SOME CONSIDERATIONS OF HIGH INTENSITY APPROACH LIGHTING

By
H J Cory Pearson and M S. Gilbert
Airport Development Division

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SOME CONSIDERATIONS OF HIGH INTENSITY APPROACH LIGHTING

SUMMARY

This report discusses the high intensity approach lighting problem and various types and applications of lights that are being offered as solutions to the problem.

It shows that under conditions of restricted visibility a light having a relatively moderate candlepower value can be seen from a certain maximum distance. As this candlepower is multiplied many times, the distance from which the light can be distinguished is increased very little, until a limit is reached beyond which it is impractical to increase the candlepower. There are other factors which enter into the case. The background illumination is very important, as a light that could be seen against a bright background such as prevails in daylight would be so uncomfortably glaring as possibly to blind a pilot trying to land at night with lamps of that brightness, and, conversely, lights of proper brilliancy for normal night flying would be invisible under daylight conditions These facts, known to engineers, determine the limits to which the designer may go in selecting his tools for solving the problem.

It is obvious that there is need for brightness variation control to provide adequate brightness for visibility under diverse conditions, such as those prevailing during daytime fogs as compared with nighttime.

Various approach lighting systems that have been, or are being tried out are discussed and criticized. The old systems had faults which the new systems attempt to eliminate by various means. There are different methods for accomplishing the same results

The only system which attempts to indicate to the pilot his position with respect to the glide path is the proposed CAA slope-line system. This is thoroughly discussed and explained.

With the aid of knowledge gained through exhaustive experimentation, it is believed that the engineering profession soon will find the optimum solution to the approach light problem.

INTRODUCTION

Although recent congressional discussions and their attendant publicity have brought to general notice the matter of high intensity approach lighting, the subject is not a new one.

Of all the types of lighting that interest an airport lighting engineer, high intensity approach lighting has evoked more argument and heated discussion than have all of the other types together. Fortunately, these differences of opinion among the experts arise not over the need for better intensity approach lighting but over what such lighting is to accomplish and over the design and type of light and the method of installation that will best solve the problem

All experts (pilots, radio engineers, and lighting engineers) are agreed that the landing of an aircraft, safely, in all kinds of weather will not be accomplished with certainty by any single device or method, but will require the combined use of a number of facilities including various radio devices, visual aids such as lighting, and in some cases fog dispersal.

Briefly, the problem of landing an airplane when visibility is restricted involves the use of radio landing aids to lead the airplane into the approach path, and to bring it to within approximately 200 feet of the ground, and then the use of visual aids on the ground to enable the pilot to complete his landing.

The following discussion is not presented for the purpose of giving the reader a complete and exhaustive coverage of the subject of approach lighting, but rather to show the over-all picture of the problems involved.

WHAT IS HIGH INTENSITY APPROACH LIGHTING?

Let us consider what is meant by the term "high intensity approach lighting " Lights used as visual aids are employed as signal lights rather than as illuminants. A simple definition of approach lighting is "a system of signal lights indicating the path to a runway." By "high intensity" we mean lights that are too bright for comfort in clear weather.

A formula has been developed to determine the brightness needed for visibility of a light for any required distance and in any fog. A layman, knowing of this formula, could assume that all that is required of a lighting engineer in designing a light for approach lighting, is to provide lights of sufficiently high intensity to be seen in the worst weather anticipated, and the brighter the light, the better it will be Unfortunately, this is not the case, as there are other facts and limiting factors which must be taken into consideration

LIMITS WITHIN WHICH ENGINEER MAY WORK WITH LIGHTS

It has been found that there is a limiting distance for each degree of fog beyond which it is impractical to make a light visible. Such a distance may be achieved with relatively moderate candlepower, and even a ten times increase or 100 times increase in this candlepower will give very little added distance.

The worst fogs for which we expect to design approach lighting restrict visibility to about 1/16-mile or 330 feet. Under such conditions a light of 10,000 candlepower can be seen for a distance of approximately 1100 feet and a light of 100,000 candlepower can be seen for a distance of about 1270 feet. See Fig. 1. Even if the light intensity is increased to 1,000,000 candlepower the distance from which it is visible will be only about 1335 feet

The minimum brightness at which a light can be seen in the dark by a normal eye dark-adapted is known as "night threshold." It would seem that once a threshold illumination value has been established, it would be a simple matter to make a light bright enough to stay above this limit for a given distance. However, the problem is not that simple, as the brightness of the background enters into the picture. The threshold for day conditions is on the order of 1000 times the night threshold, so that a light which is several hundred times as bright as needed during the night could become invisible during the day at the same distance. Under foggy conditions, with reported visibility of 1/16-mile, a certain light would be visible for a distance of 1000 feet at night, but this distance would be reduced to 610 feet in the daytime under the same fog condition due to the difference in background brightness

It has been found by experiment with a number of observers that a light 1000 times threshold brightness produces an effect of glare which becomes uncomfortable to the point of blinding as it increases above that value. This is particularly marked as the time of exposure increases. Thus a light which is barely visible by daylight, can be uncomfortably glaring at night Therefore, since a light bright enough to be satisfactory by night can be invisible by day, and one bright enough for daytime visibility can be too bright to be viewed without dazzle by night, it is apparent that the designer must provide a means for adjusting the brightness of the approach light system to the conditions under which it must be used. By adjusting the brightness we do not mean doubling it or increasing it tenfold, we mean increasing or decreasing it a thousandfold.

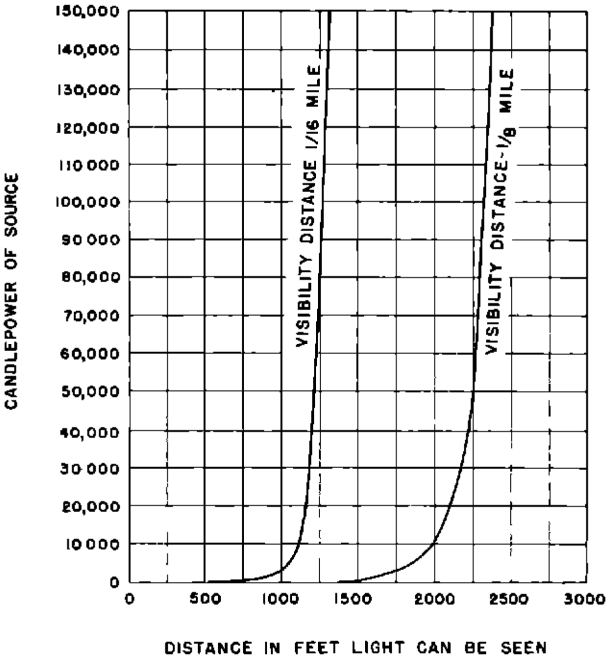

Fig 1 Curves Showing Relationship Between Brightness and Distance for Fixed Visibility Values

In stating that a light is so bright that it can be glaring or blinding, we do not mean that it is thereby rendered unusable A much brighter light can be tolerated momentarily than can be watched and studied.

From the foregoing it is readily apparent that there are definite limits within which the lighting engineer must work. First, we are limited to a working distance of 800 to 1200 feet from which the light can be made visible, and within this distance an approach light pattern must be constructed to give the pilot all possible assistance in making his landing. Second, the brightness of any light which will have to be seen more than momentarily must be held to a maximum of not more than 1000 times threshold, or subject the pilot to uncomfortable or even blinding dazzle.

These facts are generally known and accepted by the lighting engineers.

How then, do the various experts attempt to apply this knowledge?

CAA STANDARD NEON APPROACH LIGHT SYSTEM

Various patterns of approach lights have been developed and tested. Until recently there has been only one "standard" pattern of approach lighting for civil use. It consists of a single row of fifteen, 6-foot long red bars (lighted neon tubes) spaced 100 feet apart and located 85 feet to the left of the center line of the runway extended, as viewed on approach. A green incandescent "course light" at the end of the row of neon bars marks the end of the approach area See Fig. 2. Although this approach light system is adequate at night under visibility conditions of three-quarters of a mile or better, it is inadequate under conditions of more restricted visibility. When this standard was adopted, about 1937, it was considered adequate for the landing speeds and types of operation then in use, but with the advent of larger and faster aircraft and increasing emphasis on reliability of schedules, it became evident that further experimentation and development would be necessary in order to achieve the goal of satisfactory approach lighting By no stretch of the imagination can the present standard neon approach lights be considered an example of adequate high intensity approach lighting. They are the only approved lights, however, that are now available at most airports CAA regulations require that they be turned on whenever the natural light intensity is equivalent to that existing between dusk and dawn, regardless of weather conditions Operation of these lights is tied in with the operation of the Instrument Landing System at all airports where the ILS has been installed by the CAA. It is intended that high intensity approach lights will supersede the neon lights on all instrument runways.

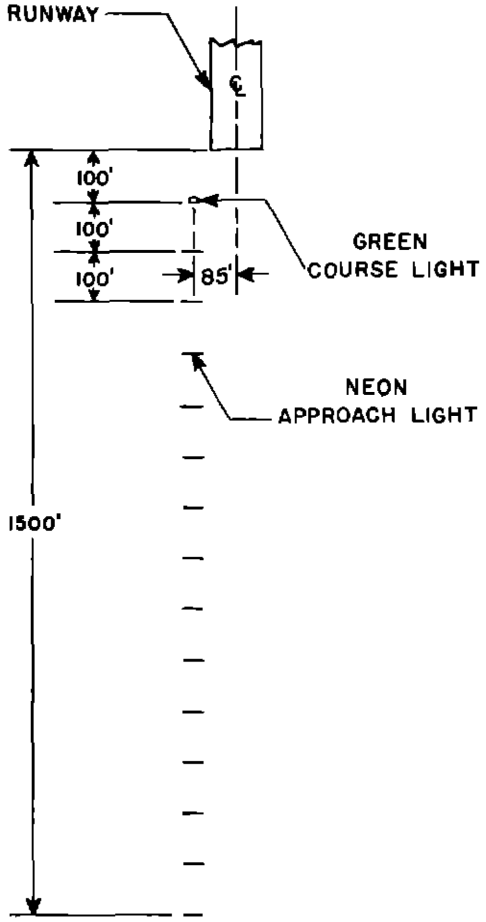

Fig. 2 Diagram of Standard Approach Light System

BARTOW LIGHTS ONE OF THE FIRST ATTEMPTS AT SOLUTION OF HIGH INTENSITY APPROACH LIGHT PROBLEM

The earliest type of high intensity approach light system was that developed by John Bartow. His concept of approach lighting was to provide two rows of lights equally spaced and symmetric about the approach path The candlepower distribution of these lights was so designed that to a pilot on the correct approach path, all lights appear of equal brightness. Bartow designed a lighting unit consisting of a housing in which was mounted a lamp, reflector and lens, with brightness adjustment, producing a beam of about 300,000 candles maximum. The lamps were movable in the optic by means of small synchronous motors, so that the beams could be rotated about the vertical axis from about two degrees toe-out to about nine degrees toe-in. See Fig 3 In good visibility weather the beams were toed out, and when fogs occurred the beams were toed in to intersect the glide path closer to the lights.

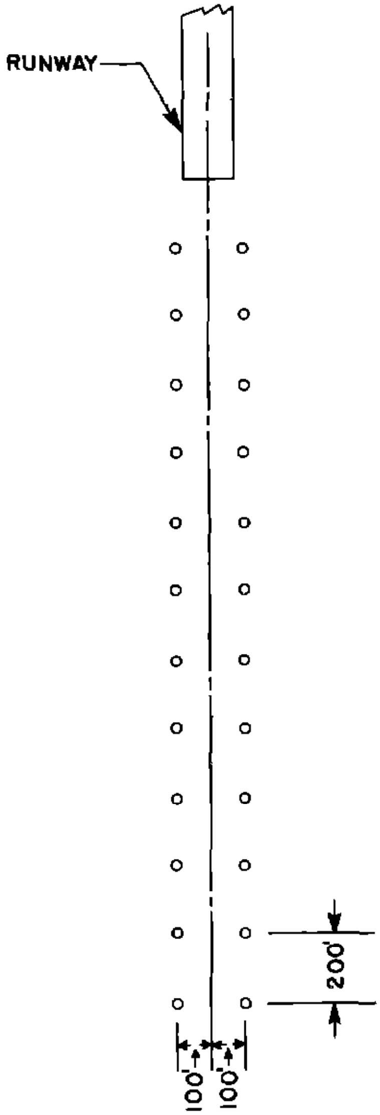

Fig. 3 Diagram of Parallel Line Approach Light System

Although this type of Bartow light was installed at the CAA Experimental Station, at Indianapolis and given extensive flying and observation tests, it was not generally adopted When the United States became involved in World War II, however, the Army and Navy adopted another form of Bartow light, known as AAF type D-1 This light had beams in opposite directions, with some light emitted in all directions The light was fixed, with no provision for beam control, and produced about 40,000 candles in the clear beams, or 7000 candles when equipped with red filters A number of installations of these lights, using the unit with a red filter as an approach light, and without the filter, or with split yellow filters for runway marker lights, were made by the armed services in various parts of the world, and as a result there were many successful airplane landings made under conditions of low visibility

However, on many occasions in bad weather, pilots missed seeing the approach lights entirely and it became evident that there was still need for further development, especially in the direction of wider beam distribution. Many ideas have been offered and studied and the solution is not too far out of hand. Let us examine some of these ideas

SINGLE ROW APPROACH LIGHT SYSTEMS

One prominent pilot has advanced the theory that a pilot needs only a single row of lights of sufficient brightness to mark the center line of the runway extension. In order to test this idea the Air Transport Association, with the assistance of the CAA, has made two test installations at Newark, New Jersey. One installation, illustrated in Fig. 4, consists of a line of units using a 5-KW incandescent lamp in an optic giving wide spread both vertically and horizontally Part of the line consisted of two units set eight feet apart horizontally All of these units have red filters The other installation, illustrated in Fig. 5, consisted of combinations of neon bars and condenser discharge flashing tubes, which may be used in various combinations as desired Some technicians believe that the brilliance of the flashing lights, and the suddenness of their incidence will be too great for comfort Many commercial transport aircraft are built with such restricted fields of vision from the cockpit, that with a single line arrangement, in very restricted weather, the first light visible from the pilot's seat is beyond the visible range, too far to be seen by the pilot,

These neon and flashing lights now have been removed from Newark and transferred to the Landing Aids Experiment Station at Arcata, California, for comprehensive testing in every kind of weather, in order to check their effectiveness against other systems and designs

Another single row approach light system, developed by the Westinghouse Electric Corporation, is being procured for installation at Arcata This system, consisting of either steady-burning or flashing neon units, alternating with krypton condenser discharge lamps, will be installed at the left side of the approach lane.

An axial single row incandescent lighting system was installed at Arcata in 1947, and also will be tested.

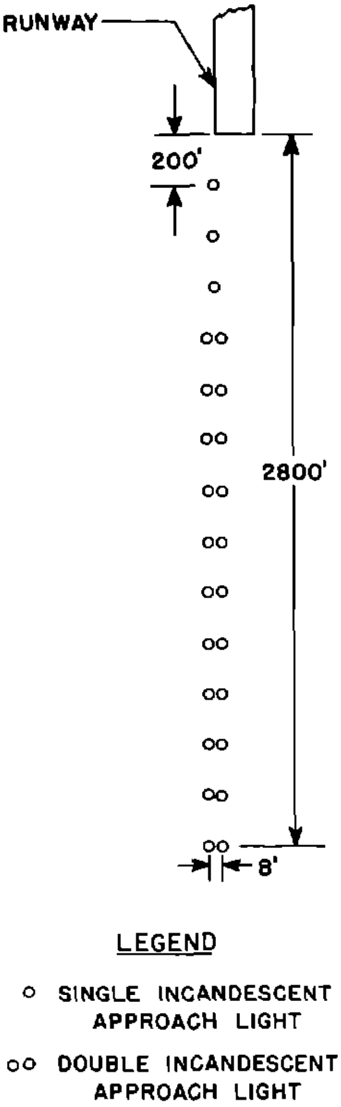

Fig. 4 Diagram of ATA Single Line Incandescent Approach Light System

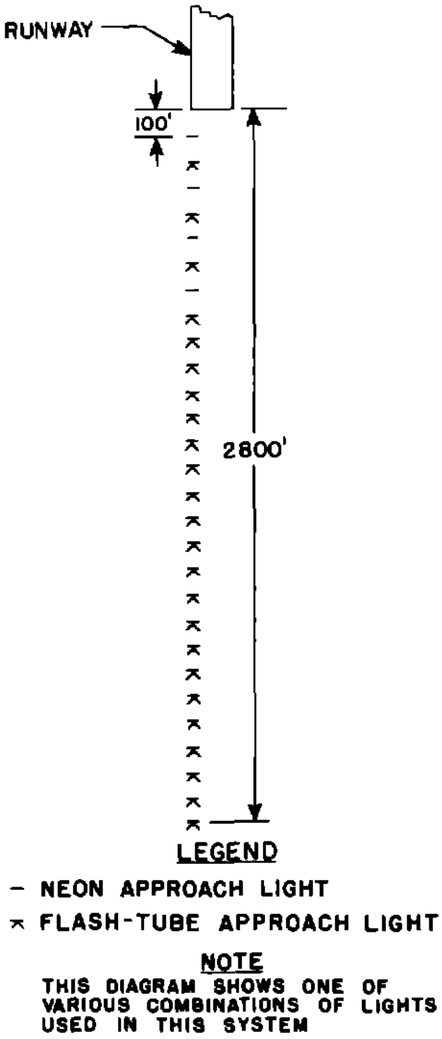

Fig. 5 Diagram of ATA Single Line Combination Neon and Flash Tube Approach Light System

PERSPECTIVE EFFECT

As a pilot sees the approach marker lights from several hundred feet distance, his binocular depth perception is practically useless, and a perspective analysis of the pattern seen by him gives an accurate representation of what he can see and use. Furthermore, although he has been approaching on instruments with his wings level, any maneuvering to adjust his course after he picks up the lights necessitates his departure from level Hence, to enable him to regain a level attitude it is necessary

(a) To be able to readjust his eyes from the bright approach lights to the instrument illumination level, and correct his attitude by reference to the instruments, or

(b) To be able to see some lights or marks on the horizon for a reference, or

(c) To have one man watch for lights while the other stays on instruments and adjusts the attitude of the airplane, or

(d) That he be given sufficient information by the approach light pattern to determine a horizontal reference, and to correct his attitude by the appearance of the lights.

Of these alternates, (a) involves a delay in eye adjustment at a very critical time, (b) is impossible in thick weather, and (c), while it is generally used, requires two men's attention and makes it difficult or hazardous for a single operator to land the airplane. It would appear that (d) is the safest and most practical procedure, if the lighting system is designed to furnish the necessary information.

A perspective analysis of a single line and of two or more parallel lines indicates that it is impossible to distinguish between the appearance of the pattern when the pilot is off line, as compared with the appearance when the airplane is banked.

In recognition of this, several systems have been developed that are intended to present to the pilot a pattern of lights that will give him all the necessary information as to altitude, attitude, direction and progress.

AAF FUNNEL SYSTEM

The Army Air Forces have tested at Arcata, California, with some degree of success, a so-called funnel system of approach lighting. See Fig. 6 This system makes use of the same incandescent lighting unit that the Air Transport Association installed at Newark but arranged in two lines that converge until a point 700 feet from the runway is reached, after which the lines are parallel up to the last pair of lights before the end of the runway It has been found in testing these lights that some means will have to be provided to insure that the pilot will be more certain as to which row of lights he sees when, during low visibility, he sees only one row. Also, it might be said that the pilot is not given enough information by the lights alone to determine his correct lateral and vertical path when visibility permits only a few lights to be seen at one time.

The installation at Arcata has been modified recently to conform to a parallel row pattern and is being tested under conditions of restricted visibility.

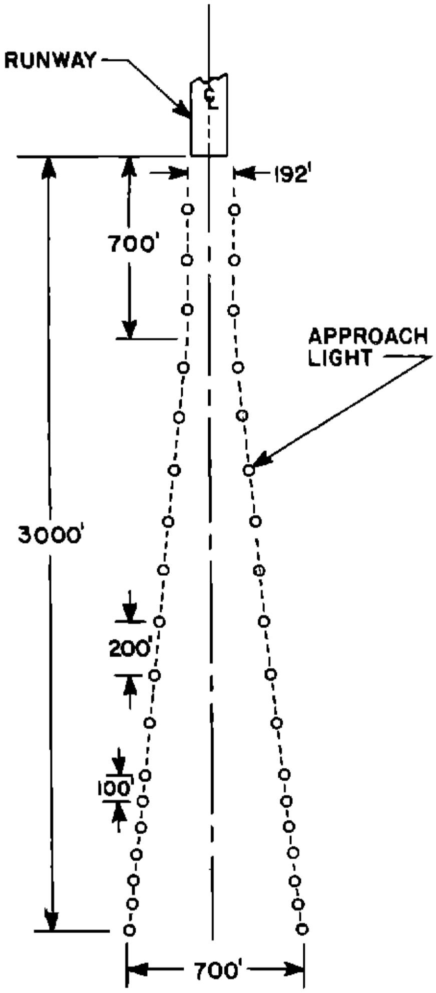

Fig 6 Diagram of AAF Funnel Type Approach Light System

WHAT COLOR SHOULD APPROACH LIGHTS BE?

Before going into a discussion of additional approach light systems, let us reconsider for a moment the units used in the systems described thus far It will be noted that they make use of a minimum number of lighting units, on the order of fifty or less, and with the exception of the flash tube system all employ the color, red, which was selected as standard years ago by representative CAA personnel and pilots There have since been repeated unsuccessful attempts to change this color, the argument being that red is a very inefficient color, requiring considerably more electrical energy to produce the same candlepower as white, for instance Also, since red is the standard for obstruction lights, a pilot might mistake the obstruction lights of a power high-line for an approach light system The international agreements on colors for approach lights cover only low intensity approach lights which may be either red or yellow

BARTOW MULTI-LINE SYSTEM

The U. S Navy, Bureau of Aeronautics, has installed another proposed type of approach lighting system for a trial installation at the Naval Air Station at Patuxent River, Maryland. This installation in its latest form employs 158 lights of the Bartow D-1 type in multiple rows. See Fig. 7. In practice, if this system is adopted, the lights would be provided with controllable beams, the beams of the respective rows being controllable in varying planes, each row tilting at a higher angle than its inner neighbor. Also, it is planned in this system to provide all of the lights on the right side with green filters and all those on the left side with yellow filters.

Although it is very complicated and requires a multiplicity of lights and controls which would increase the cost of an installation to a considerable degree, this system is based on the concept of a lighted area as contrasted with a lighted channel. It also provides a method of distinguishing one side of the path from the other by means of color It provides a greater degree of lateral tolerance in locating the approach path, by virtue of the arrangement of the lights

An installation of the Bartow multi-line system in modified form has been made at Arcata, using a different light source.

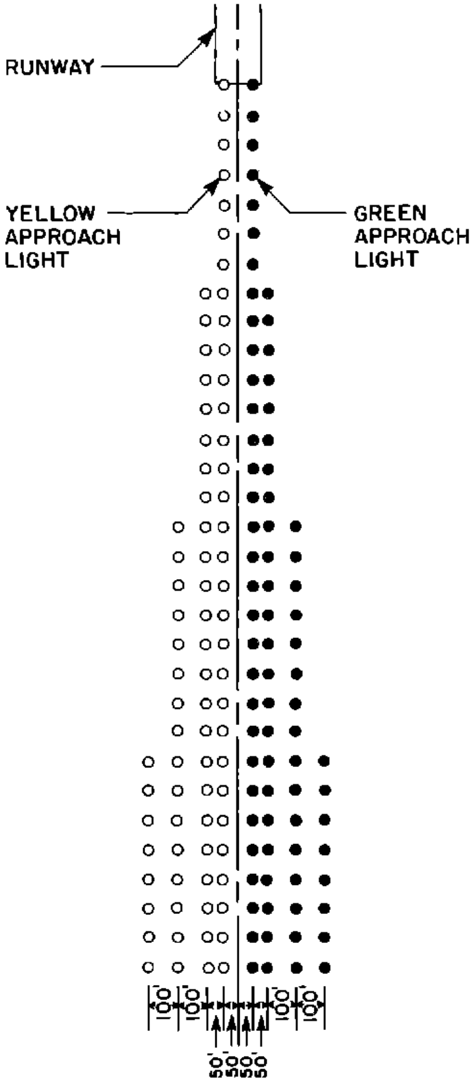

Fig 7 Diagram of Bartow Multi-Line Approach Light System

NBS PATH-OF-FLIGHT SYSTEMS

Still another approach lighting system known as the "path-of-flight" is proposed by engineers of the National Bureau of Standards. This method in the symmetrical form (see Fig. 8) makes use of two parallel straight lines of lights with curved lines merging into the straight lines. The system is designed to provide the pilot with lighted paths leading from every section of the portal to the runway. Each line is designed to be sufficient guidance in itself, consisting of pairs of lights which provide the pilot with a horizon indication The inner light of each pair is white for maximum visual range. The outer light is red or green indicating on which side of the center the light is. The lights have approximately 20-degree lateral coverage. The vertical spread is narrow to keep dazzling to a minimum. Like the multi-line system this design also provides a lighted area.

Another version of this system is the "asymmetrical" system (see Fig. 9) which is predicated on the theory that the co-pilot's use of the lights is limited to discovering them and that the pilot's lights must be located well to his left to be visible through the cockpit windows.

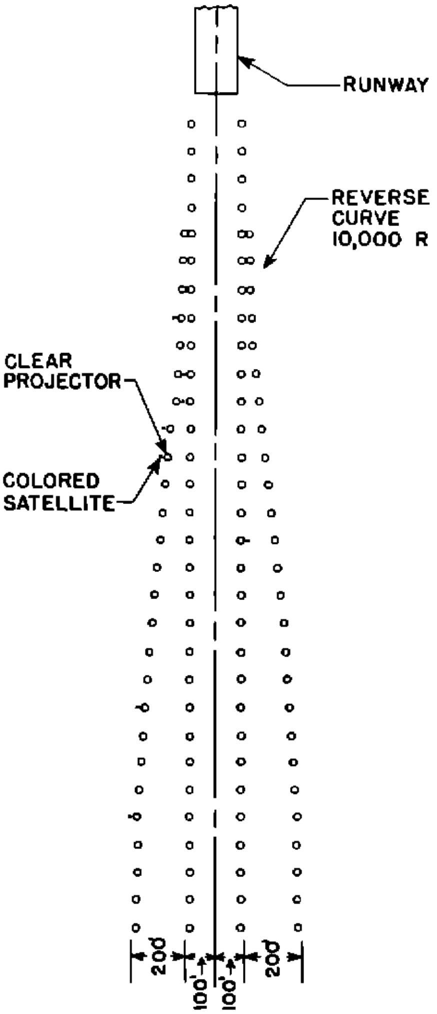

Fig. 8 Diagram of Path of Flight Symmetrical Approach Light System

CAA SLOPE-LINE SYSTEM

Another type of approach light system is the "slope-line" system, proposed by Mr. A. J Sweet and the authors of this paper. This system is designed especially to indicate to the pilot the position of his airplane with respect to the glide path. This information is not given by any of the systems previously discussed, but is indicated by the "slope-line" system if as few as two pairs of lights can be seen at one time.

The design of the "slope-line" system provides that the individual lights will be seen as lines rather than as points. Each unit is made up of 10 lights arranged in a line to form a composite unit 14 feet long. Each of the component lights will have a fairly wide candlepower distribution laterally, with a controlled narrow distribution vertically. The lights will be visible from the front through 180 degrees only, for the definite reason that it is desired to eliminate as far as possible background illumination of the fog.

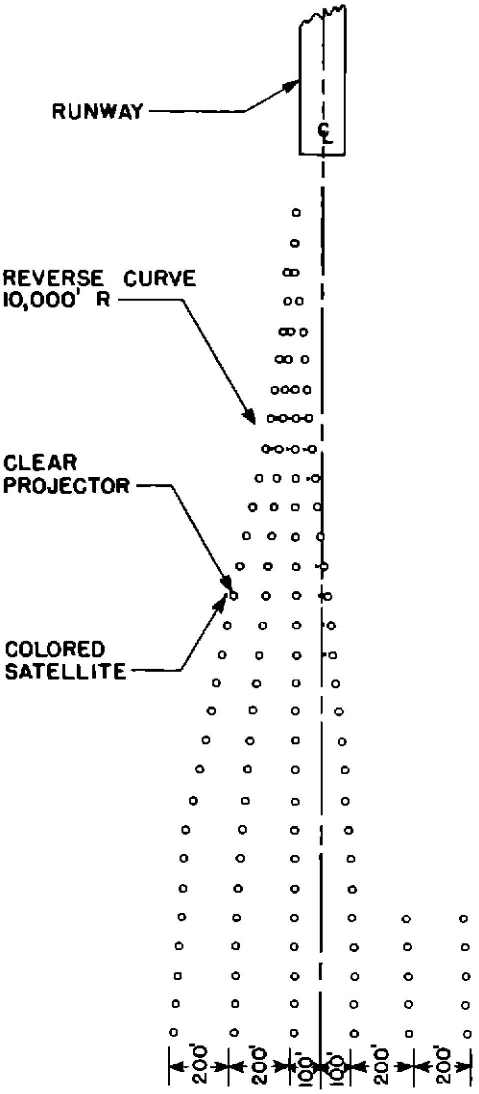

Fig. 9 Diagram of Path of Flight Asymmetrical Approach Light System

The "slope-line" system derives its name from the fact that the lighting units are mounted in a geometrical pattern, the outside ends of the units being nearest the ground, the inner ends being so elevated that the 14-foot long units make a 45-degree angle with the horizontal (see Fig 10) They are so arranged that if the units of any pair were extended in length the extensions would intersect on the glide path, as shown in Fig. 14.

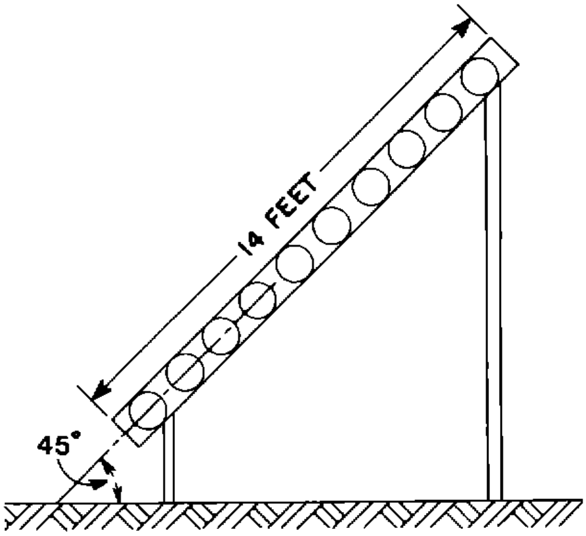

Fig. 10 Slope Line Approach Light Left Side Unit (Front View)

In order to carry out this design, then, as the beginning of the runway is approached the respective units of the pairs of "slope-line" lights are brought closer together so that the intersection of the imaginary extension lines always occurs on the glide path which is decreasing in elevation as the near end of the runway is approached. See Fig. 11. In this system it is not necessary for all the units to be on the same level. It is only necessary that each unit lie in the same 45-degree plane as the other units on the same side. These planes, intersecting on the proper approach path, define that path. Thus, if the ground level is lower at one area of the approach, it is only necessary to move the units farther from the center until they fall on the 45-degree lines.

When a pilot on the proper glide path looks ahead he sees all of the "slope-line" lights lying in only two lines, one line on either side of the approach as shown in Fig. 12. As soon as he deviates from the proper path the lights break up into echelon, the exact appearance of each echelon depending upon the amount and direction of deviation. This is shown in Fig 13 This is true regardless of position along the approach or the number of lights seen. It will require training with these effects, however, for the pilot to be able to determine readily his exact position in the approach, but this is true to some extent of any approach light system. When properly trained in its use, a pilot will have a most sensitive tool in this system, to aid him in making safe landings

At present it is intended to use white lights of approximately 100,000 candlepower for the "slope-line" system. However, the color of lights is not critical and the system can be adapted to whatever color is selected as standard for high intensity approach lights.

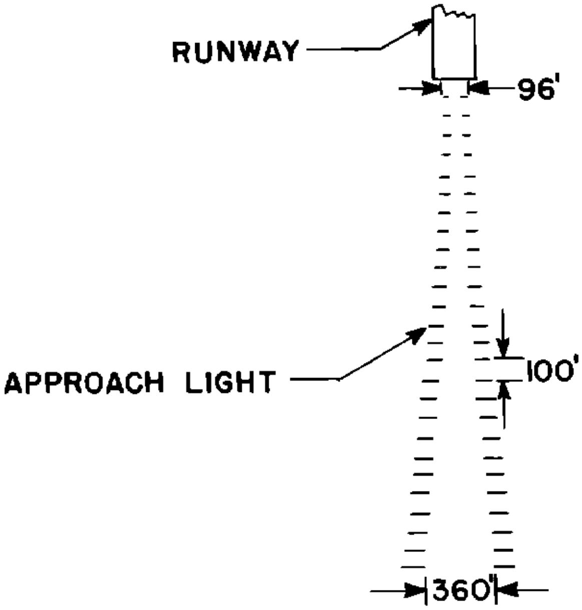

Fig 11 Plan View of Slope Line System

Several models of this type of lighting were studied, including a short length of a full-scale model which was flight tested at the CAA Experimental Station As the results seemed promising, complete systems were installed both at Arcata and Indianapolis, the system at Arcata making use of 500-watt sealed-beam airplane landing lamps, and the one at Indianapolis using 50-watt, 12-volt special sealed-beam lamps. The latter, used with 30-degree spread roundels, have a maximum candlepower of approximately 40,000 at full brightness, less than one-half that of the Arcata units. However, as these lights are bright enough to be seen approximately one-quarter mile during a nighttime visibility of

1/16-mile, and approximately 3/16-mile during daytime visibility of 1/16-mile, it is believed that they will be sufficiently bright for the average airport. For airports where very heavy fogs are incident, the brighter lights probably will be more desirable. The brighter lights are now undergoing severe service tests at Arcata, while those at Indianapolis are being used and demonstrated nightly.

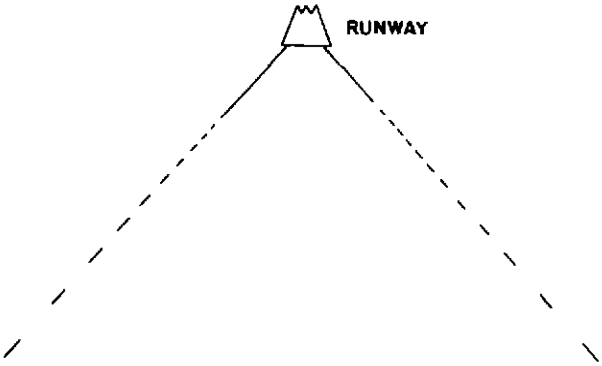

Fig 12 Glide Path "On Course" View of Slope Line Lights

APPROACH LIGHT EVALUATION COMMITTEE

In 1947 an Approach Light Evaluation Committee was formed as a subcommittee of the Air Force-Navy-Civil Committee on Aviation Ground and Seadrome Visual Aids Equipment and Installations This committee studied the test results of the various high intensity approach lights at the Landing Aids Experiment Station at Arcata, California, formulated the Operational Requirements for Approach Light Systems (See Appendix I), and submitted a report to the parent committee, recommending the adoption of a standard system for high intensity approach lights for visibility conditions down to one-quarter mile. These recommendations are given in Appendix II.

A minority report of the Approach Light Evaluation Committee was submitted also, objecting to the two row system recommended, and favoring a single axial row.

The decision of the Aeronautical Board was to adopt the recommendation of the committee for the two parallel rows as standard for visibilities down to one-quarter mile, but that on airports for civilian use only, the right-hand row will be omitted for the present.

After all of the systems installed at Arcata have been flight-tested and compared during the current fog season, it is anticipated that a recommendation will be prepared to amplify or to supersede the standard recommended in Appendix II.

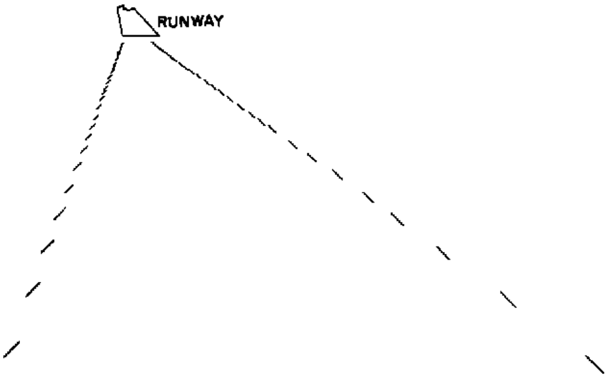

Fig 13 Approach "Off Course" View of Slope Line Lights

HOW SHOULD "BEST HIGH INTENSITY APPROACH LIGHT SYSTEM" BE DETERMINED AND USED?

At this point let us quote excerpts from a paper[1] which most aptly describe extremely important conditions which must be taken into consideration in studying and evaluating tests on any system of approach lights.

"Even if we had available today a system of approach lights. . which had completely satisfied all the requirements of laboratory investigation and a comprehensive series of field tests, including ample flight tests, the problem would still not be solved. The final solution of the problem requires the accumulation of sufficient successful experience under actual service conditions to warrant pilots generally in placing confidence in the system. This confidence can only be acquired by actually making landings under conditions of bad visibility and great credit is due those . .

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[1] Breckenridge, F. C., and Douglas, C. A., "Development of Approach-and Contact-Light Systems," Illuminating Engineering, Vol XL, No. 9, Nov. 1945

who are attempting at this time to carry out landings with the systems which they have available One word of caution, however, may not be inappropriate To attempt to force the systems which they are using beyond their capacity may set back rather than advance progress since one bad accident will undo the confidence accumulated in a hundred successful landings.

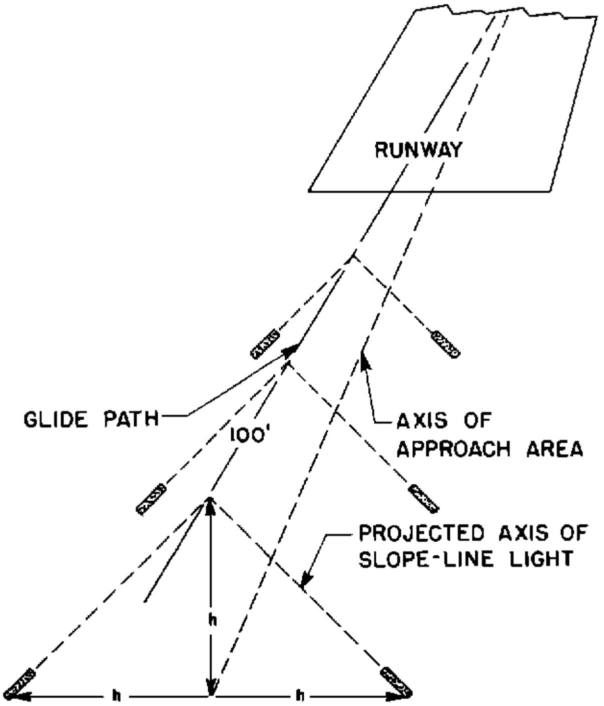

Fig. 14 Perspective View of Slope Line of Lights with Reference to the Approach Lights Showing Positions

It is doubtful if any system of approach lights will ever be satisfactory for a pilot to use in thick fog unless he is thoroughly familiar with it. Even with 3000 feet of approach lighting .a pilot travelling 120 miles an hour is over the system for only 17 seconds To this we may add from 4 to 13 seconds for the time the first light is visible before the pilot reaches it Whatever change in flight path is to be made will have to be made within this period of 21 to 30 seconds and during this time the pilot does not see the entire system at any time. A successful landing requires that the pilot recognize at the first glance what part of the system he is seeing and what his position is relative to that part of the system Such recognition can only come from seeing the system frequently The chances of error will be increased if the same pilot is called upon to use different systems in which the same idea is expressed by different means. To allow the same means to have different significance in different systems used by the same pilots would certainly invite accidents. With frequent and consistent experience in clear and semi-clear weather, the pilot should be able to construct the whole picture of the approach-light system from the part he is able to see in fog.

In the long run, the pilot must be satisfied If he cannot use the lighting system, no one else will ...For flight testing, the pilot is obviously indispensable. In the acquisition of service experience it is the pilot alone who counts. But after allowing for the pilot's importance in all of these aspects of the work, the organization of the program is still a problem for the engineer It is to the engineer that we must look for the development of techniques which will eliminate prejudice and chance from our results, for when we get beyond the limitations of laboratory investigation, prejudice and chance are our greatest difficulties. It is the engineer who must study the pilot's observations and determine what is relevant and what is accidental."

CONCLUSION

If the importance of the above principles is kept in mind, it should be possible, with the aid of knowledge gained through exhaustive experimentation, for the engineering profession to find the correct solution to the problem of approach lighting Most of the preliminary work has been done. It remains yet for the several proposals to be weighed, carefully appraised and put to practical application

On one requirement all of the authorities and all of the proposed high intensity systems agree. They all call for 3000 feet of approach lighting for every instrument landing runway. Hence, provision for 3000 feet of land in the approach should be included with every airport where scheduled operations are anticipated, and 500 feet additional to allow for the middle marker

APPENDIX I

OPERATIONAL REQUIREMENTS FOR APPROACH LIGHT SYSTEMS

1 DEFINITIONS

As used in this statement of operational requirements, the following terms are to be understood as defined below

1.1 LIMITING VISIBILITY, the meteorological visibility for which the approach light system is designed

1 2 REGION OF GUIDANCE, the region of space within which it is essential that the visual aids be sufficiently visible to the pilot to provide adequate guidance for the safe approach of aircraft for landing.

1.3 AXIS, a horizontal line extending the center line of the runway through the approachway, that is, in the same vertical plane as the centerline and intersecting it, or coinciding with it at the approach end.

1 4 THRESHOLD, a horizontal line perpendicular to the axis marking the approach end of the runway and also the vertical plane through this line

1.5 PORTAL, an area, through which aircraft may be expected to pass, lying in the vertical plane perpendicular to the axis and 3500 feet from the threshold. (The middle marker is generally located in this plane)

1 6. GLIDE PATH, a path determined by electronic aids and designed to be followed by aircraft in landing. The slope varies between two degrees and four degrees, and the intersection with the runway lies at a distance of from 500 feet to 1500 feet from the approach end.

2 LIMITING VISIBILITIES

2.1. For the purpose of these requirements, two limiting visibilities are recognized

2 1 1. For direct instrument approaches, the limiting visibility is 1/4 mile daylight object visibility (Transmissivity, 0.375 per 100 meters)

2.1.2 For all other approaches and circling, the limiting visibility is 3/4 mile (Transmissivity, 0 722 per 100 meters.)

2.2. These operational requirements are based on visibilities of 1/4 mile unless otherwise stated

3 IDENTIFICATION

3 1 At all points within the region of guidance (Section 4), the lights visible shall be immediately identifiable as part of an approach light system.

3 2 At all points within the region of guidance (Section 4), any lights on either side of the axis shall be immediately distinguishable from any lights on the other side of the axis, and any lights on the axis shall be recognizable as such.

3.2.1 This identification shall be accomplished without possible confusion with any means used to mark any portion of the runway, or with other lights in the area.

3 3. At all points outside the region of guidance (Section 4), any approach lights visible shall immediately indicate to the pilot that he is left or right, and if possible, above or below the region of guidance respectively

4. GUIDANCE

4 1. For instrument landings, the region of guidance shall have the form and dimensions shown in figure 1 of Appendix I.

4 2. At all points within the region of guidance sufficient lights shall be visible to indicate the location and direction of the axis.

4.2.1. Within the region of guidance, the location of the threshold shall be positively identified for a maximum distance of 500 feet.

4 3 Within the region of guidance it is highly desirable that sufficient lights be visible to indicate the following

4.3 1 The approximate height above the runway, or, alternatively, the departure vertically from the glide path

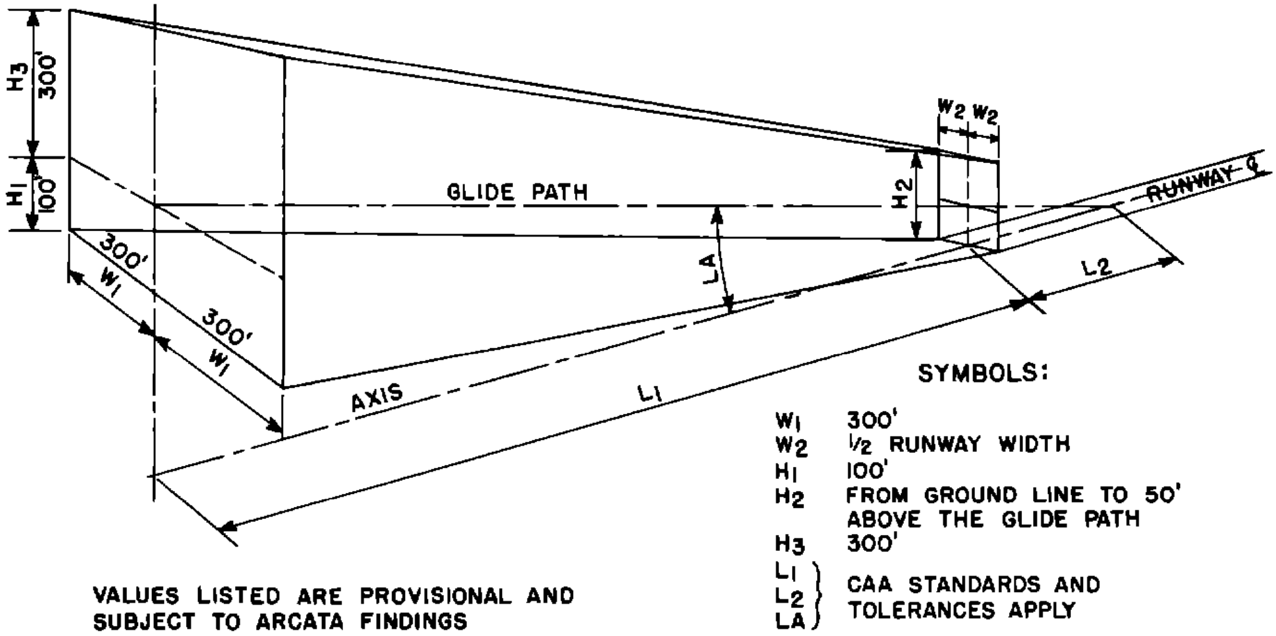

Fig. 1 Region Guidance for Approach Light Systems

4.3.2. The approximate distance to the threshold

4 3 3. The attitude of the aircraft with respect to the horizontal plane, both longitudinally and laterally, provided the means used shall not detract from the guidance furnished to indicate the location and direction of the axis and the location of the threshold

4.4 For visibility conditions of not less than 3/4 of a mile, daylight object visibility, the approach light system shall furnish guidance for a distance of 3/4 mile along any path of the approach within 90 degrees left or 90 degrees right of the axis, the vertex being the intersection of the threshold and the axis *

4 5 For all visibility conditions the location of the middle marker, or the point on the axis 3500 feet from the threshold shall be indicated by a flashing light visible 3500 feet under 1/2 mile daylight object visibility except within a sector directed toward the runway and extending 22 5 degrees either side of the axis *

5 ILLUMINATION

5.1 The illumination provided at points from which lights are required to be visible shall be adequate for visibility without visual concentration in excess of what is readily feasible for a pilot whose attention must be divided among several responsibilities

5 2. The illumination visible at points on or above the level of the glide path shall not be excessive. (There is no agreement as to the maximum acceptable degree of dazzling, and additional experimental results are urgently needed)

6 COLORS

6 1 The number of different colors used in approach- and runway-light systems should be kept to a minimum to avoid possible confusion.

7. CHARACTERISTICS

7 1 At present, only fixed lights have been found satisfactory for guidance to meet the requirements in Section 4

7.1 1 Flashing lights used as auxiliary lights or satellites may be considered as meeting the requirements for identification, (Section 3)

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* This is a provisional requirement based upon currently available information and is subject to verification obtained from flight tests

APPENDIX II

PROPOSED A.N C STANDARD FOR APPROACH LIGHT SYSTEMS

The following standard describes an approach light system designed for use with electronic aids and adequate runway lights to facilitate the landing of airplanes in weather normally characterized as not below 1/4 mile visibility. These standards are based on provisions contained in the Operational Requirements (Appendix I).

1. Configuration

The system shall consist of two rows of lights horizontally parallel to the center line of the runway

2. Length

The rows shall extend from the end of the runway proper -- a distance of 3000 feet in the direction from which landing airplanes approach.

3. Location

The rows shall be symmetrically located with respect to the center line of the runway at a distance of not less than 100 feet nor more than 125 feet from that center line (extended). They shall be as nearly in the plane of the runway as is practicable, but if it is not practicable to locate all the lights in the same horizontal plane the echelon principle may be followed.

4. Spacing

The lights shall be spaced in the rows preferably 100 feet, but not more than 200 feet apart, in such positions that the lines connecting corresponding units in the two rows are perpendicular to the lines of the rows.

5. Characteristics

The lights shall be of the fixed (not flashing) type. Those in the left row, as seen by approaching pilots, shall be red. Those in the right row shall be yellow.

6. Coverage

The intensity distribution of the lights shall be such as to provide satisfactory guidance throughout the region of space defined by Figure 1 of Appendix I when the atmospheric transmissivity is not less than 0.375 per 100 meters, commonly called 1/4 mile daylight object visibility

7. Threshold

In addition to the lights described above, the approach end of the runway shall be marked by a row of green lights of higher intensity than the threshold lights normally specified for runways which are not lighted for instrument approaches.

8. Obstructions

Each pair of lights shall be located above any obstructions in the approach area between it and the runway threshold

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