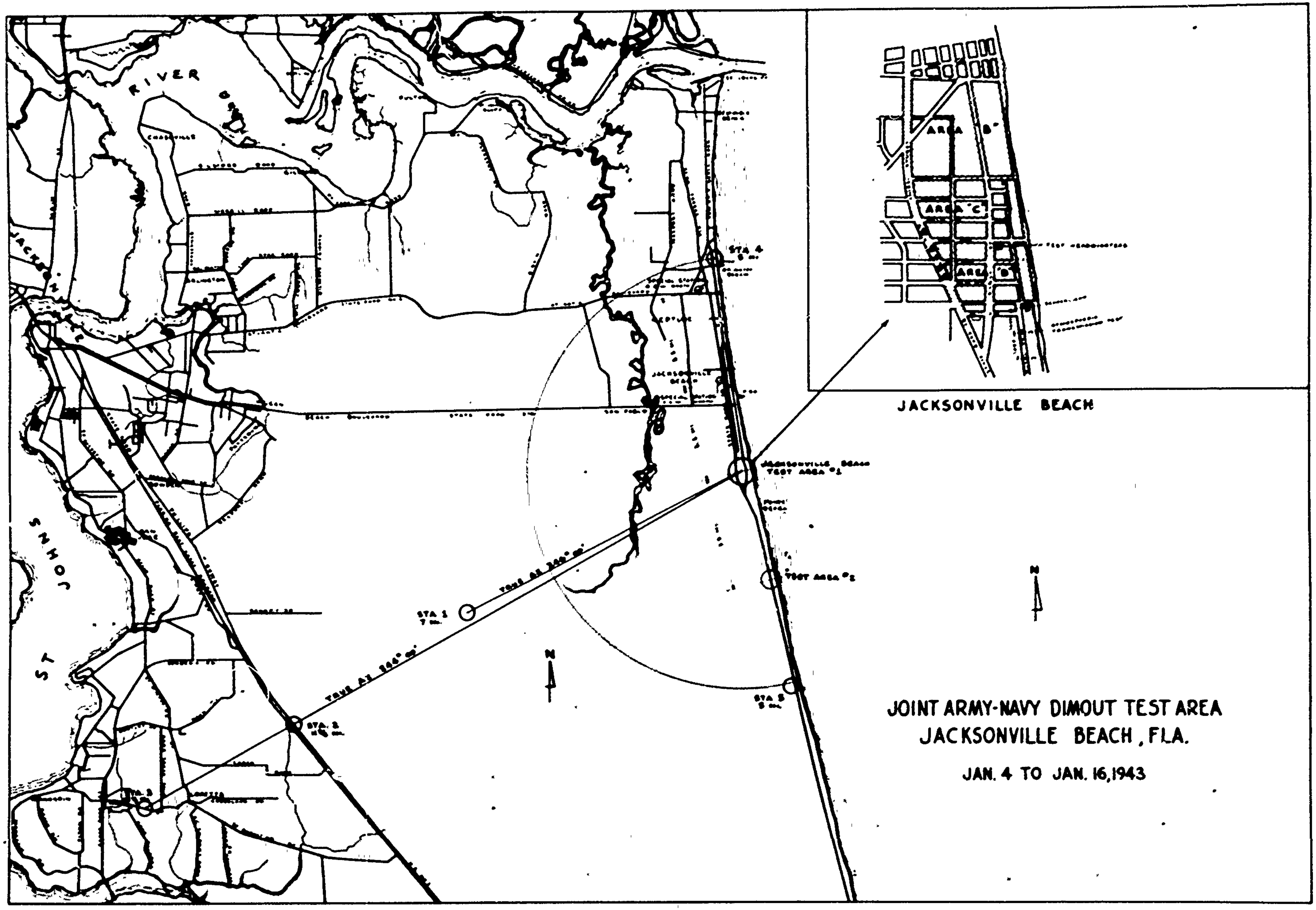
APPENDIX A

JOINT ARMY-NAVY DIMOUT TEST LOCATIONS



JOINT ARMY-NAVY DIMOUT TEST AREA
POINT PLEASANT N.J.

NOV. 11 TO NOV. 19, 1942



JOINT ARMY-NAVY DIMOUT TEST AREA
JACKSONVILLE BEACH, FLA.
JAN. 4 TO JAN. 16, 1943

APPENDIX B

TEST PROCEDURES

RESTRICTED

TEST 1

THE EFFECT OF DISTANCE ON EFFECTIVENESS OF SHIP SILHOUETTING AND BRIGHTNESS OF A CONSTANT SKY GLOW

November 12-13, 1942

1. PURPOSE.- The purpose of this test is (a) to establish the relationship between the effective silhouetting of a ship by a sky glow of constant brightness to observers at various distances from the source of sky glow, (b) to study the effect of distance on the apparent brightness of the known sky glow, and (c) to determine the threshold visibility distance of a known sky glow brightness.

2. TEST CONDITIONS.- a. Sky glow.- Maximum sky glow will be produced by pointing all lighting units directly upward. There will be no change in position of lighting units during test.

b. Ground observers.- Ground observers will be stationed at Stations OB. S#1, OB. S#2, and OB. S#3. Designated party will determine atmospheric absorption near shore line proximate to test area.

c. Marine observers.- Observers on O-boat will begin test at a point 15 miles offshore and move progressively inshore as set forth in program of operations. T-boat will begin test 5 miles offshore and move inshore on instructions from Central Control Station.

3. TIME TEST IS TO BEGIN.- All observers, boats, and equipment will be in position at 10:00 p.m. Test will begin at 10:05 p.m.

4. PROGRAM OF OPERATIONS.- a. Air observer.- Blimp flies directly east and records threshold visibility distance of sky glow.

SERIES NO.	GROUND OBSERVERS	MARINE OBSERVERS
1 - 1	Stations OB. S#1, #2, and #3 occupied Weather and sky conditions Zenith brightness Inland horizon brightness Sky glow brightness Designated party determines atmospheric absorption along shore line.	Weather and sky conditions Ocean conditions Ocean horizon brightness Zenith brightness Water brightness at T-boat Sky glow brightness Lateral and vertical spread of sky glow (degrees) Angle of vision subtended by target ship (degrees) Height of dark area between sky glow and sea (degrees) *Effect of water brightness in delineating target ship Hazard visibility of target ship with unaided eyes and with night glasses Notify shore when readings and observations are completed.
1 - 2	Observers at Station OB. S#3 proceed west on U. S. Highway 37 until threshold visibility of sky glow is reached. Record distance from Station OB. S#3 to that point.	O-boat proceeds to location 10 miles offshore.
1 - 3	Station OB. S#3 observers return to that station. Central Control Station notifies T-boat, when marine observations are completed, to move to 1 mile offshore	Water brightness at T-boat Sky glow brightness Lateral and vertical spread of sky glow (degrees) Angle of vision subtended by target ship (degrees) Height of dark area between sky glow and sea (degrees) Effect of water brightness in delineating target ship Hazard visibility of target ship with unaided eyes and with night glasses Notify shore when readings and observations are completed.

SERIES NO.	GROUND OBSERVERS	MARINE OBSERVERS
1 - 4		O-boat moves to location 5 miles offshore. T-boat moves to location 1 mile offshore.
1 - 5	Observers for Stations OB. S#4 and OB. S#5 leave for those stations and proceed with Series 1 - 7 upon arrival.	Water brightness at T-boat Sky glow brightness Lateral and vertical spread of sky glow (degrees) Angle of vision subtended by target ship (degrees) Height of dark area between sky glow and sea (degrees) Effect of water brightness in delineating target ship Hazard visibility of target ship with unaided eyes and with night glasses Notify shore when readings and observations are completed.
1 - 6	Central Control Station notifies Stations OB. S#1, #2, and #3 to proceed with Series 1 - 7.	O-boat moves to location 2 miles offshore.

SERIES NO.	GROUND OBSERVERS	MARINE OBSERVERS
1 - 7	Weather and sky conditions Zenith brightness Inland horizon brightness Sky glow brightness Notify Central Control Station when readings are completed. Designated party determines atmospheric absorption along shore line.	Weather and sky conditions Ocean conditions Ocean Horizon brightness Zenith brightness Water brightness at T-boat Sky glow brightness Lateral and vertical spread of sky glow (degrees) Angle of vision subtended by target ship (degrees) Height of dark area between sky glow and sea (degrees) Effect of water brightness in delineating target ship. Hazard visibility of target ship with unaided eyes and with night glasses Notify shore when readings and observations are completed.
1 - 8	Central Control Station notifies ground crew in test area to change angular position of lighting units to 60° above the horizontal, position A. Ground crew notifies Central Control Station when this is completed. Central Control Station notifies all ground stations of completion, also radio truck which in turn notifies marine observers.	O-boat moves to location 5 miles offshore. They will remain at this location throughout Test 2.

TEST 2

SKY GLOW VARIATION DUE TO FLUX DISTRIBUTION

November 13, 1942

1. PURPOSE.- The purpose of this test is to establish the changes which take place in sky glow produced by a source of known light output when such output is directed at various angles.

2. TEST CONDITIONS.- a. Sky glow.- Sky glow will be produced by same units used in Test 1. The angular position of the lighting units will be changed and diffusing screens attached to change amount of sky glow.

b. Ground crew.- Ground crew will change lighting units as directed by Central Control Station.

c. Ground observers.- Ground observers will occupy Stations OB. S#1, #2, #3, #4, and #5. At completion of land and marine observations, atmospheric absorption will be determined by designated party.

d. Marine observers.- Observers on O-boat will be stationed 5 miles offshore. The T-boat at a distance of one mile offshore will move back and forth in front of sky glow. Boats will not change positions during test.

3. TIME TEST IS TO BEGIN.- This test will immediately follow Test 1. Series 1 - 8 of Test 1 places observers and equipment in position to begin Test 2. Light units are set 60° above horizontal, position A, for beginning of test.

4. PROGRAM OF OPERATIONS.-

SERIES NO.	MARINE OBSERVERS	GROUND OBSERVERS	OPERATIONS IN TEST AREA
2 - 1	Water brightness near target ship Sky glow brightness Lateral and vertical spread of sky glow (degrees) Effect of water brightness on ship visibility Hazard visibility of T-boat with unaided eyes and with night glasses Notify shore when readings and observations are completed.	Sky glow brightness Notify Central Control Station at completion.	Central Control Station notifies ground crew when all readings and observations are completed.
2 - 2			Ground crew changes angular position of lighting units to 30° above the horizontal (position B), and notifies Central Control Station on completion. Central Control Station notifies ground and marine observers.

SERIES NO.	MARINE OBSERVERS	GROUND OBSERVERS	OPERATIONS IN TEST AREA
2 - 3	Water brightness near target ship Sky glow brightness Lateral and vertical spread of sky glow (degrees) Effect of water brightness on ship visibility Hazard visibility of T-boat with unaided eyes and with night glasses Notify shore when readings and observations are completed.	Sky glow brightness Notify Central Control Station at completion	Central Control Station notifies ground crew when all readings and observations are completed.
2 -4			Ground crew changes angular position of lighting units to 15 degrees above the horizontal (position C) and notifies Central Control Station on completion. Central Control Station notifies ground and marine observers.
2 - 5	Water brightness near target ship Sky glow brightness Lateral and vertical spread of sky glow (degrees) Effect of water brightness on ship visibility Hazard visibility of T-boat with unaided eyes and with night glasses Notify shore when readings and observations are completed.	Sky glow brightness Notify Central Control Station at completion.	Central Control Station notifies ground crew when all readings and observations are completed.

SERIES NO.	MARINE OBSERVERS	GROUND OBSERVERS	OPERATIONS IN TEST AREA
2 - 6			Ground crew changes angular position of lighting units to the horizontal and notifies Central Control Station on completion. Central Control Station notifies ground and marine observers.
2 - 7	Water brightness near target ship Sky glow brightness Lateral and vertical spread of sky glow (degrees) Effect of water brightness on ship visibility Hazard visibility of T-boat with unaided eyes and with night glasses Notify shore when readings and observations are completed.	Sky glow brightness Notify Central Control Station at completion.	Central Control Station notifies ground crew when all readings and observations are completed
2 - 8			Ground crew changes angular position of lighting units to 45 degrees below the horizontal (position D) and notifies Central Control Station. Central Control Station notifies ground and marine observers.

SERIES NO.	MARINE OBSERVERS	GROUND OBSERVERS	OPERATIONS IN TEST AREA
2 - 9	Water brightness near target ship Sky glow brightness Lateral and vertical spread of sky glow (degrees) Effect of water brightness on ship visibility Hazard visibility of T-boat with unaided eyes and with night glasses Notify shore when readings and observations are completed.	Sky glow brightness Notify Central Control Station at completion	Central Control Station notifies ground crew when all readings and observations are completed.
2 - 10			Ground crew attaches diffusing screens to lighting units, changes their angular position to the vertical, and notifies Central Control Station on completion. Central Control Station notifies ground and marine observers
2 - 11	Weather and sky conditions Ocean conditions Ocean horizon brightness Zenith brightness Water brightness at target ship Lateral and vertical spread of sky glow (degrees) Effect of water brightness on ship visibility Hazard visibility of T-boat with unaided eyes and with night glasses	Zenith brightness Inland horizon brightness Sky glow brightness Designated party in test area determines atmospheric absorption Test Completed.	

TESTS 1 AND 2

DETERMINATION OF MAXIMUM PERMISSIBLE SKY GLOW

TEST 1 - TARGET BOAT 2 MILES OFFSHORE
TEST 2 - TARGET BOAT 5 MILES OFFSHORE

1. PURPOSE.- The purpose of this test is to determine the maximum increment of brightness of a lighted background above inland horizon brightness which will not silhouette shipping when observed under conditions applicable to submarine operations.

2. TEST CONDITIONS.- a. Sky glow.- At beginning of test, first readings will be made with all lighting units extinguished. Sky glow then will be produced by pointing all lighting units with diffusing screens attached directly upward. Angular position of lighting units will not be changed during this test. However, sky glow will be reduced by shielding the units for various parts of their diameter at direction of sea observers.

b. Ground crew.- Ground crew will place shields at positions indicated by Headquarters during test.

c. Target boat.- Target boat will ply back and forth in front of lighted background provided by the sky glow on a line two miles offshore. (5 miles offshore for Test 2)

d. Sea observers.- Observers on O-boat will begin test 500 yards farther offshore than the T-boat. Maximum permissible sky glow when sea observers use night glasses for those distances will be determined; then O-boat will move to a position 1000 yards offshore from T-boat, determine maximum permissible sky glow at that point; then repeat for each 500 yards up to 3000 yards between T-boat and O-boat. After permissible brightness at 3000 yards is recorded, O-boat moves towards T-boat and observers record permissible brightness for each 500 yard step as they approach the T-boat.

e. Land observers.- Observations from land side of sky glow will be conducted from Stations 1, 2, 4, and 5. Observers will record data at direction of headquarters. Also, any other data or more frequent readings should be obtained at discretion of observers.

f. Atmospheric absorption.- Designated party will determine atmospheric absorption in the test area each $1\frac{1}{2}$ hours during course of test.

g. Weather and cloud conditions.- Pertinent data on weather and cloud conditions, such as height of overcast, will be recorded as necessary by a representative of the weather bureau.

3. TIME TEST IS TO BEGIN.- All observers, boats, and equipment will be in position and ready to begin tests at 7:00 p.m., January 4th (See NIGHTLY SCHEDULE for other starting times.)

4. PROGRAM OF OPERATIONS.- T-boat 2 miles offshore, O-boat 500 yards farther; land observers at Stations 1, 2, 3, 4, and 5. Lighting units prepared with diffusing screens, but unshielded and extinguished, pointed directly upward. Headquarters notifies all observers when to begin recording the data.

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
1 - 1 (2 - 1)	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Test area horizon brightness Other pertinent data. When readings are completed, transmit results to headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Test area horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Other pertinent data When readings are completed, transmit results to headquarters.	
1 - 2 (2 - 2)			Headquarters notifies ground crew to turn on all units. Ground crew notifies headquarters when all units are on. Headquarters notifies all observers to proceed with Series 1 - 3.
1 - 3 (2 - 3)	Weather and sky conditions Unaffected inland horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow for test horizon and cloud in degrees Lateral and vertical spread of sky glow on test horizon and on cloud in degrees Other pertinent data	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon and on cloud Other pertinent data	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
	When readings are completed, transmit results to headquarters.	When readings are completed, transmit results to headquarters and direct headquarters to reduce sky glow until it no longer silhouettes T-boat.	
1 - 4 (2 - 4)			Headquarters directs ground crew to reduce sky glow by indicating shield position. Ground crew notifies headquarters when shields are in position. Headquarters notifies all observers to proceed with Series 1 - 5.
1 - 5 (2 - 5)	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow for test horizon and cloud in degrees Lateral and vertical spread of sky glow on test horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon and on cloud Other pertinent data When readings are completed, transmit results to headquarters	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
1 - 6 (2 - 6)		O-boat proceeds to location 1000 yards offshore from T-boat. Upon arrival at this location sea observers direct headquarters to increase sky glow until maximum brightness which will not delineate T-boat is obtained.	Headquarters directs ground crew to change shield positions as desired. Ground crew notifies headquarters when shields are in position. Headquarters notifies all observers to proceed with Series 1 - 7.
1 - 7 (2 - 7)	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow for test horizon and cloud Lateral and vertical spread of sky glow on test horizon and on cloud Other pertinent data When readings are completed, transmit results to headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon and on cloud Other pertinent data When readings are completed, transmit results to headquarters.	
1 - 8 (2 - 8)		O-boat proceeds to location 1500 yards offshore from T-boat. Upon arrival at this location sea observers direct headquarters to increase sky glow until maximum brightness which will not delineate T-boat is obtained.	Headquarters directs ground crew to change shield positions as desired. Ground crew notifies headquarters when shields are in position. Headquarters notifies all observers to proceed with Series 1 - 9.

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
1 - 9 (2 - 9)	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow for test horizon and cloud Lateral and vertical spread of sky glow on test horizon and on cloud Other pertinent data When readings are completed, transmit results to headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness. Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon and on cloud Other pertinent data When readings are completed, transmit results to headquarters.	
1 - 10 (2 - 10)		O-boat proceeds to location 2000 yards offshore from T-boat Upon arrival at this location sea observers direct headquarters to increase sky glow until maximum brightness which will not delineate T-boat is obtained.	Headquarters directs ground crew to change shield positions as desired. Ground crew notifies headquarters when shields are in position. Headquarters notifies all observers to proceed with Series 1 - 11.
1 - 11 (2 - 11)	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow for test horizon and cloud in degrees Lateral and vertical spread of sky	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness. Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon and on cloud	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
	glow on test horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to headquarters.	Other pertinent data When readings are completed, transmit results to headquarters.	
1 - 12 (2 - 12)		O-boat proceeds to location 2500 yards offshore from T-boat. Upon arrival at this location sea observers direct headquarters to increase sky glow until maximum brightness which will not delineate T-boat is obtained.	Headquarters directs ground crew to change shield positions as desired. Ground crew notifies headquarters when shields are in position. Headquarters notifies all observers to proceed with Series 1 - 13.
1 - 13 (2 - 13)	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow for test horizon and cloud in degrees Lateral and vertical spread of sky glow on test horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon and on cloud Other pertinent data When readings are completed, transmit results to headquarters.	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
1 - 14 (2 - 14)		O-boat proceeds to location 3000 yards offshore from T-boat. Upon arrival at this location sea observers direct headquarters to increase sky glow until maximum brightness which will not delineate T-boat is obtained.	Headquarters directs ground crew to change shield positions as desired. Ground crew notifies headquarters when shields are in position. Headquarters notifies all observers to proceed with Series 1 - 15.
1 - 15 (2 - 15)	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow for test horizon and cloud in degrees Lateral and vertical spread of sky glow on test horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon and on cloud Other pertinent data When readings are completed, transmit results to headquarters.	
1 - 16 (2 - 16)		O-boat moves to location 2500 yards offshore from T-boat. Upon arrival at this location sea observers direct headquarters to decrease sky glow until maximum brightness which will not	Headquarters directs ground crew to change shield positions as desired. Ground crew notifies headquarters when shields are in position.

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
		delineate T-boat is obtained.	Headquarters notifies all observers to proceed with Series 1 - 17.
1 - 17 (2 - 17)	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow for test horizon and cloud in degrees Lateral and vertical spread of sky glow on test horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon and on cloud Other pertinent data When readings are completed, transmit results to headquarters.	
1 - 18 (2 - 18)		O-boat moves to location 2000 yards offshore from T-boat. Upon arrival at this location sea observers direct headquarters to decrease sky glow until maximum brightness which will not delineate T-boat is obtained.	Headquarters directs ground crew to change shield positions as desired. Ground crew notifies headquarters when shields are in position. Headquarters notifies all observers to proceed with Series 1 - 19.
1 - 19 (2 - 19)	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness	Weather and sky conditions Sea conditions Sea horizon brightness	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
	Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow for test horizon and cloud in degrees Lateral and vertical spread of sky glow on test horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to headquarters.	Zenith brightness Unaffected inland horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon and on cloud Other pertinent data When readings are completed, transmit results to headquarters.	
1 - 20 (2 - 20)		O-boat moves to location 1500 yards offshore from T-boat. Upon arrival at this location sea observers direct headquarters to decrease sky glow until maximum brightness which will not delineate T-boat is obtained.	Headquarters directs ground crew to change shield positions as desired. Ground crew notifies headquarters when shields are in position. Headquarters notifies all observers to proceed with Series 1 - 21.
1 - 21 (2 - 21)	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow for test horizon and cloud in degrees	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
	Lateral and vertical spread of sky glow on test horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to headquarters.	and on cloud Other pertinent data When readings are completed, transmit results to headquarters.	
1 - 22 (2 - 22)		O-boat moves to location 1000 yards offshore from T-boat. Upon arrival at this location sea observers direct headquarters to decrease sky glow until maximum brightness which will not delineate T-boat is obtained.	Headquarters directs ground crew to change shield positions as desired. Ground crew notifies headquarters when shields are in position. Headquarters notifies all observers to proceed with Series 1 - 23.
1 - 23 (2 - 23)	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow for test horizon and cloud in degrees Lateral and vertical spread of sky glow on test horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon and on cloud Other pertinent data When readings are completed, transmit results to headquarters.	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
1 - 24 (2 - 24)		O-boat moves to location 500 yards offshore from T-boat. Upon arrival at this location, sea observers direct headquarters to decrease sky glow until maximum brightness which will not delineate T-boat is obtained.	Headquarters directs ground crew to change shield positions as desired. Ground crew notifies headquarters when shields are in position. Headquarters notifies all observers to proceed with Series 1 - 25.
1 - 25 (2 - 25)	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow for test hroizon and cloud in degrees Lateral and vertical spread of sky glow on test horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon and on cloud Other pertinent data When readings are completed, transmit results to headquarters	
1 - 2C (2 - 26)			Headquarters directs ground crew to extinguish all lighting units. Ground crew notifies headquarters when all units are extinguished. Headquarters notifies all observers to proceed with Series 1 - 27.

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
1 - 27 (2 - 27)	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Test area horizon brightness Other pertinent data When readings are completed, transmit results to headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Test area horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat. Other pertinent data When readings are completed, transmit results to headquarters.	During period of these readings ground crew removes shields from lighting units.
1 - 28 (2 - 28)			Headquarters notifies ground crew to turn on all units. Ground crew notifies headquarters when all units are on. Headquarters notifies all observers to proceed with Series 1 - 29.
1 - 29 (2 - 29)	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow for test area horizon and for cloud in degrees Lateral and vertical spread of sky	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test area horizon and on cloud	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
	glow on test area horizon and on cloud in degrees Other pertinent data	Other pertinent data	
	When readings are completed, transmit results to headquarters.	When readings are completed, transmit results to headquarters.	

This completes TEST 1. If time is available, TEST 2 will immediately follow. The T-boat will move to a location 5 miles offshore and the O-boat to a location 500 yards further in order to begin TEST 2. Repeat TEST 1 procedure for TEST 2. TEST 2 series numbers are inclosed in parentheses.

TEST 3

PART A - DETERMINATION OF THRESHOLD VISIBILITY DISTANCE OF SEVERAL SKY GLOW BRIGHTNESSES.

PART B - DETERMINATION OF SKY GLOW BRIGHTNESS PRODUCED BY A GIVEN UPWARD FLUX

PART C - DETERMINATION OF RELATIVE AMOUNT OF SKY GLOW PRODUCED BY DRIVING AND PASSING BEAMS OF SEALED BEAM AUTOMOBILE HEADLAMPS.

1. PURPOSE.- The purpose of this test is (a) to secure data by which the "beacon" effect provided to enemy aircraft by sky glow over cities may be evaluated, (b) to determine the sky glow brightness which is produced by a given amount of upward light flux for a stated atmospheric condition, and (c) to study the contribution made to sky glow by automobile headlamps.

2, TEST CONDITIONS.--a. Sky glow.- At beginning of test, first readings from land stations will be made with all lighting units extinguished. Sky glow then will be produced for Parts A and B by pointing all lighting units, with diffusing screens attached, directly upward; however, sky glow will be reduced by shielding the units for various parts of their diameter at direction of Headquarters. For Part C, sky glow will be produced by setting units in a horizontal position, pointing them all north (toward Station 4), and switching from driving to passing beams when units are unshielded, shielded for upper 1/4 and 1/2 of their diameter, and shielded for the lower 1/2 of their diameter.

b. Ground crew.- Ground crew will place shields in position and change position of lighting units during test as directed by Headquarters according to procedure set forth in program of operations.

c. Target boat.- Target boat is not required for this test.

d. Sea observers.- Observations from the sea will not be made during this test.

e. Air observer.- Air observer will fly east from test area on a line which permits observation of test area sky glow without interference from sky glow over Jacksonville. This observer will obtain threshold visibility distance of sky glow produced by the unshielded lamps, radio findings to Headquarters, then approach test area and obtain threshold visibility distance when the units are shielded for 1/4, 1/2, and 3/4 of their diameter.

f. Land observers.- For Parts A and B, land observations will be conducted from Stations 1, 2, 3, and 5. For Part C, Stations 1, 4, and 5 will be occupied. Observers will record data at direction of Headquarters. Also, other data or more frequent readings should be obtained at discretion of observers.

g. Atmospheric absorption.- Designated party will determine atmospheric absorption in the test area each 1-1/2 hours during course of test.

h. Weather and cloud conditions.- Pertinent data on weather and cloud conditions, such as height of overcast, will be recorded as necessary by a representative of the Weather Bureau.

3. TIME TEST IS TO BEGIN.- All observers, plane, and equipment will be in position and ready to begin tests at 7:00 p.m.

4. PROGRAM OF OPERATIONS.- Land observers at Stations 1,2,3, and 5. Plane in air and ready to fly east. Lighting units prepared in up position with diffusing screens attached, unshielded, and extinguished.

SERIES NO.	AIR OBSERVER	LAND OBSERVERS	OPERATIONS IN TEST AREA
3 - 1		Weather and sky conditions. Unaffected inland horizon brightness. Zenith brightness Unaffected sea horizon brightness Test area horizon brightness Other pertinent data When readings are completed, transmit results to headquarters	
3 - 2			Headquarters notifies ground crew to turn on all units. Ground crew notifies Headquarters when all units are on. Headquarters notifies land and air observers to proceed with series 3 - 3

SERIES NO.	AIR OBSERVER	LAND OBSERVERS	OPERATION IN TEST AREA
3 - 3	Flies east and obtains threshold visibility distance.	Weather and sky conditions Unaffected inland horizon brightness. Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area Hoirzon and on clouds Height of brightest spot of sky glow for test area horizon and cloud in degrees Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees Other pertinent data. (Above readings should be taken each 15 min. if time permits)	
	Radio distance to Headquarters	When readings are completed, transmit results to Headquarters.	
3 - 4			Headquarters notifies ground crew to place shields at position 2 (shielded 1/4) Ground crew notifies Headquarters when all shields are in position. Headquarters notifies land and air observers to proceed with series 3 - 5.
3 - 5	Flies toward test area and obtains threshold visibility distance.	Weather and sky conditions Unaffected inland horizon brightness. Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and on cloud Height of brightest spot of sky glow for test area horizon and cloud in degrees Lateral and vertical spread of sky glow on test area horizon	

SERIES NO.	AIR OBSERVERS	LAND OBSERVERS	OPERATION IN TEST AREA
3 - 5 (cont.)	Radio distance to Headquarters.	and on cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters.	
3 - 6			Headquarters notifies ground crew to place shields at position 4 (shielded 1/2) Ground crew notifies Headquarters when all shields are in position Headquarters notifies land and air observers to proceed with series 3 - 7.
3 - 7	Flies toward test area and obtains threshold visibility distance. Radio distance to Headquarters.	Weather and sky conditions Unaffected inland horizon brightness. Zenith brightness Unaffected sea horizon brightness Sky glow brigtness on test area horizon and on cloud. Height of brightest spot of sky glow for test area horizon and cloud in degrees. Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees. Other pertinent data When readings are completed, transmit results to Headquarters.	
3 - 8			Headquarters notifies ground crew to place shields at position 6. (Shielded 3/4) Ground crew notifies headquarters when all shields are in position. Headquarters notifies land and air observers to proceed with series 3 - 9.

SERIES NO.	AIR OBSERVERS	LAND OBSERVERS	OPERATION IN TEST AREA
3 - 9	Flies toward test area and obtains threshold visibility distance. Radio distance to Headquarters and return to base.	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and on cloud. Height of brightest spot of sky glow for test area horizon and cloud in degrees. Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees. Other pertinent data. When readings are completed, transmit results to Headquarters	
3 - 10			Headquarters notifies ground crew to turn off lighting units and remove shields. Ground crew notifies headquarters when all units are extinguished. Headquarters notifies land observers to proceed with series 3 - 11.
3 - 11		Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Test area horizon brightness Other pertinent data When readings are completed, transmit results to Headquarters.	

SERIES NO.	AIR OBSERVERS	LAND OBSERVERS	OPERATION IN TEST AREA
3 - 12			Headquarters notifies ground crew to turn on all lighting units. Ground crew notifies Headquarters when all units are turned on. Headquarters notifies land observers to proceed with series 3 - 13.
3 - 13		Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and on cloud. Height of brightest spot of sky glow for test area horizon and cloud in degrees. Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees. Other pertinent data. When readings are completed, transmit results to Headquarters.	
3 - 14			Headquarters notifies ground crew to remove diffusing screens. Ground crew notifies Headquarters when all screens have been removed. Headquarters notifies land observers to proceed with series 3- 15.
3 - 15		Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and on cloud. Height of brightest spot of sky	

SERIES NO.	LAND OBSERVERS	OPERATION IN TEST AREA
3 - 15 (cont.)	glow for test area horizon and on cloud in degrees. Other pertinent data. When readings are completed, transmit results to Headquarters.	
3 - 16	Observer at Station 2 moves to Station 4 for Part C of test. Observer at Station 3 returns to test area	Headquarters notifies ground crew to face all units to the north and insure that they are on driving (high) beams. Ground crew notifies Headquarters when this operation is complete. Headquarters notifies land observers to proceed with series 3 - 17.
3 - 17	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and on cloud Height of brightest spot of sky glow for test area horizon and on cloud in degrees Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees Other pertinent data. When readings are completed, transmit results to Headquarters	
3 - 18		Headquarters notifies ground crew to switch all units to passing (low) beams. Ground crew notifies Headquarters when all units are on passing beams. Headquarters notifies land observers to proceed series 3 - 19.

SERIES NO.	LAND OBSERVERS	OPERATION IN TEST AREA
3 - 19	Weather and sky conditions. Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and on cloud Height of brightest spot of sky glow for test area horizon and cloud in degrees Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters.	
3 - 20		Headquarters notifies ground crew to place shields at position 2 (shielded 1/4) Ground crew notifies Headquarters when shields are at position 2. Headquarters notifies land observers to proceed with series 3 - 21
3- 21	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and on cloud. Height of brightest spot of sky glow for test area horizon and cloud in degrees Lateral and vertical spread of sky glow on cloud in degrees Other pertinent data. When readings are completed, transmit results to Headquarters.	

SERIES NO.	LAND OBSERVERS	OPERATION IN TEST AREA
3 - 22		Headquarters notifies ground crew to switch to driving (high) beams. Ground crew notifies Headquarters when all units are on driving beams Headquarters notifies land observers to proceed with series 3 - 23.
3 - 23	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and cloud in degrees Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees Other pertinent data when readings are completed, transmit results to Headquarters.	
3 - 24		Headquarters notifies ground crew to place shields at position 4 (shielded 1/2) Ground crew notifies Headquarters when all shields are at position 4 Headquarters notifies land observers to proceed with series 3 - 25
3 - 25	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and cloud in degrees. Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees Other pertinent data	

SERIES NO.	LAND OBSERVERS	OPERATION IN TEST AREA
3 - 25 (cont.)	When readings are completed, transmit results to Headquarters	
3 - 26		Headquarters notifies ground crew to switch units to passing (low) beams Ground crew notifies Headquarters when all units are on passing beams Headquarters notifies land observers to proceed with series 3 - 27
3 - 27	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and on cloud. Height of brightest spot of sky glow for test area horizon and cloud in degrees. Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees Other pertinent data. When readings are complted, transmit results to Headquarters	
3 - 28		Headquarters notifies ground crew to place shields at position 6 (shielded 3/4) Ground crew notifies Headquarters when all shields are at position 6. Headquarters notifies land observers to proceed with series 3 - 29

SERIES NO.	LAND OBSERVERS	OPERATION IN TEST AREA
3 - 29	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and on cloud. Height of brightest spot of sky glow for test area horizon and cloud in degrees Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters.	
3 - 30		Headquarters notifies ground crew to switch units to driving (high) beams Ground crew notifies Headquarters when all units are on driving beams Headquarters notifies land observers to proceed with series 3 - 31
3 - 31	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and on cloud Height of brightest spot of sky glow for test area horizon and cloud in degrees... Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters.	

SERIES NO.	LAND OBSERVERS	OPERATION IN TEST AREA
3 - 32		Headquarters notifies ground crew to remove shields and shield units for lower 1/2. Ground crew notifies Headquarters when all shields are in position Headquarters notifies land observers to proceed with series 3 - 33
3 - 33	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and on cloud Height of brightest spot of sky glow for test area horizon and cloud in degrees Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters.	
3 - 34		Headquarters notifies ground crew to switch to passing (low) beams Ground crew notifies Headquarters when all units are on passing beam Headquarters notifies land observers to proceed with series 3 - 35.
3 - 35	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon, and on cloud Height of brightest spot of sky glow for	

SERIES NO.	LAND OBSERVERS	OPERATION IN TEST AREA
3 - 35 (cont.)	test area horizon and cloud in degrees Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters	
3 — 36		Headquarters notifies ground crew to turn off all units. Ground crew notifies Headquarters when all units are turned off Headquarters notifies land observers to proceed with series 3 - 37
3 - 37	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Test area horizon brightness Other pertinent data When readings are completed, transmit results to Headquarters	

This completes Test 3. All observers return to test area.

TEST 4

PART A - DETERMINATION OF THE EXTENT ADJACENT AREAS OF UPWARD LIGHT FLUX AFFECT SKY GLOW PRODUCED

PART B - DETERMINATION OF EFFECT ON APPARENT BRIGHTNESS OF TWO SKY GLOWS SEPARATED BY DISTANCE WHEN MEASURED ON AN AXIS THROUGH THEM.

1. PURPOSE.- The purpose of this test is (a) to determine the extent which spill light from an area affects sky glow brightness over an area adjacent to it, and (b) to determine where sky glows separated by distance have the effect of addition of their residual brightness when observed on a line through both of them.

2. TEST CONDITIONS.- a. Sky glow.- At beginning of test (Part A), first readings will be made with all lighting units extinguished. Sky glow will then be produced for Part A by pointing all units in the Ponte Vedra test area directly upward. Diffusing screens will be used on the units. As Part A progresses, certain sub-areas of lighting units will be turned on and off as set forth in program of operations at direction of Headquarters.

Sky glow for Part B will be produced by two separate locations containing lighting units. One location will be the test area of Ponte Vedra Beach and the other will be near U. S. Highway 1 on azimuth of 62° from center of test area at Ponte Vedra Beach. At beginning of Part B, sky glow at Ponte Vedra Beach will be on alone. Sky glow at both locations will be turned on and off as set forth in program of operations at direction of Headquarters.

b. Sub-areas.- For Part A, the Ponte Vedra test area will be divided into the following sub-areas:

(1) Area A - Third Street only

(2) Area B - Bounded by beach front, and 23rd Ave., 30th Ave., and Third Street but not including Third Street.

(3) Area C - Bounded by beach front, and 30th Ave., 34th Ave., and Third Street, but not including 30th Ave., 34th Ave., or Third Street.

(4) Area D - Bounded by beach front, and 34th Ave., 36th Ave., and Third Street, but not including Third Street.

c. Ground crew.- Ground crew will turn lighting units on and off in each area and at both locations as set forth in program of operations at direction of headquarters.

d. Target boat.- Target boat will not be used during this test.

e. Sea observers.- Sea observers will station themselves at a location 5 miles offshore with azimuth of 242° from center of Ponte Vedra Beach test area and remain there throughout test.

f. Land observers.- For Part A, land observations will be conducted from Stations 1, 4, and 5. For Part B, land observations will be conducted from Station 3 only.

g. Atmospheric absorption.- Designated party will determine atmospheric absorption at the Ponte Vedra test area each $1\frac{1}{2}$ hours during course of test.

h. Weather and cloud conditions.- Pertinent data on weather and cloud conditions, such as height of overcast, will be recorded as necessary by a representative of the Weather Bureau.

3. TIME TEST IS TO BEGIN.- All observers, boat, and equipment will be in position for Part A at 8:00 p.m. Part B will be conducted immediately following completion of Part A.

4. PROGRAM OF OPERATIONS.- All lighting units at both locations extinguished, but prepared with diffusing screens and pointed directly upward. O-boat 5 miles offshore on azimuth of 242°. Land stations 1, 4, and 5 occupied.

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
4 - 1	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Test area horizon brightness Other pertinent data When readings are completed, transmit results to Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Test area horizon brightness Other pertinent data When readings are completed, transmit results to Headquarters.	
4 - 2			Headquarters notifies ground crew to turn on all units in Ponte Vedra test area. Ground crew notifies headquarters when all units are on. Headquarters notifies observers to proceed with Series 4 - 3.
4 - 3	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow on test area horizon and on cloud in degrees Lateral and vertical spread of sky glow on test area horizon and cloud in degrees Other pertinent data	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Sky glow brightness on test area horizon and on cloud Other pertinent data	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
	When readings are completed, transmit results to Headquarters.	When readings are completed, transmit results to Headquarters.	
4 - 4			Headquarters notifies ground crew to turn off units in Areas B, C, and D. Ground crew notifies headquarters when units in Areas B, C, and D are turned off Headquarters notifies observers to proceed with Series 4 - 5.
4 - 5	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow on test area horizon and on cloud in degrees Lateral and vertical spread of sky glow on test area horizon and cloud in degrees Other pertinent data	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Sky glow brightness on test area horizon and on cloud Other pertinent data	
	When readings are completed, transmit results to Headquarters.	When readings are completed, transmit results to Headquarters.	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
4 - 6			Headquarters notifies ground crew to turn off units in Area A and to turn on units in Areas B, C, and D. Ground crew notifies headquarters when this operation is completed. Headquarters notifies observers to proceed with Series 4 - 7.
4 - 7	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow on test area horizon and on cloud in degrees Lateral and vertical spread of sky glow on test area horizon and cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Sky glow brightness on test area horizon and on cloud Other pertinent data When readings are completed, transmit results to Headquarters.	
4 - 8			Headquarters notifies ground crew to turn off units in Area B. Ground crew notifies headquarters when units in Area B are off. Headquarters notifies ob-

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
			servers to proceed with Series 4 - 9.
4 - 9	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow on test area horizon and on cloud in degrees Lateral and vertical spread of sky glow on test area horizon and cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Sky glow brightness on test area horizon and on cloud Other pertinent data When readings are completed, transmit results to Headquarters.	
4 - 10			Headquarters notifies ground crew to turn off units in Area C. Ground crew notifies Headquarters when units in Area C are off. Headquarters notifies observers to proceed with Series 4 - 11.
4 - 11	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness	Weather and sky conditions Sea conditions Sea horizon brightness	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
	Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow on test area horizon and on cloud in degrees Lateral and vertical spread of sky glow on test area horizon and cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters.	Zenith brightness Unaffected inland horizon brightness Sky glow brightness on test area horizon and on cloud Other pertinent data When readings are completed, transmit results to Headquarters.	
4 - 12			Headquarters notifies ground crew to turn on units in Area B. Ground crew notifies Headquarters when units in Area B are on. Headquarters notifies observers to proceed with Series 4 - 13.
4 - 13	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow on test area horizon and on cloud in degrees Lateral and vertical spread of sky	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Sky glow brightness on test area horizon and on cloud Other pertinent data	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
	glow on test area horizon and cloud in degrees Other pertinent data		
	Observers at Station 1 and on boat may have to record data for Areas B and D separately.		
	When readings are completed, transmit results to Headquarters.	When readings are completed, transmit results to Headqu.rters.	
4 - 14			Headquarters notifies ground crew to turn off units in Area D and to turn on units in Area C. Ground crew notifies Headquarters when this operation is completed Headquarters notifies observers to proceed with Series 4 - 15.
4 - 15	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow on test area horizon and on cloud in degrees Lateral and vertical spread of sky glow on test area horizon and cloud in degrees Other pertinent data	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Sky glow brightness on test area horizon and on cloud Other pertinent data	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
	When readings are completed, transmit results to Headquarters.	When readings are completed, transmit results to Headquarters.	
4 - 16			Headquarters notifies ground crew to turn off units in Area C. Ground crew notifies Headquarters when units in Area C are off. Headquarters notifies observers to proceed with Series 4 - 17.
4 - 17	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow on test area horizon and on cloud in degrees Lateral and vertical spread of sky glow on test area horizon and cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Sky glow brightness on test area horizon and on cloud Other pertinent data When readings are completed, transmit results to Headquarters.	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
4 - 18			Headquarters notifies ground crew to turn off units in Area B. Ground crew notifies Headquarters when units in Area B are off. Headquarters notifies observers to proceed with Series 4 - 19.
4 - 19	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Test area horizon brightness Other pertinent data When readings are completed, transmit results to Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Test area horizon brightness Other pertinent data When readings are completed, transmit results to Headquarters.	

This completes Part A of Test. Observers at Stations 1, 4, and 5 return to test area. Land observations for Part B are conducted from Station 3 only.

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
4 - 20			Headquarters notifies ground crew to turn on all units in Ponte Vedra test area (A, B, C, and D). Ground crew notifies Headquarters when all units in Ponte Vedra area are on. Headquarters notifies observers to proceed with Series 4 - 21.

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
4 - 21	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow on test area horizon and on cloud in degrees Lateral and vertical spread of sky glow on test area horizon and cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Sky glow brightness on test area horizon and on cloud Other pertinent data When readings are completed, transmit results to Headquarters.	
4 - 22			Headquarters notifies ground crew at U. S. Highway 1 location to turn on those units. Ground crew on U. S. 1 notifies Headquarters when units there are on. Headquarters notifies observers to proceed with Series 4 - 23.
4 - 23	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Sky glow brightness on test area	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
	Height of brightest spot of sky glow on test area horizon and on cloud in degrees Lateral and vertical spread of sky glow on test area horizon and cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters.	horizon and on cloud Other pertinent data When readings are completed, transmit results to Headquarters.	
4 - 24			Headquarters notifies ground crew at Ponte Vedra to turn off those units. Ground crew notifies Headquarters when those units are off. Headquarters notifies observers to proceed with Series 4 - 25.
4 - 25	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test horizon and on cloud Height of brightest spot of sky glow on test area horizon and on cloud in degrees Lateral and vertical spread of sky glow on test area horizon and cloud in degrees Other pertinent data	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Sky glow brightness on test area horizon and on cloud Other pertinent data	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	GROUND CREW
	When readings are completed, transmit results to Headquarters.	When readings are completed, transmit results to Headquarters.	
4 - 26			Headquarters notifies ground crew on U. S. Highway 1 to turn off these units. Ground crew notifies Headquarters when those units are off. Headquarters notifies observers to proceed with Series 4 - 27.
4 - 27	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Test area horizon brightness Other pertinent data When readings are completed, transmit results to Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Test area horizon brightness Other pertinent data When readings are completed, transmit results to Headquarters	

This completes Test 4.

TEST 5

PART A - SKY GLOW PRODUCED BY MAXIMUM CONCENTRATION OF CITY TRAFFIC
PART B - SKY GLOW PRODUCED BY NORMAL NIGHT TIME OPEN HIGHWAY TRAFFIC
PART C - THE EFFECT OF BAFFLES LOCATED AT ENDS OF STREETS OPEN TO THE SEA
PART D - PROPER STREET LIGHTING FOR SAFE DRIVING ON STREETS OPEN TO THE SEA

1. PURPOSE.- The purpose of this test is to determine by actual test (a) the amount of sky glow to be expected from maximum night time city traffic, (b) the amount of sky glow in the direction of the sea to be expected from normal night time traffic on roads which face the sea; (c) to study the value and feasibility of shielding ends of streets open to the sea and to study the effect on vehicle operation without headlights when such baffles are illuminated to a low level, and (d) to determine the proper street lighting levels for safe driving without headlamps on such streets without creating a hazard to shipping from the light source or the illuminated area when baffles are and are not employed.

2. TEST CONDITIONS.- a. <u>Sky glow</u>.- For Part A, the Ponte Vedra test area will be used. Sky glow will be produced by 462 lighting units, without diffusing screens and with beams horizontal, located as follows:

(1) <u>Third Street between 23rd Ave. and 36th Ave</u>.- 34 units facing north, roughly spaced 92 feet apart; and 34 units facing south with same spacing.

(2) <u>Augustine Boulevard between First Street and Third Street</u>.- 12 units facing northeast, roughly spaced 90 feet apart; and 12 units facing southwest with same spacing.

(3) <u>Second Street between Third Street and 26th Avenue</u>.- 26 units facing north, roughly spaced 83 feet apart; and 26 units facing south with same spacing.

(4) <u>First Street between 23rd Avenue and 36th Avenue</u>.- 33 units facing north, roughly spaced

85 feet apart; and 33 units facing south with same spacing.

(5) Ocean Avenue between 30th Avenue and 36th Avenue.- 20 units facing north, roughly spaced 80 feet apart; and 20 units facing south with same spacing.

(6) 23rd Avenue between ocean front and Third Street.- 18 units facing east, roughly spaced 70 feet apart; and 18 units facing west with same spacing.

(7) 30th Avenue between ocean front and Third Street.- 18 units facing east, roughly spaced 75 feet apart; and 18 units facing west with same spacing.

(8) 31st Avenue between Ocean Avenue and Third Street.- 14 units facing east, roughly spaced 75 feet apart; and 14 units facing west with same spacing.

(9) 32rd Avenue between Ocean Avenue and Third Street.- 14 units facing east, roughly spaced 75 feet apart; and 14 units facing west with same spacing.

(10) 33rd Avenue between Ocean Avenue and Third Street.- 12 units facing east, roughly spaced 85 feet apart; and 12 units facing west with same spacing.

(11) 34th Avenue between Ocean Avenue and Third Street.- 12 units facing east, roughly spaced 75 feet apart; and 12 units facing west with same spacing.

(12) 35th Avenue between Ocean Avenue and Third Street.- 10 units facing east, roughly spaced 80 feet apart; and 10 units facing west with same spacing.

(13) 36th Avenue between Ocean Avenue and Third Street.- 8 units facing east, roughly spaced 85 feet apart; and 8 units facing west with same spacing.

Switching from driving to passing beams will be done and shields applied as set forth in schedule of operations.

For Part B, a one mile section of Atlantic Boulevard in Atlantic Beach will be used. In this one mile of road 35 vehicles with a spacing of 150 feet between consecutive vehicles will face in one direction; in the other direction 15 vehicles with a spacing of 350 feet between consecutive vehicles will face in the other direction. These vehicles will change position and have their headlights modified as indicated in program of operations.

b. Baffles.- Present baffle at the seaward end of Atlantic Boulevard will be used for Part C. This baffle may have to be treated in order to obtain a white surface on the land side. At completion of Part B, vehicles used in that part will drive east on Atlantic Boulevard toward baffle at speeds between 20 and 30 miles per hour. These vehicles will use headlamps on driving beams and with upper half of lens opaque. Upon reaching north-south street nearest baffle, these vehicles will turn south, then west on the next east-west street, and assemble.

After this phase of Part C is completed, baffle will be illuminated on the land side to a level designated by sea observers as non-hazardous to shipping. Vehicles without lights will then operate on Atlantic Boulevard toward and away from the baffle. Drivers of these vehicles will judge the adequacy of light furnished by the illuminated baffle from the standpoint of safe vehicle operation.

c. Street lighting.- At completion of Part C, street will be illuminated to a level declared non-hazardous to shipping by sea observers by use of flood light type lamps arranged in such a manner that the light source and glow around the reflector are invisible from the sea and that direct light is not a source of glare to approaching vehicle operators. Operators of vehicles will then judge the adequacy of the light provided from the standpoint of safe vehicle operation. The baffle is then removed and above procedure is repeated for street lighting levels declared non-hazardous without use of baffle.

d. Ground crew.- For Part A, ground crew will switch from driving to passing beams and shield the units as directed by Headquarters.

For Parts B, C, and D, ground personnel will be selected and instructed prior to beginning of test.

e. Target boat.- Target boat will be used for entire test. This boat will be located 2 miles offshore.

f. Sea observers.- At all times O-boat will be located 500 yards farther offshore than the T-boat.

For Parts A and B, sea observers will record brightness of sky glow and judge the hazard to shipping caused by the lighted background.

For Part C, sea observers will judge whether or not glow around baffle produced as vehicles approach it is hazardous to shipping; and then direct the illumination of the baffle to a level non-hazardous to shipping.

For Part D, sea observers will direct the illumination of the street to levels non-hazardous to shipping and will check the hazard produced by direct light and glow from flood lamps.

g. Land observers.- For Part A, land observations will be conducted from Stations 1, 4, and 5.

For Part B, land observations will be conducted from a station on Atlantic Boulevard located 2 miles west from the inland end of the selected one mile test section.

For Parts C and D, vehicle operators will judge ability to drive safely under the illumination furnished.

h. Atmospheric absorption.- Designated party will determine atmospheric absorption in the test area each 1½ hours during course of test.

i. Weather and cloud conditions.- Pertinent data on weather and cloud conditions, such as height of overcast, will be recorded as necessary by a representative of the Weather Bureau.

3. TIME TEST IS TO BEGIN.- Part A will begin at midnight on night of January 11-12, 1943.

4. PROGRAM OF OPERATIONS.- Lighting units prepared as set forth in subparagraph 2a, but extinguished. Target boat 2 miles offshore; O-boat 500 yards farther. Land stations 1, 4, and 5 occupied.

PART A

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	OPERATIONS IN TEST AREA
5 - 1	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Test area horizon brightness Other pertinent data	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Water brightness at T-boat Unaffected inland horizon brightness Test area horizon brightness Effect of horizon brightness in delineating T-boat Effect of water brightness in delineating T-boat	
	When readings are completed, transmit results to headquarters.	When readings are completed, transmit results to headquarters.	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	OPERATIONS IN TEST AREA
5 - 2			Headquarters notifies ground crew to turn on units and set them on driving (high) beams. Ground crew notifies Headquarters when this operation is completed. Headquarters notifies observers to proceed with series 5-3.
5 - 3	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and on cloud Height of brightest spot on test area horizon and on cloud in degrees Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon and on cloud Effect of sky glow in delineating T-boat Other pertinent data When readings are completed, transmit results to Headquarters.	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	OPERATIONS IN TEST AREA
5 - 4			Headquarters notifies ground crew to switch to passing (low) beam. Ground crew notifies Headquarters when units are on passing beam. Headquarters notifies observers to proceed with series 5-5.
5 - 5	Weather and sky conditions Unaffected inalnd horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and on cloud Height of brightest spot on test area horizon and on cloud in degrees Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon and on cloud Effect of sky glow in delineating T-boat Other pertinent data When readings are completed, transmit results to Headquarters.	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	OPERATIONS IN TEST AREA
5 - 6			Headquarters notifies ground crew to place shields at position 4 (shielded ½). Ground crew notifies Headquarters when shields are at position 4. Headquarters notifies observers to proceed with series 5-7.
5 - 7	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky glow brightness on test area horizon and on cloud Height of brightest spot on test area horizon and on cloud in degrees Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon and on cloud Effect of sky glow in delineating T-boat Other pertinent data When readings are completed, transmit results to Headquarters.	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	OPERATIONS IN TEST AREA
5 - 8			Headquarters notifies ground crew to switch to driving (high) beams. Ground crew notifies Headquarters when shields are on driving beams. Headquarters notifies observers to proceed with series 5-9.
5 - 9	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Sky-glow brightness on test area horizon and on cloud Height of brightest spot on test area horizon and on cloud in degrees Lateral and vertical spread of sky glow on test area horizon and on cloud in degrees Other pertinent data When readings are completed, transmit results to Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Unaffected inland horizon brightness Water brightness at T-boat Effect of water brightness in delineating T-boat Sky glow brightness on test horizon and on cloud Effect of sky glow in delineating T-boat Other pertinent data When readings are completed, transmit results to Headquarters.	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	OPERATIONS IN TEST AREA
5 - 10			Headquarters notifies ground crew to turn off all units. Ground crew notifies Headquarters when all units are off. Headquarters notifies observers to proceed with series 5-11.
5 - 11	Weather and sky conditions Unaffected inland horizon brightness Zenith brightness Unaffected sea horizon brightness Test area horizon brightness Other pertinent data When readings are completed, transmit results to Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Water brightness at T-boat Unaffected inland horizon brightness Test area horizon brightness Effect of horizon brightness in delineating T-boat Effect of water brightness in delineating T-boat When readings are completed, transmit results to Headquarters.	
5 - 12	Observers at Stations 1, 4, and 5 proceed to selected mile section of Atlantic Boulevard. Observer assigned to special station on Atlantic Boulevard proceeds to that location.	O-boat and T-boat proceed to location 2 miles off Atlantic Boulevard for Part B of test.	Headquarters and selected ground personnel proceed to selected mile section of Atlantic Boulevard. Vehicles and operators take up their designated positions on selected mile section of Atlantic Boulevard. Vehicle lights are extinguished for first reading. 35 vehicles face the sea and 15 face away from the sea.

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	OPERATIONS IN TEST AREA
5 - 13	Weather and sky conditions Inland horizon brightness Zenith brightness Sea horizon brightness Other pertinent data When readings are completed, notify Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Inland horizon brightness Other pertinent data When readings are completed, notify Headquarters.	
5 - 14			Headquarters notifies test vehicles to turn on headlamps and put them on driving (high) beams. Headquarters notifies observers to proceed with series 5-15 when are headlamps are properly set.
5 - 15	Weather and sky conditions Inland horizon brightness Zenith brightness Sea horizon brightness Sky glow brightness Other pertinent data When readings are completed, notify Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Inland horizon brightness Sky glow brightness Other pertinent data When readings are completed, notify Headquarters.	
5 - 16			Headquarters notifies test vehicles to switch to passing (low) beams. Headquarters notifies observers to proceed with series 5-17 when headlamps are on passing beams.

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	OPERATIONS IN TEST AREA
5 - 17	Weather and sky conditions Inland horizon brightness Zenith brightness Sea horizon brightness Sky glow brightness Other pertinent data When readings are completed, notify Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Inland horizon brightness Sky glow brightness Other pertinent data When readings are completed, notify Headquarters.	
5 - 18			Headquarters notifies vehicle operators to shield upper half of headlamp lens. Headquarters notifies observers to proceed with series 5-17 when headlamps are half shielded.
5 - 19	Weather and sky conditions Inland horizon brightness Zenith brightness Sea horizon brightness Sky glow brightness Other pertinent data When readings are completed, notify Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Inland horizon brightness Sky glow brightness Other pertinent data When readings are completed, notify Headquarters.	
5 - 20			Headquarters notifies vehicle operators to switch to driving (high) beams. Headquarters notifies observers to proceed with series 5 -19 when headlamps are on driving beams.

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	OPERATIONS IN TEST AREA
5 - 21	Weather and sky conditions Inland horizon brightness Zenith brightness Sea horizon brightness Sky glow brightness Other pertinent data When readings are completed, notify Headquarters.	Weather and sky conditions Sea conditions Sea horizon brightness Zenith brightness Inland horizon brightness Sky glow brightness Other pertinent data When readings are completed, notify Headquarters.	
5 - 22	Observer proceeds to baffle at end of Atlantic Avenue.		Test vehicles using driving beams and half shielded headlamps proceed east on Atlantic Boulevard to north-south street nearest baffle, turn south to next east-west street, turn west and assemble for instructions.
5 - 23		Sea observers the extent of hazard to shipping caused by glow at baffle produced by approaching vehicles. If possible, brightness readings should be taken of this glow.	
5 - 24		After last vehicle has turned from baffle, sea observers direct ground crew in illuminating land side of baffle to highest level non-hazardous to shipping. Take brightness reading on baffle.	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	OPERATIONS IN TEST AREA
5 - 25			Members of test party operate vehicles without lights toward and away from illuminated baffle and record their observations and comments on driving conditions. Notify sea observers when this is completed.
5 - 26		Sea observers direct ground crew in illuminating street by means of flood light lamps until maximum illumination non-hazardous to shipping is reached. Take brightness reading at street, if possible. Sea observers insure that light sources and glow around reflectors of lamps are not such that hazard to shipping is produced. If hazardous glow at lamps cannot be eliminated in any other way, lamps must be reduced in light output until glow is not hazardous.	

SERIES NO.	LAND OBSERVERS	SEA OBSERVERS	OPERATIONS IN TEST AREA
5 - 27			Members of test party operate vehicles without lights on illuminated street and record their observations and comments on driving conditions. Remove baffle and notify sea observers.
5 - 28		Sea observers direct ground crew to change level of street illumination, if necessary, until maximum illumination non-hazardous to shipping is reached. Take brightness reading at street, if possible. Boats then return to base.	
5 - 29.			Members of test party operate vehicles without lights on illuminated street and record their observations and comments on driving conditions.
		Test completed.	

TEST 7

PART A - MAXIMUM PERMISSIBLE BRIGHTNESS OF WINDOWS VISIBLE FROM THE SEA
PART B - MAXIMUM PERMISSIBLE BRIGHTNESS OF LARGE VERTICAL SURFACES VISIBLE FROM THE SEA
PART C - DETERMINATION IF INDOOR BLACKOUT LAMPS USED OUTDOORS WILL CONSTITUTE A HAZARD TO SHIPPING

1. PURPOSE.- The purpose of this test is (a) to determine whether windows visible to the sea must be completely opaque in order not to aid submarine observers in detection of shipping and, if some brightness can be permitted, what is the maximum brightness, (b) to determine the maximum permissible brightness of large vertical surfaces when visible from the sea as affected by area of the surface, and (c) to determine if indoor blackout lamps used for illumination of porches, entrances, exits, and other small outdoor areas visible from the sea will constitute a hazard to shipping.

2. TEST CONDITIONS.- a. Window brightnesses.- Ten consecutive windows will be covered with tracing paper and brightness will be produced by special light boxes so designed that various intensities are obtainable without color change in the lighting.

b. Brightness of large vertical surfaces.- A large, white vertical surface, such as the side of a building, visible from the sea will be selected and brightness thereof produced by light from the special light boxes.

c. Indoor blackout lamps.- A number of consecutive porches of cottages visible from the sea will be illuminated by indoor blackout lamps.

d. Target boat.- T-boat will be stationed two miles offshore for this test.

e. Sea observers.- O-boat will take up position offshore from T-boat at a distance to be decided by the naval observer. Observations from the sea will be made with the unaided eye and with the aid of night glasses.

For Part A, sea observers direct ground personnel to reduce brightness of windows until the maximum brightness which does not silhouette shipping when sea observers use unaided eyes only is obtained. After ground personnel measure this brightness, sea observers direct ground personnel to reduce the brightness further until the maximum brightness which does not silhouette shipping when sea observers use night glasses is obtained.

For Part B, the procedure for Part A is repeated with a large vertical surface substituted for the windows.

For Part C, sea observers **study** the lighted proches with unaided eyes and with night glasses and determine whether brightness of them constitutes a hazard to shipping.

f. Ground personnel.- Ground personnel will reduce window brightness and brightness of large vertical surfaces, and will record non-hazardous brightnesses obtained.

g. Communications.- A mobile radio unit will provide ship to shore communications.

h. Atmospheric absorption.- Designated party will determine atmospheric absorption in the Ponte Vedra test area each $1\frac{1}{2}$ hours during course of test.

i. Weather and cloud conditions.- Pertinent data on weather and cloud conditions, such as height of overcast, will be recorded as necessary by a representative of the Weather Bureau.

3. TIME TEST IS TO BEGIN.- Test will begin at 1 a.m. on the night of January 13-14, 1943.

4. PROGRAM OF OPERATIONS.- For Part A windows are at maximum brightness.

SERIES NO.	SEA OBSERVERS	GROUND PERSONNEL
7 - 1	Direct reduction in window brightness until maximum safe brightness when sea observers use unaided eyes is obtained.	Reduce window brightness as directed by sea observers.
7 - 2		Record non-hazardous brightness. Notify sea observers to proceed with series 7-3.
7 - 3	Direct further reduction in window brighness until safe brightness when sea observers use night glasses is obtained.	Reduce window brightness as directed by sea observers.
7 - 4		Record non-hazardous brightness. Notify sea observers to proceed with series 7 - 5.
	PART B- Vertical surface at maximum brightness	
7 - 5	Direct reduction in brightness of vertical surface until maximum safe brightness when sea observers use unaided eyes is obtained.	Reduce brightness of vertical surface as directed by sea observers.
7 - 6		Record non-hazardous brightness. Notify sea observers to proceed with series 7-7.

SERIES NO.	SEA OBSERVERS	GROUND PERSONNEL
7 - 7	Direct reduction in brightness of vertical surface until maximum safe brightness when sea observers use night glasses is obtained.	Reduce brightness of vertical surface as directed by sea observers.
7 - 8		Record non-hazardous brightness. Notify sea observers to proceed with series 7-9.
7 - 9	Observe porches illuminated by indoor blackout lamps and judge the hazard to shipping when sea observers use unaided eyes and when sea observers employ night glasses. Notify ground personnel on completion.	

TEST N

DETERMINATION OF SILHOUETTE EFFECT OF LOW POWERED AIDS TO NAVIGATION

1. PURPOSE - The purpose of this test is to determine if there are any silhouette effects produced when a target ship passes in front of a minor aid to navigation and if so what is the relative effects of changing (a) the color, (b) the flashing characteristic and (c) the candlepower of the aid.

2. TEST CONDITIONS - (a) - At the beginning of the test the navigation lights will be on with combination A.

(b) Target boat - Will ply back and forth in front of the lights on a line 3000 yds. offshore.

(c) Sea observers - Observers on O-boat will begin the tests at a distance of 1000 yards offshore from the T-boat. All test combinations will be tested. (See list attached hereto).

(d) Atmospheric absorption - Designated party will determine atmospheric absorption in the test area each $1\frac{1}{2}$ hours during the test.

(e) Weather and Cloud conditions - Pertinent data on weather and cloud conditions, such as height of overcast, will be recorded by a representative of the weather bureau.

(f) Ground crew - To operate three navigation lights, one red, one white and one green, set up at intervals of one quarter mile on the beach with focal plane heights of about 20 feet. To change flashing characteristics and candlepower when instructed by Headquarters and to notify Headquarters when change has been made.

3. TIME TEST IS TO BEGIN - All observers, boats and equipment will be in position and ready to begin tests at 9:00 p.m. January 8, 1943.

4. PROGRAM (F OPERATIONS -T-boat 3000 yards offshore, O-boat 1000 yards farther out. All three lights on combination A. Headquarters notifies observers when to begin tests.

TEST NO.	SEA OBSERVERS	GROUND CREW
N-1	Weather and Sky conditions Sea conditions Sea horizon brightness Unaffected inland horizon brightness Silhouette hazard data for each color light Other pertinent data When readings are completed, notify Headquarters	
N-2		Headquarters notifies ground crew to replace combination A by combination B. Ground crew notifies Headquarters when change has been effected. Headquarters notifies observers to proceed with test N-3.
N-3	Weather and Sky conditions Sea conditions Sea horizon brightness Unaffected inland horizon brightness Silhouette hazard data for each color light Other pertinent data When readings are completed, notify Headquarters.	

TEST NO.	SEA OBSERVERS	GROUND CREW
N-4		Headquarters notifies ground crew to replace combination B by combination C. Ground crew notifies Headquarters when change has been effected. Headquarters notifies observers to proceed with test N-5.
N-5	Weather and Sky conditions Sea conditions Sea horizon brightness Unaffected inland horizon brightness Test area horizon brightness Water brightness at T-boat Silhouette hazard data for each color light Other pertinent data When readings are completed, notify Headquarters.	
N-6		Headquarters notifies ground crew to replace combination C by combination D. Ground crew notifies Headquarters when change has been effected. Headquarters notifies observers to proceed with test N-7.

This test to be continued until all combinations A through J are tested(See list attached)

TEST N

Station ____________ Observer ____________ Date ____________

Observation	Color Light	Combination									
		A	B	C	D	E	F	G	H	I	J
Could silhouette be seen-- YES or NO	RED										
	WHITE										
	GREEN										
If seen - describe POOR - FAIR - GOOD	RED										
	WHITE										
	GREEN										
Could type ship be identified - YES or NO	RED										
	WHITE										
	GREEN										
Do you consider the light hazardous from the submarine menace viewpoint YES or NO	RED										
	WHITE										
	GREEN										
REMARKS											

COMBINATION A

White	Red or Green
1.15 amps.	3.05 amps.
12 volts	12 volts
1.0-4.0 sec.	1.0-4.0 sec.
220 c.p.	210 c.p.

COMBINATION B

White	Red or Green
1.15 amps.	3.05 amps.
12 volts	12 volts
1.0-9.0 sec.	1.0-9.0 sec.
220 c.p.	210 c.p.

COMBINATION C

White	Red or Green
0.58 amps.	1.35 amps.
12 volts	12 volts
0.2-2.8 sec.	0.2-2.8 sec.
90 c.p.	90 c.p.

COMBINATION D

White	Red or Green
0.58 amps.	1.35 amps.
12 volts	12 volts
0.2-4.8 sec.	0.2-4.8 sec.
90 c.p.	90 c.p.

COMBINATION E

White	Red or Green
0.58 amps.	1.35 amps.
12 volts	12 volts
1.0-4.0 sec.	1.0-4.0 sec.
90 c.p.	90 c.p.

COMBINATION F

White	Red or Green
0.58 amps.	1.35 amps.
12 volts	12 volts
1.0-9.0 sec.	1.0-9.0 sec.
90 c.p.	90 c.p.

COMBINATION G

White	Red or Green
0.25 amps.	0.72 amps.
6.2 volts	6.2 volts
0.2-2.8 sec.	0.2-2.8 sec.
15 c.p.	15 c.p.

COMBINATION H

White	Red or Green
0.25 amps.	0.72 amps.
6.2 volts	6.2 volts
0.2-4.8 sec.	0.2-4.8 sec.
15 c.p.	15 c.p.

COMBINATION I

White	Red or Green
0.25 amps.	0.72 amps.
6.2 volts	6.2 volts
1.0-4.0 sec.	1.0-4.0 sec.
15 c.p.	15 c.p.

COMBINATION J

White	Red or Green
0.25 amps.	0.72 amps.
6.2 volts	6.2 volts
1.0-9.0 sec.	1.0-9.0 sec.
15 c.p.	15 c.p.

APPENDIX C

CHRONOLOGICAL RECORD OF SKY GLOW DATA

THE EFFECT OF DISTANCE ON APPARENT BRIGHTNESS OF SKY GLOW
TEST ON NIGHT OF NOVEMBER 12-13, 1942 - PART ONE

Point Pleasant, N. J.
1836 sealed beam units
All lamp beams vertical and unshielded.
Street lights on. Moon set at 10:00 p.m.

		SEA STATIONS (a)			LAND STATIONS														Threshold Visibility Distance in Miles	
		Mi. East of Test Area			No. 1 5 Miles West of Test Area						No. 2 10 Miles West of Test Area							No. 3 15 Miles West		
		15	10	5																
Weather and sky conditions		Broken clouds at 5000 ft.		Some mist 45-50 m.p.h. wind	Overcast high		Overcast high	Overcast low	Overcast low	Average readings	Overcast high	Overcast medium	Overcast medium	Overcast low	Overcast low	Overcast low	Average reading	Overcast high	Land—due west	From blimp at 700 Ft. altitude
Ocean conditions		Wind whipping off tops of white caps. Water highly phospherescent																		
Brightness Micro-Footlamberts	Ocean horizon	26																		
	Zenith	43			108		96	60	54	79	72	96	102	102	78	59	84	84		
	Water (at target)	No readings possible due to phosphorescence																		
	Inland horizon (b)				96	78	84	210	144	122	204	108	108	168	126	108	138	51		
	Sky Glow Test area horizon				312	300	168	270	210	252	180	156	126	180	192	108	156	78	18	
	Sky Glow Cloud	348	660	1800	900	2100	1800	1140	1800	1545	270	228	750	270	853	853	536	300	25	48
Effect of sky glow in delineating target ship		Phosphorescence of water made such a determination impossible.																		
Time completed		10:30	10:50	11:15	10:06	10:20	11:55	12:30	1:10		10:15	11:30	12:00	12:30	1:00	1:17		10:20		

Atmospheric transmission per 1000 feet measured along shore line: 86% at 9100 a.m.; 100% at 12:01 a.m.; 92% at 5:12 a.m.
Temperature: 42 F at 9:41 p.m.; 48 F at 12:35 a.m.; 52 F at 5:02 a.m.

(a) Sea observers report: a. Water phosphorescence has the following effects: (1) Destroyed dark-adaptation, hence interfering with night vision. (2) Every white cap, bow wave, and wave was highly phosphorescent. (3) Hulls appeared brightly lighted. (4) Spray on deck had the appearance of molten metal. (5) Tug used as target boat was visible at 2,100 yards due to phosphorescence.

1. From 15 miles off-shore, sky glow on test area horizon was dim when silhouette effect was considered; glow reflected from cloud was relatively bright.

2. Target ship cannot be seem beyond 4000 yards.

(b) Inland horizon readings of stations 1 and 2 were at times affected by a sky glow to the west.

SKY GLOW VARIATION DUE TO FLUX DISTRIBUTION - PART I

Nov. 12-13th, 1942
Flux produced by 1836 sealed beam headlamps
Point Pleasant, N. J.
Moon set at 9:55 a.m.
Lighting units facing south except for vertical position.
Street lamps on.

ITEM			Beams Vertical				Beams Vertical with diffusing screens(a)				Beams 60° above horizonatal				Beams 30° above horizonatal			
			Sta #5 5 miles south	Sta. #4 5 miles north	Sta. #1 5 miles west	Sta #2 10 miles west	Sta. #5 5 miles south	Sta #4 5 miles north	Sta. #1 5 miles west	Sta. #2 10 miles west	Sta #5 5 miles south	Sta #4 5 miles north	Sta #1 5 miles west	Sta. #2 10 miles west	Sta #5 5 miles south	Sta. #4 5 miles north	Sta. #1 5 miles west	Sta. #2 10 miles west
Weather and sky conditions			Overcast low	Overcast high	Overcast low	Overcast low	Overcast high	Overcast high	—	Overcast low	—	—	—	Broken clouds med height	—	—	—	Broken clouds med. height
Brightness Micro-Footlamberts	Zenith		60	49	54	59	54	54	108	114	81	—	--	96	160	—	—	—
	Inland horizon		48	48	144	108	—	50	114	99	—	—	—	75	—	—	—	—
	Sky glow	Test area horizon	300	—	210	108	246	282	210	132	600	—	—	182	1020	—	—	90
		Cloud	720	557	1800	853	540	840	660	312	1200	1200	2100	780	810	420	360	—
Time completed			1:20	1:26	1:10	1:17	2:40	2:45	2:40	2:47	3:25	3:20	3:20	3:27	3:50	3:50	3:45	3:48

Atmospheric transmission per 1,000 feet measured along shore line: 86% at 9:00 p.m., 100% at 12:01 a.m., 92% at 5:12 a.m.; Average 93%.

Temperature: 42° F at 9:41 p.m., 48° F at 12:35 a.m., 52° F at 5:02 a.m.

Remarks: Changing clouds formations above test area cause high, unpredictable brightnesses to be reflected from them. Such clouds, however, do not appear to affect test area horizon brightnesses.

(a) Tracing paper used for diffusing screens has transmission of 50%.

SKY GLOW VARIATION DUE TO FLUX DISTRIBUTION - PART II
November 12 - 13th, 1942
Point Pleasant, N. J.
Flux produced by 1836 sealed beam headlamps
Moon set at 9:55 a.m.
Lighting units facing south except for vertical position - St. lamps on.

ITEM			BEAMS 15° ABOVE HORIZONTAL				BEAMS HORIZONTAL				BEAMS 45° BELOW HORIZONTAL			
			Sta. No.5 5 miles south	Sta. No.4 5 miles north	Sta. No.1 5 miles west	Sta. No.2 10 miles west	Sta. No.5 5 miles south	Sta. No. 4 5 miles north	Sta. No.1 5 miles west	Sta. No.2 10 miles west	Sta. No.5 5 miles south	Sta. No.4 5 miles north	Sta. No.1 5 miles west	Sta. No.2 10 miles west
WEATHER AND SKY CONDITIONS						Broken clouds medium height				Overcast low				Overcast low
Brightness Micro-foot lamberts	ZENITH		60	—	—	—	78	—	—	—	60	54	—	90
	INLAND HORIZON		—	—	—	—	—	—	—	—	42	64	—	73
	SKY GLOW	TEST AREA HORIZON	4200	—	150	87	1140	216	96	73	270	No perceptible glow	78	69
		CLOUD	—	450	—	—	—	—	—	—	—		—	—
TIME COMPLETED			4:20	4:05	4:10	4:12	4:35	4:28	4:30	4:35	4:55	5:00	5:00	4:59

Atmospheric transmission per 1000 feet measured along shore line:
86% at 9:00 p.m., 100% at 12:01 a.m., 92% at 5:12 a.m., Average 93%
Temperature: 42° F. at 9:41 p.m., 48° F. at 12:35 a.m., 52° F. at 5:02 a.m.

Remarks: Changing cloud fromations above test area cause high, unpredictable brightnesses to be reflected from them. Such clouds, however, do not appear to affect test area horizon brightnesses.

SKY GLOW PRODUCED BY AUTOMOBILE SEALED BEAM HEADLAMPS - PART I

November 13 - 14, 1942
Point Pleasant, N. J.
Flux produced by 1836 sealed beam headlamps
Moon set at 11:00 p.m.
Lighting units facing south except for vertical position - St. lamps off.

			BEAMS VERTICAL				BEAM TILTED 5° UPWARD							
							PASSING BEAM				DRIVING BEAM			
ITEM			Sta. No.5 5 mi. South	Sta. No.4 5 mi. North	Sta. No. 1 5 mi. west	Sta. No.2 10 mi. west	Sta. No.5 5 mi. South	Sta. No.4 5 mi. North	Sta. No.1 5 mi. West	Sta. No.2 10 m. West	Sta. No.5 5 mi. South	Sta. No.4 5 mi. North	Sta. No.1 5 mi. West	Sta. No.2 10 mi. West
WEATHER AND SKY CONDITIONS			Clear			Broken high clouds			Clear	Clear				Clear
Brightness micro-Footlamberts	ZENITH			114	192	129	108	90	126	164	120	120	120	126
	INLAND HORIZON		72(a)	186(b)	132	104	84	108	108	90	60	108	114	90
	SKY GLOW	TEST AREA HORIZON	108	278	240	222	1620	258	114	168	4020	438	114	102
		CLOUD	3300	351	510	240	-	-	-	204	-	-	-	210
TIME COMPLETED			12:00	12:00	12:00	12:00	12:55	12:50	12:50	12:55	1:20	1:15	1:20	1:23

Atmospheric transmission per 1000 feet: 97% at 1:00 a.m.

Notos: (a) Inland horizon readings of sta. #5 are unaffected by artificial sky glow.
(b) Sta. #4 read sky glow S. SW of station as inland horizon.

Remarks: Rapidly changing cloud formations above test area and between test area and observers affect observers ability to see sky glow and the brightness values thereof. Brief snow flurry occurred at Point Pleasant at 1:58 a.m.

Station #5 reported no snow there at 2:31 a.m. Sky glow invisible.
Station #5 reported snow at 2:52 a.m.
Station #1 reported snow at 2:56 a.m.

Weather report from Station #4 was as follows: 1:31 a.m. overcast sky; 1:40 a.m., snow storm approaching from north, test area darkest on southern horizon; 1:55 a.m. clear in north, 2:15 a.m. clear in north and west, overcast to south; 2:33 a.m., clear all around, cloud 15 above test area reads 2200 micro-footlamberts.

SKY GLOW PRODUCED BY AUTOMOBILE SEALED BEAM HEADLAMPS - PART II
November 13-14, 1942
Point Pleasant, N. J.
Flux produced by 1836 sealed beam headlamps. Lighting units facing south except for vertical position - street lamps off.
Moon set at 11:00 p.m.

ITEM			BEAMS TILTED 2-1/2° UPWARD								BEAM TILTED 45° DOWNWARD-STS. WET.			
			PASSING BEAM				DRIVING BEAM							
			Sta. #5 5 mi. South	Sta. #4 5 mi. North	Sta. #1 5 mi. West	Sta. #2 10 mi. West	Sta. #5 5 mi. South	Sta. #4 5 mi. North	Sta. #1 5 mi. West	Sta. #2 10 mi. West	Sta. #5 5 mi. South	Sta. #4 5 mi. North	Sta. #1 5 mi. West	Sta. #2 10 mi. West
WEATHER AND SKY CONDITIONS						No readings taken because of cloud bank over entire area.		Overcast		Overcast low				Clear overhead. Low overcast-test area
BRIGHTNESS (Microfootlamberts)	Zenith		120	84	270		120	210	134	114	—	75	240	210
	Inland Horizon		54	318	—		72	72	—	66	42	75	180	72
	Sky Glow	Test Area Horizon	450	360	150		3000	258	120	104	54	108	240	66
		Cloud	—	—	—	—	—	—	—	168	—	—	—	—
TIME COMPLETED			2:15	2:15	2:20	2:20	1:50	1:50	1:50	1:50	2:50	2:55	2:56	2:55

Atmospheric transmission per 1000 feet: 97% at 1:00 a.m.

Remarks: Rapidly changing cloud formations above test area and between test area and observers affect observers ability to see sky glow and the brightness values thereof. Brief snow flurry occurred at Point Pleasant at 1:58 a.m. Snow stopped at approximately 2:20 a.m.

Station #5 reported no snow there at 2:31 a.m. Sky glow invisible.

Station #5 reported snow at 2:53 a.m.

Station #1 reported snow at 2:56 a.m.

Weather report from Station #4 was as follows: 1:31 a.m. overcast sky; 1:40 a.m., snow storm approaching from north, test area darkest on southern horizon; 1:55 a.m. clear in north; 2:15 a.m. clear in north and west, overcast to south; 2:33 a.m., clear all around, cloud 15° above test area reads 2200 microfootlamberts.

SKY GLOW PRODUCED BY SEALED BEAM HEADLAMPS

November 14 - 15th, 1942
Point Pleasant, N. J.

PART 1

Flux produced by 1836 sealed beam headlamps
Moon set at 12:10 a.m.
Lighting units facing south except for vertical position - Street lamps off at midnight

ITEM		BEAMS-VERTICAL										ALL LAMPS OFF-STREET LIGHTS OFF							
		ST. LIGHTS ON				STREET LIGHTS OFF													
		Sta. #5 5 mi. South	Sta. #4 5 mi. North	Sta. #1 5 mi. West	Sta. #2 10 mi. West	Sta. #5 5 mi South		Sta. #4 5 mi North	Sta. #1 5 mi.-West		Sta. #2 10 mi. West	Sta. #5 5 mi South		Sta. #4 5 mi. North		Sta. #1 5 mi West		Sta. #2 10 mi. West	
WEATHER AND SKY CONDITIONS		Clear						Clear	Clear			Clear							
BRIGHTNESS (Micro-footlamberts)	Ocean Horizon	—	78	—	—	—	—	72	—	—		—	—	69	192	—	—	—	—
	Zenith	120	90	132	114	—	—	84	132	—	120	—	90	96	75	132	156	126	138
	Inland Horizon	72	120	240	126	—	—	108	228	162	105	—	90	96	90	164	180	102	108
	Sky Glow	300	180	360	192	300	420	270	360	348	210	240	108	51	87	168	194	114	264
TIME COMPLETED		11:55	11:50	12.00	11:55	2.03	1:05	1:10	12:05	1:05	1:10	12:16	5:50	12:20	6:00	12:18	5:55	12:25	5:55

Atmospheric transmission per 1000 feet: 87% at 1:20 a.m.; 76% at 4:05 a.m.

PART 2

SKY GLOW PRODUCED BY SEALED BEAM HEADLAMPS

November 14 - 15th, 1942
Point Pleasant, N. J.
Flux produced by 1836 sealed beam headlamps
Moon set at 12:10 a.m.
Lighting units facing south except for vertical position - St. lamps off at midnight

ITEM		BEAMS 45° DOWN				BEAMS TILTED 5° UPWARD								BEAMS - HORIZONTAL							
						PASSING BEAM				DRIVING BEAM				PASSING BEAM				DRIVING BEAM			
		Sta. #5 5 mi. South	Sta. #4 5 mi. North	Sta. #1 5 mi West	Sta. #2 10 mi West	Sta. #5 5 mi. South	Sta. #4 5 mi North	Sta. # 1 5 mi. West	Sta. #2 10 mi. West	Sta. #5 5 mi South	Sta. #4 5 mi. North	Sta. #1 5 mi. West	Sta. #2 10 mi. West	Sta. #5 5 mi. South	Sta. #4 5 mi. North	Sta. #1 5 mi. West	Sta. #2 10 mi. West	Sta. #5 5 mi South	Sta. #4 5 mi. North	Sta. #1 5 mi. West	Sta. #2 10 mi. West
WEATHER AND SKY CONDITIONS		Clear				Clear				Clear				Clear				Clear			
BRIGHTNESS (Micro-footlamberts)	Ocean Horizon	—	60	—	—	—	75	—	111	—	78	—	—	—	69	—	75	—	66	—	93
	Zenith	—	87	138	132	90	84	132	138	—	84	168	—	90	75	138	120	—	78	180	132
	Inland Horizon	—	84	180	108	56	78	156	93	72	72	180	123	54	93	166	114	60	84	144	72
	Sky Glow	24	72	168	108	4200	156	90	162	5100	510	164	132	1050	204	174	120	1500	342	180	93
TIME COMPLETED		1:32	1:35	1:30	1:37	1:58	2:00	1:50	2:03	2:25	2:30	2:25	2:30	3:15	3:20	3:15	3:20	2:50	2:50	2:45	2:50

Atmospheric transmission per 1000 feet: 87% at 1:20 a.m., 76% at 4:05 a.m.

PART 3

SKY GLOW PRODUCED BY SEALED BEAM HEADLAMPS

November 14 - 15th, 1942
Point Pleasant, N. J.
Flux produced by 1836 sealed beam headlamps
Moon set at 12:10 a.m.
Lighting units facing south except for vertical position - St. lamps off at midnight

ITEM		BEAMS HORIZONTAL 1/4 SHIELDS								BEAMS HORIZONTAL- 1/2 SHIELDS								
		Passing beam				Driving beam				Passing beam				Driving beam				
		Sta. no.5 5 miles south	Sta. no.4 5 miles north	Sta. no. 1 5 miles west	Sta. no. 2 10 miles west	Sta. no. 5 5 miles south	Sta. no. 4 5 miles north	Sta. no. 1 5 miles west	Sta. no. 2 10 miles west	Sta. no. 5 5 miles south	Sta. no. 4 5 miles north	Sta. no. 1 5 miles west	Sta. no. 2 10 miles west	Sta. no. 5 5 miles south	Sta. no. 4 5 miles north	Sta. no. 1 5 miles west	Sta. no. 2 10 miles west	
Weather and sky conditions		Clear				Clear				Clear				Clear				
Brightness Microfootlamberts	Ocean horizon	—	90	—	84	—	69	—	—	—	7.5	—	—	—	72	—	—	
	Zenith	—	90	138	111	90	60	168	14 4	—	72	16.8	—	90	66	162	10 8	
	Inland horizon	60	9.6	11 4	108	84	10 4	19 2	96	84	120	240	—	84	90	180	93	
	Sky glow	540	12 6	15 6	12 6	900	19 2	180	16.2	32 2	10.2	No glow	21 6	660	10 2	16 8	18 6	
Time completed		4:07	4:07	4:00	4:05	4:38	4:40	4:35	4:40	5:32	5:35		5:40	5:08	5:12	5:10	5:10	

Atmospheric transmission per 1000 feet: 87% at 1:20 a.m., 76% at 4:05 a.m.

MAXIMUM PERMISSIBLE SKY GLOW
Nov. 15-16th, 1942
Flux produced by 1836 sealed beam headlamps pointed upward.
Point Pleasant, N. J.
Moon set at 1:15 a.m.
Street lights off at 1:00 a.m.

ITEM		SEA STATIONS				LAND STATIONS					
		17 miles east		9 miles east	6 1/2 miles east	Sta. #1, 5 miles west			Sta. #2, 10 miles west		
		Lamps unshielded	Lamps shielded 1/2	Lamps shielded 1/2	Lamps shielded 1/2	Lamps unshielded	Lamps shielded 1/2	Lamps off	Lamps unshielded	Lamps shielded 1/2	Lamps off
Weather and sky conditions		Appears slightly hazy at test area				-	Clear				
Ocean conditions		Average swell				-	-				
Brightness micro-footlamberts	Ocean horizon	-	-	-		-	-	-	-	-	-
	Zenith	156	-	-		120	87	81	102	102	96
	Inland horizon	-	-	-		120	90	66	45	78	-
	Water (at target)	-	-	-		-	-	-	-	-	-
	Sky glow	144	78	114	138	252	68	66	180	84	48
Sky glow spread	Lateral	5°	-								
	Vertical	7°	-								
Hazard visibility of target ship silhouetted against sky glow		Hazardous	Not hazardous even when target ship is within 500 yds. of observer		Lt. Fintel reports safety would be reached with one half of illumination						
Time completed		1:20	2:30	3:00	3:37	1:25	2:25	4:30	1:25	2:20	4:30

Atmospheric transmission per 1000 feet: 99%.

MAXIMUM PERMISSIBLE SKY GLOW

November 16 - 17, 1942
Point Pleasant, New Jersey

Flux produced by 1836 sealed beam headlamps pointed upward.
Moon set at 2:20 a.m.
Street lights off at midnight.

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TEST PROCEDURE.- Lamps were at first shielded to 5/8 of their diameter. Observers on boat 5 miles offshore notified shore that illumination produced was hazardous in respect to silhouetting of target ship plying back and forth between observers and shore. Lamps were then shielded to 3/4 of their diameter and observers offshore declared resulting brightness of sky glow to be the maximum which would not silhouette ships when observers used night binoculars.

Lamps shielded 3/4

ITEM		SEA STATION	LAND STATIONS	
		5 miles east	Sta. No. 1 5 miles west	Sta. No. 2 10 miles west
Weather and sky conditions		Clear overhead Appears to be light mist toward horizon	-----	-----
Ocean conditions		Average swell	-----	-----
Brightness micro-foot-lamberts	Ocean horizon	54	-----	-----
	Zenith	138	87	108
	Inland horizon	63	46	66
	Water (at target)	36	-----	-----
	Sky glow	66	51	54 ⓐ
Hazard visibility of target ship silhouetted against sky glow. ⓒ		Maximum permissible brightness from all sources when observers use nightglasses ⓑ	-----	-----
Time completed		3:12	2:45	2:45

Atmospheric transmission not taken.

\- Notes -

(a) Sta. #2 reported that there was no perceptible sky glow over test area.

(b) Target boat was 5 miles offshore; observation boat, 1000 yards farther Observation boat and target boat stopped to minimize effect of phosphorescence.

(c) At two miles offshore, shaded street lamps on shore were hazardous at 4 miles offshore, they were non-hazardous.

RECHECK ON SHIELDED SEALED BEAM HEADLAMPS AND MAXIMUM PERMISSIBLE UPWARD FLUX

November 17 - 18, 1942

Flux produced by 1836 sealed beam headlamps
Moon set at 3:20 a.m.
Street lights off at midnight
Point Pleasant, New Jersey

ITEM		LAMPS HORIZONTAL---PASSING BEAMS						LAMPS VERTICAL		
		1/2 Shielded			3/4 Shielded			Unshielded		
		Sea Station	Land Stations		Sea Station	Land Stations		Sea Station	Land Stations	
		5 miles east	Sta. #1 5 miles west	Sta. #5 5 miles south	5 miles east	Sta. #1 5 miles west	Sta. #5 5 miles south	5 miles east	Sta. #1 5 miles west	Sta. #5 5 miles south
Weather and Sky Conditions		Clear Many stars	– – –	– – –	Slight Overcast	– – – –	– – –	More Overcast	– – – –	– – – –
Ocean Conditions		Smooth with long roll some phospho-rescence	– – –	– – –	Smooth with long roll-some phospho-rescence	– – –	– – –	Smooth with long ~~roll~~ few white caps-some phosphorescence	– – –	– – –
Brightness micro-footlamberts	Ocean Horizon	31.8 off starboard bow 84.0 off port bow	– – –	– – –	– – – – –	– – – –	– – – –	– – – – – –	– – –	– – –
	Zenith	10 2	10 2	– –	– –	7 2	– –	– –	7 9	– –
	Inland Horizon	5 1.5	7 8	5 7	– –	6 6	5 4	– –	6 7	5 7
	Water (at target)	4 0	– –	– –	– –	– –	– –	– –	– –	– –
	Sky Glow	9 9	54	390	111	4 8	210	15 3[(a)]	17 5	16 2
Hazard Visibility of Target Ship Silhouetted Against Sky Glow		Definitely too bright			(b)			Definitely hazardous even with naked eye		
Time completed		3:40	3:45	3:41	4:10	4:05	4:01	4:30	4:25	4:30

Atmospheric Transmission Per 1000 Feet: 81% at 3:30 A.M.

(See next page for footnotes)

THE EFFECT OF HOODING SEALED BEAM HEADLAMPS
November 18-19, 1942
Point Pleasant, N. J.
Flux produced by 1836 sealed beam headlamps set horizontal, pointed south, and hooded by 6 inch horizontal hoods.
Moon set at 4:23 a.m.
Street lights off at midnight.

Item		LAMPS HORIZONTAL POINTED SOUTH 6" HOODS ATTACHED						ALL LAMPS OFF		
		Passing Beams			Driving Beams *					
		Sta. No. 5 5 miles South	Sta. No. 1 5 miles West	Sta. No. 2 10 miles West	Sta. No. 5 5 miles South	Sta. No. 1 5 miles West	Sta. No. 2 10 miles West	Sta. No. 5 5 miles South	Sta. No. 1 5 miles West	Sta. No. 2 10 miles West
Weather and sky conditions				Clear. Test area slightly hazy			Clear. Test area slightly hazy	Did not take reading		Clear. Test area slightly hazy
Brightness micro-footlamberts	Ocean horizon	-	-	81	-	-	150		-	126
	Zenith	84	84	102	240	183	162		-	111
	Inland horizon	60	93	126	840	415	162		-	128
	Sky glow	240	69	177	900	402	468		54	180
Time completed		4:32	4:30	4:38	4:05	4:05	4:13		4:58	4:55

* These readings were taken while moon was still in sky.
Atmospheric transmission per 1000 feet - 97%.

(a) 10 mile threshold distance from blimp - altitude 700 feet.

(b) Slight overcast causes general glow to north of test area - appeared as bright as test area. Target boat silhouetted against the glow outside test area. Basis of judgement has to be on whether or not test area made detecting target boat any easier. With target boat 5 miles off-shore, this brightness was hazardous with unaided eye when observation boat was 400 yards farther, but non-hazardous when observation boat was 1000 yards farther; and was threshold by careful search with 7.5 binoculars when observation boat was 2000 yards farther (target boat seen but course and speed not determined).

Notes for Table on "RECHECK ON SHIELDED SEALED
BEAM HEADLAMPS AND MAXIMUM PERMISSIBLE UPWARD
FLUX--November 17 - 18, 1942

DETERMINATION OF MAXIMUM PERMISSIBLE SKY BRIGHTNESS

JACKSONVILLE BEACH, FLORIDA
JANUARY 4-5, 1943
2358 UNITS POINTED UP WITH DIFFUSING SCREENS
TARGET BOAT 2 NAUTICAL MILES FROM SOURCE OF SKY GLOW

CONDITION OF UNITS			UNSHIELDED						SHIELDED $\frac{3}{4}$					SHIELDED $\frac{13}{16}$				SHIELDED $\frac{7}{8}$			
MEASURED FROM			11¾ MILES WEST		5 MILES NORTH		5 MILES SOUTH	BOAT	7 MILES WEST	11¾ MILES WEST	5 MILES NORTH	5 MILES SOUTH	BOAT	7 MILES WEST	5 MILES NORTH	5 MILES SOUTH	BOAT	7 MILES WEST	5 MILES NORTH	5 MILES SOUTH	BOAT
BRIGHTNESS MICRO-FOOTLAMBERTS	INLAND HORIZON		67	50	75	75	75	74	85	50	75	75	90	83	–	86	–	118	–	70	80
	ZENITH		110	104	130	120	110	115	150	120	110	115	130	125	140	160	–	110	150	150	100
	SEA HORIZON		50	52	60	60	85	57	75	48	60	80	58	82	65	82	–	102	60	83	55
	WATER AT TARGET		–	–	–	–	–	66	–	–	–	–	58	–	–	–	75	–	–	–	–
	SKY GLOW	TEST AREA HORIZON	63	76	600	450	700	500	150	62	130	130	360	90	110	86	85	100	90	80	85 to 125
		CLOUD	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
REMARKS			–	–	–	–	–	T-BOAT DELINEATED SHARPLY	–	–	–	–	T-BOAT DELINEATED SHARPLY	–	–	–	TOO BRIGHT BY 30 %	–	–	–	TOO BRIGHT BY 5 %
TIME COMPLETED			12:20 A.M.	1:32 A.M.	2:10 A.M.	1:25 A.M.	1:20 A.M.	1:55A.M	2:35 A.M.	2:10 A.M.	2:20 A.M.	2:50 A.M.	2:40 A.M.	3:35 A.M.	3:30 A.M.	4:00 A.M.	EXACT TIME NOT RECORDED	4:45 A.M.	4:40 A.M.	4:35 A.M.	EXACT TIME NOT RECORDED
DISTANCE BETWEEN O-BOAT AND T-BOAT			4000 YARDS						1800 YARDS					2100 YARDS				1500 YARDS			

ATMOSPHERIC	TRASMISSION
TIME	TRANSMISSION IN PER CENT PER 1000 FEET
1:00 A.M.	88.5
2:12 A.M.	79.7
3:40 A.M.	72.9
4:55 A.M.	81.0

THRESHOLD VISIBILITY DISTANCES FROM THE AIR OF VARIOUS SKY GLOW
BRIGHTNESSES AND RELATIVE AMOUNT OF SKY GLOW PRODUCED BY
DIFFUSED LIGHT AND DIRECT UPWARD BEAMS
JACKSONVILLE BEACH, FLORIDA
JANUARY 5-6 1943
2358 LIGHTING UNITS POINTED UP

CONDITION OF UNITS			DIFFUSING SCREENS ATTACHED																	WITHOUT SCREENS		
			UNSHIELDED			¼ SHIELDED			½ SHIELDED			¾ SHIELDED			DARK		UNSHIELDED			UNSHIELDED		
MEASURED FROM			7 MILES WEST	11¾ MILES WEST	5 MILES SOUTH	7 MILES WEST	11¾ MILES WEST	5 MILES SOUTH	7 MILES WEST	11¾ MILES WEST	5 MILES SOUTH	7 MILES WEST	11¾ MILES WEST	5 MILES SOUTH	7 MILES WEST	5 MILES SOUTH	7 MILES WEST	11¾ MILES WEST	5 MILES SOUTH	7 MILES WEST	11¾ MILES WEST	5 MILES SOUTH
BRIGHTNESS MICRO-FOOTLAMBERTS	INLAND HORIZON		80	80	80	65	–	72	82	80	72	65	–	75	64	90	72	–	80	74	60	84
	ZENITH		155	110	150	155	–	150	185	110	126	195	–	150	170	–	250	–	160	195	120	–
	SEA HORIZON		72	60	76	78	–	70	70	60	71	68	–	70	64	50	67	–	80	57	60	73
	SKY	TEST AREA HORIZON	120	65	680	93	60	500	60	60	330	55	–	103	40	65	105	–	540	150	75	530
	GLOW	CLOUD	97	–	–	–	60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TIME COMPLETED			10:15 P.M.	10:15 P.M.	10:50 P.M.	11:55 P.M.	–	11:40 P.M.	12:18 A.M.	12:15 A.M.	12.00	12:34 A.M.	–	12:30 A.M.	1:10 A.M.	12:50 A.M.	1:25 A.M.	–	1:25 A.M.	1:55 A.M.	1:53 A.M.	1:45 A.M.
THRESHOLD VISIBILITY DISTANCE (MILES) FROM THE AIR. A TITUDE 2500 FEET			34			30			17			11										

ATMOSPHERIC	TRANSMISSION
TIME	PER CENT PER 1000 FEET
9:25 P.M.	72.8
10:25 P.M.	85.8
11:40 P.M.	69.0
12:25 A.M.	85.0
1:25 A.M.	66.1

RELATIVE AMOUNTS OF SKY GLOW

PRODUCED BY DRIVING AND PASSING BEAMS
OF AUTOMOBILE HEADLAMPS AND REDUCTION
IN GLOW BY HALF-SHIELDING

JACKSONVILLE BEACH, FLORIDA
JAN -5-6, 1943
2358 units set with beams horizontal and pointed north.

CONDITION OF UNITS		UNSHIELDED						SHIELDED FOR UPPER ONE-HALF					
HEADLIGHT BEAM		PASSING			DRIVING			PASSING			DRIVING		
MEASUREMENT FROM		7 MILES WEST	5 MILES NORTH	5 MILES SOUTH	7 MILES WEST	5 MILES NORTH	5 MILES SOUTH	7 MILES WEST	5 MILES NORTH	5 MILES SOUTH	7 MILES WEST	5 MILES NORTH	5 MILES SOUTH
BRIGHTNESS MICRO-FOOTLAMBERTS	INLAND HORIZON	65	70	82	85	80	98	83	70	79	88	80	78
	ZENITH	170	120	110	130	140	102	130	120	108	110	140	-
	SEA HORIZON	66	60	50	78	80	60	75	70	52	72	80	55
	SKY GLOW-TEST AREA HORIZON	86	8500	400	85	15000	720	85	3000	360	83	5800	500
TIME COMPLETED		2:50 A.M.	2:50 A.M.	2:45 A.M.	3:40 A.M.	3:35 A.M.	3:30 A.M.	5:12 A.M.	-	3:00 A.M.	4:38 A.M.	-	4:20 A.M.

ATMOSPHERIC TRANSMISSION	
TIME	PER CENT PER 1000 FEET
2:15 A.M.	85.3
2:55 A.M.	71.0
3:50 A.M.	90.4
4:40 A.M.	72.9

Determination of maximum permissible sky brightness
Jacksonville Beach, Florida
January 6-7, 1943

2358 lighting units pointed up without diffusing screens

Target boat 2 nautical miles from source of sky glow

Condition of units			Shielded 3/4 (a)				Shielded 7/8 (b)					Shielded 3/4 of way between 7/8 shielded and edge of lamp (c)				
Measured from			7 miles west	5 miles north	5 miles south	5 miles east	7 miles west	11¾ miles west	5 miles north	5 miles south	Boat	7 miles west	11¾ miles west	5 miles north	5 miles south	Boat
Brightness micro-footlamberts	Inland horizon		98	60	84	–	110	90	60	58	70	105	80	80	66	–
	Zenith		130	100	110	–	152	140	110	150	93	175	180	100	135	–
	Sea horizon		100	60	56	–	–	70	60	44	63	–	80	60	75	–
	Sky glow	Test area horizon	125	150	130	182	83	70	120	85	200	85	70	75	68	100
		Cloud	–	–		–	–	–	–	97		–	–	–	65	–
Time completed			10:15 p.m.	10:25 p.m.	10:30 p.m.	10:30 p.m.	11:05 p.m.	10:50 p.m.	10:55 p.m.	11:05 p.m.	10:53 p.m.	11:40 p.m.	11:15 p.m.	11:25 p.m.	11:33 p.m.	11:21 p.m.
Remarks			Brightness recorded from boat (5 miles east) was considered hazardous				Glow is entirely too bright from silhouette standpoint					Tug not visible with naked eye. With night binoculars, course determinable but speed not determinable. 3% less bright would be non-hazardous				
Distance between O-boat and T-boat			–				–					4000 yards				

Condition of units			Shielded at edge of lamps (d)					Shielded all the way in to box (e)					Unshielded		Dark	
Measured from			7 miles west	11¾ miles west	5 miles north	5 miles south	Boat	7 miles west	11¾ miles west	5 miles north	5 miles south	Boat	11¾ miles west	5 miles south	7 miles west	5 miles north
Brightness micro-footlamberts	Inland horizon		112	85	80	62	–	100	65	70	77	60	57	58	140	80
	Zenith		180	140	120	135	–	240	120	110	160	–	160	160	–	120
	Sea horizon		–	55	60	54	–	–	65	60	53	–	65	55	–	60
	Sky glow	Test area horizon	67	65	65	80	92	110	55	60	85	83	160	350	85	60
		Cloud	–	–	–	66	–	–	–	–	66	–	900	550	–	–
Time completed			12:15 a.m.	11:45 p.m.	12:10 a.m.	12:15 a.m.	12:03 a.m.	12:45 a.m.	1:05 a.m.	12:35 a.m.	12:36 a.m.	12:35 a.m.	1:55 a.m.	1:45 a.m.	1:08 a.m.	1:00 a.m.
Remarks			Glow too bright from silhouette standpoint					Tug visible with naked eye - very much so with glasses					–		–	
Distance between O-boat and T-boat			2500 yards					1000 yards					–		–	

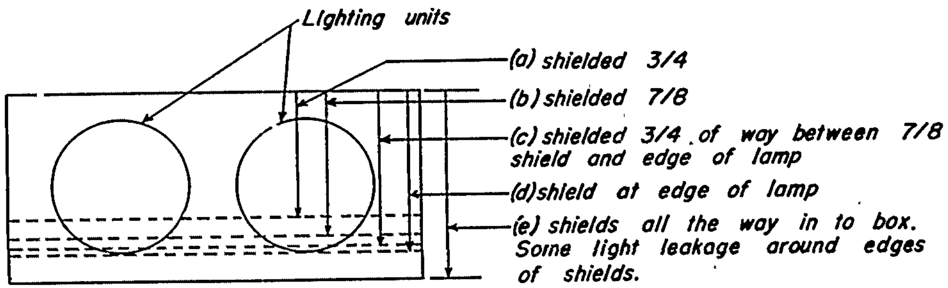


Diagram of shield positions
No scale

Atmospheric	transmission
Time	Per cent per 1000 feet
10:18 p.m.	72.5
10:55 p.m.	77.8
11:35 p.m.	63.7
12:20 p.m.	56.4

Determination of maximum permissible sky brightness

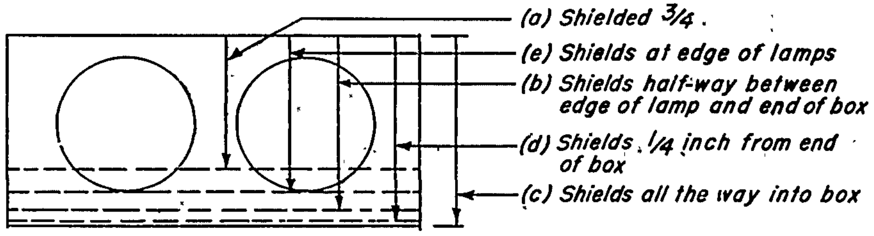
Jacksonville Beach, Florida
January 7-8, 1943
2358 lighting units pointed up without diffusing screens.

Target boat 2 nautical miles from source of sky glow.

Condition of units		Unshielded.							Shielded 3/4. (a)				Shields halfway between edge of lamp and end of box. (b)			
Measured from		7 miles west		5 miles north			5 miles south		7 miles west	5 miles north	5 miles south	Boat	7 miles west	5 miles north	5 miles south	Boat
Brightness micro-footlamberts	Inland horizon	102	106	100	100	100	45	—	95	—	50	105	78	—	58	—
	Zenith	107	130	100	90	90	140	—	142	110	150	210	130	100	135	—
	Sea horizon	68	72	45	45	45	62	—	80	55	38	56	74	55	42	—
	Sky glow: Test area horizon	95	340	550	280	600	155	470	102	180	150	240	65	80	70	87
	Sky glow: Cloud	390	2600	550	550	1800	380	2400	—	—	—	—	—	—	—	—
Time Completed		9:25 p.m.	9:45 p.m.	9:15 p.m.	9:30 p.m.	9:40 p.m.	9:35 p.m.	9:40 p.m.	10:10 p.m.	10:10 p.m.	10:10 p.m.	10:00 p.m.	10:40 p.m.	10:40 p.m.	10:37 p.m.	—
Remarks		—							—				No comment.			
Distance between O-boat and T-boat		—							2000 yds.				4000 yds.			

Condition of units		Shields all the way into box. (c)				Shields 1/4 inch from end of box. (d)				Shields at edge of lamps. (e)				Unshielded.		
Measured from		7 miles west	5 miles north	5 miles south	Boat	7 miles west	5 miles north	5 miles south	Boat	7 miles west	5 miles north	5 miles south	Boat	7 miles west	5 miles north	5 miles south
Brightness micro-footlamberts	Inland horizon	80	—	55	—	67	80	53	—	42	65	38	—	50	70	36
	Zenith	135	120	150	—	155	110	130	128	155	110	82	—	130	120	62
	Sea horizon	68	50	55	—	65	50	40	—	45	50	35	—	80	60	50
	Sky glow: Test area horizon	60	60	55	56	56	57	60	45 63	50	60	56	78	250	600	750
	Sky glow: Cloud	—	—	—	—	—	—	—	—	—	—	72	—	2400	2000	2400
Time Completed		11:10 p.m.	11:07 p...	11:05 p.m.	—	11:40 p.m.	11:38 p.m.	11:37 p.m.	11:30 p.m.	12:55 a.m.	1:00 a.m.	1:21 a.m.	12:50 a.m.	1:45 p.m.	1:45 p.m.	1:44 p.m.
Remarks		Lt. Winstead stated that there was sufficient glow to determine approx. course, size and character of ship. Could only see a blob before T-boat entered glow				No comment. (f)				Target boat could just be discerned against glow.				—		
Distance between O-boat and T-boat		4000 yds.				4000 yds.				6500 yds.				—		

(f) At 12:05 a.m., a background brightness of 84 micro-footlamberts was stated by Lt. Winstead to be just enough light to be useful for observation of target boat.



Atmospheric transmission	
Time	Per cent per 1000 feet
9:25 p.m.	71.2
10:00 p.m.	78.3
10:40 p.m.	70.3
10:55 p.m.	77.8
12:00	63.3
1:25 a.m.	85.7

RELATIVE AMOUNTS OF SKY GLOW
PRODUCED BY AUTOMOBILE HEADLAMPS
SHIELDED FOR UPPER ONE HALF AND
LOWER ONE HALF
JACKSONVILLE BEACH, FLORIDA- JAN. 7-8-1943
2358 LIGHTING UNITS POINTED NORTH WITH BEAMS HORIZONTAL

CONDITION OF UNITS			UPPER HALF OF LAMP SHIELDED				LOWER HALF OF LAMP SHIELDED			
HEADLIGHT BEAM			PASSING		DRIVING		PASSING		DRIVING	
MEASUREMENT FROM			5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH
BRIGHTNESS MICRO-FOOT LAMBERTS	INLAND HORIZON		70	52	70	38	70	21	70	24
	ZENITH		110	58	110	67	110	57	100	35
	SEA HORIZON		60	28	60	25	60	29	60	22
	SKY GLOW	TEST AREA HORIZON	4000	145	10000	210	12000	290	20000	430
		CLOUD	-	-	-	-	-	125	-	140
TIME COMPLETED			3:45 A.M.	3:35 A.M.	4:05 A.M.	4:10 A.M.	4:65 A.M.	5:20 A.M.	4:45 A.M.	4:53 A.M.

ATMOSPHERIC	TRANSMISSION
TIME	PER CENT PER 1000 FEET
1:55 A.M.	76.0
2:40 A.M	83.2
3:40 A.M.	78.0
4:45 A.M.	91.8

Sky glow produced by maximum concentration of city traffic
Jacksonville Beach, Florida.
402 units (804)lamps) set with beams horizontal and pointed as follows: 111 north, 111 south, 170 east and 190 west.
January 8-9, 1943

Condition of units		Unshielded								Shielded for upper one-half							
Headlight beam		Passing				Driving				Passing				Driving			
Measurement from		7 miles west	5 miles north	5 miles south	2 nautical mi. east	7 miles west	5 miles north	5 miles south	2 nautical mi. east	7 miles west	5 miles north	5 miles south	2 nautical mi. east	7 miles west	5 miles north	5 miles south	2 nautical mi. east
Brightness micro-footlamberts	Inland horizon		12	10	-		12	10	-		16	17	-		16	10	
	Zenith		65	24	85		45	24	-		32	47	-		45	36	
	Sea horizon		27	12	50		10	14	31		17	16	50		11	9	34
	Sky glow- Test area horizon	(a)	105	1400	4300	(a)	125	570	3700	(d)	70	40	1700	(a)	75	180	3400
Time completed			11:15 p.m.	11:08 p.m	11:10 p.m.		11:40 p.m.	11:45 p.m.	11:38 p.m		1:10 a.m.	1:10 a.m.	1:04 a.m.		12:30 a.m.	12:31 a.m.	12:25 a.m.

(a) Because of relatively high horizon of this station, low clouds prevented glow from being perceptible.

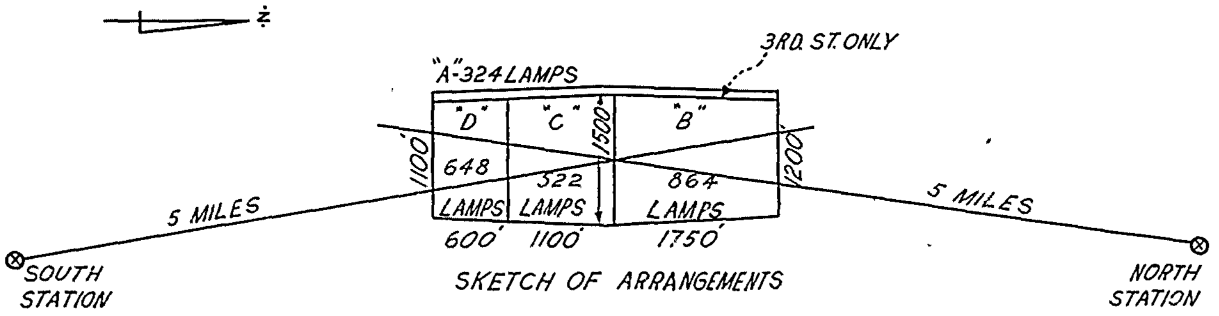
Atmospheric transmission	
Time	Per cent per 1000 ft.
10:10 p.m.	71.1
11:00 p.m.	76.3
11:40 p.m.	68.9
12:25 a.m.	73.0
1:10 a.m.	93.5

DETERMINATION OF THE ADDITION OF ADJACENT SKY GLOW BRIGHTNESSES WHEN BRIGHTNESS IS MEASURED ON THEIR AXIS
JACKSONVILLE BEACH, FLORIDA
JANUARY 8-9, 1943

2358 LIGHTING UNITS POINTED UP WITHOUT DIFFUSING SCREENS

TEST AREA DIVIDED INTO FOUR SUB-AREAS (SEE DIAGRAM BELOW FOR DIMENSIONS AND NUMBER OF LAMPS IN EACH SUB-AREA, ALSO FOR POINTS FROM WHICH MEASUREMENTS WERE MADE.)

AREAS OPERATING			ALL			"A"		"B C D"		"CD"		"D"		"BD"		"BC"		"B"		"C"	
MEASURED FROM			5 MILES NORTH	5 MILES SOUTH		5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH
BRIGHTNESS MICRO-FOOTLAMBERTS	INLAND HORIZON		11	20	11	15	13	45	8	17	11	15	10	14	8	16	11	17	9	19	13
	ZENITH		35	26	29	45	23	55	40	60	27	55	19	40	17	45	13	45	27	55	40
	SEA HORIZON		9	9	9	10	13	17	14	16	10	16	11	15	8	16	9	14	9	12	13
	SKY GIOW	TEST AREA HORIZON	400	110	180	45	21	500	260	550	230	90	400	700	75	35	26	340	138	100	50
		CLOUD	-	-	-	-	-	220	-	-	-	-	500	600	-	-	75	-	170	-	-
BRIGHTNESS OF OVERCAST IN FOOTLAMBERTS, MEASURED FROM TEST AREA			-	-	-	-	-	-	-	0.08		0.024		"B" 0035	"D" 0.05	0.075		0.0 02		0.006	
TIME COMPLETED			1:55 A.M.	9:55 A.M.	1:54 A.M.	2:25 A.M.	2:26 A.M.	2:45 A.M.	2:52 A.M.	3:15 A.M.	3:15 A.M.	3:35 A.M.	3:25 A.M.	3:55 A.M.	3:53 A.M.	4:15 A.M.	4:12 A.M.	4:35 A.M	4:26 A.M.	4:55 A.M	4:57 A.M.



SKETCH OF ARRANGEMENTS

ATMOSPHERIC	TRANSMISSION
TIME	PER CENT PER 1000 FEET
10:10 P.M.	71.1
2:10 A.M.	76.1
3:05 A.M.	89.9

DETERMINATION OF THE ADDITION OF SKY GLOW
BRIGHTNESSES SEPARATED BY DISTANCE WHEN BRIGHTNESS
IS MEASURED THROUGH BOTH GLOWS
JACKSONVILLE BEACH, FLORIDA
JANUARY 11-12, 1943

ALL LAMPS POINTED UP WITHOUT DIFFUSING SCREENS
SEE DIAGRAM BELOW FOR RELATIVE LOCATION OF TEST AREAS
AND POINTS FROM WHICH MEASUREMENTS WERE MADE

TEST AREAS OPERATING			1 AND 2		1		1 AND 2		2		1 AND 2		1	
MEASUREMENTS FROM			SO	NO	SO	NO	SO	NO	SO	NO	SO	NO	SO	NO
BRIGHTNESS MICRO-FOOTLAMBERTS	INLAND HORIZON		105	55	86	-	85	-	90	55	95	55	100	55
	ZENITH		260	120	240	-	200	-	210	-	200	-	170	-
	SEA HORIZON		95	55	89	-	80	-	85	55	90	55	92	55
	SKY GLOW	TEST AREA HORIZON	4100	290	850	330	4700	390	6800	70	5000	390	-	340
		2° ABOVE HORIZON	-	-	-	-	1250	-	1400	-	1300	-	680	-
TIME COMPLETED			12:40 A.M.		1:00 A.M.		1:15 A.M.		1:35 A.M.		1:50 A.M.		2:10 A.M.	

ATMOSPHERIC	TRANSMISSION
TIME	PER CENT PER 1000 . FEET
12:36 A.M.	86.0
1:50 A.M.	83.0
2:35 A.M.	84.5

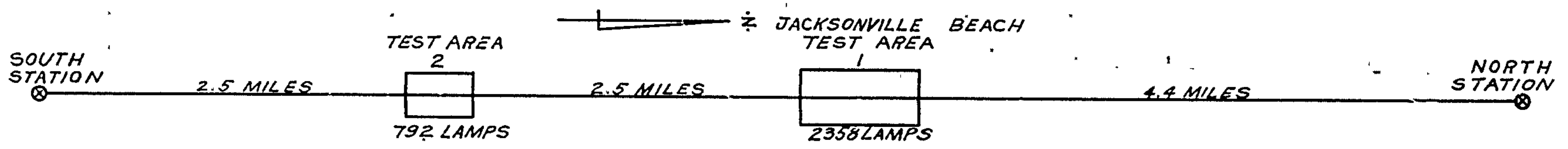


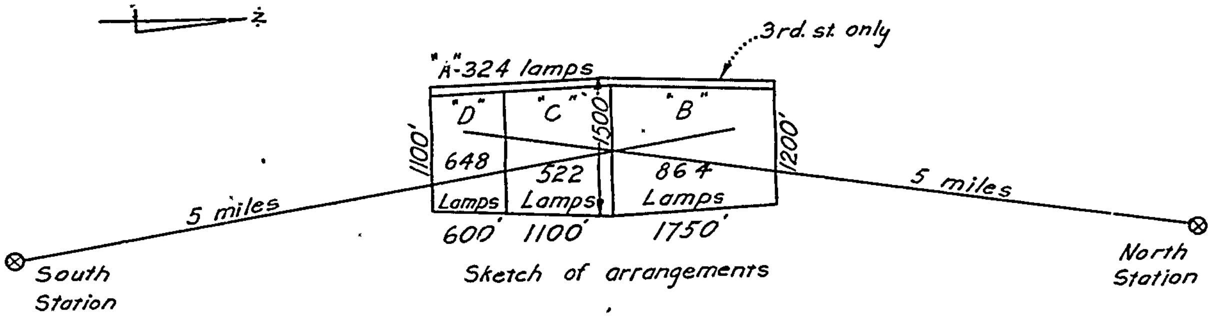
DIAGRAM OF ARRANGEMENTS

Determination Of The Addition Of Adjacent Sky Glow Brightnesses When Brightness Is Measured On Their Axis

Jacksonville Beach, Florida
January 11-12, 1943

2358 lamps pointed up without diffusing screens
Test area divided into four sub-areas (See diagram below for dimensions and number of lamps in each sub-area; also for points from which measurements were made.)

Areas operating		All		"A"		"BCD"		"CD"		"D"		"BD"		"BC"		"B"		"C"		None	
Measured from		5 miles north	5 miles south	5 miles north	5 miles south	5 miles north	5 miles south	5 miles north	5 miles south	5 miles north	5 miles south	5 miles north	5 miles south	5 miles north	5 miles south	5 miles north	5 miles south	5 miles north	5 miles south	5 miles north	5 miles south
Brightness micro-footlamberts	Inland horizon	55	100	55	110	55	95	55	106	60	110	60	120	60	102	65	98	65	110	60	-
	Zenith	130	170	130	190	130	150	120	160	110	150	120	145	110	-	110	165	110	148	110	-
	Sea horizon	55	92	55	86	55	91	60	100	60	101	60	94	60	96	70	94	75	95	70	-
	Sky Glow — Test Area Horizon	350	680	80	300	350	650	210	520	140	300	290	440	240	360	170	285	120	250	55	95
Time completed		2:38 a.m.	2:10 a.m.	2:52 a.m.		3:15 a.m.		3:35 a.m.		3:55 a.m.		4:10 a.m.		4:23 a.m.		4:35 a.m.		4:50 a.m.		5:00 a.m.	



Sketch of arrangements

Atmospheric Transmission	
Time	Per Cent Per 1000 feet
2:35 a.m.	84.5
3:40 a.m.	81.5
4:20 a.m.	87.5

Determination of additive factors of adjacent and nearby sky glow brightnesses when brightness is measured perpendicular to their axis

Jacksonville Beach, Florida.

January 11-12-1943

2358 lamps pointed up without diffusing screens. Test area divided into four sub-areas (See diagram below for dimensions and number of lamps in each sub-area; also points from which measurements were made)

	Areas operating	All		"A"		"BCD"		"CD"		"D"		"BD"		"BC"		"B"		"C"		None
	Measured from	7 miles west	2 nautical miles east	7 miles west	2 nautical miles east	7 miles west	2 nautical miles east	7 miles west	2 nautical miles west	7 miles west	2 nautical miles east	7 miles west	2 nautical miles east	7 miles west	2 nautical miles east	7 miles west	2 nautical miles east	7 miles west	2 nautical miles east	7 miles west
Brightness micro-foot lamberts	Inland horizon	105	130	120	130	140	130	115	90	110	78	115	–	120	–	125	125	105	95	110
	Zenith	135	230	145	190	130	148	120	250	130	230	130	–	135	–	145	150	125	270	135
	Sea horizon	105	110	97	110	110	87	110	78	98	68	125	–	115	–	102	115	120	115	92
	Sky glow-Test area horizon	170	800	120	220	170	700	175	850	135	620	170	700	170	940	92	620	135	680	82
	Time completed	2:10 a.m.		2:50 a.m.		3:18 a.m.		3:40 a.m		3:55 a.m.		4:10 a.m.		4:20 a.m.		4:35 a.m.		4:47 a.m.		5:03 a.m.
Sky glow spread degrees	Lateral	–	12.5	–	10	–	12	–	7	–	5	–	5	–	12	–	9	–	–	–
	Vertical	–	80	–	20	–	30	–	60	–	45	–	45	–	80	–	60	–	–	–

Note: Above readings were taken at south end of illuminated area in each case.

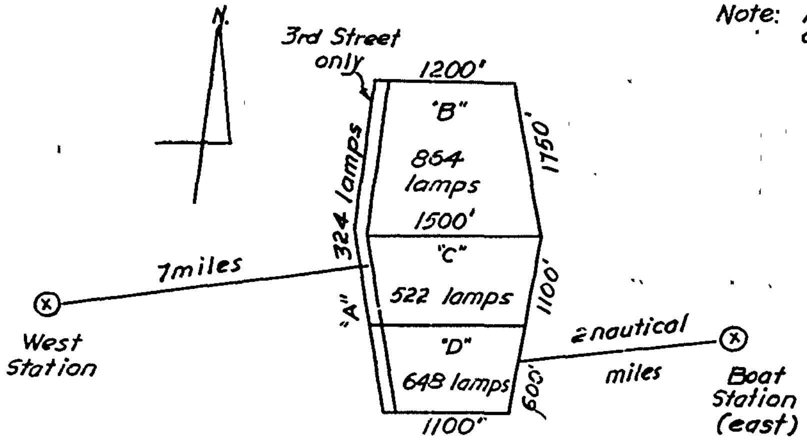
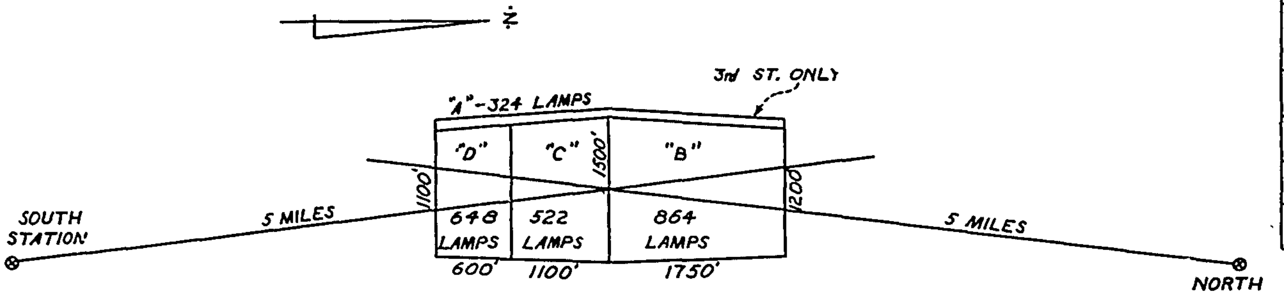


Diagram of arrangements

Atmospheric transmission.	
Time	Per cent per 1000 feet.
2:35 a.m.	84.5
3:40 a.m.	81.5
4:20 a.m.	87.5

DETERMINATION OF THE ADDITION OF ADJACENT SKY GLOW BRIGHTNESSES
WHEN BRIGHTNESS IS MEASURED ON THEIR AXIS
JACKSONVILLE BEACH, FLORIDA
JANUARY 12-13, 1943
2358 LAMPS POINTED UP WITH DIFFUSING SCREENS
TEST AREA DIVIDED INTO FOUR SUB-AREAS (SEE DIAGRAM BELOW FOR
DIMENSIONS AND NUMBER OF LAMPS IN EACH SUB-AREA, ALSO
POINTS FROM WHICH MEASUREMENTS WERE MADE.)

AREAS OPERATING			ALL		"A"		"BCD"		"CD"		"D"		"BD"		"BC"		"B"		"C"		NONE
MEASURED FROM			5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH	5 MILES SOUTH	5 MILES NORTH.	5 MILES SOUTH	5 MILES SOUTH
BRIGHTNESS MICRO-FOOTLAMBERTS	INLAND HORIZON		55	59	55	-	55	-	55	-	55	-	53	-	60	-	62	-	53	-	-
	ZENITH		150	175	130	-	110	-	120	-	110	-	130	-	145	-	130	-	106	-	-
	SEA HORIZON		55	49	50	-	50	-	47	-	49	-	50	-	53	-	57	-	50	-	-
	SKY GLOW	TEST AREA HORIZON	100	125	50	45	80	110	63	100	67	90	90	220	107	180	86	190	72	130	70
		CLOUD	160	215	-	112	100	140	95	119	90	120	-	210	-	130	-	130	-	53	-
TIME COMPLETED			1:57 A.M.		2:10 AM.		2:27 A.M.		2:44 A.M.		3:00 A.M.		3:15 A.M.		3:25 A.M.		3:40 A.M.		3:56 A.M.		4:10 A.M.



SKETCH OF ARRANGEMENTS

ATMOSPHERIC	TRANSMISSION
TIME	PER CENT PER 1000 FEET
2:35 A.M.	76.1
3:18 A.M.	74.6
4:05 A.M.	77.4
4:55 A.M.	82.0

Determination of additive factors of adjacent and nearby sky glow brightnesses when brightness is measured perpendicular to their axis

Jacksonville Beach, Florida
January 12-13, 1943

2358 lamps pointed up with diffusing screens
Test area divided into four sub-areas. (See diagram below for dimensions and number of lamps in each sub-area; also points from which measurements were made.)

Areas Operating			All		"A"		"BCD"		"CD"		"D"		"BD"		"BC"		"B"		"C"		None	
Measured from			7 miles west	2 nautical miles east	7 miles west	2 nautical miles east	7 miles west	2 nautical miles east	7 miles west	2 nautical miles east	7 miles west	2 nautical miles east	7 miles west	2 nautical miles east	7 miles west	2 nautical miles east	7 miles west	2 nautical miles east	7 miles west	2 nautical miles east	7 miles west	2 nautical miles east
Brightness micro-footlamberts	Inland horizon		–	130	–	130	–	80	–	86	–	86	–	95	–	95	–	83	–	108	–	–
	Zenith		–	180	–	80	–	250	–	190	–	190	–	220	–	220	–	220	–	175	–	–
	Sea horizon		–	52	–	52	–	67	–	90	–	90	–	90	–	90	–	60	–	72	–	–
	Sky glow - test area horizon		112	820	108	140	140	760	132	580	126	380	127	500	127	480	115	390	112	490	83	95
Height of brightest spot of sky glow (degrees)			–	0	–	½	–	½	–	½	–	½	–	½	–	½	–	½	–	–	–	–
Sky glow spread (Degrees)	Test horizon	Lateral	–	12	–	12	–	12	–	10	–	8	–	12	–	10	–	10	–	–	–	–
		Vertical	–	5	–	4	–	5	–	5	–	5	–	4	–	4	–	3	–	–	–	–
Time Completed			1:50 a.m.		2:10 a.m.		2:30 a.m.		2:49 a.m.		3:00 a.m.		3:15 a.m.		3:25 a.m.		3:45 a.m.		4:00 a.m.		4:17 a.m.	

Note: Brightness over Area "D" was recorded for all tests involving that area; otherwise brightness over areas used was recorded.

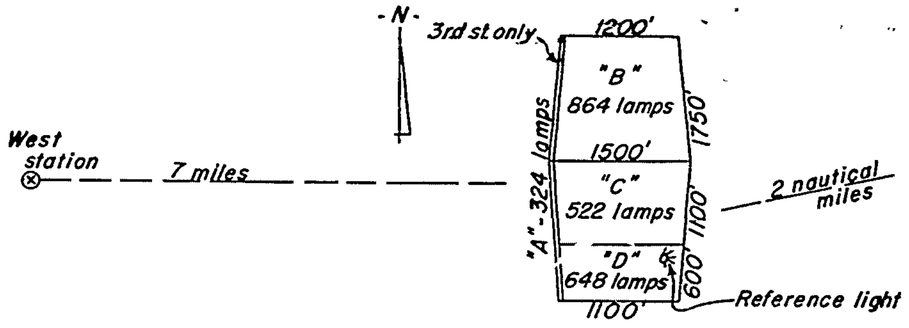


Diagram of arrangements

Atmospheric Time	transmission Per cent per 1000 feet
2:35 a.m.	76.1
3:18 a.m.	74.6
4:05 a.m.	77.4
4:55 a.m.	82.0

DETERMINATION OF THE ADDITION OF SKY GLOW BRIGHTNESSES SEPARATED BY DISTANCE WHEN BRIGHTNESS IS MEASURED THROUGH BOTH GLOWS

JACKSONVILLE BEACH, FLORIDA

JANUARY 12-13, 1943

ALL LAMPS POINTED UP WITHOUT DIFFUSING SCREENS

SEE DIAGRAM BELOW FOR RELATIVE LOCATION OF TEST AREAS AND POINTS FROM WHICH MEASUREMENTS WERE MADE

TEST AREAS OPERATING			2		1 AND 2		1		1 AND 2		2		1		1 AND 2		NONE
MEASURED FROM			NORTH	SOUTH	NORTH	SOUTH	NORTH	SOUTH	NORTH	SOUTH	NORTH	SOUTH	NORTH	SOUTH	NORTH	SOUTH	SOUTH
BRIGHTNESS MICRO-FOOTLAMBERTS	INLAND HORIZON		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	ZENITH		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SEA HORIZON		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	SKY GLOW	TEST AREA HORIZON	150	360	1200	1500	1060	850	1240	650	140	500	820	380	900	900	33
		2° ABOVE HORIZON	-	650	-	1000	-	370	-	700	-	490	-	320	-	860	36
TIME COMPLETED			4:30 A.M.		4:49 A.M.		5:09 A.M.		5:29 A.M.		5:54 A.M.		6:10 A.M.		6:30 A.M.		7:00 A.M.

ATMOSPHERIC TIME	TRANSMISSION PER CENT PER 1000 FEET
4:05 A.M.	77.4
4:55 A.M.	82.0

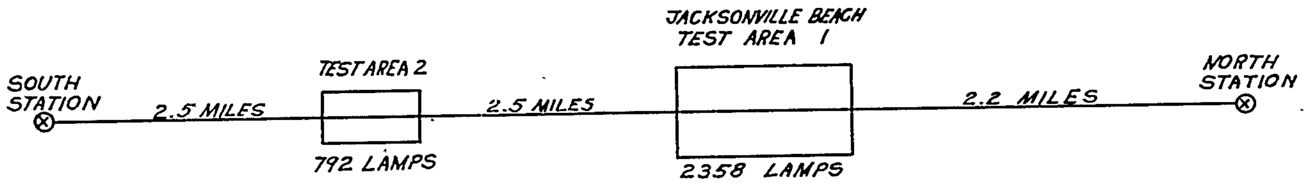


DIAGRAM OF ARRANGEMENTS

VARIATION OF SKY GLOW BRIGHTNESS WITH DISTANCE
JACKSONVILLE BEACH, FLORIDA
JANUARY 15, 1943
2358 LAMPS POINTED UP WITHOUT DIFFUSING SCREENS

MEASUREMENTS FROM		LAND-SOUTH OF SOURCE OF GLOW							SEA-EAST OF SKY GLOW				AIR (1250 FT. ALTITUDE)-EAST OF SKY GLOW				
POINT OF MEASUREMENT		1 MILE	2 MILES	3 MILES	5 MILES	$7\frac{1}{2}$ MILES	10 MILES	15 MILES	2 MILES	5 MILES	10 MILES	15 MILES	5 MILES	10 MILES	15 MILES	25 MILES	28 MILES
BRIGHTNESS MICRO-FOOTLAMBERTS	INLAND HORIZON	82	79	85	85	-	90	90	98	115	100	98	220	200	190	GLOW STILL VISIBLE	THRESHOLD-DISTANCE
	ZENITH	120	95	90	95	95	100	80	98	140	125	120	200	-	180		
	SEA HORIZON	75	75	82	70	-	-	-	84	84	77	95	-	-	-		
	SKY GLOW - TEST AREA HORIZON	2300	1200	1020	450	230	170	100	640	260	175	135	300	250	200		
* TIME COMPLETED		3:53 A.M. TO 4:53 A.M.							3:25 A.M. TO 4:43 A.M.				3:05 A.M. TO 3:50 A.M.				

ATMOSPHERIC TRANSMISSION 96.2% PER 1000 FEET

APPENDIX D

WEATHER REPORT FOR JACKSONVILLE BEACH TEST

AIRWAY WEATHER REPORTS

Station Ponte Vedra Beach (CITY) Florida (STATE)

Month and year January, 1943

Day of month	Time (E.W.T.)	Ceiling (feet)	Sky	Visibility (miles)	Weather and/or obstructions to vision	Relative Humidity %	Temperature and Dew Point	Wind direction, velocity character, shifts	Remarks and 6- or 3-hourly coded data	Thermometers	
										Dry	Wet
5	0045		Clear	7		72	41,33	NW 12		41.3	37.7
5	0145		Clear	7		66	40/29	NW 10		40.0	36.7
5	0240		Clear	7		57	38/26	NW 15		38.0	33.7
5	0345		Clear	7		64	36/26	NW 12		38.2	32.2
5	0600		Clear	7		54	36/22	NW 15		36.6	30.5
5	2130		Clear	10		55	43/29	NNE 10		43.0	37.0
5	2245		Clear	10		81	40/29	NNE 8		[illegible]	[illegible]
5	2345		Clear	8		86	38/30	N 5		38.8	33.3
6	0030		Clear	8		88	38/29	N 7		38.0	32.2
6	0130		Clear	8		80	31/28	NNW 7		31.2	30.2
6	0220		Clear	6	H	87	32/29	NNW 8		32.2	31.0
6	0305		Clear	6	H	86	30/30	NNW 8		30.5	30.1
6	[illegible]		Clear	8		72	46/38	NNE 12		46.5	41.5
6	0430		Clear	8		69	47/37	NNE 15		46.8	42.5
6	2230		Scattered Clouds	6	H	98	54/53	NE 10	2/10 high thin clouds, SW to NW horizon	54.5	53.0
6	2305		Clear	6	H	98	48/47	W 1		47.8	47.6
6	2340		Clear	6	GF	100	47/47	NW 3	Ground fog forming in patches	47.6	47.0
7	0025		Clear	5	GF	100	48/48	NNW 4	Ground fog in patches	48.0	48.0
7	0145		Clear	1	GF	100	46/46	NNW 2	Ground fog 20 ft. deep	46.1	46.1
7	2135	9500	Overcast	2	H	95	61/59	ESE 8	Clouds dense	61.0	60.1
7	2215		Scattered Clouds	2	H	95	61/59	ESE 8	Glow against clear sky; clouds on W and E horizon	61.0	60.0
7	[illegible]		High thin overcast	5	H	94	61/59	ESE 8	Dense clouds W; stars visible	61.0	60.0
7	[illegible]	20000	High thin overcast	5	H	94	61/59	SE 6	Bright stars visible through overcast	61.2	60.1
8	0100	20000	High thin overcast	5	H	93	61/59	SE 6	Bright stars visible through overcast	61.0	[illegible]
8	[illegible]	17000	Overcast	5	H	96	62/59	SE 6	Cloud layer dense	[illegible]	[illegible]
8	[illegible]	20000	Thin overcast	5	H	[illegible]	62/59	S 5	Bright stars visible through overcast	[illegible]	[illegible]
8	[illegible]	20000	Thin overcast	4	H	91	62/60	S 6	Bright stars visible through overcast	[illegible]	[illegible]
8	[illegible]	20000	Thin overcast	6	H	92	62/60	S 8	Bright stars visible through overcast	62.1	60.6
8	2235	700	Overcast	6	H	97	56/54	N 17	2nd layer at 1400 ft.; both layers dense	[illegible]	[illegible]
8	2310	750	Overcast	6	H	97	54/54	N 15	Beam fading gradually into cloud	[illegible]	[illegible]
9	0001	500	Overcast	5	H-Light drizzle	96	54/52	N 15	Beam fading gradually into cloud	[illegible]	[illegible]
9	[illegible]	300	Overcast	4	H-Light drizzle	97	58/52	N 15	Overcast ragged; beam fading gradually	[illegible]	[illegible]
9	0120	550	Overcast	6	H	97	52/51	N 10	Overcast ragged; beam fading gradually	[illegible]	51.5
9	0215	450	Overcast	4	H-Light rain	98	51/50	N 8	Overcast ragged; beam fading gradually	[illegible]	[illegible]
9	[illegible]	550	Overcast	6	H	100	51/51	N 8	Overcast ragged; beam fading gradually	[illegible]	[illegible]
9	0410	450	Overcast	3	H-Light rain	98	40/40	N 10	Overcast ragged; beam fading gradually	[illegible]	[illegible]
9	2250		Scattered Clouds	10		87	37/[illegible]	NW 3		37.0	35.5
10	0019		Clear	10		96	33/32	NW 3		33.0	32.5
10	0115		Clear	10		92	34/32	NW 3		34.0	33.2
10	0220		Clear	10		[illegible]	34/32	NW 2		34.0	33.0
10	0325		Clear	10		96	32/32	NW 4		32.5	32.0
11	[illegible]		Clear	12		71	43/34	NNW 8		43.0	38.2
11	[illegible]		Clear	12		73	40/32	NNW 6		40.0	35.7
11	[illegible]		Clear	12		80	40/30	NNW 12		40.0	36.0
12	[illegible]		Clear	6	H	91	37/36	Calm		37.0	36.0
12	[illegible]		Clear	6	H	91	37/36	W 2		36.7	36.7
12	[illegible]		Clear	6	H	[illegible]	37/34	Calm		[illegible]	[illegible]
12	[illegible]		Clear	6	H	78	37/31	W 2		37.3	[illegible]
12	[illegible]		Clear	6	H	91	36/33	W 2		[illegible]	34.2
13	[illegible]		Clear	12		86	[illegible]	NW 2	Clouds S and E	[illegible]	[illegible]
13	[illegible]		Clear	12		90	46/43	Calm	Slight haze aloft	[illegible]	[illegible]
13	0515		Scattered Clouds	12		91	46/44	Calm	Clouds N, W and SE	[illegible]	[illegible]
13	[illegible]	20000	Broken Clouds	10		86	48/46	W 5		47.5	47.0
14	[illegible]	600	Overcast	5	Light Rain	[illegible]	[illegible]	NNW 10	Cloud layers ragged from [illegible] to [illegible]; beam penetrates clouds	[illegible]	[illegible]
14	[illegible]	2300	Overcast	7	Light Drizzle	96	48/46	NNW 15	Ragged patches of cloud at 700 ft.; beam penetrates lower layer	[illegible]	[illegible]
14	0415	2100	Overcast	7	Light Drizzle	96	47/46	NW 16	Thin ragged clouds at [illegible] ft.	47.0	[illegible]
14	0445	2500	Overcast	7	Light Drizzle	96	46/46	NNW 12	Thin ragged clouds at [illegible] ft.	[illegible]	[illegible]
15	0350		Clear	Unl.		96	46/44	SW 8		[illegible]	[illegible]
15	2340		Clear	Unl.		100	46/46	SW 10		[illegible]	[illegible]
16	[illegible]	200	Overcast	1	F	100	47/47	SW 12	Overcast moved in at [illegible]	47.1	47.1

The Effect of Meteorological Factors on Light Transmission

By E. S. Sproles

The site of the tests conducted at Ponte Vedra Beach, Fla. was fairly representative of the southeastern coast of the United States so far as weather conditions are concerned. While there is some difference in conditions on the Carolina coast and the Florida coast, the essential factors in connection with sky glow are very nearly the same. It is an area of high humidity, except for occasional short periods during the winter when outbreaks of cold, dry, continental air reach the coast.

Some of the meteorological facts observed during the tests which may have a bearing on the data obtained are given below. In addition, I have given some definitions and methods used to determine certain factors, and their influence on atmospheric conditions which might affect light transmission. These factors include visibility, humidity, wind, and cloud heights.

Visibility is defined as the mean horizontal distance that objects can be seen by the normal eye; unaided by field glasses. Night visibility is based on the same principle, but must be determined by different methods. One method is by observing lights of a known distance, provided these lights do not have special penetrating qualities. On a cloudless night the brilliance of the stars can be used to determine the presence of obstructions which decrease the visibility, especially if those stars near the horizon are used. The beam of light from a powerful beacon or searchlight shows the presence of haze in the air.

Since the test area was in the blackout zone, it was necessary to estimate the visibility largely by the appearance of the stars, and the beam from the searchlight. The blinking light on the lightship, about 12 miles distant, was used when the conditions were about the same over land and at sea.

Horizontal visibility at one level cannot be used as a criterion for atmospheric transmission of light except at that level. Therefore horizontal visibility at the surface may be misleading in tests of this kind, where sky glow reaches to considerable height, and the light must be transmitted through layers of the atmosphere which differ in transmission qualities. Ordinarily the visibility is restricted more near the ground than at higher levels because foreign matter such as smoke, dust, and moisture are more prevalent near the surface where they are carried into the air. However, there are numerous cases where these obstructions are more pronounced aloft, due to distribution of heat and air currents at various levels.

Wind plays a very important part in determining visibility. For example, on a night when the wind is 10 miles per hour or more, the visibility and transmission will be better and also more constant than on a night with little or no wind. The movement of the air keeps the moisture and other obstructions equally mixed throughout the air so that there is not the formation of ground fog or layers of smoke or haze that are so common on calm nights. The wind also mixes the air so thoroughly that the temperature is kept uniform, thus preventing the formation of cold and warm layers or pockets of air which cause the formation of ground fog and smoke layers. On calm clear nights the ground cools rapidly, thus causing the shallow layer of air near the ground to cool also. When the temperature of this layer drops to the saturation point (dew point), then the moisture in the air is condensed in the form of fog, dew, or frost.

During this series of tests the visibility was noticeably better over the sea than over land. Since there is always more wind over a water surface than over an adjacent land surface, the mixing of air is greater. However, the more important factor is the fact that water surfaces are not cooled by radiation as rapidly as land surfaces, and since the water temperatures here were higher than the cooled land surfaces, the temperature of the air over water did not drop low enough to cause fog.

Relative humidity is the amount of humidity actually present in the air as compared to the total amount that the air at that temperature could hold if completely saturated. It is expressed in per cent and is determined by simultaneous readings on dry and wet-bulb thermometers. It is important in detecting moisture in the air in amounts large enough to cut down light transmission. Moisture in the air becomes visible in the form of haze or fog, depending on the amount present and the temperature of the air. Fog or ground fog forms when the temperature of the air near the ground reaches its dew point. At this temperature the relative humidity becomes 100%.

During the period of the tests there were only three nights during which the sky was overcast. On the night of January 7th and 8th, there was a high, thin overcast most of the night. Although thin enough that the brighter stars could be seen through it, the cloud layer was dense enough to reflect considerable light. The beam from the ceiling projector produced a very distinct spot at a height of about 20,000 feet.

On the night of January 8th and 9th, and on the morning of the 14th, there were almost identical conditions of low overcast skies accompanied by light rain or drizzle. The heights of the clouds were variable from 300 to 700 feet, and consisted of a ragged base through which the beam from the ceiling projector penetrated to some distance before fading gradually into the clouds in a diffuse manner. A cloud base of this type absorbs a great deal more light than a smooth, dense base, and hence is not a good reflector.

APPENDIX E

STREET LIGHTING DIMOUT

Second Interim Report on Engineer Board Request

Research Subcommittee
Committee on Street and Highway Lighting
Illuminating Engineering Society
December 31, 1942

1. Field studies. Mr. C. J. Woodside, as the official representative of the Committee, assisted throughout the recent field studies conducted by the Engineer Board and the Navy. Mr. Woodside and Mr. H. G. Clum have been invited by the military authorities to be the official representatives of the Committee in a forthcoming field study.

2. Data from field studies. On December 4 the Subcommittee Chairman received from the Engineer Board the major portion of the data obtained in the field study relating to dimout street lighting. These data were found to be adequate to establish reliably the relationship between air glow (or sky glow) and elevation of beams directed toward the point of measurement, for the conditions covered in the study. These conditions were approximately 900,000 total beam lumens in an area approximately 1/2 mile by 1/2 mile, measurements from a distance of 5 miles, and unusually clear atmosphere. Similar measurements with the beams directed away from and transversely to the point of measurement indicated the general range of values but did not establish reliably the relation between glow and beam elevation because of uncontrollable variables in the test conditions.

3. Studies at reduced scale. It was found possible to set up test facilities at reduced scale which checked closely the field results. Such facilities were employed at Nela Park in an intensive series of tests conducted in the laboratory and outdoors from December 5 to 14. Measurements covered four variable conditions on which data are required to permit computation of glow attributable to street lighting, and other forms of lighting. These four conditions are:

a. Atmospheric conditions. Weather conditions from December 5 to 14 varied from very clear to fairly clear, hazy, rainy, and snowy. The data showing the effect of atmospheric conditions are charted in Figs. 1 to 8 inclusive. In each case the atmospheric condition at the location of the glow was as stated on the drawing, but because of the reduced scale of the facilities the atmospheric transmission between the glow and the point of measurement may be taken as 100 per cent in all cases.

The Engineer Board has requested one additional item in connection with this series of tests under various weather conditions. This additional item is a correlation between the reported visibility distances, as estimated by the Cleveland Weather Bureau, and the atmospheric transmissions. Suitable facilities are being designed and it is hoped that measurements can begin within a few days.

b. Amount of light. For given conditions of atmosphere, beam distribution, and distance of measurement, it was found that the value of glow varies directly with the lumens.

c. Width of lighted area. Since the width of the lighted area in the field study was approximately 1/2 mile, the data may be applied directly to computations of glow from lighted areas of that width. When an area in which light is causing glow is wider than approximately 1/2 mile, the adjacent 1/2-mile areas on each side of a given 1/2-mile area appear to add approximately 25 per cent to the glow above the given area, for light distributions representative of street lighting. Further measurements will be included in a forthcoming field study.

d. Depth of lighted area. Since the depth of the lighted area in the field study was approximately 1/2 mile, the data may be applied directly to computations of glow from lighted areas of that depth. Where an area from which light is causing glow is deeper than approximately 1/2-mile, - that is, where there is in effect a row of 1/2-mile areas in alignment with the point of measurement - the combined glow appears to be the sum of the glows from the individual areas. Measurements at both full and reduced scale support this conclusion. However, recent Army studies indicate that the brightnesses of a row of areas in alignment with the point of measurement may not be directly additive. Further measurements will be included in a forthcoming field study.

4. Critical condition. The foregoing data show that the amount of glow produced by a given lighting condition is greater in hazy than in clear atmosphere, when measurements are made from a point close to the lighted area. The most critical condition, therefore, might exist if there were hazy atmosphere along the shore line and clear atmosphere over the sea. More commonly a hazy atmosphere along the shore line would extend out over the sea, and the greater glow due to the haze would be absorbed within a short distance. Therefore it is considered that for practical purposes clear atmosphere may be taken as the critical condition because any additive effect of sky brightness from sources inland is then present to maximum degree.

5. Computation of glow. Data at hand appear to be adequate to set up a simple and reasonably accurate method of computing glow from street lighting, provided one knows the width and depth of the lighted area, the types of street lighting luminaires employed, the total generated lamp lumens in each type of luminaire. If any dimout shielding of the luminaires is employed, the extent of such shielding must also be known. Where the distribution of street lighting throughout a large area is sufficiently non-uniform to produce an uneven glow, the large area may be broken down into smaller areas and the same computation method employed. Following is an explanation of the way the tabulated values employed in this computation method were determined and how they may be applied.

a. Glow from zones of light emission. Table I presents the amount of glow produced by 1,000,000 lumens emitted in various vertical zones and horizontal sectors. These values are based on the measurements at full and reduced scale. They apply to the critical condition of clear atmosphere, when the lighted area is viewed from a distance of 5 miles. The values in Table I include a factor to take account of the additive effect of glow from adjacent transverse areas as explained in paragraph 3-c. In any computation for an area only 1/2 mile wide this additive effect is not present and the values in Table 1 should be divided by 1.25. It may be noted that the values of average glow from all sectors (in the last column) may properly be applied for redirective as well as symmetrical types of luminaires because within areas of the size under consideration there will be reasonable diversity of directional positioning.

Table I - Glow per Million Lumens in Various Zones and Sectors

Zones- Angles Above Vertically Downward	Glow (MFL) from 90° Horizontal Sectors				Avge. Glow (MFL) in all Directions
	Toward Observers	To Right of Observers	Away From Observers	To Left of Observers	
0-60	180	40	40	40	75
60-90	280	70	70	70	120
90-120	3200	120	120	120	900
120-180	550	270	270	270	340

b. Zonal emissions from luminaires. Table II presents the Subcommittee's analysis of the per cent of the generated lamp lumens in the selected zones from representative types of street lighting luminaires.

Table II - Light Distribution from Representative Types of Street Lighting Luminaires

Zones	Zonal Lumens in Per Cent of Generated Lumens		
	Diffusing Luminaires	Redirective Luminaires	Open Reflector Luminaires
0-60	12	18	38
60-90	23	35	37
90-120	22	4	5
120-180	13	3	0
Total for all Zones	70	60	80

c. Glow from types of luminaires. The values in Table III may be applied directly in computations of glow from unshielded street lighting. These values are based on Tables I and II. For example, the values in column 2 of Table III were obtained by multiplying the values in the last column of Table I by the values in column 2 of Table II. For each type of luminaire, the total of all zones represents the glow in MFL per million generated lamp lumens in that type of luminaire, as observed from 5 miles in clear atmosphere.

Table III - Glow from Unshielded, Clean Street Lighting Luminaires

	Glow (MFL) per Million Generated Lumens		
Zones	Diffusing Luminaires	Redirective Luminaires	Open Reflector Luminaires
0-60	9	14	28
60-90	28	42	45
90-120	200	36	45
120-180	44	10	0
Total for all Zones	281	102	118

d. Computation for unshielded street lighting. The following equation may be used to determine the street lighting glow above a given area, throughout which unshielded street lights are reasonably distributed:

$$G = \frac{M(281\ L_d + 102\ L_r + 118\ L_o)}{2\ W}$$

G - Glow (MFL) as observed from a distance of 5 miles in a given direction and in clear atmosphere.

W - Approximate width of lighted area, in miles.

L_d- Total generated lamp lumens, divided by 1,000,000, in diffusing types of luminaires.

L_r- Total generated lamp lumens, divided by 1,000,000, in redirective types of luminaires.

L_o- Total generated lamp lumens, divided by 1,000,000, in open reflector types of luminaires.

M - Maintenance allowance - estimated lumen output of luminaires in per cent of lumen output with lamps and luminaires new and clean. A value of 80% may be a reasonable estimate in most municipalities.

As a check of the foregoing computation method and equation, calculated values of glow above two municipalities were compared with measured values. Above Schenectady, N. Y., the computed glow from street lighting alone was 620 MFL, while the maximum glow measured from a distance of 13 miles and including some outdoor lighting other than street lighting was 850 MFL. Above Taunton, Mass., the computed glow was 130 MFL and the glow measured from 5 miles was 136 MFL, both applying to street lighting alone. These checks are remarkably close, and it is the opinion of the Subcommittee that the computation method may properly be applied to calculations of glow from shielded as well as unshielded street lighting by taking proper account of the reduction in lumens in certain zones due to the shielding.

e. Computation for shielded street lighting. As a basis of computation of the glow above representative municipalities, three degrees of dimout street lighting restrictions were assumed. These were (1) not more than 10% of the lamp lumens above the horizontal, (2) not more than 3% of the lamp lumens above the horizontal, and (3) practically no light above the horizontal. These steps represent respectively, (1) the moderate restriction in effect on the Pacific Coast; (2) an intermediate restriction resulting in a loss in street lighting effectiveness which is substantial but perhaps not unwarranted as a compromise between the conflicting requirements in critical coastal areas, and (3) the drastic restriction in effect or proposed in certain Eastern Defense Areas.

In the judgment of the Subcommittee, the above restrictions in upward light would unavoidably be accompanied by reductions in light in zones below the horizontal as shown in Table IV. With many shielding expedients now employed the reductions in downward light are greater than indicated.

Table IV - Estimated Reductions in Downward Light Accompanying Restriction in Upward Light

Type of Luminaires	Per Cent Reductions in Zonal Lumens					
	Restriction (1)		Restriction (2)		Restriction(3)	
	0-60°	60-90°	0-60°	60-90°	0-60°	60-90°
Diffusing	0	20	5	40	10	65
Redirective	0	0	0	10	0	75
Open Reflectors	0	0	0	5	0	20

It is estimated that the overall street lighting effectiveness with the above restrictions, assuming well designed shields, would be (1) 90-95 per cent of normal, (2) 70-90 per cent of normal, and (3) 25-50 per cent of normal. Any restriction greater than that in (2) results in serious loss in lighting effectiveness, regardless of the method employed to meet the restriction.

Table V presents values of glow in MFL per million generated lamp lumens, as observed from 5 miles in clear atmosphere, for the three types of street lighting luminaires and the three degrees of shielding assumed. These values are based upon the preceding tables. They may be applied directly in computations of glow from shielded street lighting, employing the following equations with the meanings of the terms as stated in paragraph 5-d:

Restriction (1) $$G = \frac{M (121 L_d + 102 L_r + 118 L_o}{2W}$$

Restriction (2) $$G = \frac{M (52 L_d + 79 L_r + 98 L_o}{2W}$$

Restriction (3) $$G = \frac{M (18 L_d + 25 L_r + 64 L_o}{2W}$$

Table V - Glow from Clean Street Lighting Luminaires with Three Degrees of Shielding

	Glow (MFL) Per Million Generated Lumens								
	Diffusing Luminaires			Redirective Luminaires			Open Refl. Luminaires		
Zones	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
0-60	9	8	8	14	14	14	28	28	28
60-90	22	17	10	42	38	11	45	43	36
90-120	90	27	10	36	27	0	45	27	0
120-180	0	0	0	10	0	0	0	0	0
Total for all zones	121	52	18	102	79	25	118	98	64

The computed values of glow in Table VI are based on the values in Table V, with M equal to 0.80.

Table VI -- Computed Glow from Four Street Lighting Conditions

Municipality	Approximate Pop. x 1000	MFL Normal	Restriction(1) MFL	Restriction(1) %Normal	Restriction(2) MFL	Restriction(2) %Normal	Restriction (3) MFL	Restriction (3) %Normal
Schenectady, NY	100	620	300	49	145	23	50	8
Buffalo, N.Y.	600	1170	580	50	300	26	102	9
Glen Falls, N.Y.	20	115	80	70	53	46	19	17
Taunton, Mass.	40	130	96	74	68	52	35	27

It will be noted in Table VI that the three restrictions result in different percentage reductions in glow in the four cities. The reason is that the street lighting luminaires in Schenectady and Buffalo are predominantly of the diffusing type, those in Glens Falls are predimonantly of the redirective type, and those in Taunton are largely of the open reflector type. As shown in Table V, a given restriction in upward light produces different reductions in glow for the three types of luminaires.

These and other computations indicate that the glow which would result from street lighting with the above restrictions in effect would usually be of the order of (1) 50-75 per cent of normal (2) 25-50 percent of normal, and (3) 10-25 per cent of normal.

6. Permissible glow from artificial lighting. We understand the recent field studies indicated that an increment of only 30 MFL in glow -- added to sky brightness of the order of 100 MFL -- resulted in significant increase in detectability of ships relatively close to observers employing night glasses, and that the increment increased to some extent as the distance between observers and target ship increased. It is undoubtedly recognized by the armed services that an increment of any such low order is only a fraction of the variation in sky brightness on moonless nights when no artificial lighting at all is involved. Undoubtedly they also are aware that all dimout practices thus far employed result in much higher glow. The Subcommittee appreciates that from the standpoint of ship detection alone it would be desirable to limit the increment of glow from artificial lighting to the least amount producing increased detectability of ships. We judge the armed services would like from the Subcommittee the foregoing analysis of the effectiveness of the street illumination which could be provided with very low increments of glow, in order that they might appraise the gains at sea and the losses on shore in relation to the overall war effort.

In summary, the values in Table VI indicate that a limitation on glow from street lighting of the order of 30 MFL, except in small municipalities surrounded by rural areas, could be met only by curtailing street lighting so radically that practically all its effectiveness would be lost. A limitation of glow from street lighting of the order of 200 MFL would appear to offer an opportunity for design of shields affording reasonably good street visibility.

7. Street lighting a vital factor. In connection with an appraisal of dimout gains and losses the Subcommittee again emphasizes that dimout regulations resulting in lowered street lighting effectiveness cause greater traffic hazard and slower movement of men and materials. The greater traffic hazard cannot be dismissed as of minor consequence on the generalization that the victims are civilians who are of little or no importance to the war effort. Even if one might venture to disregard the humanitarian and economic aspects of accidents to civilians, recent analyses show that substantial and rapidly increasing percentages of traffic casualties are among members of the armed services and among defense workers considered sufficiently important to the war effort to warrant keeping them out of the armed services. For example, in New York State as long ago as 1940, before war production was fully under way, over one-third of all the drivers reporting traffic accidents were skilled workers. Many more skilled workers are now being killed and injured in traffic accidents than are being killed and injured at work. The President's repeated insistence on greater attention to traffic safety emphasizes the seriousness of the losses to the war effort through traffic casualties.

Further information on this aspect of the problem is presented in Appendix A.

Rather than a continuous curtailment of coastal street lighting sufficiently drastic to result in a glow increment of the order of only 30 MFL the best interests of the war effort might be served by turning out all coastal street lighting during the few hundred hours annually when such an increment of glow from artificial lighting is significant, and by leaving the normal lighting on at other times. Measurements have shown that during periods of actual or nominal moonlight, and during the heavy-traffic dusk and dawn periods of at least 1-1/2 hours duration each, the sky brightness from natural illumination is of a high order which renders insignificant the glow even from full, unshielded street lighting. During such periods, and also during adverse weather, street lighting restrictions handicap the war effort on land and are of no significant value at sea.

The Subcommittee reiterates the principle that a major part of the permissible sky glow under dimouts should be assigned to lighting for essential war activities such as street lighting, automobile headlighting, traffid signals, protective lighting, exterior war industry lighting, etc. Every effort might properly be made to minimize sky glow from other sources which do not contribute directly to the war effort or which can produce the illumination desired without the unavoidable accompaniment of sky glow.

8. <u>Further studies</u>. The Subcommittee believes that insofar as street lighting is concerned no additional field or laboratory studies of glow are needed except for further measurements of the additive effect of adjacent lighted areas.

Kirk M. Reid
Chairman, Research Subcommittee
Committee on Street & Highway Lighting
Illuminating Engineering Society
December 31, 1942

Chairman's Address:
Nela Park Engineering Dept.
General Electric Co.
Cleveland, Ohio

APPENDIX A

Traffic Accidents as Affected by Dimout Street Lighting

Hartford, Conn.

Mr. R. E. Simpson, Chairman of the Connecticut Dimout Consulting Committee, has made an analysis of the change in Bridgeport and New Haven traffic accidents per million vehicles miles during 6 months after compared with 6 months before all street illumination in the two cities was cut approximately 50 per cent to meet dimout orders. He found a decrease of 15 per cent in the day accident rate, as would be expected because of reduced traffic following gas rationing. In spite of reduced traffic, there was an increase of 21 per cent in the night accident rate.

National Safety Council

Following are extracts from the minutes of a meeting of the Committee on Traffic Engineering, Street and Highway Traffic Section, National Safety Council, on October 28, 1942.

1. Existing dimout and blackout regulations specify maximum light intensity permissible, but no minimum flooring has been prescribed. This leads to unnecessary hazard due to undue restriction of light.

2. There is a need to impress local officials with the importance of safety in dimout periods. Many unsafe practices have developed in regard to blacking out of signals, etc.

3. There is a need to impress the Army with the importance of setting up minimum as well as maximum light standards. This might be done by a formal resolution addressed to the proper officials from the National Safety Council, and it might be desirable to go so far as to provide a special committee to work with the Army in studying this subject.

4. A preliminary study of accident experience in dimout areas would be desirable.

5. There is a general need for standardization of lighting restrictions for blackouts and dimouts.

Street and Highway Lighting Safety Bureau

The attached publication "The Case for Safety Lighting on Our Essential War Roads" discusses in some detail the contribution of adequate street illumination to the war effort.

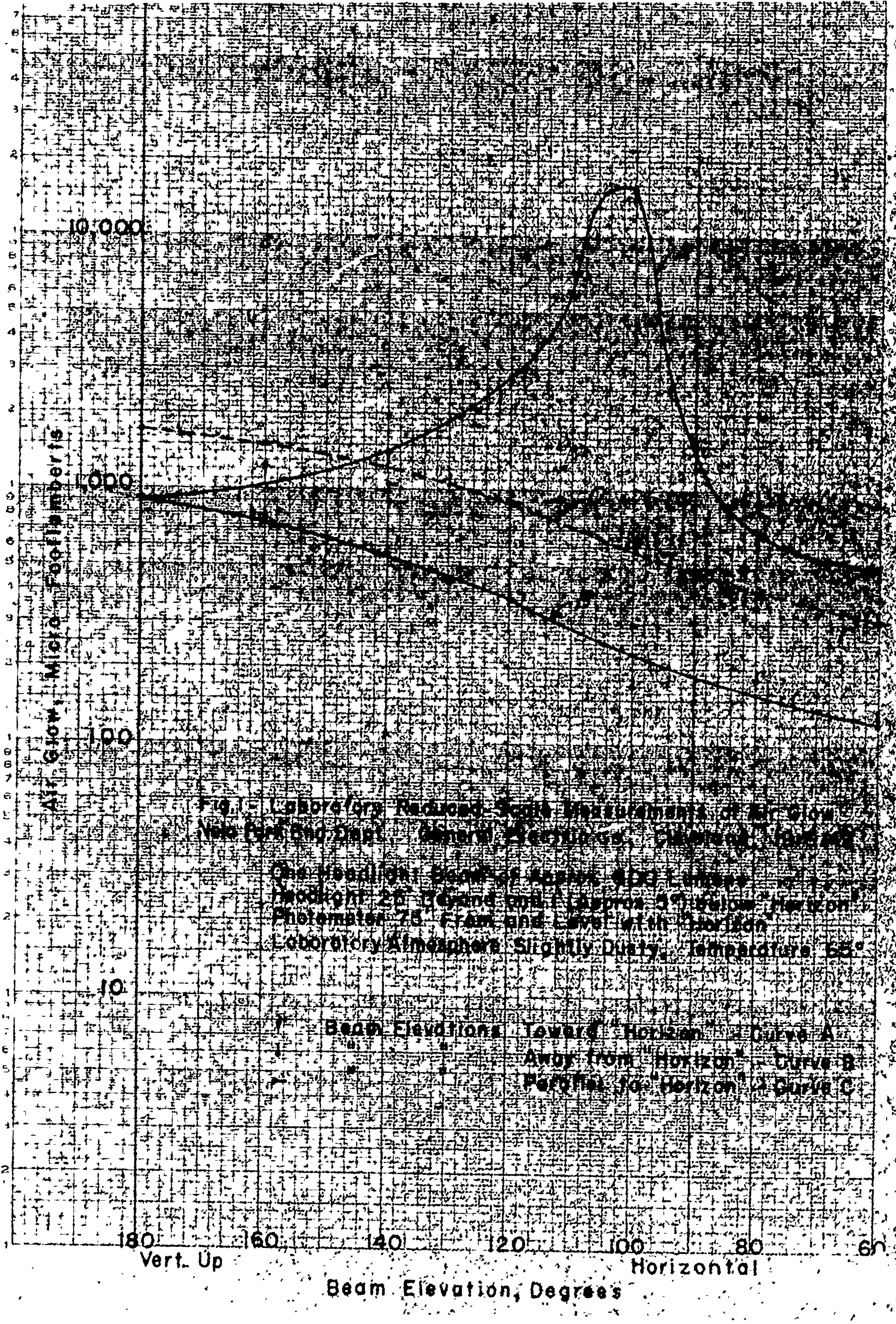
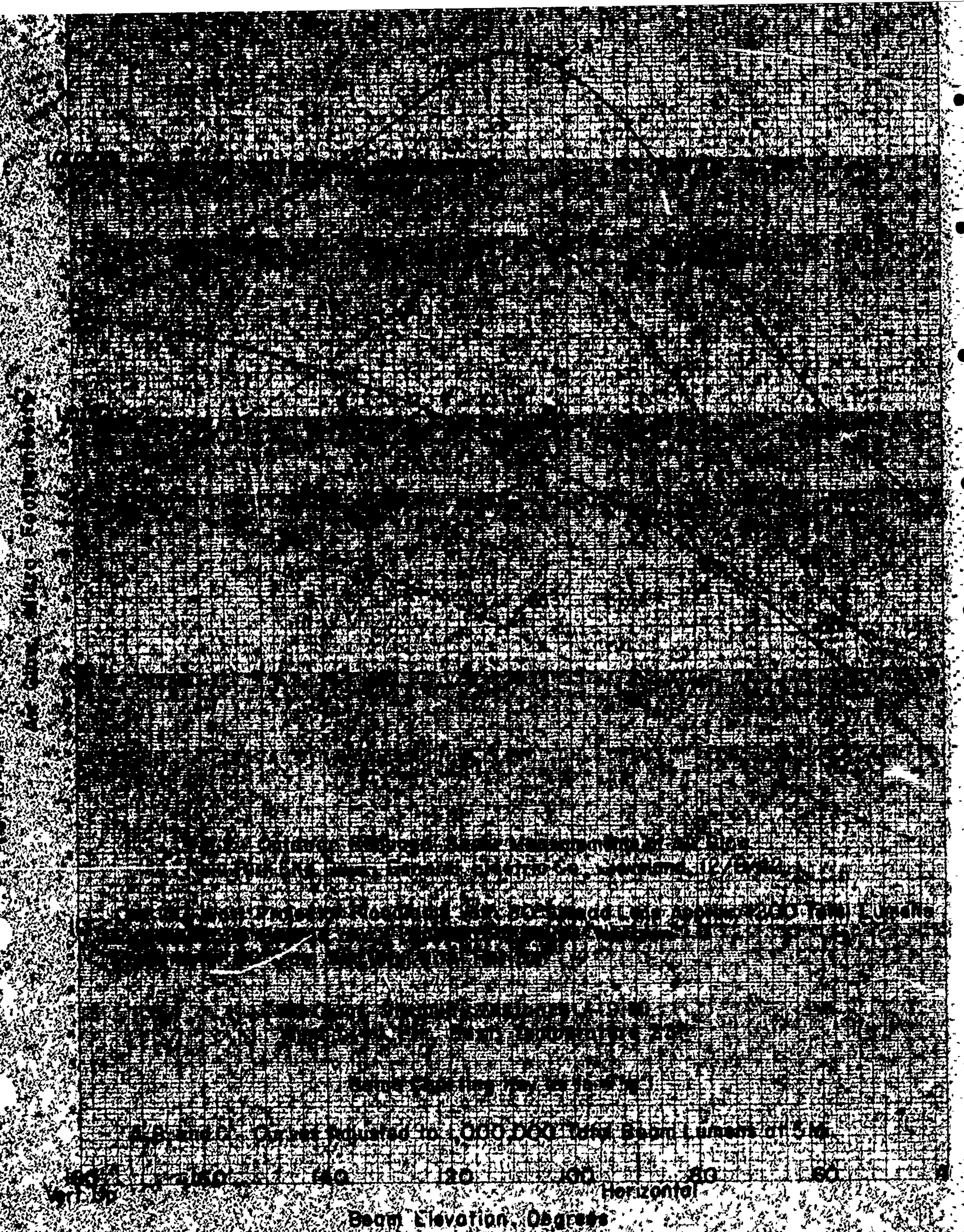


Fig. 1 – Laboratory Reduced Scale Measurements of Air Glow – Nela Park Eng. Dept., General Electric Co., Cleveland, Ohio

One Headlight Beam of Approx. 400 Lumens.
Headlight 20" Beyond and 1" (Approx. 5°) Below "Horizon"
Photometer 75" From and Level with "Horizon"
Laboratory Atmosphere Slightly Dusty. Temperature 65°

Beam Elevations Toward "Horizon" – Curve A
" " Away from "Horizon" – Curve B
" " Parallel to "Horizon" – Curve C


A, B, and C Curves Adjusted to 1,000,000 Total Beam Lumens at 5 M.
180
160
140
120
100
80
60
Vert. Up
Horizontal
Beam Elevation, Degrees

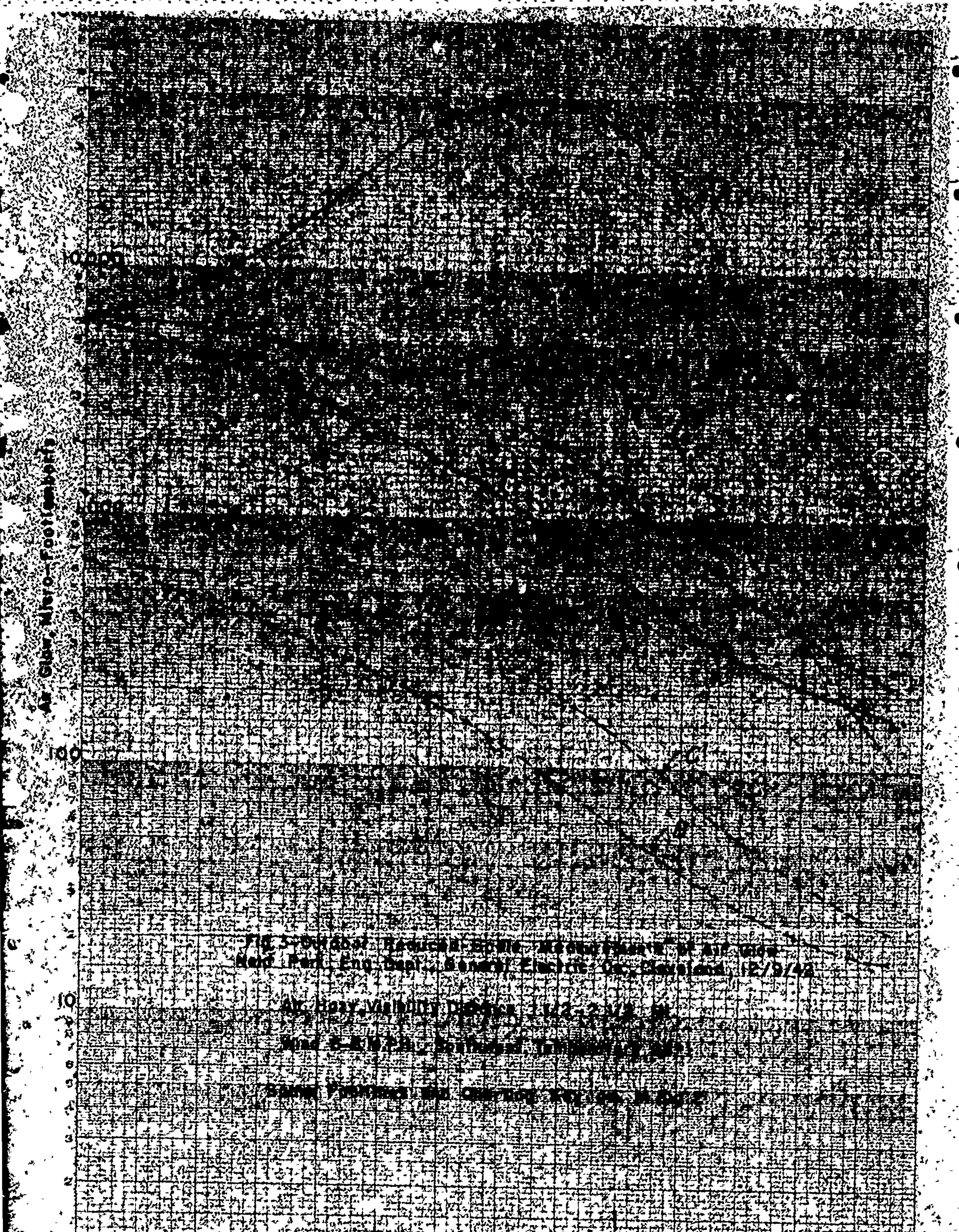


Fig. 3-Outdoor Reduced-Scale Measurements of Air Glow
Nela Park, Eng. Dept., General Electric Co., Cleveland, 12/9/42

Air, Hazy, Visibility Distance 1 1/2 - 2 1/2 Mi.

Wind 8-8 M.P.H., Southwest. Temperature [illegible]

Source Position: [illegible]

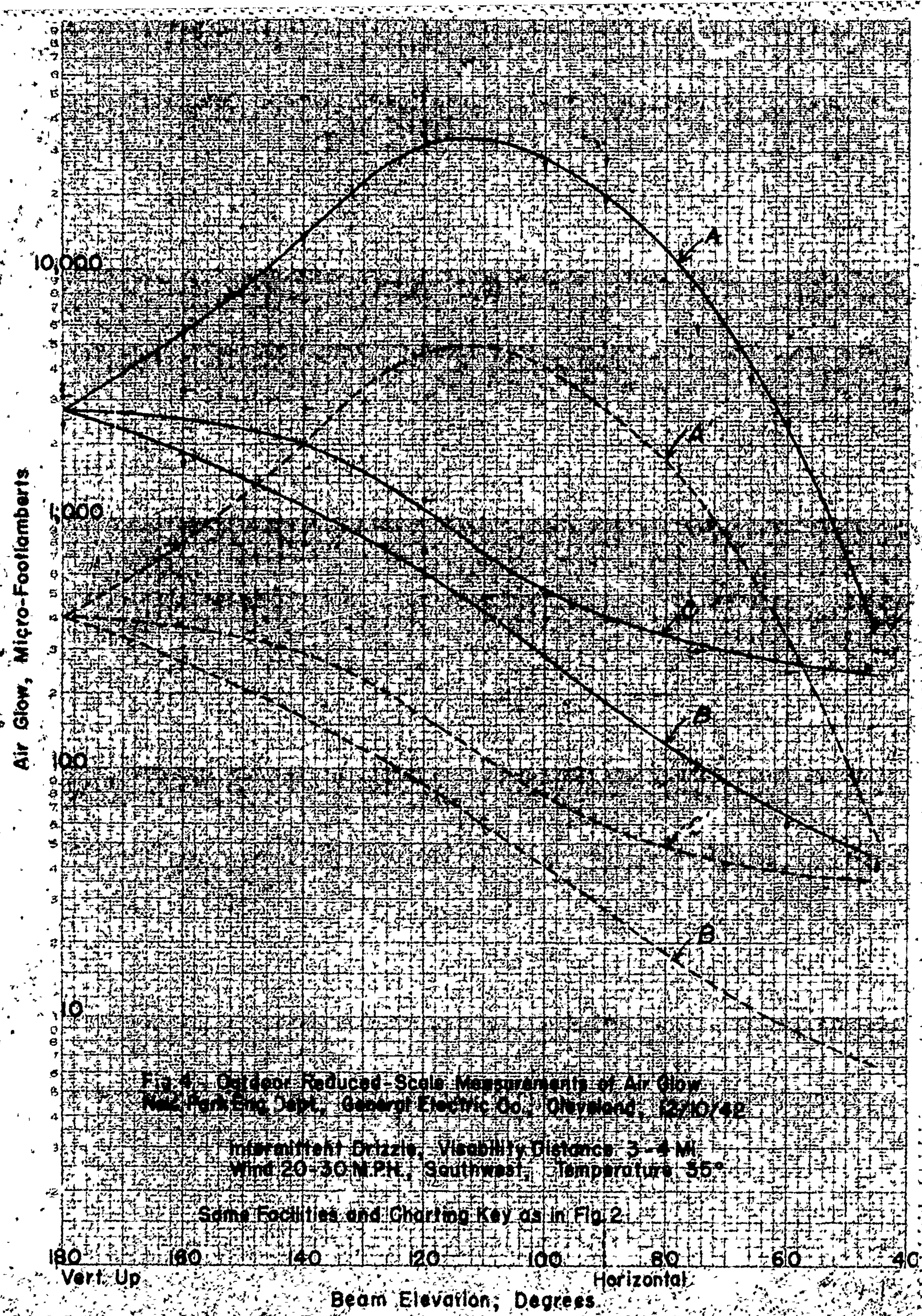


Fig 4 - Outdoor Reduced-Scale Measurements of Air Glow
Nela Park Eng. Dept., General Electric Co., Cleveland, 12/10/42

Intermittent Drizzle, Visability Distance 3-4 Mi.
Wind 20-30 M.P.H., Southwest, Temperature 55°

Same Facilities and Charting Key as in Fig. 2

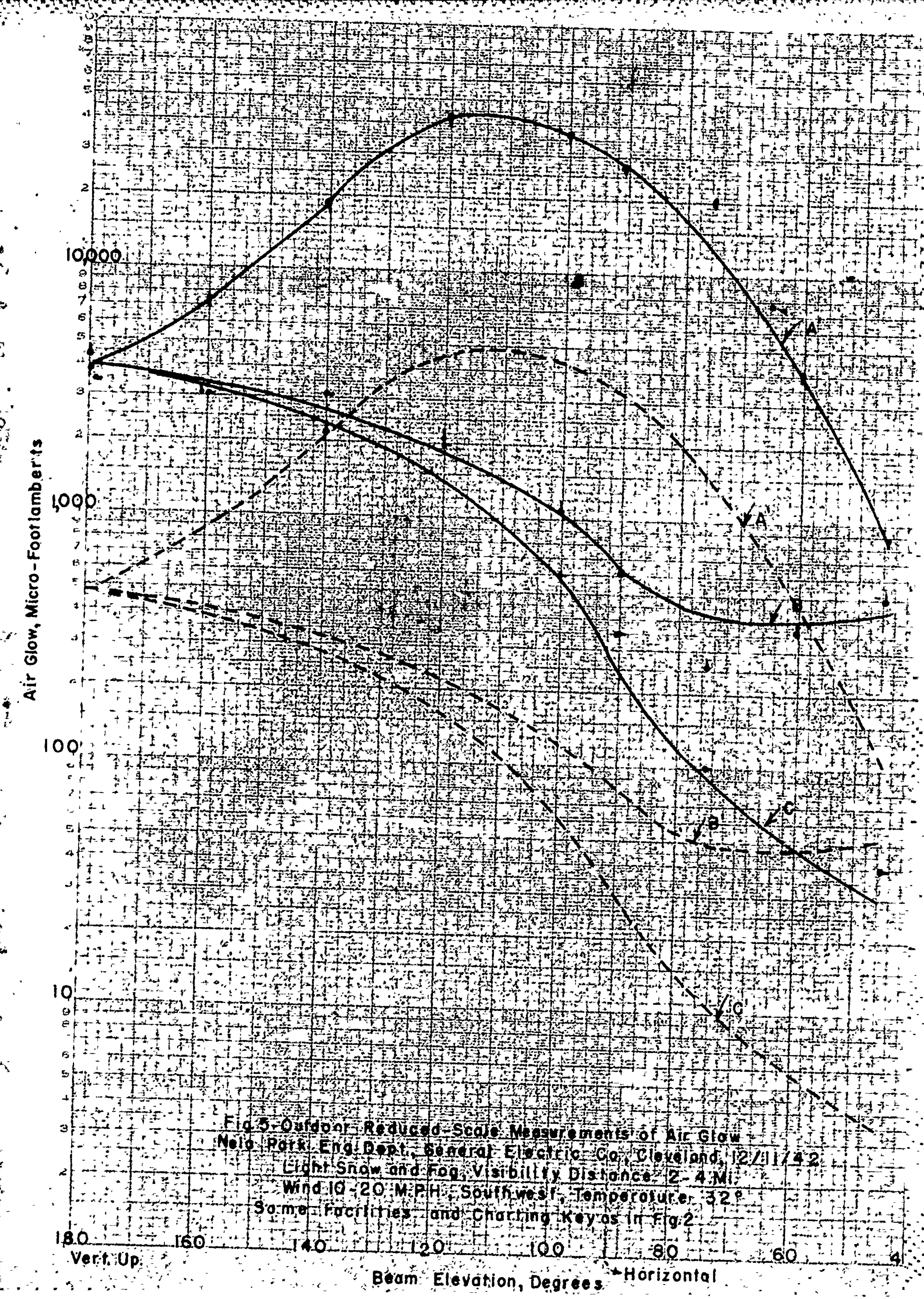


Fig 5-Outdoor Reduced-Scale Measurements of Air Glow
Nela Park, Eng. Dept., General Electric Co., Cleveland, 12/11/42
Light Snow and Fog, Visibility Distance 2-4 Mi.
Wind 10-20 M.P.H., Southwest, Temperature 32°
Same Facilities and Charting Key as in Fig 2

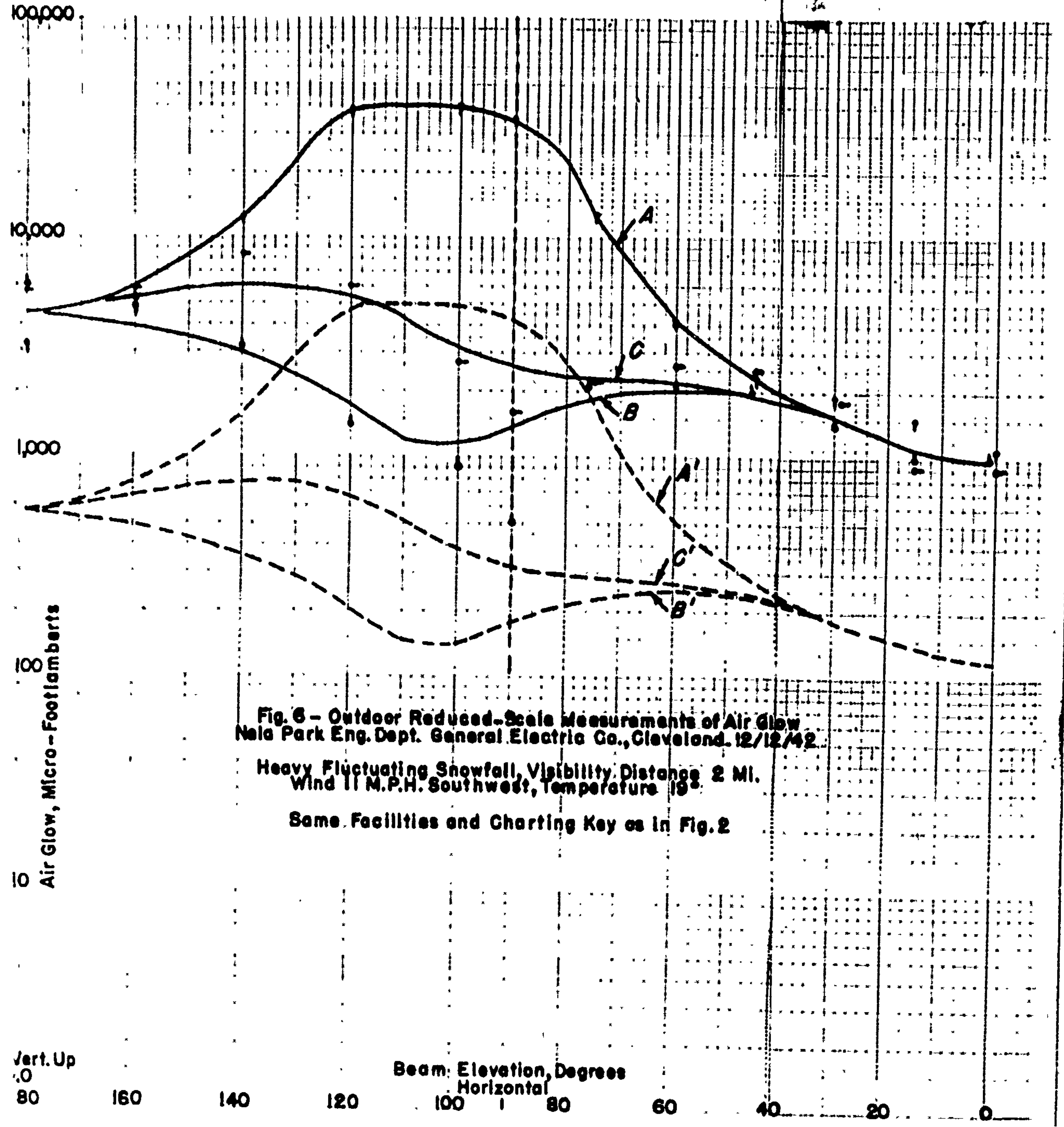


Fig. 6 – Outdoor Reduced-Scale Measurements of Air Glow
Nela Park Eng. Dept. General Electric Co., Cleveland. 12/12/42.

Heavy Fluctuating Snowfall, Visibility Distance 2 Mi.
Wind 11 M.P.H. Southwest, Temperature 19°

Same Facilities and Charting Key as in Fig. 2

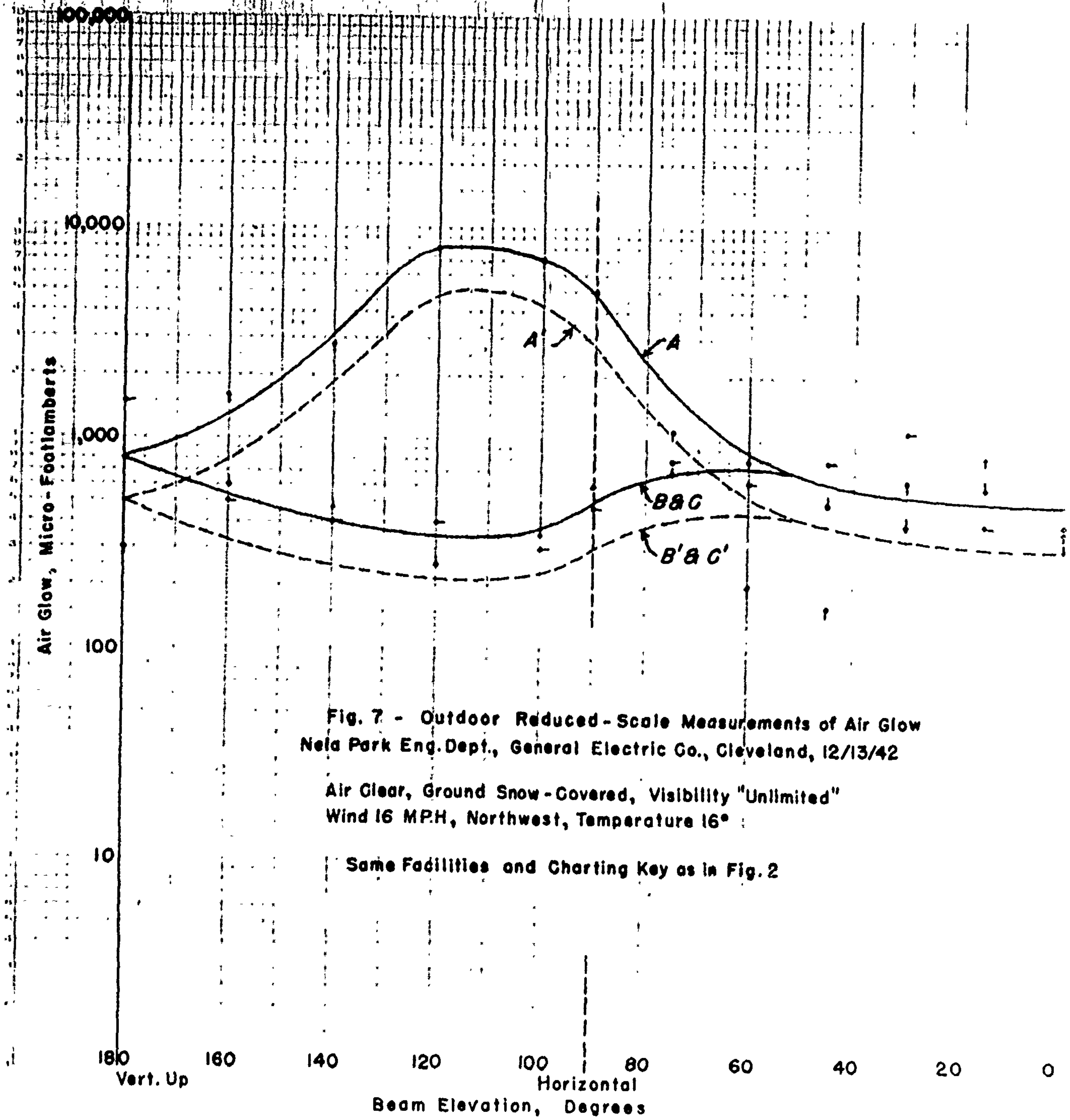


Fig. 7 - Outdoor Reduced-Scale Measurements of Air Glow
Nela Park Eng. Dept., General Electric Co., Cleveland, 12/13/42

Air Clear, Ground Snow-Covered, Visibility "Unlimited"
Wind 16 M.P.H, Northwest, Temperature 16°

Same Facilities and Charting Key as in Fig. 2

APPENDIX F

Estimate of Lumens Emitted by Lighted Show Windows of an Average Store or Service Establishment

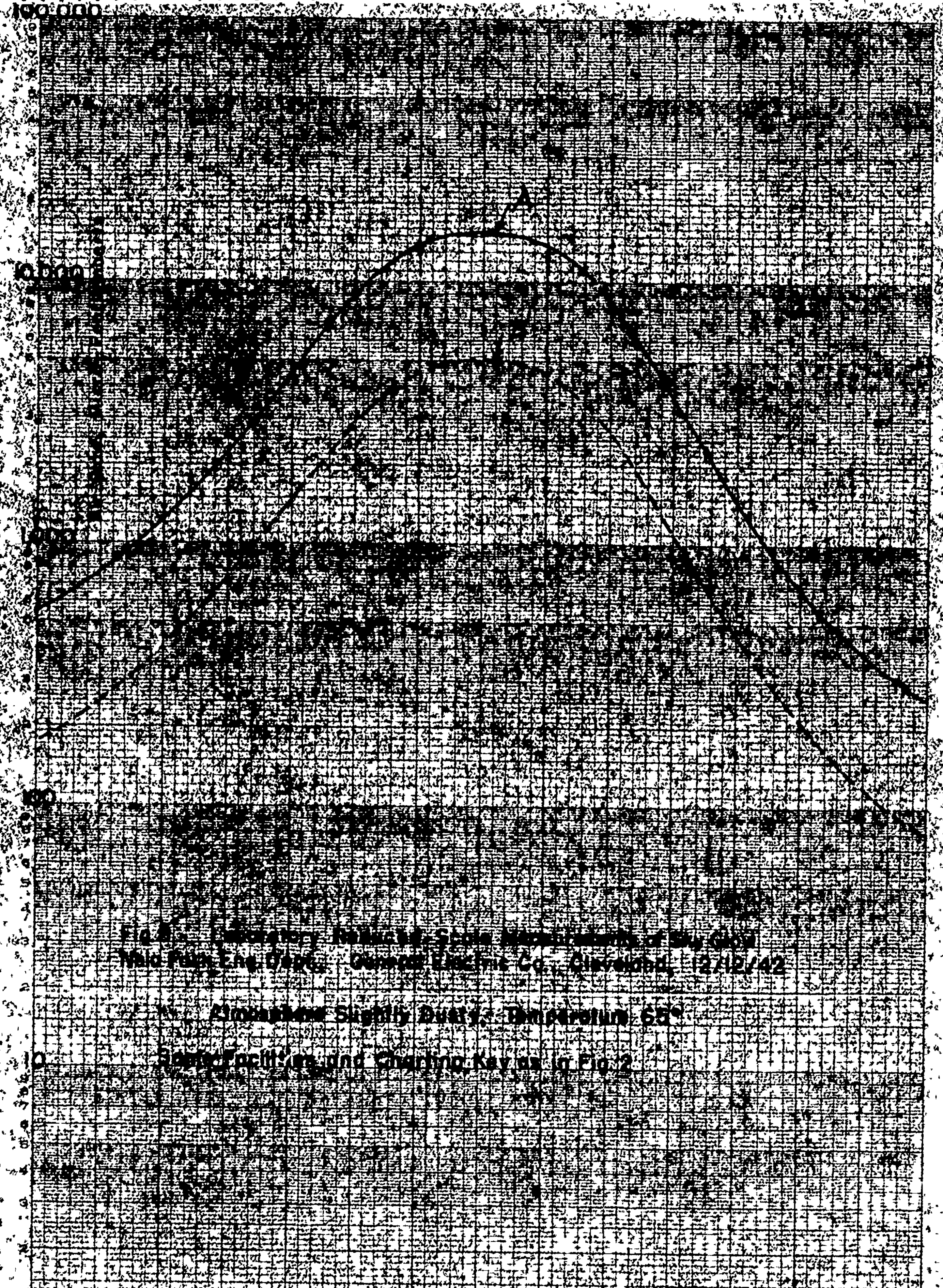


Fig. [illegible] Laboratory, [illegible] Scale Measurements of Sky Glow
Nela Park, Eng. Dept., General Electric Co., Cleveland, 12/12/42

Atmosphere Slightly Dusty; Temperature 65°

Scale Facilities and Charting Key as in Fig. 2

Estimate of Lumens Emitted by Lighted Show Windows of an Average Store or Service Establishment*

1. OBJECTIVE. - The objective of this study is data which may be correlated with other material to indicate the approximate contribution of show window lighting to sky glow.

Requested were:

a. An estimate of the lumens emitted upward by an average show window with standard lighting equipments, with both filament and fluorescent lamps, and using typical reflection factors for merchandise and backgrounds.

b. The effect of the presence of a lowered awning on a.

c. The effect of a typical show window dim-out curtain on conditions a. and b.

d. The lumens below horizontal incident on sidewalk, pavement and opposite buildings.

2. BASES OF THIS ESTIMATE - Calculations of these estimates were based upon:

a. A show window of average size and proportions, as described on Page 4 of the book, "Window Display Circulation and Market Coverage", published by The Advertising Research Foundation of The Association of National Advertisers, Inc., and American Association of Advertising Agencies. (See Appendix A 1)

b. Average wattage employed in show windows, as determined by surveys. (See Appendix A 2)

c. Calculation of illumination produced in the average show window. (See Appendix A 3)

d. Estimates of reflection factors in service, weighted by display trimplane zones. (See Appendix A 4)

e. Angular distribution of lumens reflected from the three trim plane zones and backgrounds of the average window, based on photometer measurements of a model. (See Appendix A 5)

f. Data on dim-out curtains for show windows. (See Appendix A 6)

g. Estimate of lumens emitted toward the sidewalk, based on measurements taken before a window in the General Electric Institute, Nela Park.

h. Average of 1.9 windows per establishment, based on the reference given in 2 a. above. Used to facilitate correlation with the number of establishments in a locality.

i. No light from within the store is included.

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*Study conducted at Illuminating Engineering Laboratories, General Electric Company, Cleveland, Ohio.

3. PROCEDURE - Essentially, the procedure was one of correction of the lumens emitted by various zones of the trim (background included) of the model, in amounts depending upon:

a. Calculated brightness of similar zones in the average window.

b. Area of similar zones in the average window.

4. RESULTS - It should be noted that since the variations in window features, dimensions, reflection factors and lighting are extreme, these figures should be considered as indicating only the probable order of magnitude for a representative group of windows.

a. Windows With Filament Lighting - Approximate lumens emitted by filament-lighted windows of the average store or service establishment. (Reflection factors vary somewhat among zones A, B, C.) (See Appendix A 3) (See Appendix A 6 for curtain.)

(1) For reflection factors as given in Appendix A 3.

Zone (Degrees above Nadir)	Lumens			
	No Awning		Awning	
	No Curtain	Curtain	No Curtain	Curtain
0-40	1200 - 2000	80-150	1200 - 2000	80-150
40-90	265	70	265	70
90-120	310	85	185	50
120 -180	180	35	5	-
Total Above Horiz.	490	120	190	50

(For approximate distribution by 10° Zones, (40 - 180°) (See Appendix B 1)

(2) For uniform reflection factor of 0.30.

Zone (Degrees above Nadir)	Lumens			
	No Awning		Awning	
	No Curtain	Curtain	No Curtain	Curtain
0-40	1200 - 2000	80-150	1200 - 2000	80 - 150
40-90	290	70	290	70
90-120	305	80	180	50
120-180	170	30	5	-
Total Above Horiz.	475	110	185	50

(Lumens above 40° are proportional to reflection factor.)

b. Windows with Fluorescent Lighting - Approximate lumens emitted by fluorescent lighted show windows of the average store or service establishment.

(1) With reflection factors as given in Appendix A 3).

Zone (Degrees above Nadir)	Lumens			
	No Awning		Awning	
	No Curtain	Curtain	No Curtain	Curtain
0-40	1200-2000	80-150	1200-2000	80-150
40-90	325	85	325	85
90-120	295	80	135	35
120-180	135	25	5	-
Total Above Horiz.	430	105	140	35

(For approximate distribution by 10° Zones, see Appendix B 2)

5. DISCUSSION

a. Lumens in the 0° -40° Zone - In this zone estimation is difficult since, in the typical window, the emitted light is a mixture of light direct from the overhead unlouvered equipments and reflected from the merchandise and backgrounds. Ordinarily, the units are so positioned near the top of the glass that direct light from the lamps and reflectors is incident upon the glass at a high angle. Much is reflected internally, the remainder causes a peak in illumination within a few feet of the building line. The results of this condition may be emphasized:

(1) If 1600 lumens are incident on the sidewalk (approx. 0°-40°) upward light reflected therefrom at a reflection factor of 0.15 is only about 250 lumens. Assuming that the reflection is diffuse in character, perhaps half this value or about 125 lumens per store could be expected to clear the buildings on its way upward without secondary reflection. (The building housing the show windows cuts off perhaps 40%; those across the street the remaining 10%.)

Vehicular and pedestrian traffic would reduce such reflected light.

(2) Since the greater part of the lumens in the 0°-40° zone are incident near the building line, the lowering of an awning would cut off by far the greater part of the upwardly reflected light.

(3) Since direct light from the lamps and reflectors in a downward and outward direction are incident upon the plate glass at a large angle, the louvering action of a "dim-out" curtain or other louvering would greatly reduce this emission of light and consequently the lumens reflected upward.

b. Lumens in 40°-90° Zones - In all cases this light must undergo reflection before reaching the upper air. The reflection factors encountered typically probably do not exceed 0.10 - .25 and half of that reflected probably would not emerge above, considering the usual buildings in even small business districts. Net estimated at 7%-8%.

c. Lumens in 90°-120° Zones - In business districts a considerable part of this light would be intercepted by opposite buildings, even if only 2 stories high, and would be largely reduced by absorption. Only half of that reflected diffusely would be upward.

6. CONCLUSIONS - Considering the average store or service establishment with lighted show windows, the following conclusions may be drawn:

a, With no dim-out treatment for the windows, the total upward light is less than 500 lumens, about equivalent to the total output of a 40-watt filament lamp.

b. With a lowered awning, the total upward light ranges from about 140 to 190 lumens, the lower figure representing the output of a 15-watt filament lamp.

c. With the dim-out curtain only, the total upward light is not more than 120 lumens, or less than the total output of a 15-watt filament lamp,

d. With both curtain and awning, the total upward light is about equivalent to the total output of a 6-watt filament lamp.

e. In every condition a large part of the total upward light is emitted in the 90°-120° zone, or just above horizontal (See 4 a. and b.). In the typical business district, some significant fraction of this will be intercepted by opposite buildings and will be largely absorbed. Only half of the remainder would be reflected in an upward direction.

f. All of the lumens emerging below horizontal, in the typical case, must undergo at least one or more reflections at relatively low reflection factors before reaching the upper air.

g. Use of a dim-out curtain tremendously reduces not only the upward light but the relative large numbers of lumens in the lower zones and incident upon the sidewalk.

h. A lowered awning not only greatly reduces light upward, but traps a large fraction of the lumens which are incident upon the sidewalk near the store front.

i. Fluorescent-lighted windows, on the average, will emit less light above horizontal than those with filament lamps.

APPENDIX A

1. Average Show Window as determined by National Advertising Research Foundation

(a) Length 6.9 feet — Length parallel to sidewalk
Height 6.3 " — One glass end 58.5% of windows
Depth 4.1 " — Closed ends 30.1% " "

(b) Windows per store 1.9

2.	Average wattage per linear foot of show window fil. lamps	50 (approx.)
"	linear feet per store	20.9
"	total wattage, filament lamps	1045
"	lumens per watt for 100 and 150 watt fil. lamps	16.7
"	total lumens generated	17,450

3. Estimates of Reflection Factors in Average Window

(a) Average for merchandise 0.45

(b) Weighted average Reflection Factor of Backgrounds

Background	Estimated Refl. Factor	Weights % of Stores	Weighted Av. Refl. Factors
None	0	40	
Glass	0.08	30	
Light	0.70	13.8	
Medium	0.45	12.9	
Dark	0.20	3.3	0.185

(c) Assumed average Reflection Factor of Floor 0.25

(d) Weighted Reflection Factors by Trim-Plane Zones A, B & C

	% of Area Merchan.	% of Area Backg'd	% of Area Floor	Weighted Av. Refl. Factors
Zone A	50	25	25	0.33
Zone B	40	60	0	0.29
Zone C	30	70	0	0.26

4. Distribution with and without awning shielding from angles above horizontal. From tests of a small model window whose trim planes were illuminated to a known brightness.

APPENDIX B

1. Approximate Distribution of Lumens Emitted by the Lighted Show Windows (using filament lamps) of the Average Store or Service Establishment by Angular Zones Above and Below Horizontal.

Zone (Degrees above Nadir)	Lumens			
	No Awning		Awning	
	No Curtain	Curtain	No Curtain	Curtain
40-50	12	2	12	2
50-60	28	6	28	6
60-70	51	13	51	13
70-80	75	20	75	20
80-90	96	27	96	27
90-100	108	31	88	25
100-110	105	28	65	17
110-120	97	24	35	9
120-130	79	18	6	1
130-140	52	10	1	-
140-150	31	4	-	-
150-160	14	1	-	-
160-170	3	-	-	-
170-180	-	-	-	-

2. Approximate Distribution of Lumens Emitted by the Lighted Show Windows (using fluorescent lamps) of the Average Store or Service Establishment by Angular Zones Above and Below Horizontal.

Zone (Degrees above Nadir	Lumens			
	No Awning		Awning	
	No Curtain	Curtain	No Curtain	Curtain
40-50	23	4	23	4
50-60	43	10	43	10
60-70	67	16	67	16
70-80	88	24	88	24
80-90	104	29	104	29
90-100	108	31	67	19
100-110	95	26	45	12
110-120	90	22	23	6
120-130	72	16	4	1
130-140	35	6	1	-
140-150	20	3	-	-
150-160	9	1	-	-
160-170	2	-	-	-
170-180	-	-	-	-

APPENDIX C

1. The publication, "Advertising Research Foundation", sets forth data on number of window display spaces in accordance with population for cities up to 400,000 population. These figures are given in the following table with extrapolated values for cities of 500,000 and 1,000,000 population:

Population	No. of Window Display Spaces
50,000	1300
100,000	3600
200,000	6700
300,000	9700
400,000	12600
500,000	15200 (extrapolated)
1,000,000	26300 (extrapolated)

2. From a study of the above publication, it appears that the table refers to show windows of retail stores, and a correction factor of 1.2 should be used to include service establishments, beauty parlors, dry cleaning shops, etc.

3. The original studies were made between 1933 and 1935. There appears to be no basis for estimating what changes in numbers of stores, and, consequently, of display spaces there may have been since that time.

APPENDIX G

CONCENTRATIONS OF VEHICLES USING HEADLAMPS

War Department
Refer to File No. THE ENGINEER BOARD
400.1141 (EB 135) Fort Belvoir, Virginia

October 31, 1942

City Traffic Engineer:

Dear Sir:

The problem of coastal lighting as an aid to enemy submarines remains unsolved and the Engineer Board has been assigned the job of determining immediately what lighting control measures should be taken. We wish to enlist your cooperation in this study by obtaining the data as set forth below.

The question is this: How much does automobile headlighting contribute to sky glow over cities? In order to answer this question, the number of automobiles operating with lights for certain hours of darkness must be known; that is the actual number of lighting units on the street at the time of maximum night time traffic concentrations. We are extremely desirous of obtaining, as soon as possible, estimates of traffic concentrations for the hours of darkness in typical cities of various population groups.

Preliminary contact with several cities resulted in submission of information of no value to this study due to misinterpretation of what was desired. These cities submitted total hourly traffic flow figures for all intersections within an area, whereas the data required is the actual number of automobiles at any one instant during that hour which cause those total traffic movements.

A suggested method of obtaining desired information without conducting new surveys is as follows:

1. Select an area where maximum night time concentrations of traffic movements occur. This may be taken as the downtown business district or other applicable district. As this information wanted for this study must be available by November 7, 1942, time available may limit the information to only the most concentrated traffic portion of the district selected. However, a district not less than 1 mile square is desirable.

2. Obtain latest available traffic volume counts for each

street in the district under consideration.

3. Compute the actual average number of vehicles on each street in the district between 5 and 6 p.m. by the following method:

Let X = hourly traffic flow on street or section thereof in vehicles per hour (vehicles per 1/2 hour is more desirable).

S = average speed of vehicles in feet per second.

D = length of street or section thereof in feet.

Then: S times 3600 (use 1800 if traffic flow figures are for half hour periods) = distance one vehicle covers in one hour (or half hour).

$\frac{\text{S times 3600 (1800)}}{\text{X}}$ = average spacing between vehicles in feet.

$\frac{\text{D times X}}{\text{S times 3600 (1800)}}$ = average number of vehicles at any instant of the hour (or half hour) in the section of street under consideration.

4. Add number of vehicles thus obtained for each street, the total being the number in the selected district.

5. If 24 hour characteristic curves of traffic flow for the district are available, average number of vehicles for each hour or half hour of the night may be computed by multiplying the number found for the selected hour or half hour by the appropriate factor. Submit this data for each hour or half-hour from 6 p.m. to 7 a.m.

If recent night time traffic flow figures are not available they may be estimated from old figures brought up to date by applying proper factors revealed by permanent automatic traffic counting stations.

We would also like to have the total area in square feet of the selected district, the total street area in square feet and total lineal feet of lanes contained within the district, and the most recent population and automobile registration figures for your city.

We realize that this method will only give an approximation but feel that it is sufficiently accurate for the purpose within the time available. If a faster, simpler method occurs to you, please state that method with submission of the data.

We sincerely appreciate your cooperation in this matter for we realize this involves great many time-consuming calculations;

only the extremely urgent nature of this study prompts our request.

For the Board:

Very truly yours,

TABLE 2

MAXIMUM VEHICLES PER MILE OF HIGHWAY DURING DARKNESS

State	Highway	Maximum ave. vehicles per mile	Time of max. concentration
South Carolina	U. S. Route 17 between Georgetown and North Carolina line	1.0	6 to 7 p.m.
Washington	Primary State Highway No. 9 approx. 70 miles north of Hoquiam	1.0	6 to 7 p.m.
	Primary State Highway No. 12 South Bend area-west and south	5.0	5 to 6 p.m.
	Secondary State Highway No. 13-A South Bay Bridge to Tokeland	4.0	5 to 6 p.m.
New Jersey	Route 4, Cape May to Lakewood	4.0	
	Route 4, Perth Amboy to Woodbridge	17.0	
	Route 4N, Briedle to Belmar	10.0	
	Route 4N, Belmar to Allenhurst	50.0	
	Route 4N, Allenhurst to Eatontown	16.0	
	Route 33, Route 34 to Route 4N	17.0	
	Route 34, Laurelton to Route 33	4.0	
	Route 35, Lakewood to Point Pleasant	2.0	5 to 6 p.m.
	Route 35, Point Pleasant to Belmar	9.0	
	Route 35, Belmar to Neptune	20.0	
	Route 35, Neptune to Asbury Park	17.0	
	Route 35, Asbury Park to Eatontown	20.0	or
	Route 35, Eatontown to Red Bank	30.0	
	Route 35, Red Bank to Keyport	20.0	
	Route 35, Keyport to Woodbridge	33.0	
	Route 36, Keyport to Atlantic Highlands	20.0	6 to 7 p.m.
	Route 37, Lakehurst to Toms River	3.0	
	Route 37, Toms River to Point Pleasant	2.0	
	Route 40, Route 4 to Laurelton	4.0	
	Route 49, Millville to Claremont	2.0	
	Route S-49, Dennisville to Rio Grande	2.0	
Rhode Island	Tower Hill Road (south of Saugatucket Road)	5.0	6 to 7 p.m.
	Route 1 (just north of Bridgeton Road)	6.0	6 to 7 p.m.
	Route 1 (just southwest of Tuckertown Road)	6.0	6 to 7 p.m.
	Route 1 (just west of Ross Hill Road)	8.0	5 to 6 p.m.

State	Highway	Maximum ave. vehicles per mile	Time of max. concentration
Rhode Island	Ocean Road (south of Earl Road)	2.0	6 to 7 p.m.
	Sakonnet Point Road (just north of Little Compton Commons Road)	3.0	6 to 7 p.m.
Maryland	U. S. Route 113 from Md. Route 367 to Md. Route 452	3.0	5 to 6 p.m.
	U. S. Route 213 from Md. Route 452 to Ocean City	3.0	5 to 6 p.m.
Delaware	State Route No. 14 - Rehobeth to Maryland line	1.0	6 to 7 p.m.
	U. S. Route No. 113 - Georgetown to Maryland line	2.0	6 to 7 p.m.
Georgia	State Route 26 - 99 miles from Tybee Island	3.0	6:30 to 7 p.m.
	U. S. Route 17 at junction with State Routes 63 and 144	3.0	6 to 6:30 p.m.
	U. S. Route 17 at intersection with State Route 8	3.0	7 to 7:30 p.m.
	U. S. Route 17 at junction with State Route 99	2.0	6 to 6:30 p.m.
	U. S. Route 17 - 1 mile north from Brunswick	4.0	6 to 6:30 p.m.
	U. S. Route 17 at junction with State Route 110	1.0	6:30 to 7 p.m.
	U. S. Route 17 at intersection with State Route 40	2.0	6 to 6:30 p.m.
	State Route 40 at intersection with U. S. Route 17	1.0	6 to 6:30 p.m.

Max. New Jersey Route 4N, Belmar to Allenhurst - 50 vehicles to the mile.
Vehicle spacing 106 feet.

Since the submission of above data, reports have been received from several other states too late to be included here. However, this later data falls within the limits of the above table.

APPENDIX H

METHODS USED IN CALCULATING:

1. SKY GLOW GENERATED BY VARIOUS TYPES OF LIGHTING
2. PERMISSIBLE STREET ILLUMINATION VALUES.

TABLE 1 - Part 2
NIGHT TIME NUMBER OF AUTOMOBILES USING LIGHTS IN VARIOUS CITIES
(Answers from Questionnaire)

City	Population	Auto Reg.	Area of Selected District	Concentration of Automobiles. Average 1/5 square mile at district.													
				5-6 p.m.	6-7 p.m.	7-8 p.m.	8-9 p.m.	9-10 p.m.	10-11 p.m.	11-12 p.m.	12-1 a.m.	1-2 a.m.	2-3 a.m.	3-4 a.m.	4-5 a.m.	5-6 a.m.	6-7 a.m.
New York	7,454,995	1,032,566	102,350,000	457	244	320	229	194	183	168	114	73	55	55	59	123	229
Richmond, Va.	213,000	40,000	5,508,000	422	-	-	-	-	-	-	-	-	-	-	-	-	-
Washington, D.C.	663,091	147,535	27,878,400	-	221	185	192	165	145	132	108	81	64	36	25	28	75
Dallas, Texas	300,000	110,000	20,144,000	476	-	-	-	-	-	-	-	-	-	-	-	-	-
Seattle, Wash.	368,000	160,000	13,600,000	572	475	399	348	350	277	233	140	97	55	41	38	61	178
Philadelphia, Pa.	-	-	24,150,000	487	313	279	286	227	198	259	-	-	-	-	-	-	-
Detroit, Mich.	-	-	34,848,000	290	245	232	202	176	159	138	87	64	33	26	43	133	-
Oakland, Calif.	365,000	127,000	25,000,000	496	312	321	288	205	178	148	91	55	26	16	16	28	92
Toledo, Ohio	283,000	75,000	5,170,000	-	-	Max. 910	-	-	-	-	-	-	-	-	-	-	-

TABLE 1
NIGHT TIME NUMBER OF AUTOMOBILES USING LIGHTS IN VARIOUS CITIES
(Answers from questionnaire)

City	Population	Auto Reg.	Area of Selected District	Concentration of Automobiles in Selected District													
				5-6 p.m.	6-7 p.m.	7-8 p.m.	8-9 p.m.	9-10 p.m.	10-11 p.m.	11-12 p.m.	12-1 a.m.	1-2 a.m.	2-3 a.m.	3-4 a.m.	4-5 a.m.	5-6 a.m.	6-7 a.m.
New York	7,454,995	1,032,566	102,350,000	8400	6300	5870	4200	3560	3360	3080	2100	1340	1010	1010	1090	2270	4200
Richmond, Va.	213,000	40,000	5,508,000	417	-	-	-	-	-	-	-	-	-	-	-	-	-
Washington, D.C	663,091	147,535	27,878,400	-	1105	924	959	825	624	661	538	404	321	182	125	138	376
Dallas, Texas	300,000	110,000	20,144,000	1720	-	-	-	-	-	-	-	-	-	-	-	-	-
Seattle, Wash.	368,000	160,000	13,6[illegible]00	1350	1120	940	845	835	655	550	330	230	125	98	90	145	42
Philadelphia, Pa.	-	-	24,150,000	2115	1352	1205	1235	980	854	1118	-	-	-	-	-	-	-
Detroit, Mich.	-	-	34,848,000	1800	1530	1450	1260	1100	990	860	540	400	210	160	270	830	-
Oakland, Calif.	365,000	127,200	25,000,000	2235	1414	1450	1028	920	800	665	404	247	117	73	71	125	41
Toledo, Ohio	283,000	75,000	5,170,000	-	-	846	-	-	-	-	-	-	-	-	-	-	-
Spokane, Wash.	-	-	4,374,500	874	911	983	948	774	661	510	326	218	109	73	73	145	2

APPENDIX H

1. *Sky Glow Produced by Street Lighting in Business Districts.*- a. *Method for computations.*- Since generated sky glow is a function of amount of light from a given area reaching the upper atmosphere and the atmospheric transmission, the amount of such light must be ascertained by survey or knowledge of the number and type of luminaires in service in the area, their light output characteristics, the average reflectivity of the pavements, and the amount of upward light absorbed by trees and buildings. For street lighting, total light which starts upward is the sum of the light emitted above the horizontal from the luminaires plus the light emitted downwards multiplied by the reflection factor of the pavements, or on the basis of area $\frac{1}{2}$ mile by $\frac{1}{2}$ mile T (total upward light per unit area)= PL + P_1LR, where L equals total lamp lumens, P equals percentage of lamp lumens emitted above the horizontal, P_1 equals percentage of lamp lumens emitted below the horizontal, and R is reflection factor of pavements. This upward light is reduced by absorption by trees and buildings; hence, T_A (total light reaching upper atmosphere)= FPL + F_1P_1LR, where F and F_1 are percentages of light upward from luminaires and upward from pavements, respectively, which are not absorbed by trees and buildings. Sky glow may then be computed by use of Graph 3e or by substituting T_A for L of the following equation (subpar. 16c(4):

$$B_r = \frac{10^{18.02-15.56t}(1+2f_1+2f_2)\ ALt^{5.28(n+\frac{A-1}{4})}}{1,000,000}$$

b. *Example by use of Graph 3e.*- Assume representative conditions in the business district of a city of 500,000 population as follows:

Size of business district - 1 mile by 1 mile
Distance between streets - 400 feet
Number of streets per 1/4 square mile - 13
Number of blocks per 1/4 square mile - 42
Number of luminaires per block - 6
Lumen output of lamps - 15000

Type of luminaires in service - diffusing (emitting 35 per cent of lamp lumens above the horizontal and 35 per cent of lamp lumens below horizontal)

50% of upward lumens from luminaires reach upper atmosphere

50% of light reflected from pavements reach upper atmosphere

Average reflectivity of streets - 15%

Then: Number of luminaires per 1/4 sq. mi. = 42 x 6 = 252

Total lumens emitted above horizontal per 1/4 sq. mi. = 252 x 15000 x .35 = 1,319,500

Total lumens emitted below horizontal per 1/4 sq. mi. = 252 x 15000 x .35 = 1,319,500

Total lumens reflected from pavements per 1/4 sq. mi. = 1,319,500 x .15 = 197,925

Total lumens reaching upper atmosphere per 1/4 sq. mi. = .50 (1,319,500 + 197,925) = 759,000

And: Assuming 99 per cent per 1000 feet transmission, Graph 3e gives 330 micro-footlamberts of sky glow apparent at 5 miles for an area one mile in width and one-half mile in depth having 1,000,000 lumens reaching upper atmosphere from each 1/4 square mile. For an area one mile in depth (assumed for size of business district of city of 500,000 population), the 330 value must be multiplied by 2. Hence sky glow generated by 759,000 lumens per 1/4 sq. mi. reaching upper atmosphere from an area 1 mile by 1 mile is

$$\frac{759,000}{1,000,000} \times 330 \times 2 = 502 \text{ micro-footlamberts.}$$

2. Sky Glow from Show Windows in Business Districts.- As for computations for street lighting (sub-par. 1a above), total lumens reaching upper atmosphere must be ascertained. For a unit area, 1/2 mile wide and 1/2 mile in depth, T_A (total lumens reaching upper atmosphere) equals $(PLu + P_1L_DR)\,N$, where

L_u and L_D are lumens emitted upward and downward from an average show window, respectively

P and P_1 are percentages of upward and downward light, respectively, which are not absorbed by buildings and trees.

R is the average reflectivity of the streets

N is the number of show windows in the unit area.

Sky glow may then be computed by use of Graph 3e or by equation given in sub-paragraph 1a above.

b. Example by use of Graph 3e.- Assume representative conditions in the business district of a city of 500,000 population as follows:

Size of business district - 1 mile by 1 mile

Number of show windows in city - 15,200, one half of which are in business district

Number of show windows per 1/4 sq. mi. of business district = $\frac{15200}{2}$ x 1/4 = 1900

Lumens emitted above the horizontal from average show window - 489 (sub-par. 20c(2) of main body of report)

Lumens emitted below the horizontal from average show window - 1862 (sub-par. 20c(2) of main body of report)

Average reflectivity of streets - 15%

50% of both the light emitted above the horizontal and reflected from the streets reach the upper atmosphere.

Then: Total lumens reaching upper atmosphere per 1/4 sq. mi. = (.50 x 489 + .50 x 1862 x .15) 1900 = 730,000

And: Assuming 99 per cent per 1000 feet transmission, sky glow generated by 730,000 lumens per 1/4 sq. mi. reaching upper atmosphere from an area 1 mile by 1 mile is $\frac{730,000}{1,000,000}$ x 330 (from Graph 3e for area having width of 1 mile) x 2 (depth of area factor = 482 micro-footlamberts.

3. Sky Glow Produced by Automobile Headlamps. a. Method.- (1) From Table 9b, sky glow produced 5 miles in front of, behind, and to the side of 2358 untreated automobile headlamps on driving beams, concentrated in an area of approximately 0.16 sq. mi., during an atmosphere having light transmission factor of 71% is as follows:

In front of lamps	Behind lamps	To right of lamps	To left of lamps	Total
8430	318	20	20	8788

micro-footlamberts

or, if same number of lamps were aimed in each direction, $\frac{3788}{4}$ = 2147 micro-footlamberts for any direction. On the basis of 1/4 sq. mi., the lamps would be less concentrated and the sky glow would be 2147 x $\frac{.16}{.25}$ = 1380 micro-footlamberts for 71% transmission.

(2) On the basis of 99% per 1000 feet transmission, the sky glow becomes by use of Graph 3e:

2358 lamps - 1380 x $\frac{320}{1150}$ = 384 micro-footlamberts above an area of 1/4 square mile.

b. Example for a city of stated size.- Assume city of 500,000 population with 400 automobile (800 headlamps) using headlamps on passing beams per each 1/4 square mile of business district, and size of business district 1 mile by 1 mile.

Then: For 99% transmission, the sky glow produced by 400 automobiles in an area of 1/4 sq. mi. is:

$\frac{800}{2358}$ x 384 = 130 micro-footlamberts

Since the assumed size of business area is 1 mile by 1 mile, the above figure must be increased by width and depth factors as follows:

130 x 1.022 (additive factor for adjacent widths of 1/2 mile for 99% transmission from Graph 2b) x 2 (factor for areas in depth) = 262 micro-footlamberts.

4. Sky Glow from Protective Floodlighting. a. Method.- The total lumens reaching upper atmosphere from protective floodlighting depends on the size of the illuminated area, its average reflectivity, the average horizontal footcandles maintained on the ground, and the amount of light emitted above the horizontal from the luminaires. After calculation of lumens reaching upper atmosphere, amount of sky glow may be calculated by equation or graph.

b. Example by use of Graph 3e.- Assume a protective lighting installation as follows:

Illuminated area - 5000 feet by 300 feet.
Average horizontal footcandles on ground - 0.34
No light from luminaires emitted above the horizontal.
Reflection factor of ground - 0.15
All reflected light reaches upper atmosphere

Then: Total lumens reaching upper atmosphere equals 5000 x 300 (area) x 0.34 (horizontal footcandles) x 0.15 (reflection factor) = 76500

And: Assuming an atmospheric transmission of 99% per 1000 feet, Graph 3e gives 330 micro-footlamberts over an area having width of 1 mile with 1,000,000 lumens per 1/2 mile of width, and 320 micro-footlamberts over an area having width of 1/2 mile with 1,000,000 lumens. Hence, sky glow apparent over the long dimension of the protective lighting from a distance of 5 miles is $\frac{76,500}{1,000,000} \times 330 = 25$ micro-footlamberts for 99% transmission, and over the short dimension is $\frac{38,000 \text{ (lumens per } \frac{1}{2} \text{ mile of depth)}}{1,000,000} \times 320 \times 2$ (depth of area factor) $\times \frac{2600 \text{ (width of area on which Graph 3e is based)}}{300 \text{ (width of illuminated area)}} = 211$ micro-footlamberts.

5. Maximum Permissible Upward Lumens from Street Lighting Based on the Assumption that Street Lighting is Permitted to Contribute One-half of Permissible Artificial Sky Glow.- a. Method.- Graph 3e gives the micro-footlamberts of sky glow produced by areas of various widths and ½ mile depth having 1,000,000 lumens of upward light in each 1/4 square mile (½ mile in width and ½ mile in depth) which is apparent at various distances away during various atmospheric conditions. Hence, by use of appropriate curve of Graph 3e, the number of upward lumens in each 1/4 sq. mi. of a given area required to produce a certain sky glow brightness apparent at any distance from source of upward light for a given atmospheric transmission may be computed.

b. Example.- Assume a permissible sky glow residual of 30 micro-footlamberts (one-half of which is produced by street lighting) at shipping lanes 5 miles from an area $2\frac{1}{2}$ mile by $2\frac{1}{2}$ miles. From Graph 3e, the maximum glow produced over the long dimension of an area over $1\frac{1}{2}$ miles in width occurs at 67% transmission. This maximum reading is 3,300 micro-footlamberts, caused by 1,000,000 lumens in each 1/4 sq. mi. (Graph 3e is based on an area having depth of 1/2 mile). Then permissible upward lumens from street lighting per 1/4 sq. mi. of assumed area ($2\frac{1}{2}$ miles by $2\frac{1}{2}$ miles) is:

$\frac{15}{3300}$ x 1,000,000 x 1/5 (since depth of assumed area is 5 times depth of area on which Graph 3e is based) = 900 lumens.

6. Maximum Average Illumination Which Can be Permitted on the Streets to Conform with Permissible Upward Lumens Given in First Table of Sub-paragraph 34c(5) of the Main Body of the Report.- a. Method.- The permissible upward lumens are produced by that part of the light emitted above the horizontal from the street lighting luminaires and that part of the light reflected from the pavements, which is not absorbed by buildings and trees. Hence, light which reaches upper atmosphere is computed by the following equation (see sub-par. 1a):

$T_A = FPL + F_1P_1LR$, where T_A is total light which reaches upper atmosphere, P is percentage of lamp lumens emitted above the horizontal from luminaires, P_1 is percentage of lamp lumens emitted below the horizontal from luminaires, L is generated lamp lumens, R is reflection factor of pavements and F and F_1 are percentages of light up from luminaires and reflected from pavements, respectively, which is not absorbed by buildings and trees. Then, total light which is reflected from pavements is $P_1RL = \frac{T_A - FPL}{F_1}$ and average illumination on the ground is reflected light divided by the illuminated area times the reflection factor, or $I = \frac{T_A - FPL}{F_1\ AR}$, where A is square feet of illuminated area.

a. Example.- Assume the following:

Lighted area 1/2 mile by 1/2 mile
Total of 13 streets (spaced approximately 400 feet)
33,800 lineal feet of streets
Streets average 60 feet in width
Reflection factor of streets - 15%
50% of upward lumens from luminaires reach upper atmosphere
20% of light reflected from pavements reach upper atmosphere

Diffusing luminaires emitting 35% of lamp lumens below the horizontal and limited to 10% of lamp lumens above the horizontal.

900 lumens permitted to reach upper atmosphere

Then, to find the amount of light reflected from the pavements (P_1RL) in terms of total light permitted to reach upper atmosphere (T_A) the following may be used:

U (upward light from luminaires) = 0.1L (10T of lamp lumens permitted above the horizontal)

D (downward light from luminaires) = 0.35L (diffusing luminaires emit 35% of lamp lumens below the horizontal)

Then, $U = \frac{.1D}{.35} = .286D$, and $D = \frac{P_1RL}{.15}$ (reflection factor)

$$U = \frac{.286P_1RL}{.15} = 1.91\ P_1RL.$$

And, $T_A = .5U + .2\ P_1RL$ (from assumptions on amount of light reaching upper atmosphere)

Or, $T_A = .95\ P_1RL + .2\ P_1RL = 1.15\ P_1RL$

Therefore $P_1RL = .87\ T_A$, or light reflected from pavements is 87% of total light which reaches upper atmosphere, fro the assumed luminaires, restrictions, and conditions.

But, $P_1RL = \frac{T_A - FPL}{F_1}$ (sub-par. 6a above)

Then $I = \frac{P_1RL}{AR}$ (sub-par. 6a above) $= \frac{.87\ T_A}{AR}$.

$$\frac{.87 \times 900}{33{,}800 \times 60 \times .15} = .0026 \text{ footcandle.}$$

Similarly, permissible footcandle levels may be computed for further restrictions in upward light, based on the characteristics of type of luminaire in service.

APPENDIX I

SUGGESTED INTERIM DIMOUT REGULATIONS

SUGGESTED INTERIM DIMOUT REGULATIONS

1. Application. - Interim dimout regulations are included to aid Service Commands, by providing them with a means of judging by comparison the effectiveness of their present regulations, and to encourage revision of those regulations to achieve general uniformity of light control. The interim regulations should not be considered as final, and present Service Command regulations should not be revised drastically pending the establishment of a basic dimout policy and the issuance of final dimout regulations. In those instances where Service Command regulations deviate widely from interim regulations, the former should be adjusted to conform with the latter. On the other hand, where present regulations are comparable, further revisions should be postponed until final regulations are available in the interest of conservation of materials and manpower, and of preventing additional confusion on the part of the public.

2. Regulations. - The following are the suggested interim dimout regulations:

Dimout Zones

1. Shore Zone. - The Shore Zone shall extend inland from the shore line for a distance of two (2) miles. (Shore line is defined as the open sea shore line and does not include indentations formed by rivers or bays unless otherwise specified by the appropriate Service Command.)

2. Coastal Zone. - Beginning at the inland boundary of the Shore Zone, the Coastal Zone shall extend inland for a distance of 25 miles.

3. Inland Zone. - The Inland Zone shall begin at inland boundary of the Coastal Zone and extend inland for an additional 25 miles. All cities of 200,000 or more population between the inland boundary of the Inland Zone and 25 miles farther inland shall be subject to the requirements of the Inland Zone.

Remarks: Where cities are situated partly in one zone and partly in another, such cities shall comply throughout to regulations of the zone nearest the shore line.

Period of Dimout

4. These regulations shall be in effect from one hour after sunset to one hour before sunrise or as specified by the appropriate Service Command.

Remarks: Due to variations in length of twilight with seasons of the year, period of dimout may be modified to conform to hours of darkness. On the other hand, dimout scheduled to conform to phases of the moon or enemy submarine activity should not be considered until feasibility is investigated by Basic Policy Committee.

Definitions

5. Shore Line. - Shore line as used herein is defined as the open sea shore line and does not include indentations formed by rivers or bays unless otherwise specified by the appropriate Service Command.

6. Non-essential Lighting. - a. Outdoor advertising: signs, billboards, posters, etc.

b. Window signs of all types.

c. Show and display windows.

d. Ornamental building lighting: floodlighting, outline lighting, facade lighting, marquee and canopy lighting, etc.

e. Outdoor amusement and sports lighting: playgrounds, athletic fields, amusement parks, etc.

f. Service station floodlighting (does not include pump lighting providing less than 1.5 footcandles at ground level).

g. Parking space floodlighting.

h. Pyrotechnic displays and bonfires.

i. Home garden lighting.

j. All types of outdoor lighting for decorative or advertising purposes not covered above.

7. Light Source. - Light source is defined as the light producing element such as the filament and/or bulb of incandescent lamps and the luminous tube of gas filled lamps.

8. Hours of Darkness. - Hours of darkness is intended to mean the period from one hour after sunset to one hour before sunrise.

9. Visible from the Sea. - Any installation, area, light, or illuminated surface from which the open sea beyond the shore line can be seen, or which permits direct viewing from any location beyond the shore line, is considered visible from the sea.

10. Show and Display Windows. - These are defined as all windows or similar openings in stores, restaurants, or other commercial establishments in which merchandise is or might be displayed for sale or through which merchandise or services offered to the public may be visible and through which any artificial light is visible...

Non-essential Lighting

11. Shore and Coastal Zones. - Non-essential lighting shall be extinguished, except as follows:

a. Where building openings are visible from the sea, they may be made light-tight in order to maintain interior illumination.

b. In areas not visible from the sea, windows of stores, restaurants, banks, and similar establishments may be treated as follows:

(1) In the Shore Zone, such windows shall be made opaque in order to maintain interior illumination.

(2) In the Coastal Zone, such windows, where special window lighting has been extinguished and the only light emitted comes from general interior illumination, may be treated as specified in sub-paragraph 14 a (1) (b).

12. Inland Zone. - Non-essential lighting shall be extinguished except for the following:

a. Parking space floodlighting, provided illumination on the lighted surface does not exceed 1.5 footcandles and no light is emitted from luminaires at angles above the horizontal.

b. Show and display window lighting, either filament or fluorescent, not exceeding 40 watts per ten (10) lineal feet of window provided direct light from the lamps does not illuminate adjacent sidewalk at any point; or, in lieu thereof, a luminous window sign not exceeding 25 watts and shielded in such a manner that it cannot be seen above a horizontal plane through the window ceiling. When light emitted from windows of stores, restaurants, banks, and similar establishments is only that from general interior illumination, such windows shall be treated as specified in sub-paragraph 14 a (2). In the latter case, special window lighting shall be extinguished.

c. Theater marquee lighting not in excess of 1.5 footcandles at street level. Light sources shall not be visible above a horizontal plane through them.

Essential Lighting

13. When Visible from the Sea. - All lighting, including all light sources and illuminated surfaces, visible at sea from any location beyond the shore line, shall be extinguished or treated as follows:

a. Building openings. - Building openings shall be made light-tight, or interior illumination shall be provided by War Department approved indoor blackout lamps or units spaced not less than 5 feet in any direction. Doors may require light locks.

Remarks: Openings on the sides of buildings not visible from the sea need not be made light-tight; hence, they may be used for ventilation purposes. Such openings, however, must be treated as provided in sub-paragraph 14 a.

b. Motor vehicle lighting. - Approved War Department vehicular exterior blackout lighting is permitted. All other exterior lighting shall be extinguished. Interior illumination shall not exceed 0.4 footcandle on a 45 degree plane 36 inches above the floor, and interior light sources shall not be visible outside the vehicle above a plane through the light source at 5 degrees below the horizontal.

Remarks: Baffles, matte black on the land side, may be erected to obscure motor vehicle head and tail lighting from the sea. In such cases, headlights on passing beams and with upper half of lens opaque, and normal tail lights, may be used.

c. Street and highway lighting. (1) Shore Zone. - On streets and highways perpendicular to the shore line, a special system of street and highway lighting may be employed to maintain traffic movement without use of headlights. This special system shall meet the following requirements:

(a) Maximum illumination at any point on the road surface shall not exceed 0.4 footcandle.

(b) The lamps shall be installed in deep hoods to confine the light to the roadway without spill on adjacent structures or trees, and shall be directed away from the sea and downward and mounted at least 20 feet above road level.

(c) No light from the luminaire shall be projected in the direction of the sea beyond a vertical plane parallel to the shore line and through the light source or above a horizontal plane through the light source.

Remarks: The use of the above system of street lighting should be limited to critical locations, where continued movement of vehicles is necessary and other solutions, such as re-routing or erection of baffles to permit use of half-shielded headlamps, cannot be employed.

(2) Coastal Zone. - At critical locations on streets and highways perpendicular to the shore line, the system of street lighting as described in sub-paragraph (1) above may be employed. Present street and highway lighting luminaires at any location visible from the sea shall be so treated that:

(a) No light, including light from the reflector and enclosing globe, is emitted above a plane through the light source at 60 degrees below the horizontal.

(b) The maximum illumination on the roadway at any point within the circle of light thus formed is not in excess of 1 footcandle. The average illumination shall not exceed 0.5 footcandle.

Remarks: Remarks contained under sub-paragraph (1) above also apply to the special street lighting system when used in the Coastal Zone. The restricted street lighting resulting in Coastal Zone from above treatment applied to present luminaires which are visible from the sea serves no useful function in regard to safety and facilitation of traffic. Where night traffic movement is permitted on streets or roads visible from the sea, regardless of the type of street lighting employed or the absence thereof, it is imperative that effective aids to traffic be extensively employed. White markings on pavements, curbs, and obstructions are particularly helpful in reducing the hazards to pedestrians and vehicles.

d. Traffic signals. - Traffic signals shall be invisible at distances beyond 4000 feet when viewed by dark-adapted observers on a clear, moonless night, and shall provide distinctive color indications for all distances from 10 to 300 feet during all operating periods. One method by which this can be accomplished is to equip each traffic signal lens with 7 degree downward louvers, consisting of not less than 6 vanes at least 6 inches in length and spaced evenly along lens diameter, and operating the signal during night hours at 35 per cent of rated voltage for 60 watt lamps (32 per cent for 100 watt lamps, 43 per cent for 40 watt lamps) and at rated voltage during all other periods.

Remarks: Reducing signal visibility by reduction in voltage alone or application of masks either provides inadequate night indications or destroys daylight effectiveness. Generally, traffic signals visible from the sea should be extinguished. The above treatment should be confined to those where continued operation is essential for safety and expedition of traffic and other solutions cannot be employed.

e. Illuminated traffic signs. - Illuminated signs may be used wherever necessary to guide, safeguard, or regulate traffic, provided the light source and reflector are obscured from all locations at sea and the illuminated surface, if facing any location at sea, cannot be detected by dark-adapted observers on a clear, moonless night for distances in excess of 4000 feet.

f. Lighting of railroad trains, elevated trains, and subway trains when operated above ground. - (1) Headlights of road locomotives shall be operated in the dim position.

(2) The upper three-quarters of the lens of headlamps of elevated trains, and subway trains if operated above ground, shall be made opaque. All exterior lighting of such vehicles not required for safe operation shall be extinguished.

(3) Head and tail lights of street cars shall be so reduced in intensity by filters or voltage reduction that they are invisible beyond 4000 feet when viewed by dark-adapted observers on a clear, moonless night.

(4) Window shades shall be drawn completely or interior illumination shall not exceed 0.4 footcandle on a 45 degree plane 36 inches above the floor and light sources shall be so shielded that they are invisible above 5 degrees below the horizontal.

(5) Interior illumination of ferries shall not exceed 0.4 footcandle at the windows, and interior light sources shall be so shielded that they are invisible above 5 degrees below the horizontal.

g. Residential yard and porch lighting. - A low level of illumination may be provided in yards and on porches by War Department approved indoor blackout lamps or units spaced not less than 5 feet in any direction.

Remarks: Shields on the lamps or units are unnecessary to provide safety to shipping.

h. Outdoor production lighting. - Light sources of all exterior lights for outdoor manufacturing, in railroad yards, on wharves, for repair work, shipbuilding, necessary handling of raw or finished materials, or for any type of outdoor production work shall be so shielded that they are invisible from any location at sea and that no light is emitted above the horizontal. Surfaces shall be illuminated when and to the minimum required for conduct of the work.

Remarks: The above is intended to apply to those processes which cannot be carried out under cover. Other processes should be performed indoors. These regulations will serve to reduce but will not eliminate hazard to shipping.

i. Anti-sabotage lighting. - Anti-sabotage lighting shall conform to the following:

(1) Light sources shall be so shielded and directed that they are invisible above a plane through them at 3 degrees below the horizontal.

(2) Maximum illumination on the ground shall not exceed 0.2 footcandle.

(3) The light shall not be incident on vertical or angular surfaces.

14. When Invisible from the Sea. - When in use, essential lighting shall be treated as follows:

a. Building windows. - (I) Shore and Coastal Zones. - (a) Windows of offices, residences, hotels, and similar installations, shall be covered for the upper three-quarters of the glass area by standard window shades not exceeding 25 per cent light transmission factor, venetian blinds with slats angled downward to the outside, or at least one thickness of newspaper; and, in addition, interior light sources shall not be visible outside above a horizontal plane through the bottom of the treated portion of the window.

(b) Windows of industrial plants shall be made opaque for the upper three-quarters of the glass area, or the interior lighting shall be so shielded or the windows so treated that the brightness measured on the outside surface of the glass shall not exceed one (1) footlambert at any point. Brightness on the outside surface of sky lights shall not exceed 0.5 footlambert.

Remarks: Ventilation and obscuration of daylight are factors to be considered in application of the above regulations. Awnings of cloth or wood or venetian blinds which can be lowered at night provide a possible solution to these problems. Shielding light fixtures to reduce lighting levels at windows is often undesirable since visibility on work benches and machines may be affected to the extent that reduced production and waste would result. On the other hand, the installation of venetian blinds or awnings may improve daylighting conditions.

(2) Inland zone. - Windows of industrial plants for one-half of the glass area shall be made opaque or covered with standard window shades not exceeding 25 per cent light transmission factor or material having equal or lower light transmission properties, venetian blinds with slats closed, or at least one thickness of newspaper. Brightness on the outside surface of sky lights shall not exceed 0.5 footlambert.

b. Vehicular headlighting. - Upper one-half of lens of headlamps shall be made opaque and headlamps shall be operated on passing (depressed) beams only.

Remarks: More restrictive control of headlighting such as use of 250 beam candlepower or three-quarter masking reduces sky glow slightly more, but provides totally inadequate road illumination for driving even at reduced speed.

c. Street and highway lighting. - (1) Shore Zone. - (a) Lighting of open highways shall be extinguished or the luminaires shall be so [illegible] that no light is emitted above the horizontal and that the maximum illumination on the roadway at any point does not exceed 0.4 footcandle.

(b) Street lighting of cities and towns shall be extinguished or conform to the following: At points of heavy pedestrian movement, hazardous locations, focal points of traffic flow, and similar locations, an illumination level not in excess of 0.4 footcandle may be maintained on the street surface provided no light is emitted from the luminaires above the horizontal. At other locations luminaires may be masked or shielded in such a way that no light is emitted above a plane at 60 degrees below the horizontal through the light source and that the maximum illumination on the roadway within the circle of light thus formed is not in excess of 0.4 footcandle.

(2) Coastal Zone. - Light emitted above the horizontal from street and highway lighting luminaires shall not exceed 3 per cent of the luminaire lumens. Minimum illumination on the street shall not be reduced to less than 0.02 footcandle.

(3) Inland Zone. - Light emitted above the horizontal from street and highway lighting luminaires shall not exceed 7 per cent of the luminaire lumens. Minimum illumination on the street shall not be reduced to less than 0.02 footcandle.

Remarks: Present shields should be retained and, if above regulations are not met, painting of lamp or globe should be resorted to, since proper shielding will depend on final regulations founded on basic policy. Change in shielding at the present may result in waste of material and labor and the unwarranted expenditure of funds. For assurance of reduction of sky glow to proper levels, maximum street illumination values will eventually be specified. However, such values are dependent on establishment of basic policy.

d. Outdoor production lighting. - In the Shore, Coastal, and Inland Zones, exterior lights for outdoor manufacturing, in railroad yards, for repair work, shipbuilding, necessary handling of raw or finished materials, or for any type of outdoor production work shall conform to the following:

(1) Light emitted from the lighting units at angles above the horizontal shall be zero for the Shore Zone, and shall not exceed 3 and 7 per cent of the luminaire lumens for the Coastal and Inland Zones respectively.

(2) Surfaces shall be illuminated only when and to the minimum required for the work.

e. Anti-sabotage lighting. - In the Shore and Coastal Zones, anti-sabotage lighting shall conform to the following:

(1) Light sources shall be so shielded and directed that no light is emitted above the horizontal.

(2) Maximum illumination on the ground shall not exceed 0.2 footcandle for Shore Zone and 0.5 footcandle for Coastal Zone.

f. Residential yard and porch lighting. - (1) Shore Zone. - Yard and porch lighting shall be extinguished, or provided by War Department approved indoor blackout lamps or units.

(2) Coastal and Inland Zones. - Lighting of yards and other outdoor residential installations shall not exceed that provided by 25 watt incandescent lamps spaced not less than 20

feet in any direction. Such lamps shall be so treated that no light is projected above the horizontal. Lighting of porches, doorways, and steps shall be provided by not more than one lamp not exceeding 15 watts per entrance or exit; and not more than 25 per cent of the light shall be emitted above the horizontal.

Types of Lighting Which do not need Regulating.

15. In areas not visible from the sea, the following types of lighting shall not be treated for dimout purposes:

a. Exterior and interior lighting of railroad trains, elevated trains, and subway trains.

b. Railroad signals.

c. Traffic signals.

d. Illuminated aids to water navigation.

e. Airport and airway lighting needed for safety of aircraft and the handling of passengers and materiel.

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U.S. ARMY CORPS OF ENGINEERS, ENGINEER RESEARCH AND
DEVELOPMENT LABS., FORT BELVOIR, VA. (REPORT NO. 746)

CONTROL OF COASTAL LIGHTING ANTI-SUBMARINE WARFARE
AND APPENDIXES A-I

OSCAR P. CLEAVER 30 APRIL '43 219PP PHOTOS, TABLES, DIAGRS,
GRAPHS, MAP

MILITARY OPERATIONS (24) WARFARE, ANTISUBMARINE
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