NATIONAL BUREAU OF STANDARDS REPORT

5753

Some Problems in Approach Lighting

By
C. A. Douglas

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NBS PROJECT		NBS REPORT
0201-20-2331	January 1958	5753

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Wright Air Development Center
Department of the Air Force

NBS

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I. INTRODUCTION

With the development of improved electronic approach aids and couplers, and of improved visual landing aids, we are approaching the goal of "all-weather" take-offs and landings. As we work toward this goal and weather minimums are lowered, we can expect some of the perennial problems in approach lighting to reappear, possibly in new form. The purpose of this paper is to analyze briefly several of these problems in an effort to obtain solutions or procedures for solving these problems.

The problems selected for discussion are:

1. Standardization
2. Field Testing
3. Elevation Guidance
4. Control of Glare

II. PROBLEMS IN STANDARDIZATION

Standardization in all phases of aviation lighting and marking is highly desirable both on a national and an international scale.

Progress in obtaining standardization in approach-light configurations has been very slow during the past decade even though many pilots have stated that they considered standardization so important that they would willingly accept a system which they considered considerably less than optimum in order to expedite the installation of approach lights. It is not my purpose to belabor the lack of standardization in approach-light configurations which has existed, but instead to explore the reasons for this in an effort to find means of improvement in standardization procedures.

Perhaps these problems should have been expected. There are different views as to the relative importance of the different types of guidance to be supplied by the approach-light configuration; there are differences in the accuracy of the coupling to the instrument landing system; there are differences in the capabilities of pilots and in the characteristics of aircraft; there are sometimes restrictions placed on the length of the system and on the permissible location of lights which are based on requirements other than lighting; and last, but by no means least, are the differences in opinions as to the value of the various components which might be used to build a system. There are differences of opinion not only between the pilot and the engineer, but also between engineer and engineer and pilot and pilot. This latter point is well illustrated by a quotation from the Report of the Sixth Session of the AGA Division of ICAO: "Many pilots in IFALPA regard the flashing condenser-discharge lights as an important element in the ALPA approach-light system, while many others take a contrary view."

With all these factors to consider, the wonder is not that standardization has been so slow, but that standardization can be obtained at all.

Perhaps we have been too much concerned with obtaining complete standardization of configuration when we should have first worked for configurations which were compatible. Two configurations are compatible if a pilot who is experienced with one configuration will not be misled if he takes a reflexive action when flying the other system. Thus a left-hand-row configuration is incompatible with a center-row configuration. Several of the variants of the Calvert system are compatible with one another. An ALPA system plus additional crossbars is considered compatible with an ALPA system if the identity of the 1000-foot crossbar is maintained in the former system.

A greater use of the principle of compatibility should provide sufficient flexibility in the design of configurations so that differences in operational requirements, differences in thinking, and limitations because of terrain can be met and should reduce the effort spent in trying to attain a complete and rigid standardization. (Complete standardization may not even be a desirable goal.)

A review of the present status of approach-light configurations will illustrate where the principle of compatibility has been applied and where it has been ignored.

National Standard AGA-NS1 of July 20, 1953 specified three approach-light configurations. Configuration C is a Navy modification of the slope-line system using slope-line bars, transverse bars, side-guidance bars, and a line of single lights along the axis of the approach zone. Only one system of this type has been installed (at the Naval Air Test Center, Patuxent River) and no additional installations are planned. It is reported that pilots assigned to the station like it and that transient pilots find it confusing.

Configuration B was developed from Configuration A to meet Air Force requirements for a clear overrun for use at Air Force-Civil joint use fields. This system with the centerline section (tail) limited to 500 feet has been the Air Force standard. Both Configurations B and C are now being deleted from the National Standard.

Configuration A, the ALPA system, shown is the standard configuration for civil fields and is now being installed in place of other configurations as rapidly as funds permit. It is composed of 14-foot, 5-lamp barettes located at 100-foot intervals on the extended centerline of the runway with a 100-foot bar 1000 feet from the threshold. Condenser-discharge lights flashing in sequence with a one-half-second period are installed at the center of the barettes in the outer 2000 feet of the system when a need for them is established. The Air Force has recently adopted this configuration as standard with the following modifications. Sequenced-flashing lights extending to the 200-foot bar are to be installed and cross-bars will be added when authorized at the Command level. Thus we are rapidly approaching an era of compatible approach-light systems in the United States.

A 1500-foot long parallel row and cross-bar system was tested at NAS Atlantic City and at McGuire AFB in 1955. One pile-mounted system of this type is now being installed as a seadrome approach-light system at NAS Norfolk. It is probable that parallel-row systems will continue to be used for seadromes because of the hazards created by pile-mounted structures in the center of the approach lane.

III. PROBLEMS IN TESTING

Obtaining conclusive results in the comparative evaluation of approach-light configurations is a very difficult, if not impossible, task. This is clearly demonstrated by the general reluctance to accept test results of organizations other than one's own, and the fact that formal flight tests have rarely, if ever, resolved major differences of opinion regarding the relative value of different types of approach- and runway-lighting systems. The moment-to-moment and place-to-place variations in fog density are generally so great that no two approaches are made in the same visibility condition. The number of approaches that can be made in low visibility conditions during the period allowed for testing is seriously limited. Hence it is very difficult to develop an experimental design which will satisfactorily randomize the tests and which will provide sufficient controls so that a quantitative measure of the difference can be obtained of the guidance furnished by the systems under test.

For example, we tried to evaluate the results of the 1947 approach-light tests at Arcata on the basis of the frequency of missed approaches and found to our surprise that the approach-light system considered the least satisfactory by the test pilots and flight-test personnel had a slightly lower percentage of missed approaches than did the other systems.

Thus, in the past evaluations have generally been based upon either pilot opinion or the application of arbitrary criteria as a measure of performance. Neither of these alternatives is entirely satisfactory. The results obtained with either are very dependent upon the personal bias.* It is very difficult for one to be objective about his own creations and other matters in which he has a strong personal interest. Yet nearly all tests of lighting configurations are under the direction of people with a strong personal interest in one of the configurations being tested. Frequently the opinions of these persons influence not only their own conclusions, but also the conclusions of others participating in the tests. Knowing the background of those conducting the tests, it is often possible to predict the test conclusions in advance of the tests.

Because of this difficulty in obtaining conclusive results from formal flight test programs, a much more extensive use of service tests is needed. Thus, where major differences of opinion can not be resolved by a series of flight tests, one or more installations of each of the systems under consideration should be made in order to obtain service experience. This will produce some departures from standardization. However, this is considered more advantageous than delaying installations while additional, and often futile, efforts are made to resolve the differences by further flight testing.

Other factors which tend to invalidate or give misleading results in the testing are:

1. Failure to separate the variables.

   Because of the difficulty in obtaining a sufficient number of flight tests, there is a tendency to vary

*The term "bias" is used here in a technical, not a derogatory sense.

too many components of the systems being tested at one time with the result that the merits of the separate components can not be determined.

2. Application of results obtained with special test crews or in special test flights to service conditions in general.

The results obtained with experienced test crews making many low-visibility approaches within a short period are not always applicable to the pilot who makes only a few low-visibility approaches a year, since the test pilot is able to use a more complex system than is the "typical" pilot. Similarly, the results obtained with any test crew making a number of approaches in a few hours are not representative of those obtained by a pilot making the first approach of the day. For example, an approach-light system deficient in height guidance might be considered satisfactory to a test pilot whose first approach is a high pass over the system to check the glide path and the altimeter.

3. Lack of suitable controls in the design of the experiment.

Pilots have obtained erroneous impressions of the visual range of lights under test simply because no comparison lights of known intensity were included in the tests.

4. Extrapolation of results to visibility conditions considerably lower than those in which the tests were made.

For example, the required horizontal beam spread of the lights and maximum downward angle of view from the cockpit are roughly inversely proportional to the visual range of the lights. Hence, if a five-degree horizontal beam spread is adequate when the visual range is one mile, a 40-degree beam spread is required for a visual range of one-eighth mile. Similarly, a four-degree maximum downward angle of view is just sufficient to permit seeing the outermost lights of the approach system when the visual range is one mile,

> a 15-degree downward angle of view is required if the outermost lights are to be seen when the visual range is one-fourth mile, and less than half of the approach-light system will be seen with this downward angle of view when the visual range is one-eighth mile. Thus the guidance received when the visual range is one-eighth or one-quarter mile may be very different from that received when the visual range is one mile.

5. Deficiencies in reporting such weather data as visibility and ceiling.

> If the meteorological visibility is reported as "zero" whenever the visibility is very low or whenever the pilot fails to obtain adequate guidance, the engineer can not tell whether the system under test is deficient or whether the visibility is very low. All future test installations should now have adequate visibility meters, ceilometers, and illuminometers in the areas of interest.

Despite the difficulties in formal flight tests, the need is for more, not less, testing of this type. Although the tests do not resolve major differences of opinion of the relative values of systems, they are, when properly conducted, very useful in the improvement of the individual systems to the point where the systems are ready for service testing.

It is highly desirable that a joint test facility, available to all agencies, be established. Such a facility should be equipped so that systems can be easily and cheaply installed for preliminary and operational suitability testing. Its staff should include persons qualified in the design of experiments so that flight test procedures will be established which will avoid, in so far as possible, the pitfalls of the past.

IV. PROBLEMS IN ELEVATION GUIDANCE

The mirror landing system and other optical glide-path systems supply elevation guidance by defining the glide path and indicating to the pilot his angular deviation from this path. These systems provide not only a sensitive indication of the departure from the indicated glide path, but also a good indication of the rate at which the airplane is changing the departure from this path. However, these devices must be located on the line of intersection of the plane of the glide path and the ground. Hence they are not visible until very late in the approach if the visibility is much less than one-half mile. The slope-line and the Navy composite approach-light systems indicated the direction of displacement from a preferred glide path when three or more lights on each side of the system could be seen. However, a considerable amount of experience was required to obtain a quantitative measure of the displacement from the preferred path and the rate of change of displacement especially when the airplane was displaced from the centerline of the approach zone.

In the other approach-light systems the pilot receives visual information indicating his height above the runway and his rate of descent from the changes in the appearance of the pattern of approach lights and from the appearance of the lighting units themselves. The barette type of unit appears ideal for this purpose, supplying considerably more guidance than can be obtained from a system composed of lights which are essentially point sources. These units are of sufficient size so that an indication of their distance can be obtained from distances of more than a mile, and when viewed from short distances, the angular separation of the individual lamps in the units provides a sensitive indication of distance.

Use of this type of information to determine visually if the path of the aircraft will cross the threshold at a satisfactory height presupposes a knowledge of the distance of the aircraft from the threshold. When the slant visual range is of the order of one-half mile or more, the first bar of the system, the 1000-foot bar, and the threshold configuration are all used as distance indicators. However, in very restricted visibility conditions, less than one-fourth mile, only a few barettes can be seen at a time. The barette is then not a satisfactory distance indicator since one can not be sure that the first barette seen is the first one of the system. Thus it is possible for the pilot to fly visually ten seconds or so without receiving any visual information as to his distance from the threshold. It appears that, if suitable coding can be devised, the addition of more distance markers, probably roll bars, would be desirable. This would be particularly useful to pilots coming in to unfamiliar fields. In many cases the pilot coming in to a familiar field receives distance information, consciously or subconsciously, from items which are not part of the approach-light system.

The possibilities of systems of elevation guidance based upon principles other than those discussed above should be explored. The following factors should be considered in these studies. 1) Knowledge of the rate of change of displacement from the glide path or height above the runway is perhaps as important as knowledge of the displacement or height. 2) An indication to the pilot that his present course will lead to a safe touchdown, an undershoot, or an overshoot seems preferable to an indication that he is on, below, or above the glide path.

V. PROBLEMS IN THE CONTROL OF GLARE

As problems in the control of glare have been discussed in detail in NBS Report 5747, they will be summarized only here. In order to avoid excessive glare in the inner part of the approach zone at night, the approach-light system should not be operated at more than 5% of full intensity even in dense fog. Reducing the intensity to this value can seriously reduce the effectiveness of the outer part of the approach-light system. For example, if the meteorological visibility is 1000 feet, the outermost light of a 3000-foot approach-light system can be seen about 1400 feet when the system is operating at full intensity and will be obscured by the cockpit soon after it comes into view. However, if the lighting system is operated at 5% intensity, the first light which will not be obscured by the cockpit for all distances less than its visual range is the light which is about 1700 feet from the threshold. Thus the outer 1300 feet of the system will not be seen.

The solution to this problem appears to be the use of lights of different types in the outer and inner approach zones and setting the intensity of the lights in the outer approach zone one step higher than those in the inner approach zone.

VI. CONCLUSIONS

Standardization of approach-light configurations is now being accomplished. Compatibility of systems appears to be a more desirable and attainable goal than complete and rigid standardization.

Although methods of flight test can be improved considerably, it appears unlikely that formal flight tests will resolve major differences in opinion. A much more extensive use of service testing appears to be the most satisfactory way to resolve these major differences of opinion. However, formal flight tests are very valuable in developing and improving systems. A test facility available to all groups at which lighting systems could be easily and cheaply installed and tested would greatly expedite the development of the systems to service-test stage.

The need for elevation guidance is expected to become more critical as minimums are lowered. Development of new methods of elevation guidance may be required.

Operating the present approach-light systems at reduced intensity in order to reduce the glare in the inner approach zone can seriously reduce the effectiveness of the outer part of the approach-light system. Modification of the systems so that the lights in the outer zone have a considerably higher intensity than those in the inner zone appears desirable.

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

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

THE NATIONAL BUREAU OF STANDARDS

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WASHINGTON, D. C.

Electricity and Electronics. Resistance and Reactance. Electron Tubes. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat and Power. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology and Lubrication. Engine Fuels.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment. AEC Radiation Instruments.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Gas Chemistry. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Organic Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Heating and Air Conditioning. Floor, Roof, and Wall Coverings. Codes and Specifications.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analogue Systems. Application Engineering.

- Office of Basic Instrumentation
- Office of Weights and Measures

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering.

Radio Standards. Radio Frequencies. Microwave Frequencies. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Calibration Center. Microwave Physics. Microwave Circuit Standards.

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