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AIRPORT MARKING AND LIGHTING SYSTEMS. A SUMMARY OF OPERATION\L TESTS AND HUMAN FACTORS. APPEND X, SELECTED ANNOTATIONS AND BIBLIOGRAPHY

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AIRPORT MARKING AND LIGHTING

OPERATIONAL TESTS
AND
HUMAN FACTORS

Final Report Appendix
Selected Annotations And Bibliography

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FOREWORD

This volume contains summaries and references of published reports on airport marking and lighting and related topics. It was prepared to support the objectives of Contract FAA/BRD-13.

The basic objectives of that contract were: to bring together results of operational tests and evaluations on airport marking and lighting; to identify unresolved problems requiring immediate and future research and development; and to review human factors research data relevant to problems identified.

This Appendix can also be used as a catalogue of information about airport marking and lighting to aid airport design engineers and FAA research personnel in identifying and locating reports.

In order to identify and locate publications easily and quickly, users are advised to first read the section entitled "How To Use The Appendix".

The authors wish to express their appreciation to Dr. H. Richard Van Saun, FAA Project Manager, and Dr. Robert K. McKelvey, both of the Human Factors Branch, Operations Analysis Division, for their contributions to the topical organization of the Appendix. Also, we are indebted to Mr. C. A. Douglas, National Bureau of Standards, for providing copies of many of the reports reviewed, and guidance in securing many others.

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HOW TO USE THE APPENDIX

Finding a Study

A quick look at the Table of Contents will reveal that the Appendix has been organized by topics. Studies on topics primarily covered in Chapter II of the Final Report are found in the BLUE pages; Chapter III studies in the RED pages.

Each study has been annotated or referenced on a page marked with code letters representing a topic. For example, the code letters AA are used for studies on the topic of angle-of-approach indicators. Topic code letters are shown in the Table of Contents. In addition, with each topic category, the studies have been arranged alphabetically by the author's last name.

Thus, to find a study, do the following:

(1) From the Table of Contents, determine the page color and page code letter(s) for the topic or contents of the study.

(2) Turn to the first page in the Appendix having the proper color and topic code letters. This page will be the first one that has annotated studies on that topic.

(3) Leaf through the pages in that topic's section until you come to the name of the author of the study for which you are looking. If an author has more than one article annotated, the annotations of his studies have been arranged by date of publication, with the earlier publications coming first.

If you have not located the study by this time, then the following possibilities exist:

(1) The study which you are seeking covered more than one topic and can be located under a topic section appearing earlier in the Appendix. Use the same procedure as above to locate the study in the next most likely topic section.

(2) No author was listed on the publication. Such studies can be found within a topic section by leafing quickly through the section and reviewing the titles or publication information. These studies have been put in among the author alphabetical ordering, according to the first word of the title.

(3) The study was not annotated, but was considered to be of more than passing interest to the topic. If so, it may be found in Selected Additional References appearing on the last page(s) of each topic section. Studies in these listings are arranged alphabetically by the author's last name. Note, however, that some topic sections do not have such listings.

(4) The study may be listed in the TAN section on pages marked AR. These studies were considered to contain important information, but were not directly focused on the objectives of the contract or were judged to be out-dated by subsequent studies.

(5) The study was not reviewed, and thus is neither annotated nor referenced in this Appendix.

In summary, there are five (5) bases for finding a study:

(1) BLUE or RED pages

(2) Topic code letters

(3) Author

(4) Title

(5) Publication Information (Reference).

It should be noted that many of the studies annotated contained information used in more than one section and/or chapter of the final report. Thus, studies with given code letters may be referenced in the final report in a number of different places.

What the Annotation Categories Mean

Four major types of content material were reviewed:

Operational Tests	-	usually flight tests of some portion of the over-all marking and lighting system.
Component Developments	-	usually descriptions of the performance characteristics of newly designed or developmental materials or equipment.
Analytic Studies	-	theoretical or empirical analyses of, or commentaries on, marking and lighting problems and related topics.
Human Factors Studies	-	reports of experimentally determined capabilities of the human which are relevant to current critical marking and lighting problems.

The five categories on the first page of each annotation are on all reports. Author and Title are self-explanatory. Reference gives information needed to acquire the report. Summary includes a concise general overview of the report, including the nature of the study and principal conclusions reached. Remarks includes comments by the reviewer on the relevance of information in the report to marking and lighting problems and, occasionally, commentary on other aspects of the report.

Beyond the initial page, a different annotation form is used for each of the four major types of reports. Categories used are as follows:

Operational Tests

Requirements:	Statements of pilot information, or other task-related requirements, in terms of which the experimental design or pattern was evaluated.
Description:	A summary description of the marking and lighting system, sub-system, or pattern tested.
Recommendations:	Specific recommendations by the author for implementation of a tested design or for additional tests.
Conclusions:	Statements of additional study results reported by the author.

Component Developments:	No additional categories used.

Analytic Studies:

Requirements/ Discussion:	Summary of the major aspects of the airport marking and lighting problem with which the analysis was concerned.
Conclusions/ Recommendations:	A restatement of the author's principal conclusions based on the analysis and any recommendations made for research or implementation.

Human Factors Studies:

Human Capabilities:	Specification of the human performance capabilities relevant to the pilot's task and, therefore, to airport marking and lighting design problems.
Influencing Factors:	Specification of those variables which were manipulated in the study in order to assess the effects of variation of the factor on the capabilities studied.
Context Conditions:	Description of the experimental conditions of the study, especially those which pertain to the degree of fidelity with which the operational situation, aircraft approach and landing, was simulated.
Results/Conclusions:	Statements of relationships between variations in influencing factors and the human capability of concern.

Within each type of report, the same categories were used with each annotation. If no information was available on a given annotation category, or if it was deemed to be not useful by the reviewer, the word NONE is inserted after the category title.

In your reading, you will notice that the line spacing of the annotations occasionally departs from a standard 1 1/2 spaces. Such departures were deliberately planned in order not to disrupt page continuity by strict adherence to a 1 1/2-space format.

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Comments to the User

"Annotate" is defined by Webster as "to furnish with notes, usually critical or explanatory". We have attempted to be explanatory because the breadth of knowledge required to critically comment on the very wide variety of disciplines and scientific specialities represented by the studies reviewed demands a lack of humility which we could not achieve.

Generally speaking, we annotated reports of Operational Tests and Evaluations of airport marking and lighting systems which have appeared since 1946. The Component Development Studies and Human Factor Studies which we annotated were of a more recent vintage and were selected on the basis of their relevance to current problems. In addition, all reports which included Analytic Studies of airport marking and lighting problems were annotated, with the exception of those primarily concerned with transmissivity problems. These latter studies were considered beyond the scope of the project, except for those which helped to identify the nature of some marking and lighting problems involved with transmissivity measurement and prediction problems.

Our selection and annotation procedures may have introduced certain biases in scope and classes of information included in this Appendix. The user, therefore, should not consider this Appendix as a primary source of information, but as a time-saving, secondary source catalogue which can be used as a guide to the more detailed information contained in original research reports.

Needless to say, we willingly assume full responsibility for the way in which we have structured the primary role of this Appendix, and for the selection of articles considered most pertinent to the airport marking and lighting problems. We offer our apologies to those authors whose relevant work we may have omitted. We would like to express our appreciation to all those authors whose reports we have reviewed.

OPERATIONAL
TESTS AND EVALUATIONS

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Harding, J. H., & Cockrum, R.
TITLE: Use of condenser discharge lights as runway-end identifiers.

REFERENCE: Indianapolis: Civil Aeronautics Administration, Technical Development Center, 1958. (Report No. 353.)

SUMMARY:

The report describes tests and observations of condenser discharge lights used as runway-end identifiers. Bright flashing lights on the approach end of the runway proved to be of assistance to pilots in determining their position with reference to the runway, especially during minimum circling approach weather conditions. Previous tests at Andrews Air Force Base, however, indicated undesirable glare to the pilot and this work explored use of baffles and colored filters to reduce glare. The use of a baffle to effect partial cutoff in the final 1000 feet of approach, along with other adjustments to the fixture, eliminated glare during the approach

REMARKS:

Number of pilots participating in the flight tests and types of aircraft involved were not specified.

REQUIREMENTS: None.

DESCRIPTION:

A pair of Sylvania condenser discharge lights was installed at the approach end of non-instrumented Runway 13 at Indianapolis, located 5 feet outside each end of the threshold bar. Each could be turned in 5-degree increments from a position parallel to the runway axis to a toe-out of 30 degrees. The main light beam was aimed 3 degrees above the horizontal.

A shutter-type baffle was constructed which could be rotated in the vertical plane to improve directivity of the light. In order to produce varying degrees of cutoff, the tilt angle of the experimental baffle blades was adjustable. The baffle was painted black to reduce reflection.

The possibility of using colored filters with the identifiers, in order to disassociate them further from surrounding lights, was explored. Plexiglass filters of several colors were obtained, and a holder was constructed to hold the filters in front of the lighting fixture.

PROCEDURES:

Pilot observations were made while circling and while approaching the runway for landings. The identifier to the left of the pilot as he approached the runway for a landing was equipped with the baffle, while the identifier to the right used either clear or colored filters.

The purpose of these observations was to determine:

- The optimum angle of toe-out for the identifier light beams (0-30 degrees).
- The optimum angle of rotation of the baffle for circling guidance (horizontal to plus 15 degrees).
- The optimum angle of tilt of the baffle blades to prevent blinding of the pilot without reducing over-all guidance effectiveness (horizontal to minus 10 degrees).
- The color of filter which presented clearest identification of the runway end (red, yellow, amber, and green).

Results of direct observations were confirmed by motion pictures taken during the flights.

RECOMMENDATIONS: None.

CONCLUSIONS:

A toe-out angle of 10 degrees gives maximum circling coverage.

A baffle rotation of 10 degrees is optimum for viewing on downwind and base legs.

A minus 5-degree tilt of the baffle blades produces the desired cutoff to reduce glare without reducing the guidance effectiveness of the light.

Some observers prefer aviation green-colored rotating units as they identify the light as a part of the threshold; otherwise, there is no observed advantage to colored lights.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Hoffman, C. S.
TITLE: Evaluation of runway identification and runway circling guidance lights.
REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, September, 1957. (Technical Note 57-262.)

SUMMARY:

The objective of the work described here was to:

Evaluate runway identification lights.

Determine if runway identification lights increased the effectiveness of circling guidance.

Determine if runway identification lights, used alone or in conjunction with circling guidance lights, should be recommended as standard.

Provide criteria necessary for the design of runway identification lights.

It was found that runway identification lights did not increase circling guidance effectiveness. Neither runway identification nor circling guidance lights, in any combination, were satisfactory for adoption as an Air Force standard.

REMARKS:

The conclusions are based on the opinions of 12 pilots. Eight of them thought the lights helpful enough to be established as a national standard. No data are reported concerning the familiarity of the participating pilots with the test runway.

REQUIREMENTS:

A satisfactory visual night landing aid system should supply a pilot with visual guidance in the approach to an airfield during the initial penetration and circling approach. The guidance for establishing a traffic pattern entry, downwind, base, and final approach, must be supplied by runway identification lights. In a circling approach, the following are important factors:

Distance from, and direction of the runway so that the downwind leg can be flown to and at the desired distance from the runway.

Location of, and direction of the runway during the turn from the downwind leg to the base leg.

In a survey conducted by the National Bureau of Standards for the Aircraft Accessories Laboratory, Wright Air Development Center, it was determined that:

Pilots desire to locate and identify the airport and the active runway from as great a distance as possible.

The runway lighting system, both medium and high intensity, should be sufficiently visible to pilots from positions off the runway axis when the lights are operated at the clear-weather brightness intensity setting.

Pilots desire more positive means of identifying the runway by means of a distinctive runway lighting system.

Pilots sometimes lose the runway lights as reference when turning onto the downwind or base leg of the traffic pattern.

The downwind corner of the runway should be well marked and identified as the pilot's start of the turn onto the base leg is determined by the position of that corner.

DESCRIPTION:

Circling Guidance Light Units

The unit tested for circling guidance was composed of three standard high-intensity approach lights. This group of lights provided coverage of 180 degrees in the horizontal and 30 degrees in the vertical planes. Seven units were installed at 1000-foot intervals along the south edge of the runway.

Runway Identification Lights

Two types of runway identification lights were used in the flight evaluation. A Pyle National Gyralite Unit was installed on the south corner of the approach end of Runway 27, and a Crouse Hinds Unit was similarly placed on Runway 9.

PROCEDURES:

Flight tests were conducted under VFR conditions to determine the usefulness of the lights in locating the runway on straight-in approaches, in circling approaches, and during ground maneuverings.

Six cargo pilots, three bomber pilots, and three fighter pilots participated in the evaluation flights. Questionnaire responses were used to assess the test lights.

RECOMMENDATIONS:

The report recommmends that neither runway identification nor circling guidance lights, in any combination, be adopted as an Air Force standard. While 8 of 12 pilots reported they would like to see both the runway identification and circling guidance lights as a standard for airfields.

CONCLUSIONS:

Runway identification lights aid pilots in the traffic pattern and indicate the end of the runway.

Runway identification lights assist pilots in locating the active runway.

Runway identification lights should be installed on each corner of a runway, or within 250 feet of the downwind end of the runway. and provide 350-360 degrees of coverage.

The test runway identification lights distracted pilots during ground operations. These adverse effects were diminished by a decrease in the flash rate of the lights.

The Crouse Hinds light was more acceptable as a runway identification light than the Pyle National Gyralite.

The aid provided by the runway circling guidance lights to a pilot in the traffic pattern and in locating the runway when inbound to the airfield was negligible.

Runway identification lights did not increase the effectiveness of circling guidance lights.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: National Bureau of Standards, Photometry and Colorimetry Section
TITLE: An approach-beacon system.

REFERENCE: Washington: Author, 1959. (Report No. 5902.)

SUMMARY:

This report gives the results of service testing at Arcata, California, of turntables of 6 approach beacons placed 1000 and 2000 feet from threshold. Test pilots reported that these units provided useful guidance for straight-in and instrument approaches, as well as circling approaches, in visibilities as low as 1 mile. It was also reported that good approach and runway identification was provided by the beacons.

REMARKS:

The following are included in the report:

Photographs and wiring diagrams of the system.

A section on equipment installation and servicing of the system.

A section on use and operation of approach beacons.

Pilot comments and the conditions on each flight.

REQUIREMENTS:

The pilot needs to identify the active runway from as great a distance as possible, especially under low-sun, twilight, and moderately-restricted dark conditions.

DESCRIPTION: None.

PROCEDURES:

Pilots who flew the system on scheduled flights at Arcata Airport submitted comments. Airline pilots, pilots for private business firms, private pilots, and military pilots took part in the evaluation. Many types of conventional aircraft, but no jet aircraft, were used. The beacons were used in VFR and IFR conditions, under daytime, twilight, and nighttime conditions, and with and without slope-line approach lights.

RECOMMENDATIONS:

The following recommendations were made on the basis of this study:

The approach beacon system should be installed on the approach to any runway where additional visual guidance is needed.

Additional threshold lights should be installed as part of the beacon system whereever threshold information is needed.

CONCLUSIONS:

The approach beacon is an effective and low-cost visual aid for both daytime and nighttime use.

A third beacon installed 3000 feet from threshold can be utilized where earlier guidance on final approach is needed.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Burke, F. J.
TITLE: Preliminary evaluation of the Navy Mirror Landing Approach System.
REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1957. (Identification No. WCLE-56-46, Project No. 60427.)

SUMMARY:

As a potential means for reducing the number of undershoot and overshoot landing accidents, the Air Force tested the Navy Mirror Landing Approach System as an applicable visual angle of approach indicator. The system was found to provide satisfactory indication of the glide slope angle during clear weather and to increase the pilot's capability to make spot landings.

REMARKS:

Data are presented which indicate increased landing accuracy and reduced variability in touch-down point with use of MLS as compared with no angle of approach indicator. However, these data are based on 18 approaches by a single Air Force pilot.

An interesting phenomenon was reported by the transport pilot who participated in the flight evaluation to the extent of four touchdowns. He tended to apply glide slope corrections in the wrong direction, presumably through interference from long practice with ILS instruments. ILS and MLS are similar except that the aircraft symbol moves in MLS, while the glide slope reference moves in ILS. Consequently, the transport pilot's habitual reaction to ILS information tended to interfere with the appropriate reaction to MLS information.

REQUIREMENTS: None.

DESCRIPTION:

The Navy Mirror Landing System (MLS) consists of the following optical components:

Concave mirror assembly 4 feet high and 3 feet wide with a horizontal datum bar for six 100-watt green lamps mounted halfway up each side. Arc of the mirror is that of a circle having a 6-foot radius, and the mirror range is 50 degrees in azimuth creating a glide path beam 1 1/2 degrees wide with a 3-degree glide slope.

A source light assembly of eight 100-watt lamps with amber lights. These lights may be varied in intensity to suit prevailing light conditions. Due to the concavity of the mirror, the source light appears to the pilot as a single light referred to as the "meatball."

PROCEDURES:

A total of 31 landing approaches, by one Air Force and one transport pilot at NAS, Atlantic City, were made utilizing the MLS. These approaches are described in the following chart:

Aircraft	Day		Night	
	wave-off	landing	wave-off	landing
F-86	4	10	1	8
C-131	4	4	0	0

A single day mission was flown with the F-86 to obtain comparative spot landing data without the aid of MLS.

All test landing approaches were made using the Navy recommended flight pattern. Touch-down point data were obtained by line of sight from the left edge of the runway and were considered accurate within plus or minus 25 feet.

The positioning of the mirror defined an ideal touch-down spot, and actual data were compared to this ideal.

RECOMMENDATIONS:

The Mirror Landing Approach System should be subjected to further Air Force evaluation by several different aircraft types. This recommendation was based on pilot comments which indicated the MLS is not hard to fly, and after a few approaches proficiency is greatly increased.

CONCLUSIONS:

MLS provides a satisfactory indication of the glide-slope angle during clear weather.

MLS increases the pilot's capability to make spot landings.

These conclusions were based on data which indicated a trend, through practice, toward more accurate touchdowns. This trend was evidenced only by the Air Force pilot.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Burke, F. J.
TITLE: Flight evaluation of visual approach angle indicators.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1958. (Technical Note 58-181, Project No. 6061.)

SUMMARY:

This report summarizes results obtained in flight evaluation of the WADC Two-Bar System, the Navy Mirror Landing System, two types of Tri-colored Glide Angle Systems, and the British Royal Aircraft Establishment System. Approximately 500 landings were made with a variety of aircraft. Of the several systems evaluated, the WADC Two-Bar System and the Navy Mirror Landing System provided the best approach-angle aid to pilots, although problems still exist in the utilization of these systems with high-performance aircraft.

REMARKS:

Test conditions and resulting strengths and weaknesses of the systems evaluated are presented in detail. Although not all test data are included in the report, the conclusions seem to be well justified.

Some apparent confusion as to requirements desired in the Tri-color Systems should be noted. Sharp definition between on- and off-course color indicators was recorded by the authors as a weakness, as was blending of colors in the marginal area.

There apparently is some disagreement on whether the RAE System tested actually followed British drawings and specifications.

REQUIREMENTS:

The pilot must be given not only displacement from glide path information, but he also must be given an adequate indication of his rate of displacement from the ideal glide path.

DESCRIPTION:

Tri-Color Glide Angle Lights

This system emits a tri-colored light beam such that if the pilot is on the glide path, he sees a green indication. A yellow beam is visible when too high, and a red signal is visible when too low. Two similar types, one manufactured by Westinghouse and the other by the Cook Electric Company, were tested during the program.

WADC Two-Bar System

This system incorporates two bars of light on each side of the runway to impart glide path information. The rear bar is set 11 feet closer to the runway at a predetermined lower level and consists of red lights. The front bar consists of white lights. The pilot's task is to control his aircraft so as to align the bars horizontally.

Navy Mirror Landing System

This system uses a large concave mirror with a horizontal datum bar of green lights mounted halfway up the mirror. Eight amber source lights are placed 150 feet in front of the mirror and are beamed into the mirror. When the pilot is on the glide path, the reflection of the source lights appearing as a single amber source ("meatball") will appear centered with respect to the green datum bars.

Interim Mirror System

This system was originally developed by the Navy when not enough suitable mirrors could be manufactured for use in the Navy Mirror Landing System. The system uses two elevated bars of light as the forward indicator. The light source ("meatball"), composed of four red lights, is placed 100 feet back of the bars and at a lower level. The "meatball" sign is seen by the pilot through a 10-foot gap in the middle of the front sign. The pilot's task is to align the red "meatball" with the bars on each side.

British Royal Aircraft Establishment System

The RAE System used for the test was fabricated by the National Bureau of Standards from British drawings and specifications. This system is composed of two units containing five white lights. With red filters over half of the light, these units give off red and white light beams separated by a narrow pink sector. The pink sector should warn the pilot when he is beginning to pass from one sector to another. The light beams are set so that when the aircraft goes too high, the furthermost bar turns first pink and then white. If the aircraft goes too low, the nearer bar turns first pink and then red.

PROCEDURES:

Fighter, bomber, and transport aircraft were used in the evaluation. A flight test engineer maintained contact with the test aircraft by radio. Pilot comments were obtained in this manner. A rectangular traffic pattern was used for all aircraft flying the test system.

Two pilots were assigned to each type of aircraft. Touch and go landings were authorized for all aircraft except the F-100.

RECOMMENDATIONS:

It was recommended that where the requirement exists for visual approach aid to pilots of transport aircraft, the Two-Bar System should be installed. This was based on the general test results, economic considerations. and a study of aircraft performance characteristics.

CONCLUSIONS:

The following conclusions are drawn from the test results:

No simple, single visual angle of approach indicator can provide pilots of all Air Force aircraft with adequate visual information for judging approaches easily and accurately. This is because of the differences in the performance and landing characteristics of various types of aircraft.

The Two-Bar System and the Navy Mirror Landing System provide the best visual glide path presentation and the most aid to pilots.

Pilots of transport aircraft such as the C-124 and the C-131 derive aid from the visual approach angle indicators tested to a greater extent than do pilots of military aircraft.

The WADC Two-Bar System is more desirable than others tested for use with transport-type aircraft on the basis of economic considerations.

None of the systems tested were entirely satisfactory for use with high performance aircraft because of their approach and landing characteristics.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Cumming, R. W., & Lane, J. C.
TITLE: Pilot notes on the double bar ground aid for visual approaches at night.
REFERENCE: Melbourne, Australia: Aeronautical Research Laboratories, 1957. (Human Engineering Technical Memorandum 2.)

SUMMARY:

A double bar ground aid for visual approaches at night is described and theoretically evaluated.

REMARKS:

Operational tests were made on the system, but no statistical results or descriptions are included. Field experiments are referred to which have shown that the use of this visual aid reduces oscillations of the glide path as compared with approaches using runway lights alone.

A diagram showing the appearance of the system under different angles of approach, as well as notes for pilots on the use of the aid, are included in the report.

REQUIREMENTS:

The double bar ground aid is based on information requirements defined in previous work by the authors. Primarily, it is designed to provide angle of approach information; and secondly, to provide a horizontal reference and rate of approach.

DESCRIPTION: None.

PROCEDURES: None.

RECOMMENDATIONS: None.

CONCLUSIONS:

The aid as described is designed for night approaches and clear visibility conditions which constitute the majority of night operations in Australia.

Elevation relative to the required glide path is shown by alignment or misalignment of the white and amber bars. Rate of approach is shown by the relative vertical movement of the two bars. In addition to providing glide path information, the bars form a valuable horizontal reference which is not often available on dark nights and which is essential for accurate tracking in azimuth.

In order to warn against the dangerously low approach, two "undershoot warning lights" are arranged on each side of the runway strip 600 feet from a threshold. These lights are high-intensity red flashing to give prominence, and placed so that they are only visible below a 1.9 degree elevation.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Day, R. H., & Baxter, J. R.
TITLE: A comparison of two types of visual approach aid.

REFERENCE: Melbourne, Australia: Department of Supply, Aeronautical Research Laboratories, Research and Development Branch, 1959. (Human Engineering Note 4.)

SUMMARY:

Flight tests were conducted under operational conditions to compare effectiveness of two principles of providing glide-path guidance represented by the Australian Precision Visual Glidepath and the British Angle of Approach Indicator. P. V. G. defines a safe glide path by the alignment of bars of light. A. A. I. defines a safe path by a specific combination of colored lights on the ground.

Results indicated moderate pilot preference for the P. V. G. but no differences in flight path traces were objectively recorded by a Theodolite.

REMARKS:

Plan and perspective views of both systems are included. Glide path traces of the test flights on both systems are plotted in terms of altitude and range to threshold.

REQUIREMENTS: None.

DESCRIPTION:

R. A. E. Two-Color System

This system is composed of two transverse bars of amber lights located on each side of the runway, 500 and 1500 feet from threshold. Each bar consists of 3 units which project a controlled beam of light. The upper half of each beam is white, the lower half, red. When the pilot is near the glide path, the nearer bar looks white, the furthermost bar, red. When the pilot is too high, both bars appear white, and when he is too low, both bars appear red. A pink sector is visible when the pilot begins to pass from one sector to another.

Precision Visual Glidepath

This system is composed of two transverse bars of light located 400 and 900 feet beyond the threshold on each side of the runway. The farther bars consist of five clear flush lights; the nearer bars consist of three amber lights elevated 25 feet above runway level. A clear retractable light located in the center of the runway 900 feet from threshold provides an aiming point. When the pilot is on the proper 2 3/4-degree glide slope, the amber and white bars form a continuous line. When the aircraft is above this slope, the white bars appear to rise above the amber bars and when the aircraft is below the path, the white bars appear to drop below the amber bar. Below a 1.9-degree glide slope, red flashing warning lights are visible to the pilot.

PROCEDURES:

Twelve experienced (7000-12,000 hours) airline captains participated in the test. They were given an orientation to the purpose and conditions of the experiment, provided with instruction in the use of each system, and were shown the actual test installation. Throughout the test procedures, the two systems were labeled and referred to as the "Red-White" (A. A. I.) and "Amber" (P. V. G.) systems.

Each pilot made three successive approaches with a DC-3 test aircraft. The three approaches consisted of:

A familiarization approach from 6 miles.
A circling approach from a base leg at 1000 feet altitude and 4 miles from threshold.
A straight-in approach from 7 miles and 1500 feet.

During the last two approaches, flight profiles were recorded by a Theodolite.

At the conclusion of each flight test, pilots were de-briefed through the use of a prepared questionnaire.

RECOMMENDATIONS: None.

CONCLUSIONS:

The small number of pilots tested limits the conclusions to tentative statements of trends. Of the 12 participating pilots, however, 9 preferred the Australian P. V. G. Of the 157 answers received on relative advantages or shortcomings of the systems, 63 favored the Australian P. V. G., 24 favored the R. A. E. Indicator, 53 favored both equally, and 17 stated that neither aid was useful.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Kevern, G. M.
TITLE: Airport lighting and marking.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1957. (Progress Report, Project No. 6061.)

SUMMARY:

The report consolidates the results of project work at WADC on the development of ground-based visual aids such as lights and markers for navigation, approach, landing, and general operations.

REMARKS: None.

REQUIREMENTS: None.

DESCRIPTION: None.

PROCEDURES: None.

RECOMMENDATIONS:

On the basis of the results of previous tests, it was recommended that additional studies be initiated to accomplish the following objectives:

Develop flush-type marker lights for installation in the pavement of runways, taxiways, and overrun areas. The following developments on this project were reported:

Westinghouse has completed development of a shallow-dome flush runway light. Tests of these lights will be included in the two-year approach and runway light test program being initiated by SAC at Dow Air Force Base.

An "expendable top" flush runway light, developed by the AGA Division of Elastic Stop Nut Corporation of America, will be included in the two-year test program at Dow Air Force Base.

Preliminary laboratory and snow plow tests at WADC indicate that another type of shallow-dome flush runway light developed by Multi Electric Manufacturing, Inc. may be more satisfactory for Air Force use than the Westinghouse light.

NACA has completed the scheduled dynamic tests to determine effects on aircraft gear striking different types of flush lights at high speed.

Because flush lights have a poor off-runway light distribution, identification lights will be required on runways equipped with flush lights so pilots can readily locate and identify the runway on circling approaches.

Determine deficiencies in existing systems resulting from the operational requirements of new aircraft, and overcome these deficiencies. The following developments on this project were reported:

NBS has recommended the addition of identification and circling guidance lights.

A study and development program by NBS includes a study of all visual landing aids required by aircraft during approach, landing, takeoff, taxiing, and high-speed ground maneuvering from a distance of 100 miles from the airport until the aircraft has reached the parking area.

Develop a completely new system of visual taxi aids to facilitate the ground movement of aircraft and expeditious clearance of runways and taxiways. The following developments on this project were reported:

Laboratory tests on sample electroluminescent panels from two manufacturers indicated they were inferior to externally lighted signs as taxiway guidance indicators.

Procurement of centerline taxiway lights has been approved in order to make a service test installation of a centerline taxiway lighting system.

Develop approach lighting which will indicate to the pilot his position relative to the proper glide path. The following developments on this project were reported:

A study of new light sources, color filters, reflectors, and lenses to determine optimum approach light design revealed that the optimum units are the ones already in use.

Flight test aircraft at Atlantic City NAS evaluated the Navy Mirror Landing System. Suitability of the Mirror System for use with Air Force aircraft and landing techniques appeared questionable. Preliminary flight tests have been made of three color glide angle lights, and on two different lighted "bar" systems designed to provide the pilot the same guidance as would be obtained from the Mirror System.

Develop a brightness control which will permit airfield lights in the same circuit to be operated at the optimum brightness required for each specific light. The following developments on this project were reported:

A brightness control system has been developed which consists of a method of connecting special lamps to standard series transformers and regulators. It requires extra regulator capacity and tends to become unstable if more than 10% of the runway lights burn out.

A new 1200-watt, 115-volt lamp was developed for use in existing airport beacon lights which resulted in sufficient vertical coverage to adequately meet requirements.

A task to provide design criteria for a runway capable of maintaining landing and take-off operations at the rate of two aircraft per minute was terminated with no significant accomplishments.

CONCLUSIONS: None.

SELECTED ADDITIONAL REFERENCES

AA6. Cumming, R. W. Precision visual glidepath. Paper presented at Flight Safety Foundation 11th Annual International Air Safety Seminar, Atlantic City, New Jersey, November 9-13, 1958.

AA7. Meatball and paddles. Approach, June, 1958, 3, (12), 4-9.

AA8. Mirror landing system. Approach, April, 1957, 2 (10).

AA9. Pennow, W. A. Advances in airport lighting. Electrical Engineering, June, 1946, 65 (6), 259-265.

AA10. Pilot notes on the precision glidepath. Commonwealth of Australia: Department of Civil Aviation, August, 1958. (Publication No. 37.)

AA11. POMOLA is here. Approach, 1958, 3 (10), 5-8.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: ANC Landing Aids Experiment Station.
TITLE: Final Reports 1949.

REFERENCE: Washington: Civil Aeronautics Administration, Office of Aviation Information, 1949.

SUMMARY:

This report covers test operations at LAES primarily during 1949, but also a great deal of the work performed earlier. The report is divided into five sections: Flight Operations, Meteorology, Electronics, Airfield Lighting, and Fog Dispersal. Within the Airfield Lighting section, results are presented of the 1949 evaluation series on various 3000-foot approach-light systems, overrun configurations, threshold-marker lights, runway-marker lights, runway-surface markings, and taxiway-marker lights. Conclusions and recommendations in each of these areas are presented.

REMARKS:

The material in this report yields a fairly comprehensive summary of the state-of-the-art in 1950. The material of interest to airport design engineers and marking and lighting researchers is so voluminous that it defies all but the most general annotation within reasonable space. The report is complete, including graphs of results, cost analyses, references, photographs and illustrations, installation and maintenance procedures, and pilot comments.

The reader is advised to read also the 1947 and 1948 Progress Reports on previous work done at Arcata.

REQUIREMENTS:

Classes of requirements specified and discussed were:

- Visual guidance
- Visual conditions
- Aircraft characteristics
- Airport lighting characteristics
- Material and operating cost comparisons.

DESCRIPTION:

3000-Foot Approach Lighting Configurations

- Slopeline with transverse bars
- Interrupted-sequence-flashing light system
- Royal Aircraft Establishment system (Calvert)
- Air Line Pilots Association system (centerline)

Overrun Configurations

- OVL - vertical "L" fixtures
- OHL - horizontal "L" fixtures
- FWB - fixed-wide-beam

Threshold Marker Lights

- Clear threshold bar
- Green threshold bar
- Green threshold bar and end zone marking with red pre-threshold warning
- Green fixed-wide-beam threshold
- Neon-bar threshold

Runway Marker Lights

Fixed-wide-beam

Runway surface markings

Longitudinal white stripes

Runway number

Transverse bars

Taxiway Marker Lights

Gaseous-tube

PROCEDURES:

Low ceiling and visibility flight test approaches (394 flights, most of them in conditions below 500 feet and 1/4 mile). Objective and subjective measures utilized. Criteria included: distance and elevation from threshold at first sight, distance travelled from first sight to pilot contact, distance from threshold at point of pilot contact, length of string carried, aircraft location at pilot contact, approach adequacy vs. ceiling and visibility, and adequacy of guidance. CAA, commercial, and military pilots utilized; varying aircraft used.

RECOMMENDATIONS:

Approach Light Systems

More testing recommended on RAE and ALPA.

Transverse bars to be used with slopeline.

Threshold Lights

Red pre-threshold

Green threshold

More testing on remaining component systems.

CONCLUSIONS:

Selected highlights:

Elevation guidance with RAE and ALPA reported inadequate.

Change in configuration in last 1000 feet (overrun area) weakens effectiveness.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR:
TITLE: Final report on operational suitability tests of airfield approach lighting configurations.
REFERENCE: March Air Force Base, California: Director of Safety, Headquarters Fifteenth Air Force, 1957.

SUMMARY:

An operational suitability test of four approach lighting configurations to facilitate landings on high performance aircraft under instrument conditions was conducted. The criteria for evaluating the approach configurations were pilot preference and adaptability to different types of aircraft. It was generally concluded that the centerline system with stroboscopic flashes was the most acceptable of the four systems tested.

REMARKS:

The report presents "typical" pilot comments. There is no detailed breakdown by aircraft, visibility, or other test condition, and no quantitative summary of the opinions gathered as evidence on which the recommendations and conclusions are based.

REQUIREMENTS:

Pilots should be provided adequate visual reference especially at night or during low visibility conditions to assist them in becoming orientated with the runway during the final approach phase of the landing pattern.

Approach lights should be quickly and easily interpretable and should require a minimum of interpretative decisions.

DESCRIPTION:

Four approach configurations, A, B, C, and D were tested at March AFB. System A consisted of a centerline of light bars. Configuration D was an extended runway edge lighting system with roll bars intersecting each row of extended edge lights. Systems B and C were combinations of centerline and extended edge lighting. Specifically, Configuration C totally merged the centerline and extended edge systems. Configuration B included the centerline and just the roll bars of System D.

PROCEDURES:

Pilots were interrogated via radio immediately following each approach and were requested to submit a general evaluation of the adequacy of each system in providing required guidance after completion of a block of approaches. Additional information gathered from group interrogation after each mission was used in the final evaluation.

Pilots of various Air Force commands and experience took part in the test. They were briefed prior to flight, but not told which configuration was to be tested on that flight. The 395 approaches are classified according to aircraft type, air command, number of approaches, and visibility conditions in the following table:

Summary of Flight Test Conditions

Air Commands	Aircraft Types	Number of Approaches	Slant Range Visibility*	General Description
TAC	F-100D	24	1 1/2 mi.	haze, evening, twilight
ADC	F-86 F-102	25	1-3 mi.	daylight, haze, twilight and/or night conditions
ADC	F-86 F-102	26	VFR	daylight, haze, twilight and/or night conditions
U.S. Navy	F-4D	28	3/4- 1 1/2 mi.	evening, twilight, and night
U.S. Navy	F-3D A-5D S2-F1	67	3/4- 2 1/2 mi.	evening, twilight, and night
MATS	C-97	14	1 mi.	daylight, twilight, haze, and night fog
APGC	B-47 B-57 KC-97E	45	1/2- 3 mi.	daylight. twilight, and night
USAF Acad.	T-29	19	200 ft.- 1 mi.	daylight, haze, twilight, and night fog
CAC, ATC, AUC	T-33	60	1 1/2 mi.	daylight, haze, twilight, and night fog
SAC	B-52 B-47 KC-97 C-97 T-33 B-25 C-47	50	1/2-3 mi.	

* minimums reported.

RECOMMENDATIONS:

Configuration A, with the addition of stroboscopic flashers for the entire system and flush light units within the 1000-foot underrun area, be adopted as standard for Air Force installations.

Present semi-flush threshold lights be replaced with Elfaka flush lights utilizing green filters to provide a positive threshold.

Minimum runway marking, for other than instrument runway, consist of flush termination bar, elevated red wing bars, and flush threshold bars of Configuration A.

Installation of one narrow-gauge runway lighting system be expedited to allow complete evaluation of integrated visual aids for landing.

Extended red edge lights, as installed at March AFB, be deactivated, and ground fixtures removed to delete unnecessary obstacles protruding into the overrun area.

CONCLUSIONS:

A requirement exists for the addition of flush green threshold lights to mark the end of the runway. Present threshold lights are not as predominant as the approach lights, and they are difficult to distinguish.

The centerline system has the confidence of the pilot as it considerably reduces the mental hazard of minimum weather approaches.

The centerline lights have a tendency to prevent the pilot from landing short of the runway.

It was noted that strobeacon light could be seen at a distance of approximately three times that of the reported visibility. With reported visibility of 1 mile, strobeacon normally was sighted at 3 miles.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Garbell, M. A.
TITLE: Recent developments in visual low-approach and landing aids for aircraft.
REFERENCE: San Francisco: Garbell Research Foundation, 1951. (Aeronautical Series No. 1.)

SUMMARY:

In this paper the author reviews his objectives and findings at LAES from July 1, 1948 to October 1, 1949 as consultant in charge of testing. A brief summary of the testing methods employed in the flight tests is presented in the first section. Factual conclusions are advanced in the second section. The third section deals with methods of meteorological instrumentation and application.

REMARKS:

The report contains a more concise review of test procedures used at LAES than does the Landing Aids Experiment Station Final Reports, 1949.

REQUIREMENTS:

The principal elements of pilot information are identification and guidance.

The concept of "identification" in an airport lighting and marking system is understood to include both the selective distinction of a given instrument-approach zone or runway from the respective surroundings, and an indication of the location, general direction, and sense of orientation of the runway axis.

The concept of "guidance" in an airport lighting and marking system is understood to include the information required by the pilot to visualize the location and direction of motion of the aircraft at any given point of the approach with respect to the runway upon which landing is intended.

Referring to the examples of either a fog or a uniform ground surface lacking in adequate reference features ("texture", protrusions of known height, a horizon, etc.), the guidance elements expected from the artificial visual aids would include the three "location" coordinates:

X - <u>longitudinal distance</u> from the runway threshold.

Y - <u>transverse distance</u> from the vertical plane through the runway axis.

Z - <u>elevation</u> with respect to the ground or to an ideal glide plane, together with an indication of two "directional" guidance elements:

The <u>direction of motion</u> of the aircraft in a horizontal plane.

The <u>attitude in bank</u> (roll) of the aircraft.

The sixth degree of freedom of the aircraft, viz., the <u>angle of pitch</u>, should not be defined through visual guidance with reference to the horizontal ground plane, inasmuch as the angle of pitch is strictly a matter of aerodynamic, not geometric, orientation. The true indicated air speed, flap setting, and power setting of the aircraft should be fully stabilized in the early stage of an instrument approach, long before transition to visual flight. Even in clear-weather approaches, the experienced pilot refers to the airspeed indicator, not to the ground plane, for his pitch guidance.

The five visual guidance elements are all part of the one essential guidance vector, namely, that of three-dimensional location and direction guidance.

Hence, their respective functions are closely interrelated; thus, for example, while good Z and Y guidance are indispensable (yet not, in themselves, sufficient) for effective directional guidance, roll guidance is equally an essential element in supplying directional guidance, relative both to the actual, current motion of the aircraft and to any anticipated changes. The closely knit interrelation between the five guidance elements makes any attempted listing of guidance "priorities" virtually meaningless, unless it is desired that some of the guidance elements be obtained from airport visual aids and others from flight instruments, a procedure ("on-and-off-instruments") that has, in numerous instances, led to disaster.

DESCRIPTION:

The following are the various systems evaluated:

3000-foot approach light system
Overrun configurations
Threshold-marker lights
Runway surface markings
Runway marker lights
Taxiway marker lights.

PROCEDURES:

Each evaluation approach was recorded via objective data (radarscope flight paths), and subjective comments.

Reliability of this method of evaluation was considered to be corroborated by the excellent correlation of the objectively recorded data (adherence of the aircraft to ideal glide path with minimum of sharp maneuvering), factual observation of lengths of strings of lights carried, etc., with comments expressed by pilot and copilot at the time of each approach.

It is worth noting that comments expressed by the test pilots after the completion of an entire flight test period, and the opinions of the flight observers, even though they too might be qualified and experienced instrument pilots themselves, do not exhibit any significant correlation either with the objective trajectory record or with each other.

CONCLUSIONS:

Approach Systems

In the opinion of the author, the two most effective approach-light systems, the Slopeline System and the Calvert Transverse-Bar System, are "competitive" in but one respect and complementary in all others.

The "competitive" element is manifested by the preference of some pilots toward flying "down a centerline of lights", and that of other pilots toward flying "down a dark lane", with an alignment of lights along either flank of the lane.

In every other respect, it appears that the highly effective elevation, transverse and direction guidance afforded by the Slopeline System should be supplemented with the excellent bank guidance provided by the Calvert System, and that an X-wise guidance element be supplied comparable in effectiveness at least to that of the Calvert System.

In order to provide optimal over-all guidance with minimal interpretative effort on the part of the pilot, the author independently conceived and developed an approach-light configuration. He feels that the horizon bars in his configuration afford excellent roll guidance and, hence, improved directional guidance. He also feels that transverse location of the horizon bars with respect to the two slope-line rows--with the 2000-foot bars contained entirely within the slope-line rows, the 1000-foot bars straddling the slope-line rows, and the runway-threshold bars placed entirely outside the slope-line rows, thereby forming a characteristic "gate" at the runway threshold--affords instantaneous distance guidance without any need for numerical counting of coded lights as used in other systems.

Runway Marker Lights and Runway Surface Markings

Day vs. Night

The relative effectiveness of runway-marker lights appears to be affected profoundly by the prevailing general brightness of the fog background as well as that of the foreground, to a still greater extent than that of the approach lights.

At night the distance at which runway-marker lights are first seen and identified by pilots during an approach was reported as equal to the horizontal meteorological visibility distance of a 25-candlepower light. This was accounted for by the appreciable increase in effective brightness-threshold values of pilots. Brightness threshold values were thought to be higher because of the relatively high foreground brightness resulting from the pilot's close proximity to the approach lights over the terminal portion of the approach-light system.

In daylight the visual range of all runway-marker lights tested at LAES was reduced to the order of magnitude of the "contrast visibility" on the runway; that is, somewhat greater than the meteorological "daylight object visibility" reported by the meteorologist. Pilot's comments reportedly substantiated this conclusion.

It was deduced that in dense daylight fog (with high prevailing brightness and meteorological visibility less than 1/4 mile), lights with runway markings are more effective than runway-marker lights alone, both in visual range and in directional guidance.

<u>Fixed Wide-Beam Lights vs. Adjustable Narrow-Beam Lights</u>

Visual Range

At night, the effectiveness of the two types of lights was substantially the same. The lights were first seen at approximately the same distances, and the respective strings of runway-marker lights "carried" were approximately of equal length.

In daylight, the fixed wide-beam lights appeared to be consistently visible at a greater distance than the adjustable narrow-beam lights.

Directional Guidance

The reports on the length of the strings of lights "carried" appeared also to favor the fixed wide-beam lights. In addition, it was reported that the uniformity of two strings of fixed wide-beam lights afforded more effective directional guidance than that provided by the more spotty-appearing sequence of the adjustable narrow-beam lights.

Elevation Guidance

At LAES and elsewhere, the comments of pilots were reported as explicit and specific in deploring the inadequate direction and elevation guidance provided by runway-marker lights alone. A configuration of highly reflective runway surface markings with easily recognizable texture was recommended to fill this need.

Taxiway-Marker Lights

The author taxied over most of the systems in restricted visibility and tested them on the RAE Cyclorama. He reported that the requirement for clear and unequivocal indication of the desired taxiing path, especially following curves and across wide intersections, was being currently met by the flush centerline lights only.

Meteorological Instrumentation for Use With Visual Low-Approach and Landing Aids

The proposed instrumentation for a completely automatic system of operational weather reporting during the summer of 1948 included a short-base rapid-scan ceilometer, a horizontal transmissometer, a prevailing brightness meter in the approach zone, and a combined transmissometer/brightness meter in the touchdown zone of the runway.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Hoffman, C. S.
TITLE: New approach and runway lighting system.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1957. (Identification No. WCLE 57-5, Project No. 6061-60423.)

SUMMARY:

The adoption of an adequate standardized approach lighting configuration has been complicated by the conflicting requirements of the Air Force, Navy, ALPA, and CAA. This report summarizes the effectiveness of the approach lighting systems installed at March Air Force Base, California, and the runway lighting systems tested at Andrews Air Force Base, Maryland, as solutions to the standardization problem. It was concluded that not enough flights under poor visibility conditions were made at Andrews or March to warrant a recommendation that either be used as a standard.

REMARKS: None.

REQUIREMENTS: None.

DESCRIPTION:

Summary descriptions of the centerline approach system, floodlighting, and narrow-gauge runway systems are presented.

PROCEDURES: None.

RECOMMENDATIONS: None.

CONCLUSIONS:

The following conclusions were made on the basis of test results at March and Andrews:

Strobeacon units are good "attention getters" which assist pilots in locating the approach lighting; however, they are likely to cause glare to the pilot in later stages of the approach.

The light output of Elfaka units was satisfactory for aircraft on the final approach, but it needs to be tested under winter conditions.

Runway edge floodlighting is not necessary when aircraft landing lights are used, except in low visibility fog conditions when landing lights do not penetrate the fog.

Insufficient approaches were made with the narrow-gauge runway system at Andrews to determine their merit, although the system shows promise of eliminating the "black hole."

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR:
TITLE: Joint USN-USAF comparative operational suitability test to determine a standard airfield approach lighting configuration.
REFERENCE: Eglin Air Force Base, Florida: Air Proving Ground Command, 1955. (Project No. APG/CSC/800-A.)

SUMMARY:

This report describes evaluations of several variations in airfield approach lighting patterns which included the requirements agreed upon by the Joint U. S. Navy-U. S. Air Force Ad Hoc Committee on Airfield Approach Lighting. Three patterns were judged suitable by pilots of various types of aircraft and the simplest of these was selected for consideration as a standard military system.

REMARKS:

Specific details of the test installation and maintenance, including economic considerations, are included in the report.

REQUIREMENTS:

Pilots should be provided with a visual reference which will assist them to orient, vertically and horizontally, with the runway during the final approach phase of the landing pattern.

DESCRIPTION:

Sixteen approach configurations were constructed for operational tests at McGuire Air Force Base, New Jersey. The general shape of these configurations is described by sketches in the report. In general, the test configurations represented variations in the basic extended runway edge lighting approach system.

PROCEDURES:

Pilot opinion was the basic measure used to evaluate the systems. Pilot comments were collected by means of tape recordings of communications between the pilot and the ground controller. Additional information was collected through questionnaires which pilots completed after every test landing.

Responses were subjected to statistical treatment, with a requirement for a confidence level at or above 95% as a basis for decision as to the desirability of any feature. In analysis, the data were checked to determine differences of opinion between fighter and other pilots, and between pilots who made visual approaches and those who made instrument approaches.

The test installation was operated during hours of darkness when the instrument runway was the active runway. In addition, it was operated during daylight periods of reduced visibility.

Reports on 666 approaches by Air Force and Navy aircraft made under varying visibility conditions were received and evaluated. A total of 81 instrument approaches were made under ceiling conditions as low as 200 feet and visibility of 1/4 mile.

Pilots were urged to make repeated approaches over the systems in order to permit comparison of two or more approach light arrangements. Where repeated approaches were made, the approach light operator changed the light arrangement to permit the pilot to form an opinion concerning the desirability of some major feature, e.g., a system with crossbars compared to the same system without them.

RECOMMENDATIONS:

While test approach Configuration M was found operationally suitable as a military standard, final selection should be withheld pending results of additional Navy tests.

CONCLUSIONS:

Three of the 16 patterns are rated as good or excellent by 95% of the test pilots. Repeated comparisons of the three failed to establish a significant preference, so the selection of test Configuration M was made on the basis of economy of installation, power, and maintenance considerations. Approach System M consists of a single right row, a double left row, four pairs of crossbars outboard of the rows, and three pairs of crossbars intersecting each row.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Naval Air Test Center.
TITLE: Installation and evaluation of the Navy Composite Approach Lighting System.
REFERENCE: Patuxent River, Maryland: Author, 1954. (Report No. 2, Project No. PTR AE 10007.1.)

SUMMARY:

Effectiveness of guidance provided by the Navy Composite System as compared to the slope-line system and others in general use was investigated. Evaluation flights during both good and poor visibility conditions indicated that this system afforded optimum guidance for all types of Navy aircraft. It was recommended for adoption as a Navy approach lighting standard.

REMARKS:

No statistical techniques are reported.

Pilot comments evaluating the system are included.

REQUIREMENTS: None.

DESCRIPTION:

Slope-line units were combined with centerline and cross-bar units. A plan view is presented in the report, as well as low visibility photographs.

PROCEDURES:

Control tower personnel recorded flight data. Pilot comments and additional questionnaires filled out by station operators were used.

Ceiling conditions from zero to unlimited, and visibility conditions from 1/16-15 miles were the observed flight conditions.

Twenty-five scheduled flights were made on the lighting system; control tower personnel were requested to record data from other flights utilizing the system. Several discussions were arranged at squadron pilot's meetings to familiarize them with the Composite Approach Light System so that the various guidance features would be more readily discernible.

RECOMMENDATIONS:

The Composite Approach Lighting System was recommended for use at Naval installations.

Test results indicate that the Composite Approach Lighting System is an improvement over the present Navy standard slope-line system and is satisfactory for use by all types of Naval aircraft.

An evaluation of existing high-intensity flush-type runway lights was suggested. The use of portable runway lights was recommended as an interim measure.

Satisfactory flush-type runway lights were considered necessary to accomplish the change over from approach to runway light guidance.

CONCLUSIONS:

The omission of any of the guidance features of the Composite System, although these features are not necessary in all instances, was not considered advisable.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR:
TITLE: Operational suitability test of Joint USAF-CAA overrun and approach lighting.
REFERENCE: Eglin Air Force Base, Florida: Air Proving Ground Command, 1956. (Final Report, Project No. APG/CSC/994-A.)

SUMMARY:

Three approach lighting systems were selected for operational flight test by a Joint USAF-CAA Ad Hoc Committee on Underrun, Overrun, and Approach Lighting. Configuration X, a red centerline system in combination with extended edge lighting in the final 1000 feet, was considered to be the best system for all types of aircraft.

REMARKS:

Tables showing a breakdown of pilot preference for approach configurations as a function of aircraft type, approaches on which pilots reported confusion, and point of disappearance of lights from pilots view are presented.

REQUIREMENTS:

Pilots need a visual reference at night or during low visibility conditions which will assist them in becoming oriented, both vertically and horizontally, with the runway during the final approach phase of the landing.

DESCRIPTION:

Configuration X was composed of two approach systems. Configuration A was the basic centerline approach system and Configuration B was the same as X, but with the overrun area (the area bounded by the 1000-foot bar, the threshold bar, and the extended runway edges) clear of lights.

PROCEDURES:

The test was conducted at McGhee-Tyson Airport, Knoxville, Tennessee. All approaches were made under night VFR conditions. Instrument approach assistance by GCA, ILAS, or ASR/PPI was utilized on 95% of the approaches in order to simulate as nearly as possible an actual instrument letdown and approach path. The remaining approaches were made using visual references.

Pilots made a minimum of three approaches per test flight. In order to get an immediate comparison, pilots were interrogated via radio immediately following each approach. After completion of a block of three approaches or a series of blocks, pilots were requested to state their first and second choice as to configuration, and their comments on each configuration were solicited.

RECOMMENDATIONS:

The report recommended that Configuration X be considered as the most desirable approach lighting configuration for Joint USAF-CAA airfields.

CONCLUSIONS:

All three configurations tested are deemed acceptable as approach lighting systems. Configuration A, using red centerline lights, is considered suitable for all aircraft, except possibly the RF-84F and F-94C for which it is considered marginal.

Limited testing using white centerline lights indicated glare and reflection are more prevalent for white centerline lights than red.

Additional comments from pilots indicate that the white lights made the transition from instrument to visual and back to instrument more difficult than the red lights.

The inboard threshold lighting used on Configuration A is slightly more desirable than the outboard threshold lights used on Configuration B.

These conclusions are based on general pilot opinions and comments.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Pearson, H. J. C.
TITLE: Modifications of the slope line approach light system.

REFERENCE: Indianapolis: Civil Aeronautics Administration, Technical Development and Evaluation Center, 1952. (Report No. 167.)

SUMMARY:

This report describes the results of certain modifications in the design and arrangement of the basic slope-line approach system. The purpose of these modifications was to improve lateral coverage, provide more effective lead-in guidance, reduce glare, improve roll guidance and threshold marking, and provide distance marking.

Service testing demonstrated that with the modifications, effective distance marking was provided, and that material improvement was achieved in lateral coverage, lead-in guidance, roll guidance, and threshold marking. Reduction in glare was indicated, but had not yet been completely substantiated.

REMARKS:

Some excellent diagrams on beam coverage of approach lights are included.

REQUIREMENTS:

See the study by Pearson (1950) for a detailed presentation of operational requirements for approach lights.

DESCRIPTION:

The modifications included changes in horizontal and vertical settings of the lamps, changes in the lamp wattage, the addition of horizontal bars, and changes in the threshold light pattern.

PROCEDURES:

Observation and service flights were made with the modified system, and pilot comments solicited.

RECOMMENDATIONS: None.

CONCLUSIONS:

Each of the modifications was judged to make the system more satisfactory than the unmodified system, and thus was recommended for implementation. A problem of threshold light glare was identified and it was recommended that a research and development program be initiated to solve the problem.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Warren, R. E., & Pearson, H. J. C.
TITLE: 30-degree modified slope-line approach-light system.

REFERENCE: Indianapolis: Civil Aeronautics Administration, Technical Development and Evaluation Center, 1951. (Report No. 137.)

SUMMARY:

This report presents the results of an analytic evaluation to determine the feasibility of widening the spacing between pairs of slope-line lights. A field installation was constructed in which the bars at the inner end of the approach path were set at 30 degrees instead of a 45-degree angle with respect to the ground plane, while the bars of the outer portion were left at 45 degrees. In general, the sensitivity of the guidance furnished by the 30-degree bars was found to be less sharp than that furnished by the 45-degree pattern.

REMARKS:

Day and night photographs of the system are included, as well as the pilot's view of the lights from different positions in the approach zone.

REQUIREMENTS:

The regular slope-line (45-degree angle) units were considered to be an underrun hazard to some type of aircraft traffic. The 30-degree angle mountings provide added clearance at the approach end of the runway and therefore represent a reduced underrun hazard.

DESCRIPTION:

The standard slope-line approach system was modified by placing at a 30-degree, rather than a 45-degree, angle the light units on the 1000 feet of nearest threshold and increasing the separation between rows of this inner section to 150 feet.

PROCEDURES:

The system was evaluated analytically with the result that horizontal guidance was found substantially reduced. Flight tests at Arcata confirmed the analytic study.

RECOMMENDATIONS: None.

CONCLUSIONS:

It is concluded that the guidance disadvantages inherent in the split system outweigh any advantages it contains as a less hazardous underrun area.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Pearson, H. J. C.
TITLE: Test of airway beacons as approach-angle indicators.

REFERENCE: Indianapolis: Civil Aeronautics Administration, Technical Development and Evaluation Center, 1955. (Report No. 264.)

SUMMARY:

A pair of airway beacons, which are equipped with red and green filters, was mounted side by side at Weir Cook Airport. The zone covered in common by their beams was checked to determine whether the area where the colors balanced to produce white light was usable to provide angular guidance toward the beacons. Results indicated that the beacons do not produce a pattern usable for that purpose.

REMARKS:

Observations were made from aircraft in horizontal flight for 10 miles and toward the beacons. The observers visually determined:

Whether the adjacent light sources appeared to merge.

What color the merged light appeared to the observer.

Whether the area of color balance produced a zone from which the lights would appear white.

Whether the zone formed a sufficiently narrow and clearly-defined path to be useful as a guiding means.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: National Bureau of Standards, Photometry and Colorimetry Section.
TITLE: Photometric tests of 21 colored retroreflective samples.

REFERENCE: Washington: Author, 1955. (Report No. 4343, Project No. 0201-20-2301.)

SUMMARY:

This report gives the results of photometric tests made of 21 samples of colored (red, amber, green, and blue) retroreflective devices or materials produced by four manufacturers. These might have possible use in runway markers. The following manufacturers materials were tested: Stimsonite, Scotchlite, Reflexite, and Cataphote. No conclusive results were reported.

REMARKS:

Much numerical data are included as are graphs indicating specific intensity per square inch as a function of angle of divergence.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: National Bureau of Standards, Photometry and Colorimetry
TITLE: Photometric tests of 36 retroreflective samples. /Section.

REFERENCE: Washington: Author, 1954. (Report No. 3789, Project No. 0201-20-2301.)

SUMMARY:

This report gives the results of photometric tests made on samples of retroreflective devices or materials from several manufacturers. All but two samples included were colorless; the retroreflected light of these was colorless. No conclusive results were reported.

The materials tested were from the following manufacturers: Stimsonite, Scotchlite, Reflexite, Cataphote, Persons-Majestic, Gortelite, and Prismo.

REMARKS:

Much numerical data are included, as are graphs indicating specific intensity per square inch as a function of angle of divergence.

All samples were tested on the 750-foot photometric range at the Bureau of Standards by visually matching the apparent intensity of the reflector with that of a calibrated comparison lamp.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Moynihan, L. J.
TITLE: Runway marking tests report.

REFERENCE: Salem, Massachusetts: Sylvania Electric Products, Inc., January 22, 1958.

SUMMARY:

This article describes tests that have been made to determine the best method of marking runway surfaces in conjunction with fluorescent strip lighting. The tests were to determine:

The best reflective material available.

The best type of surface on which to apply the material.

The tests conducted indicate that of the paint samples tested, standard MIL Specification paint with glass beads gives the best reflectivity at low angles of illumination and viewing.

REMARKS:

Photographs of the five paving surfaces are included. Because insufficient samples were taken and because many variables which might have had considerable influence on test results were uncontrolled, the results presented in this article may be far from conclusive; this, of course, does not mean that the results obtained are incorrect. Various color fluorescent paints were found to have an outdoor life of only 2 to 6 months.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Kevern, G. M.
TITLE: Visual effectiveness of flush lights.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1958. (Technical Memorandum WCLE-TM-58-49.)

SUMMARY:

The purpose of this report was to determine the relative visual effectiveness of four types of flush lights intended for use as threshold lights and as approach lights within paved overrun areas. Requirements of flush units for this purpose are presented. All four lights tested satisfactorily met the requirements for overrun and threshold lights, with an expendable top light having the best candlepower distribution.

REMARKS:

Expendable top lights, being unidirectional, are not as effective when used as a threshold light. It is stated that the over-all cost of a system using the open-grid lights is ten times that of a comparable system using any of the other three lights. Valuable data on the requirements of approach lights are included in this report.

The four flush lights tested were:

- 200-watt, expendable top
- proposed 500-watt, prismatic (1 inch high)
- 200-watt prismatic (1 inch high)
- 300-watt, open grid.

Photometric diagrams are included.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Kevern, G. M.
TITLE: Type LR/22-5D flush runway light.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1956. (Technical Memorandum No. WCLE-TM-56-76.)

SUMMARY:

The British-Type LR/22-5D semi-flush runway light was subjected to laboratory photometric tests to evaluate its utility as a threshold, underrun, or runway light. It was concluded that the light was satisfactory for use in runway and underrun areas where British lighting systems components are used.

REMARKS:

Candlepower distributions in both vertical and horizontal planes are graphically presented for the light, with and without green filters. More specific technical data on the light are also included.

The photometric performance of the light is satisfactory for a semi-flush light, but the light output of each beam of the Type LR/22-5D is approximately 36% of the USAF Type C-1 elevated light.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Irwin, L. K.
TITLE: Results of questionnaire on forces on landing gears due to guidance lights on runways.
REFERENCE: Washington: National Bureau of Standards, 1957. (Report 5676.)

SUMMARY:

The shape of lighting equipment which projected above the runway surface not only increased the roughness of the surface but also introduced areas which may have a coefficient of friction different from that of the runway surface. After a preliminary analysis of the landing gear loads due to taxiing an aircraft over a proposed runway light, it was decided that the manufacturers of aircraft, including fighter, bomber, transport and cargo aircraft, should be asked for comments on the effects of use of proposed flush or semi-flush lighting equipment. The report summarizes replies of aircraft manufacturers.

REMARKS:

Various diagrams and technical data on the effect of flush lights on landing gear of aircraft are included. Positive and negative comments of manufacturers are abridged and presented in the text.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Hoffman, C. S.
TITLE: Runway distance markers.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1957. (Technical Note 57-142.)

SUMMARY:

The purpose of this test program was to determine which type of runway distance marker would adequately assist pilots in determining their longitudinal position on the runway during takeoffs and landings, and to formulate criteria for the design and installation of a suitable runway distance marker for all United States Air Force airfields. In determining the optimum marker design, eleven runway distance markers of various sizes, colors, and light combinations were evaluated. A 5-foot square sign with a white numeral and border on a black background was recommended.

REMARKS:

Pilots made normal day and night takeoffs and landings, then completed a questionnaire on the effectiveness of the markers in determining longitudinal position on the runway. Requirements for the installation of the recommended marker are as follows:

Located 65 feet from the runway edge, at even 1000-foot intervals.
Lighted with a 75-watt lamp.
Runway remaining indicated.

Various diagrams and photographs of the sign and its installation are included.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Hoffman, C. S.
TITLE: Evaluation of modified 24 inch duplex rotating beacon light.
REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1957. (Technical Note 57-77.)

SUMMARY:

The purpose of this flight test program was to determine if a new lamp developed for the 24-inch, duplex, rotating beacon corrected the deficiencies of the standard lamp which is not visible from the altitudes at which jet aircraft are operating when inbound VFR to an airfield. It was concluded that the modified beacon was much better for aircraft operating at above 15,000 feet, and it was recommended as an Air Force standard.

REMARKS:

Aircraft were flown inbound to Wright-Patterson Air Force Base, Ohio on a track that was approximately a perpendicular bisector of a line drawn between the Wright and Patterson Field beacons. These inbound tracks were flown at indicated altitudes of 15,000, 20,000, 30,000, and 40,000 feet. Test pilots noted the maximum and minimum distance out from the beacons at which they were able to be seen.

A chart of the reported distances at which pilots were able to see the beacon is included, as are photographs of the beacon assembly. The actual light distribution is plotted against ideal distribution.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Hemelt, B. A., & Gilbert, M. S.
TITLE: The development of an airport taxi guidance system.

REFERENCE: Indianapolis: Civil Aeronautics Administration, Development and Evaluation Center, 1952. (Report No. 171.)

SUMMARY:

This report discusses the need for and development of a system of signs to furnish guidance by day and by night to pilots who are taxiing toward a particular destination of the airport. Basically, the system consisted of a number of conspicuous signs properly placed to identify intersections and turn-off points to specified destinations. The system described was recommended for adoption as a Civil Aeronautics Administration standard.

REMARKS:

A complete and lengthy number of recommendations for a taxiway guidance system for airports is included. Diagrams are included to help in the discussion. It was felt that as a result of the test program, an integrated and very effective taxiway guidance system was evolved.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Harding, J. H., et al.
TITLE: Further evaluation of a modified controllable-beam runway light.
REFERENCE: Indianapolis: Civil Aeronautics Administration, Technical Development Center, 1957. (Report No. 325.)

SUMMARY:

The report describes additional flight testing of a controllable-beam runway light developed in 1954. A complete set of experimental fixtures was installed on the instrument runway at General Mitchell Field, Milwaukee, and along 1/3 of the instrument runway at Indianapolis. Under minimum weather conditions for circling approaches, it was determined that generally the lights gave adequate circling and straight-in guidance.

REMARKS:

Photographs, candlepower distributions, schematic diagrams, and other technical data of the test light are included. Particular background and results on each test flight also are included. Flights were conducted under restricted visibility conditions along pre-determined paths using radar or other distance measuring equipment for orientation and guidance. Using these systems, it was possible to determine the visual threshold of the lights from pre-selected directions and, in addition, to judge whether adequate guidance was realized at these points.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Gilbert, M. S., et al.
TITLE: Evaluation of a controllable-beam runway light.

REFERENCE: Indianapolis: Civil Aeronautics Administration, Technical Development and Evaluation Center, 1954. (Report No. 238.)

SUMMARY:

Photometric and operational flight tests were conducted to assess the adequacy of a newly developed controllable-beam runway light.

The light did not entirely meet the theoretically ideal candlepower distribution; however, the ideal requirements were approached to a greater degree than any current operational light. The lights provided effective circling and straight-in guidance in good or moderately restricted visibility.

REMARKS:

The photometric analysis of the experimental light was compared to the ideal candlepower distribution which is calculated theoretically in another study (Gilbert & Pearson, 1952). Further operational assessment of the light under low visibility conditions is reported in a later study (Harding, Phillips, & Herner, 1957).

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Gilbert, M. S., & Pearson, H. J. C.
TITLE: An analysis of the candlepower distribution requirements of runway lights.
REFERENCE: Indianapolis: Civil Aeronautics Administration, Technical Development and Evaluation Center, 1952. (Report No. 178.)

SUMMARY:

Candlepower distribution requirements of runway lights were specified through a theoretical analysis of the guidance requirements of the pilot, conditions of aircraft position, and atmospheric transmissivity involved in circling and straight-in approaches.

Three isocandle curves present the major conclusions of the theoretical analysis conducted:

- Requirements for circling approaches during 1 mile visibility conditions.
- Requirements for day straight-in approaches during 1/4 mile visibility conditions.
- Requirements for night straight-in approaches during 1/4 mile visibility conditions.

REMARKS:

The fundamental approach to the problem of runway light and candlepower distribution requirements served as a base for later development and flight testing of lighting equipment. See later studies (Gilbert, Pearson, & Adkins, 1954; Harding, Phillips, & Herner, 1957).

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Gilbert, M. S., & Pearson, H. J. C.
TITLE: Development of a retractable slope-line approach-light unit.

REFERENCE: Indianapolis: Civil Aeronautics Administration, Technical Development and Evaluation Center, 1952. (Report No. 156.)

SUMMARY:

This report discusses the development and operational evaluation of a slope-line light bar unit capable of retracting into a position on the ground when not in use in order to reduce the possible hazard to aircraft taking off over the system. A hinged-type unit was selected for fabrication and test. The experimental model operated satisfactorily in various kinds of weather during the period of 18 months in which it was used.

REMARKS: None.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Garbell, M. A., & Jones, J. R.
TITLE: Advance report on an evaluation of the effectiveness of three types of runway marker lights tested at LAES during 1948.
REFERENCE: Arcata, California: Landing Aids Experiment Station, 1949. (Memorandum Report No. 49-3.)

SUMMARY:

Comparative evaluation of three types of runway marker lights was made at LAES. Examination of test results revealed a consistent superiority of fixed wide-beam lights over adjustable narrow-beam lights.

The two types of light were: fixed, wide-beam runway edge lights (Type 2 of CAA specification L-819) and adjustable narrow-beam lights (Type 1 of CAA specification L-819). Controllable beam lights initially were considered a part of the test, but too few approaches were made with them to draw comparisons with other light types.

REMARKS:

The details of test procedures are not presented. However, an appendix is included which presents pilot comments and covers some descriptive data concerning aircraft used, pilots, and test trials.

Effectiveness of runway lights is a major result of the brightness level of the background.

Contrasting runway surface markings are more effective than runway lights alone in daylight.

Effectiveness of the two types of lights is equal under night conditions.

Effectiveness of the wide-beam is consistently superior to the narrow-beam in daylight

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Dreher, R. C., & Batterson, S. A.
TITLE: Landing and taxiing tests over various types of runway lights.
REFERENCE: Washington: National Advisory Committee for Aeronautics, 1958. (Coordination No. AF-AM-65.)

SUMMARY:

The purpose of this study was to obtain data on the landing-gear loads developed during landing and taxiing over various types of runway lights. The tests were conducted at the Langley landing-loads track using forward speeds of 112-167 feet per second with a fighter nose landing gear, and 13.8 -143 feet per second with a larger main landing gear.

Two landing gears were used in the tests:
F-94C nose gear,
B-57 main gear.

The principal results indicated by these tests are as follows:
Larger vertical loads were obtained during landings of the F-94C nose landing gear on the Elfaka and Westinghouse light than on plain concrete.
Yawing oscillations of the F-94C nose landing gear wheel were developed during landings on the yawed Elfaka light when initial touchdown occurred on the grating, or less than a foot in front of it.
The loads developed on the small nose landing gear while taxiing over the lights were relatively more severe than those developed on the larger main gear.

REMARKS:

Elfaka
Rather violent yawing oscillations of the nose wheel occurred during tests in which the light unit was yawed, and initial touchdown occurred on the unit or less than a foot in front of it. Target loading occurred in this condition also.

Westinghouse
Maximum vertical load developed during landing impact is approximately the same as for the Elfaka unit.

AGA Expendable Top
One taxi test was made with this light. While loads developed in the landing gear were slight, some tire damage occurred.

C-1 Edge Light
One taxi test was made in which the landing gear struck a light unit. Highest loads developed during the investigation occurred at this trial, and a considerable amount of tire cutting also resulted.

ANL-9 Light
One taxi test was made over this light, resulting in a bent wheel.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR:
TITLE: Columnar taxiway marker light.

REFERENCE: New York: Port of New York Authority, 1958.

SUMMARY:

This report describes the technical findings in the experimental development of an improved taxiway light. Advantages of the light are discussed.

REMARKS:

Photographs and schematic diagrams of the new taxiway light are included.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Barbrow, L. E.
TITLE: Photometric tests on an Elfaka flush light (USA Model C).

REFERENCE: Washington: National Bureau of Standards, Photometry and Colorimetry Section, 1958. (Test 21P-17/58.)

SUMMARY:

This report gives the results of photometric tests of an Elfaka flush light, USA Model C, manufactured by Structural Concrete Products Corporation. These tests were made to determine the effects of the intensity distribution of a change in lamp design and of variations in construction resulting from manufacturing tolerances. Improved intensity distribution curves were noted after these adjustments, but it was stated that optimum adjustments would be very hard to make on actual airfield installations.

REMARKS:

Photometric curves are included.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Barbrow, L. E.
TITLE: Photometric tests of three 35-watt and three 100-watt reflector marker-light lamps.
REFERENCE: Washington: National Bureau of Standards, Photometry and Colorimetry Section, 1958. (Test 21P-14/58.)

SUMMARY:

This report gives the results of photometric tests on three 100-watt lamps (for use with reflector markers), manufactured by N. V. Philips' Gloeilampenfabrieken. No conclusive results were stated.

REMARKS:

The 100-watt lamps are designed for runway distance markers and operate without the use of a protective cover. Various test data and intensity distribution graphs are included.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Barbrow, L. E.
TITLE: Photometric tests of a feasibility model of a flush light.

REFERENCE: Washington: National Bureau of Standards, Photometry and Colorimetry Section, 1958. (Test 21P-8/58.)

SUMMARY:

This report gives the results of photometric tests of a feasibility model of a flush-type, prismatic light manufactured by Outlook Engineering Corporation. The light tested was intended for installation in the surface of runways or in overrun areas. The performance of the light indicated that lights of this type would be very satisfactory in the overrun area and in other locations where a unidirectional light is desired.

REMARKS:

The unit consists of a sealed-reflector lamp and a specular metal reflector located below the runway surface. A prismatic cover glass, through which light is directed, is mounted at only a slight angle to the surface. Photometric curves and a schematic diagram of the unit are included.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Barbrow, L. E.
TITLE: Photometric and life tests of eight 500-watt 20-ampere PAR-56 approach-light lamps.
REFERENCE: Washington: National Buraau of Standards, Photometry and Colorimetry Section, 1958. (Test 21P-3/58.)

SUMMARY:

This report gives the results of photometric and life tests of seven 500-watt PAR-56 General Electric approach-light lamps. It was concluded that the useful life of these lamps is much less than their total operating life. It was recommended that a maintenance procedure be established which would insure replacement of the lamps at the end of their useful life rather than operating life.

REMARKS:

Various numerical data and photometric curves are included.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Barbrow, L. E.
TITLE: Mechanical and thermal tests of runway marking materials.

REFERENCE: Washington: National Bureau of Standards, Photometry and Colorimetry Section, 1958. (Test 21P-15/58.)

SUMMARY:

Five typical marker materials were subjected to various laboratory tests as part of an investigative program seeking to provide information on materials and test methods for use in the preparation of a Federal Specification for aircraft runway markers. Properties evaluated in this laboratory program included plasticity, abrasion resistance, weathering resistance, effects of temperature cycling, impact resistance, and adhesion. No outstanding conclusive results were reported.

REMARKS:

Implied or assumed requirements for aircraft runway markers are:

The markers shall withstand normal weathering.
The markers shall have abrasion resistant properties.
Markers shall retain their information content after being subjected to heavy loading, then abrupt load removal.
Markers shall withstand the stresses attendant to an aircraft landing, (i.e., impact loading).

The more tangible results reported were:

Material T was rated highest on abrasion resistance test.
All materials except C passed laboratory weathering and temperature cycling tests.
Material N passed impact abrasion test. (only one tested).

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Barbrow, L. E.
TITLE: Intensity distribution measurements of a condenser-discharge approach light Type CD-2.
REFERENCE: Washington: National Bureau of Standards, Photometry and Colorimetry Section, 1957. (Test 21P-20/56.)

SUMMARY:

This report gives the results of intensity distribution measurements of a CD-2 condenser-discharge approach light made by Sylvania Electric Products, Inc. Only photometric data are presented; no conclusive results are stated.

REMARKS:

A rough comparison of the photometric curves in this paper with those of the Westinghouse Type CD-1 light shows the CD-2 light has a larger range. The effective intensity on the axis of the beam is 14,100 candles.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Barbrow, L. E.
TITLE: Intensity distribution measurements of a condenser-discharge approach light Type CD-1.
REFERENCE: Washington: National Bureau of Standards, Photometry and Colorimetry Section, 1957. (Report 21P-6/57.)

SUMMARY:

This report gives the results of intensity-distribution measurements of one Type CD-1 condenser-discharge approach light manufactured by the Westinghouse Electric Corporation. No conclusive results were reported; only photometric results are given.

REMARKS:

Results of earlier tests on a similar light are given in another report by the author (1956).

Effective intensity on the axis of the beam was 13,900 candles.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Barbrow, L. E.
TITLE: Type M-1 elevated runway marker lights.

REFERENCE: Washington: National Bureau of Standards, Photometry and Colorimetry Section, 1955. (Test 21P-17/55.)

SUMMARY:

This is an evaluation report giving results of photometric tests with Type M-1 elevated runway marker lights. The lights were operated with a clear asymmetric and with a blue symmetric lens, and with a 45-watt and a 30-watt lamp. These lamp-lens combinations substantially met required specifications.

REMARKS:

Graphs of obtained intensity distributions are included.

Intensity distribution measurements were made by the use of a photoelectric photometer employing a color-corrected photocell at a distance of 50 feet from the light when the clear lens was used and 12 feet when the blue lens was used.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Beggs, E. W.
TITLE: Optical applications of mercury short-arc lamps.

REFERENCE: Paper presented at the National Technical Conference of the Illuminating Engineering Society, Atlanta, 1957.

SUMMARY:

The arc of a mercury short-arc lamp is a "ball of light" about 10 times as bright as a tungsten filament and approaches the intrinsic brightness of a high-intensity carbon-arc.

This report describes technical operating characteristics of short-arc lamps and how they have improved the performance of searchlights.

REMARKS:

The lights have high brightness and operate simply and consistently. Schematic diagrams of the lamp are included.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Baker, C. A., & Chinetti, P. J., Jr.
TITLE: The use of reflex-reflective materials in military aviation.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1957.

SUMMARY:

This report gives the results of using reflex-reflective materials on aircraft for providing more positive identification. Results indicate that the use of reflex-reflective materials for identification numerals on aircraft will at least double the distance at which interceptors can positively identify aircraft at night. This material may have possible use in runway markers.

REMARKS:

The recognition of Scotchlite digits on black background was better than any other scheme tested.

Reference is made to night flight tests made by 4th Troop Carrier Squadron using this material on runways. Using landing lights only, it was concluded that these markers could adequately outline the edges of runways and landing areas.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Alcott, W. S.
TITLE: Airfield approach lights.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1955. (Technical Note 55-778.)

SUMMARY:

United Engineers, Incorporated explored methods for producing color through light sources and filters which would be an improvement over present colored glass filters. Several possibilities were located, including the use of interference coatings in place of dyes or stains to produce thermally stable filters of increased efficiency; the use of red or green fluorescent sources to eliminate the use of filters; the use of an unfiltered mercury source to produce green light.

REMARKS:

The reports include extensive bibliographies in such basic fields as magneto-optics, polarization, reflectance, dispersion, diffraction, light absorption, etc. Industrial manufacturers, American and European, involved in the development of filters and light sources are listed.

Progress Reports of this series are referenced.

SELECTED ADDITIONAL REFERENCES

H3. Aids to Air Navigation & Landing -- Proposal for marking and lighting tall structures and tall guyed structures, including guy wires beyond present standards. Washington: Air Coordinating Committee, 1955. (ACC 59/10.12.)

REQUIREMENTS: None.

DESCRIPTION: None.

PROCEDURES: None.

RECOMMENDATIONS: None.

CONCLUSIONS: None.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR:
TITLE: Proposal for marking and lighting tall structures and tall guyed structures, including guy wires beyond present standards.
REFERENCE: Washington: Air Coordinating Committee, August, 1954 to May, 1956. (ACC 59/10.12-59/10.12C.)

SUMMARY:

This is a series of progress reports with respect to a detailed plan for the development, installation, assessment, and operational evaluation of special lighting and marking systems for tall towers. It was recommended that obstructions be marked with steady burning red lights, the more hazardous of these with flashing red lights. Photometric specifications were determined for these lights.

REMARKS: None.

REQUIREMENTS: None.

DESCRIPTION: None.

PROCEDURES: None.

RECOMMENDATIONS: None.

CONCLUSIONS: None.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Greenlee, P. H.
TITLE: Lights, hazard marker, battery-operated.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1951. (Memorandum Report No. WCEEE-656-2115B-1.)

SUMMARY:

The purpose of this report was to determine the types of battery-operated hazard marker lights which would be most satisfactory for Air Force use, and to obtain technical information for preparation of specifications.

Eight lights from six companies were submitted. Complete descriptions of the above lights together with photographs and test results are included in Appendices B-G of the report.

REMARKS:

It is reported that

The visual effectiveness (equivalent candlepower) of flashing lights is approximately proportional to the total visible energy radiated which in turn, is proportional (except for minor variations in efficiency) to the energy drawn from the power source

Battery-operated, flashing, red lights having an equivalent candlepower not less than 0.1 and a continuous battery life of not less than 75 hours (similar to the Emarco Model AW) are considered satisfactory for marking hazards to ground traffic, at moderate temperatures.

Battery-operated, flashing, red lights having an equivalent candlepower of not less than 2.0 and a continuous battery life of not less than 75 hours (similar to the McDermott Model 1 F 50-7-75) are considered satisfactory for applications requiring short range visibility from the air, such as marking closed runways soft spots, etc., during moderate temperature and good visibility conditions.

SELECTED ADDITIONAL REFERENCES

TW3. Vipond, L. C. New signs lighten dark airports. Aviation Age, 1954, 21 (5), 76-79.

REQUIREMENTS:

Visual means must be provided the pilot to enable him to identify the taxiway location in advance, to determine the point of turnoff upon arrival there, and then to maneuver this turnoff with ease.

DESCRIPTION:

A yellow, reflectorized, 12-inch, centerline stripe extending from the beginning to the end of the entrance curve was the basic marking configuration used for daytime guidance. The point of turn was indicated by a yellow stripe perpendicular to the centerline. This stripe was placed at the entrance end of the curve and was 3 feet wide and 20 feet long. The exit centerline was offset 18 inches from the runway centerline.

Nighttime guidance was provided by two basic lighting designs: an edge lighting system, and an edge lighting combined with centerline lighting system.

Some variations in light spacing, color, and intensity were explored within the test patterns. Taxi centerline spacings were 100 and 10 feet; runway centerline 100 and 20 feet; taxiway and runway edge lighting 100 and 33 feet.

Most of the tests were run with white lights; a few runs included blue lights.

PROCEDURES:

Comments of pilots and airline observers were obtained. Aircraft-mounted cameras recorded deviations from taxiway centerlines.

Test aircraft which included F-100, Convair 240 and 340, Super Constellation, Cessna 310, and B-47 maneuvered the exit patterns at speeds varying between 58 and 67 miles per hour. No aircraft landing or taxiing lights were used.

RECOMMENDATIONS:

Further study is required to determine optimal pattern, color, intensity, and spacing of lights to indicate taxiway exits.

Centerline taxiway should project onto, rather than offset to, runway centerline.

CONCLUSIONS:

The yellow cross stripe intended to signal the start of the turn to taxiway is unsatisfactory in the opinion of pilots.

Centerline spacing is unsatisfactory when the lights are spaced more than 40 feet apart. Linear effect is apparently lost beyond this spacing. Guidance is best at the 10-foot spacing.

Turn-off guidance is better when the taxiway entrance is not "closed" by runway lights.

Blue centerline lighting is satisfactory for taxiways, except for one pilot who confused the centerline for edge lights.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Horonjeff, R., et al.
TITLE: Exit taxiway location and design.

REFERENCE: Berkeley: University of California, Institute of Transportation and Traffic Engineering, August, 1958.

SUMMARY:

The purposes of this study were to determine the speeds at which representative civil and military aircraft could safely and comfortably turn off a runway; to develop exit taxiway configurations appropriate to these speeds; to obtain information which would aid the airport designer in locating exit taxiways; and to obtain data on visual guidance to indicate desirable lines of further study.

REMARKS:

The primary purpose of this work was the determination of structural properties required of runway exits to handle high-speed turnoffs by a range of military and commercial aircraft. The problem of marking and lighting guidance is addressed only secondarily.

The work in the marking and lighting area is abstracted here. Readers interested in the results of the physical analysis are referred to the original document.

REQUIREMENTS:

Inbound route or destination guidance.
Outbound route or destination guidance to a runway or dispersal area.
Identification of particular taxiway sections so that an aircraft that cannot be seen from the tower can report its location.
Markers shall be designed for both day and night visibility.
Markers shall be sufficiently distinct to attract attention prior to the time they are legible.
Markers shall be designed for maximum contrast with other airfield lights and objects, and provide maximum legibility.
Markers shall be designed for installation adjacent to the pavement edge so as to effect a minimum of interference from runway lights.
Distinctive intersection markers are required to provide advance indication of approach to intersection.
Markers shall be constructed, masked, or hooded so that they will be visible from only the areas in which taxiing guidance is required.
The system shall consist of advance intersection markers, exit markers, destination markers, and section markers.

DESCRIPTION: None.

PROCEDURES:

General methods used in approaching this problem included literature survey, pilot interviews and questionnaires, laboratory and field tests of information coding, and legibility of signs.

RECOMMENDATIONS: None.

CONCLUSIONS:

Pilots stress the need for a standardized system of taxiway marking.
Pilots prefer ground visual aids as opposed to tower radio as a means of control during the taxi mode.
Pilots prefer selective marking systems--differential coding of inbound or outbound taxiways, for example.
As military aircraft have no landing lights, military pilots prefer self-illuminated signs. Commercial pilots prefer reflective material.
Words and abbreviated words are more readily interpretable than shape-coded symbols.
Illuminated letters on an opaque background are more visible than opaque letters on illuminated backgrounds.
Black letters on yellow backgrounds are most visible as markings on macadam surfaces.
Yellow letters on black backgrounds are most visible as markings on concrete surfaces. A letter stroke width of 3/4 inch is most effective in terms of legibility.
Pilots expressed a preference for open arrowheads as directional markers.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Casperson, R. C., et al.
TITLE: Taxiway lighting, routing and destination marking system for airfields.
REFERENCE: New York: Dunlap and Associates, Inc., 1952. (Technical Report 32-1.)

SUMMARY:

The purpose of this study was to design and test a taxiway lighting, routing, and destination marking system for airfields within the bounds of Bureau of Aeronautics Specification XAE-42. The marking system which is recommended by the study designates taxiway routes for inbound and outbound traffic on the basis of their destinations. Information presented by taxiway markers should be standard short words, abbreviations, numbers, or single letters rather than shape codes. For optimum day and night legibility, all information on taxiway marker signs should be displayed by yellow figures on a black background.

REMARKS: None.

SELECTED ADDITIONAL REFERENCES

R6. Centerline runway lighting is approved. Aviation Week, 1951, 55 (18), 65-66.

R7. Finch, D. M. An evaluation of surface-mounted lights for runway guidance. Berkeley, California: University of California, The Institute of Transportation and Traffic Engineering, 1959. (Interim Report.)

R8. Garbell, M. A. A new system of surface markings for aircraft runways. (2nd ed.) San Francisco, California: Garbell Research Foundation 1953. (Garbell Aeronautical Series No. 2.)

R9. Illuminating Engineering Society. Report of runway lighting subcommittee. Unpublished Draft. New York: Author, 1957.

R10. Muehlberg, R. H. Low-cost reflectors simplify runway lighting. Aviation, 1946, 45 (5), 90.

R11. Peek, S. C. Fluorescent strip runway lighting. Paper presented at the National Technical Conference of the Illuminating Engineering Society, Atlanta, September, 1957.

R12. Runway shorthand. Approach, 1958, 3 (8), 4-13.

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

The two markers were placed side by side perpendicular to the edge of the runway. The international orange marker was located 20 feet from the edge; the fluorescent orange marker was about 25 feet from the edge. Observations were made from a vehicle along the centerline of the 150-foot runway so the markers were approximately 100 feet from the line of observation.

RECOMMENDATIONS:

Markers should be constructed with the international orange background

For darkness conditions, markers should be illuminated by a lamp reflecting light towards the runway surface.

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

CONCLUSIONS:

The effective range of the international orange markers appears adequate for daytime use.

For nighttime use in visibility conditions of 1 mile or more, an externally illuminated marker provides a satisfactorily effective range.

The useful range at night, between 300 and 1400 feet, is less than desired (especially for low visibilities).

The illumination on the marker should be between 5 and 20 footcandles when the visibility is 1 mile or more. When visibility is 1/4 mile or less, the illumination on the marker should be between 25 and 150 footcandles.

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

REQUIREMENTS:

The pilots need accurate information on length of runway used or remaining. Markers must be visible, but cannot become a hazard through excessive size.

DESCRIPTION:

Two types of markers were discussed and rejected from consideration. Internally illuminated markers are so large that they are a potential hazard. Retro-flective markers provide inadequate information when the aircraft has no landing or taxiway lights, or when the runway is wide and in restricted visibility. The following were then tested for operational suitability:

Plywood markers with international orange background and white numerals.

Plywood markers with fluorescent paint background and white numerals.

PROCEDURES:

Visual observations were made and the following were recorded for each test condition:

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

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

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

The average distances for both types of background paint for each of the above ranges were computed and then compared. The useful range should be between the recognition range and the conspicuous range.

Observations were made under both daytime and nighttime conditions. The visibility varied from below 1/4 mile to over 10 miles.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Simeroth, J. W., et al.
TITLE: Field tests of runway distance markers.

REFERENCE: Washington: National Bureau of Standards, 1957. (Report No. 5466, Project No. 0201-20-2327.)

SUMMARY:

The pilot's need for more accurate information about the length of runway remaining or used is described. Runway markers using two types of orange paint for background were proposed as solutions to the problem. Increased recognition distance of a numeral resulted from the use of international orange as background. Optimum levels of nighttime illumination and location of lamps were also determined.

REMARKS:

It is stated that the visual range of the marker is greater as a marker with the fluorescent orange background than with the international orange background. It might be possible that a marker employing a fluorescent orange numeral with a white background would have a greater visual range than the one accepted in this report. The feasibility of a fluorescent white numeral might also be considered.

Two of the three measures utilized to evaluate the markers involved a stationary observer and the third employed a vehicle other than operating equipment. Conclusions of the study, therefore, must be generalized to operational conditions of movement and cockpit visibilities which may not have been characteristic of the present test conditions.

REQUIREMENTS:

Any practical runway lighting system must identify the runway centerline and provide some form of roll guidance.

A distinction between the approach lighting and beginning of the landing area lighting must be clearly defined, but it must be done in such a way that no break in the guidance occurs between approach and landing.

DESCRIPTION:

The first 2000 feet of Runway 28 at Soesterberg Airport is patterned in flush lights by a centerline and four crossbars which extend the Calvert approach lights.

PROCEDURES:

Two aircraft (Varsity and Devon) and four pilots participated in the flight tests.

The experimental pattern was evaluated through comparison with the standard lighting configuration in terms of pilot opinion and flight path description via radio altimeter.

The weather conditions for all test flights were good, smooth air, good visibility, and an average wind The trials were carried out when there was no moonlight.

To simulate as far as possible all-weather conditions and also to provide a common starting point for each individual run, the airfield GCA radar was used Each run commenced at 5 miles range, the pilots reverting to visual guidance at 1/2 mile from the glide path reference point at a height of 150 feet. Each pilot made a total of eight recorded landings on the test pattern and the standard, making a total of 64 recorded landings

RECOMMENDATIONS: None

CONCLUSIONS:

The test pattern is unsatisfactory as an aid for final landing because of the excessive number of lights and the high directional properties of the lights which cause glare and dazzle

Even with such serious limitations, three out of the four pilots preferred landing on the lighted pattern compared with landing with conventional edge-runway lighting. The fourth pilot preferred the latter, but admitted that a pattern in the runway could prove advantageous in bad weather and restricted visibility.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Hooten, E. N.
TITLE: Brief landing trials using the flush lighting pattern in the runway at the Royal Netherlands Air Force Station at Soesterberg.
REFERENCE: London, England: Ministry of Supply, March, 1957. (Technical Note No. BL. 45.)

SUMMARY:

This report describes flight tests of the Calvert approach system extended into the runway itself by the use of flush units. Although, in detail, far from ideal in providing visual guidance during final flare and landing, the provision of a pattern within the runway was considered an improvement over runway edge lighting by three of the four pilots who took part in the test.

REMARKS:

The author points out that if visual contact is established at a height of 100-200 feet, much of the approach lighting pattern will then pass depending on visibility and downward view, with only one or two bars of the approach pattern remaining to be seen before the runway itself provides the vital information to allow the landing to be completed. In the majority of the existing airfield installations, the runway edge lighting is the sole source of information and such lighting is intended only to outline the landing strip. This would imply that bars of light similar to perhaps narrow-gauge flush lighting would be more valuable in providing height guidance in the last 100-200 feet of height before making runway contact.

The author realizes the need for a reliable method of measuring pilot concentration and effort when performing a given task.

REQUIREMENTS:

Pilots need information as to their longitudinal position on the runway on takeoffs and landings. On takeoffs, pilots need to know runway used until they pass their refusal point, and then they need to know runway remaining.

During landing, the pilot requires knowledge of the length of runway remaining in order to determine how he will apply his brakes.

Markers must be in the pilot's normal field of vision during takeoffs and landings. It is critical that markers be visible at night and during periods of reduced visibility, as this is when the aircraft's position on the runway is most difficult for the pilot to determine.

DESCRIPTION:

White numerals indicating thousands of feet of runway remaining on an international orange background constituted the basic marker design. The runway distance markers were placed on each side of the runway 25 feet from runway edge, 175 feet from runway centerline, and at 1000-foot intervals. The first marker was 1000 feet from the runway threshold. The markers indicated runway remaining.

PROCEDURES:

Pilots made normal day and night takeoffs and landings, and then completed questionnaires on the effectiveness of the marker in determining the aircraft longitudinal position on the runway after each takeoff and landing. A total of 52 pilots participated, 19 of bomber-type aircraft and 33 of fighter-type aircraft.

In some of the trials the markers were illuminated by light fixtures. The light fixtures varied mainly in wattage and in color.

RECOMMENDATIONS:

Special emphasis should be given to the development of runway distance markers that will be adequate for night operations.

The addition of a border on the present markers should be evaluated as a potential improvement in marker visibility

CONCLUSIONS:

Based upon proportions of pilot opinion, which were not subjected to statistical evaluation, the following were concluded:

Runway distance markers are satisfactory for day operations.

Runway distance markers are not satisfactory for night operations even when artificially illuminated.

Runway distance markers should be as close to runway edge as safety considerations permit.

Runway distance marker should indicate distance of runway remaining and should be placed on both sides of runway.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Hoffman, C. S.
TITLE: Evaluation of experimental runway distance markers.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1957. (Technical Note 56-393, Project No.6001.)

SUMMARY:

Usefulness of runway distance markers as indicators of length of runway remaining is examined. General requirements of these markers are defined and a marker design suggested to satisfy these requirements. This marker design was found satisfactory during day operations, but was considered unsatisfactory even when floodlighted for night operations.

REMARKS:

Solution to the problem of providing pilots with runway distance information is restricted to markers erected along the runway edges. The basic problem is not sufficiently explored to permit the feasibility of other solutions, e.g., flush runway lights, runway markings, etc. Also, solutions are limited here to edge of runway marking while centerline marking solutions may be of greater value. Some pilots, for example, expressed the idea that a take-off acceleration check point be marked by a 3-foot wide stripe 3000 feet from threshold. The addition of a flasher light was also suggested to mark these lines for night operations.

REQUIREMENTS:

During takeoff and landing, the pilot requires information about the distance of runway remaining or the distance used.

DESCRIPTION:

The marker signs used as test items were wooden frames 4 feet by 4 feet. The numerals were 22 inches wide and 44 inches high. The markers were installed so that they indicated the amount of runway used, rather than the amount of runway remaining.

PROCEDURES:

Twenty-three pilots participated in the test using 13 bomber aircraft (B-47, 29, 26) and ten fighter aircraft of the 80 and 90 series.

Pilots made normal takeoffs and landings, and then completed a questionnaire.

RECOMMENDATIONS:

A lighted "knockdown" type of runway distance marker should be provided so that it can be located close enough to the runway to be within the pilot's visual field during takeoff.

CONCLUSIONS:

Thirteen of 23 pilots reported not seeing the markers prior to take-off roll.

Seventeen of 23 pilots reported not seeing the markers during take-off roll.

Pilots prefer markers on both sides of runway; left side, if only one is feasible.

Pilots prefer to know length of runway remaining (rather than used) on takeoff.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Hoffman, C. S.
TITLE: Evaluation of runway distance markers.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1955. (Technical Note 55-588.)

SUMMARY:

Runway distance markers were evaluated to determine their effectiveness in providing information to the pilot as to his longitudinal position along the runway. Pilots experienced difficulty in seeing the markers during daylight operations and were unable to see them during night operations.

REMARKS:

Although runway distance information is required by the pilot during both takeoff and landing, the questionnaire items were restricted to visibility of the signs during takeoff only.

Height guidance from narrow-gauge pattern was disappointing. Many approaches were carried to actual touchdown with the pilots "feeling" for the runway surface.

Efforts to enhance the effective illumination of the floodlights by the use of painted checker-board markings and by the addition of light reflecting crystals of aluminum sylicate were of doubtful value. Apparently, the roughness of the pavement itself provided sufficient patterning. Effective pavement width and surface type are subjects for further tests.

Sylvania Electric Products, Incorporated experimental floodlighting units were placed in continuous rows along both edges of the runway for a distance of 715 feet, 500 feet from the approach end of the runway. The units produced approximately a 1-foot lambert level of illumination at the runway centerline.

PROCEDURES:

Both civilian and military pilots took part in the evaluation. They were briefed as to the facilities available for guidance, and were encouraged to file written reports and comments on their observations.

Test flights were scheduled on late nighttime periods. Low visibility weather conditions were utilized to the fullest possible extent, but it was also possible to utilize fair weather flights to obtain comparative observations of certain test variables.

A motion-picture camera mounted adjacent to the head of the co-pilot was used to keep a permanent record of the appearance of the lighting system on most approaches.

RECOMMENDATIONS: None.

CONCLUSIONS:

The narrow-gauge runway lighting, when visible throughout landing was effective in sharpening directional guidance and providing roll guidance.

The optimum configurations for the narrow-gauge system were composed of 8-foot bars of 200-foot longitudinal spacing a gauge width of 60 feet, and toe-in angles of the lights to intersect the runway centerline at a distance of about 700 feet.

A beam width of about 14 degrees was adequate for a reasonably well-centered approach.

Low-level illumination of the runway surface was most critical with night landings in heavy ground fog. The floodlights also provided directional, pitch, and roll guidance in the touchdown area.

REQUIREMENTS:

High intensity approach lighting has improved guidance up to the threshold, but has accentuated the need for comparable improvements in the guidance provided by lighting systems. Runway lights should provide roll guidance, directional guidance, and sensitive height guidance.

DESCRIPTION:

The narrow-gauge systems tested consisted of two rows of light bars centered about the runway centerline and extended for a distance of 3000 feet from the approach threshold. Frangible mock-up units which approximated candlepower distributions of the Elfaka units were used in the test patterns of the narrow-gauge system.

The following table summarizes the variables examined in the test and the specific values of each variable of the narrow-gauge system.

Bar lengths	8 feet	15 feet
Longitudinal distances between units	200 feet	100 feet
Gauge widths	60 feet	90 feet

Angles of toe-in	Inner Light (degrees)	Middle Light (degrees)	Outer Light (degrees)
	4	5	6
	3	3 1/4	3 1/2
	0	1 1/2	3

	Beam Width (degrees)	Vertical Spread (degrees)	Max. Intensity (candlepower)
Narrow-beam	8.2	0.2 - 11.4	38,000
Medium-beam	13.8	2.5 - 9.4	36,800
Wide-beam	25.2	2.5 - 9.4	36,800

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Harding, J. H., et al.
TITLE: A preliminary evaluation of narrow-gauge runway lighting and runway surface illumination.
REFERENCE: Indianapolis: Civil Aeronautics Administration, Technical Development Center, 1958. (Report No. 338.)

SUMMARY:

Preliminary flight tests were conducted of the narrow-gauge runway lighting and floodlighting concepts as aids to landing in reduced visibility conditions. The tests were generally conducted to provide information on capabilities in low visibility landings, and specifically to determine optimum values of gauge width, longitudinal spacing, light bar length, beam spread, and toe-in angles for the narrow-gauge system. The optimum system for operation under the lowest visibility nighttime conditions may be a combination of runway illumination for touchdown with a simplified narrow-gauge or centerline pattern for supplementary guidance during takeoff and landing rollout.

REMARKS:

The report is not explicit with respect to the numbers or characteristics of the pilots and aircraft used in the test, number of approaches, or the percentage of actual landings as opposed to passes without touchdown. Pilot opinions contrary to these conclusions have been published. See Robson. Descriptions of actual test flights by four pilots who participated in the test can be found in another study (Little, 1957).

SELECTED ADDITIONAL REFERENCES

TL3. Pearson, H. J. C. Requirements of threshold lights. Indianapolis, Indiana: Civil Aeronautics Administration, Technical Development and Evaluation Center, 1955. (Report No. 272.)

TL4. Runways and lighting. The Aeroplane, June 13, 1958, 821.

REQUIREMENTS:

The primary purpose of a runway lighting system is to define the limits of the ground area on which aircraft can safely operate. The system must be easily identifiable from the air as a runway, and it must indicate to the pilot the location, direction, and extent of the runway.

An optimum runway and threshold lighting system should:

- Positively identify the runway.
- Outline the runway.
- Distinguish between the touch-down zone, the center zone, and the warning zone of the runway.
- Define the beginning and end of the landable area.

DESCRIPTION:

Two general sytems of zone marking the runway through colored lights were tested. The first system utilized extra lights in line with the regular runway lights. The second system of zone marking consisted of colored lights, called satellites, located adjacent to the regular runway lights on a line perpendicular to the runway centerline. Five variations of the general in-line system and 17 variations of the satellite system were tested.

PROCEDURES:

The principal criteria used by observers to judge the value of the various systems were: the ability of the patterns to indicate the zones, the lack of misleading guidance at various angles of view, and the procurement and operating economics of the system.

On the basis of flight evaluations one of the satellite patterns was determined to be optimal. This pattern was kept in operation for three months during which time 29 visiting pilots completed a questionnaire evaluating the system.

RECOMMENDATIONS: None.

CONCLUSIONS:

The optimal zone marking system from among those tested was composed of a pair of colored satellites outboard of the runway edge lights and placed perpendicular to the runway longitudinal axis along 2000 feet of each runway end. The satellites were placed on each side of the runway and at alternate runway lights (400-foot intervals). The satellites were filtered so as to be green in the direction of the approach end and red in the direction of the takeoff.

A majority of the 29 pilots completing the questionnaires expressed favorable attitudes and 15 responded affirmatively to the question of its adoption as a national standard. Five were opposed, and nine abstained.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Tiedemann, A. T.
TITLE: A lighting pattern for runway zone identification.

REFERENCE: Indianapolis: Civil Aeronautics Administration, Technical Development and Evaluation Center, 1954. (Report No. 208.)

SUMMARY:

Various methods of providing a pilot with visual information for determining his longitudinal position along the runway were investigated.

The recommended runway zone-marking system employed colored lights located in the section at each end of the runway to define a safe touchdown area on the approach end and a caution area on the far end.

REMARKS:

The results of this study were reviewed by Wright Air Development Center, Air Research and Development Command. The runway zone identification system recommended here was endorsed by the Air Force agency which recommended that the system be adopted as a USAF standard. See the study by Kevern (1954).

REQUIREMENTS:

During circling approaches the pilot must be able to identify and locate the approach threshold lighting from the latter part of the downwind leg, from the point at which he turns into the final approach, and during the final letdown.

The threshold lighting must be distinguished from the approach, overrun, and runway lighting.

The threshold area must be visible to the pilot for at least several seconds during straight-in approaches under conditions of restricted visibility so that he does not pass it unknowingly.

The lighting should not cause uncomfortable glare.

The exit threshold lighting must be visible to a pilot on any part of the runway for a distance great enough to allow him to take emergency action to stop his aircraft or to lift it before he passes the end of the runway.

DESCRIPTION:

Six patterns of threshold lights were tested:

Two bars of C-1 units with 200-watt series lamps and green filters, normal to the runway axis and inward from the lines of runway lights. The units are on 10-foot centers, and the gap between the bars is 136 feet.

The identical bars as in Pattern No. 1, extended outward beyond the runway lights to form T patterns with the runway edge lights instead of L patterns as in Pattern No. 1.

Similar to Pattern No. 2, but including a line of ANL-9 flush lights filling in the gap between the two bars.

Bars with wings parallel to the runway axis and extending into the approach area.

Similar to Pattern No. 5, but with the wings folded back along the lines of the runway lights instead of extending into the approach area.

PROCEDURES:

No tests or other evaluative procedures are reported.

RECOMMENDATIONS: None.

CONCLUSIONS:

Pattern No. 6 is reported as the most effective pattern. It included two 40-foot bars made up of Type C-1 light units, plus wings extending in along the runway and one flashing light unit at each end of the runway offset from the ends of the bars toward the downwind leg.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Pearson, R. J. C.
TITLE: Tests of threshold lighting patterns.

REFERENCE: Indianapolis: Civil Aeronautics Administration, Technical Development and Evaluation Center, 1955. (Report No. 276.)

SUMMARY:

This report describes results of ground and flight observations on six patterns of threshold lighting. One pattern was recommended which incorporated the most effective improvements.

REMARKS:

The report refers to a long series of flight tests and ground observations that provided the basis for evaluating the threshold patterns. The details of these tests, however, are not included in this report.

AL21. Kevern, G M. Approach and runway lighting: past, present, and future. A paper prepared for conference of Major Commands Instrument Advisory Group, Wright-Patterson Air Force Base, August 20, 1953.

AL22. Kevern, G. M. Hazards or aids? Flying Safety, 1955, 11 (7), 2-9.

AL23. Moore, F. L. The way out of the approach gloom. Aviation Week, 1950, 53 (24), 46-52.

AL24. Naval Air Test Center. Flight tests of approach light systems. Patuxent River, Maryland: Author, 1952. (Report No. 2, Project No. PTR 892.)

AL25. Norwell, W. C. Airport approach lighting for landings. Westinghouse Engineer, 1949, 9 (5), 130-133.

AL26. Pearson, H. J. C. The slope line approach light system. Indianapolis, Indiana: Civil Aeronautics Administration, Technical Development and Evaluation Center, 1950. (Report No. 104.)

AL27. Perreault, W. D. Breach widens on high-intensity light plans. American Aviation, 1952, 16 (4), 13-14.

AL28. Pilots, ATA favor centerline lighting. Aviation Week, 1952, 57 (2), 75-76.

AL29. Slope line light approval near. Aviation Week, 1948. 49 (23), 15-16.

AL30. Slope-line system adopted as landing aid for aircraft. Illuminating Engineering, 1949, 45 (8), 500.

AL31. USAF, CAA test approach lights. Aviation Week, 1955, 63 (23), 131.

AL32. U. S. to try Dutch approach lights. Aviation Week, 1955, 62 (2), 21-25.

SELECTED ADDITIONAL REFERENCES

AL10. Approach lighting systems for airports. Electrical Engineer and Merchandiser, March 15, 1951, 359-362.

AL11. ANC Landing Aids Experiment Station. Airfield lighting. Washington: Civil Aeronautics Administration, Office of Aviation Information, 1948. (Progress Report, Contract No. C13ca-136.)

AL12. ANC Landing Aids Experiment Station. Preliminary summary of data on approach tests in restricted visibility from 7 June to 1 September 1948. Washington: Civil Aeronautics Administration, Office of Aviation Information, 1948. (Memorandum Report No. 48-3, Contract No. C13ca-136.)

AL13. CAA withdraws slope line support. Aviation Week, 1950, 52(4), 15-16.

AL14. Coggins, D. I. EFAS - A new and vital aid to low visibility landings by aircraft. Salem, Massachusetts: Sylvania Electric Products, Inc.

AL15. Davis, J. E., & Gudmundsen, V. Airfield lighting. Washington: Civil Aeronautics Administration, Office of Aviation Information, 1947. (Final Report.)

Al16. Discussing approach and runway lighting. The Aeroplane, June 1956, 624-625.

AL17. Fry, H. J. Approach and runway lighting for jet-age aircraft. Paper prepared for presentation at Jet Age Airport Conference, New York, May, 1957.

AL18. Garbell, M. A. Explanatory summary of information included in flight test reports beginning with LAES FTR 48-1. Washington: Civil Aeronautics Administration, Office of Aviation Information, 1948. (Memorandum Report No. 48-1, Contract No. C13ca-136.)

AL19. Garbell, M. A. Recent developments in visual low-approach and landing aids for aircraft. Illuminating Engineering, 1951, 46(7), 353-358.

AL20. Kevern, G. M. Approach and runway lighting for adverse weather conditions. Illuminating Engineering, 1946, 41(6), 455-473.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Price, J. I., & Irwin, L. K.
TITLE: Static load-deflection relations for 20 x 4.4 and 32 x 8.8 aircraft tires on an Elfaca (sic.) Model C runway light cover.
REFERENCE: Washington: National Bureau of Standards, 1957. (Report No. 5403, Project No. 0201-20-2331.)

SUMMARY:

The results of static load tests of two sizes of aircraft tires on a modified Elfaca (sic.) light cover are reported. Results indicate that the tires roll over the light without significant damage to either tire or light unit.

REMARKS:

Visual examination of the test wheels and light unit revealed no damage to wheels or light.

Static tests have not accounted for the effects of the following factors:

Differences in coefficient of friction between light and pavement.
Vibration in aircraft structure due to periodic spacing of light units.
Skidding tires impacting the light unit.
Reduction in "life" of units as a function of prolonged use.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Retzer, T. C., & Gerung, G. W.
TITLE: New developments in short arc lamps.

REFERENCE: Paper presented at National Technical Conference of the Illuminating Engineering Society, Boston, 1956.

SUMMARY:

This report describes the improved short arc lamp which has been proposed to fulfill the need for a brilliant, long-life, bulb-type light source for use in searchlights.

REMARKS:

Electrical characteristics, arc brightness, spectral energy distribution curves and application of the lamps in searchlights are presented. Photographs of searchlights incorporating this lamp are also included.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR:

TITLE: Sylvania fluorescent runway strip lighting.

REFERENCE: Salem, Massachusetts: Sylvania Electric Products, Inc., 1957. (Report No. 2.)

SUMMARY:

This report describes how fluorescent strip runway lighting may be utilized to eliminate the "black hole" problem. This is essentially the same report as (Peek, 1957) with the addition of sections on power requirements, installation requirements, and fixture specifications. Diagrams are included to simplify the discussion of these topics.

REMARKS: None.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Wallis, A. E.
TITLE: Type MB-2 approach light and lamp, Multi Electric Part No. 894, Westinghouse Electric Corp., Lamp No. 200PAR 56/6.6.
REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1955. (Technical Memorandum Report No. WCLE-55-45.)
SUMMARY:

This report evaluates a Type MB-2 approach light and lamp manufactured by the Multi Electric Manufacturing Company, and Westinghouse Electric Corporation, respectively. The light was designed for use in the overrun area of the centerline system (i. e., the "centerline tail"). It was concluded that the light and the lamp were both suitable for use.

REMARKS:

The Type MB-2 approach light extends about 1 foot above the ground. The housing is pivoted on the mounting support, so the light can be adjusted in the vertical plane through a range of 30 degrees below and 30 degrees above the horizontal.

Photometric curves and a photograph of the unit are included. Curves showing the candlepower change caused by temperature rise of red filters are included also.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Wallis, A. E.
TITLE: Type MC-1, semi-flush, runway marker light and lamp, Revere Electric Mfg. Co. Part 7012, Radiant Lamp Corp. Lamp ASBI.
REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1955. (Technical Memorandum Report No. WCLE-55-48.)
SUMMARY:

The report evaluates a Type MC-1 runway marker light and lamp respectively manufactured by Revere Electric Manufacturing Company and Radiant Lamp Corporation. The Type MC-1 light was a semi-flush light intended for use as a threshold marker light in high intensity runway lighting systems. As an interim light, it was considered satisfactory.

REMARKS:

The particulars of the test procedure are included in the report as are the photometric results. A section on installation and maintenance is also included.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Wallis, A. E.
TITLE: Expendable top, flush runway marker light, AGA Division of Elastic Stop Nut Corporation of America Part Number 2032-A1.
REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1957. (Technical Memorandum WCLE-TM-57-38.)
SUMMARY:

The report provides technical data concerning the performance, construction, installation, and maintenance of a flush runway light manufactured by the AGA Division of Elastic Stop Nut Corporation. The lights met photometric requirements and were found structurally very promising, it was recommended that they be tested under operational conditions.

REMARKS:

Important advantages reported are:

- The lights provide wide, high candlepower beams which are equivalent to those obtained from the standard, elevated Type C-1 runway marker lights.
- The light output is not restricted during mild snowfalls because of the elevated top (and raised reflectors).
- Lamp and dome replacement is readily accomplished by inexperienced personnel.

Disadvantages reported are:

- The elevated domes of the lights are readily damaged by any aircraft, snowplows or other vehicles which run over the light, thereby making the light ineffective and a hazard to jet engine operation.
- Quantities of spare domes are needed as a supply for replacement purposes.

Complete sections on description, installation, test results, and photometric characteristics are included.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Wallis, A. E.
TITLE: Flush type runway marker light, Westinghouse Electric Corporation Part Number 45A-2194-G01.
REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1957. (Technical Memorandum WCLE-TM-57-44.)
SUMMARY:

The report provides technical data on the performance, construction, installation, and maintenance of a newly developed (gradually sloped dome) flush-type light manufactured by Westinghouse Electric Corporation. The lights were considered almost structurally ideal, but they did not meet all photometric requirements.

REMARKS:

Photometric curves are included, as are sections on technical description, photographs, installation, and test results of the light. Results of previous tests on the light also are included.

Important advantages reported were:
- The light extends only 7/8 inch above the pavement surface.
- The light can withstand being run over by snowplows, aircraft, or other vehicles without damage to either the light or the vehicles.
- Lamp replacement can be readily accomplished by inexperienced personnel.

Disadvantages reported were:
- The light output in the main beams is far below that of the standard elevated Type C-1 runway marker lights.
- The very limited light output on the off-runway side will be of little value to pilots; hence, circling guidance lights and/or identification lights will be necessary to assist pilots in locating and identifying a runway during VFR conditions.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Wallis, A. E.
TITLE: High altitude rotating airport beacon.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1957. (Technical Memorandum WCLE-TM-57-12.)

SUMMARY:

This technical memorandum concerns determination of the optimum method of modifying the standard rotating airport beacon so that it will be suitable for high altitude aircraft. The report recommended that new lamps developed to accommodate high altitude aircraft be installed in existing beacons. Favorable flight test results are reported in a later report.(Hoffman, 1957).

REMARKS:

Extensive photometric data are presented.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Wallis, A. E.
TITLE: Runway marker light, flush, Type MC-2, Multi Electric Manufacturing, Incorporated Part Number 950.
REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1957. (Technical Memorandum WCLE-TM-57-113.)
SUMMARY:

This memorandum provides technical data on the performance, construction, installation, and maintenance of the Type MC-2 flush prismatic runway marker light manufactured by Multi Electric Manufacturing, Incorporated. The Multi Electric light is a round, bidirectional, flush light for use in overrun, threshold, or runway lighting systems. The dome extends about 1 inch above the runway surface. It was determined that the light will not cause excessive stresses on aircraft nor cause damage to snow plows. The light output of the unit was reported superior to that of other flush lights.

REMARKS:

Appendices contain a description, diagram, and photographs of the light, test results, photometric curves, description of snow plow tests, and applications and installation of the unit itself.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Wallis, A. E.
TITLE: Flush, fluorescent, centerline taxiway light.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1958. (Technical Memorandum WCLE-TM-58-57.)

SUMMARY:

This document describes a preliminary model of a fluorescent, flush, bar-type light for use as centerline taxiway indicator being made by Revere Electric Manufacturing Company. No conclusive results were stated, except that the lights should be service tested. There was some question of whether the color of the emitted light would conform to specifications.

REMARKS:

The over-all length, width, and depth of the top frame are, respectively, 53 1/2, 6 1/8, and 1 1/4 inches. The over-all length, width, and depth of the lower case were 50 1/4, 3 1/4, and 3.7.8 inches, respectively. The conduit hub at the bottom projects 5/8 inch.

A 40-watt, blue, rapid start, fluorescent lamp (Sylvania F40T12/B/RS) is utilized in the lights. The lamp is held in place just below the plastic cover. A trough-type, aluminum reflector with a high, specular finish, is provided below the lamp. A standard ballast for 40-watt rapid-start fluorescent lamps is located at the bottom of the case. The ballast is designed for operation from a 118-volt, 60-cycle source. At 118 volts, the power to the ballast was 55.5 watts, 1.1 amperes. The weight of the complete assembly is 75 lbs.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Wallis, A. E.
TITLE: Surface mounted, flush, centerline taxiway marker light.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1958. (Technical Memorandum WCLE-TM-58-56.)

SUMMARY:

This report provides laboratory data on the design and performance of centerline marker lights used in the high-speed taxiway turn-off tests at McClellan Air Force Base. The lights were considered satisfactory for interim use or test purposes only. Requirements for flush lights intended for use in centerline taxiway systems at permanent installations are specified.

REMARKS:

A description of the test light and its photometric curves are included in the appendix.

The lights used at McClellan were small, smooth-dome lights which were laid on top of the pavement and held in place by tape.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Wallis, A. E.
TITLE: Taxiway marker light, Flush Revere Electric Manufacturing Company Part Number 7701.
REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1958. (Technical Memorandum WCLE-TM-58-6.)
SUMMARY:

The report provides technical data on the performance, construction, installation, and maintenance of Revere Flush Taxiway lights. The lights had satisfactory light output for taxiway lights and were not considered a hazard to snow plows or aircraft.

REMARKS:

A description and photographs of the light, the test results, and installation procedures are delineated in the appendices. The report states that the lights should not be used indiscriminately, since the standard M-1 elevated taxiway light has greater light distribution and costs less to install.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Wylie, R. R.
TITLE: The Sylvania Panelescent Lamp.

REFERENCE: Salem, Massachusetts: Sylvania Electric Products, Inc., Commercial Engineering Department, 1958. (O-194.)

SUMMARY:

This bulletin gives technical data on, and discusses possible uses of, a new panelescent lamp developed by Sylvania. It can be used in the design of distance markers. This light source uses the phenomenon of electroluminescence for its operation. The lamp operates through the conversion of electricity into light within a solid phosphor. Due to inherent construction characteristics of the lamp, light appears to come from a plane or area source.

REMARKS:

The lamp is discussed as to physical structure, optical characteristics, brightness, maintenance and life, and electrical characteristics and operating circuits.

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C43. Airport lighting and marking. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, March, 1958. (Project No. 6061.)

C44. Boardman, L. J. The use of radioactive self-luminous markers as sources of illumination. Washington: Naval Research Laboratory, July, 1955. (Report No. 4546.)

C45. Davis, J. E. Report of a survey of visual landing aids. Washington: National Bureau of Standards, 1954. (Report No. 3260, Project No. 0201-20-2327.)

C46. Downs, D. G. Westinghouse semiflush runway marking light. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1955. (Technical Memorandum Report No. WCLE-55-91.)

C47. Fitts, P. M. Report of working group on airfield taxiway lighting and destination marking systems. Ann Arbor, Michigan: University of Michigan, January, 1953.

C48. Gilbert, M. S., & Faucett, R. E. The development of airport taxi guidance signs. Indianapolis, Indiana: Civil Aeronautics Administration, Technical Development and Evaluation Center, June, 1952. (Technical Development Report No. 170.)

C49. Gilbert, M. S., & Pearson, H. J. C. A study of the visibility and glare ranges of slope-line approach lights. Indianapolis, Indiana: Civil Aeronautics Administration, Technical Development and Evaluation Center, November, 1951. (Report No. 150.)

C50. Hicks, G. T. Visibility and uses of self-luminous markers. Washington: Naval Research Laboratory, Photometry Branch, April, 1954. (Memorandum Report No. 284.)

C51. Kevern, G. M. Light, overrun, Type C-2, American Gas Accumulator Part Number 1847-A1. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, January 1953. (Technical Memorandum Report No. WCLE-53-129.)

C52. Lighting an airport taxiway sign. Illuminating Engineering, February, 1954. (I. E. S. Lighting Data Sheet 27-6.)

C53. Runway light nears CAA ideal. Aviation Week, 1953, 58 (26), 58.

C54. Runway-taxiway marker lights. Milwaukee, Wisconsin: Line Material Company.

C55. Seeing through fog. Engineering Research Review, 1958, 8 (1), 3-5.

C56. Stockwell, R. E. The lights that bring them in. Milwaukee, Wisconsin: Line Material Company, July, 1946.

SELECTED
STANDARDS, RULES
AND
RECOMMENDED PROCEDURES

SELECTED STANDARDS, RULES and RECOMMENDED PROCEDURES

S1. Aerodromes. Montreal, Canada: International Civil Aviation Organization, September, 1958. (Annex 14.)

S2. Approach lighting at land aerodromes. Washington: Air Coordinating Committee, April, 1958. (AGA-NSla.)

S3. Civil Aeronautics Administration. Aeronautical beacons. Washington: Author, December, 1947. (TSO-N7a.)

S4. Civil Aeronautics Administration. Fixed focus uni-directional high intensity runway light. Washington: Author, January, 1951. (Specification L-820.)

S5. Civil Aeronautics Administration. Closed airport, closed runway and airport hazard marking. Washington: Author, May, 1952. (TSO-N16a.)

S6. Civil Aeronautics Administration. Runway and taxiway marking. Washington: Author, April, 1953. (TSO-N10a.)

S7. Civil Aeronautics Administration. Runway and strip marker light. Washington: Author, September, 1953. (Specification L-802.)

S8. Civil Aeronautics Administration. Taxi sign system. Washington: Author, 1953. (TSO-N23.)

S9. Civil Aeronautics Administration. Elevated taxiway marker light. Washington: Author, April, 1954. (Specification L-822.)

S10. Civil Aeronautics Administration. Approach lighting. Washington: Author, June, 1954. (TSO-N24.)

S11. Civil Aeronautics Administration. Obstruction light. Washington: Author, April, 1955. (Specification L-810.)

S12. Civil Aeronautics Administration. Airport taxi guidance sign. Washington: Author, October, 1955. (Specification L-829.)

S13. Civil Aeronautics Administration. Obstruction lighting basic requirements. Washington: Author, February, 1956. (TSO-N25.)

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S15. Civil Aeronautics Administration. Standard specifications for construction of airports. Washington: Author, June, 1956. (Revisions and Supplements No. 2.)

S16. Civil Aeronautics Administration. General operation rules. (2nd ed.) Washington: Author, December, 1956. (Civil Aeronautics Manuel 43.)

S17. Civil Aeronautics Administration. Specification for 500-watt high intensity runway light with automatic beam control. Washington: Author, March, 1957. (Specification L-818a.)

S18. Civil Aeronautics Administration. Runway and landing strip lighting. Washington: Author, May, 1957. (TSO-N1c.)

S19. Civil Aeronautics Administration. Taxiway lighting. Washington: Author, February, 1958. (TSO-N3a.)

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ANALYTIC STUDIES
ON
AIRPORT MARKING AND LIGHTING PROBLEMS

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Calvert, E. S.
TITLE: Visual aids for landing in bad visibility with particular reference to the transition from instrument to visual flight.
REFERENCE: London, England: International Air Transport Association, 1950. (Report of Flight Technical Group, Second Meeting.)

SUMMARY:

Calvert discusses the need of systematic study for determining the best pattern for use in providing visual aids to the pilot on landing. The nature of the perceptual problem is discussed, requirements for visual aid patterns are indicated, and an expansion pattern theory of perception is put forth as the basis for optimal airport marking and lighting design. Implications of the expansion pattern theory for airport marking and lighting are presented as recommendations.

REMARKS:

Note similarity to Gibson's approach.

REQUIREMENTS:

The airport marking and lighting pattern must contain cues that enable the pilot to determine the aircraft's position, attitude, angular rotations and direction of motion, and give these indications in a form which the pilot can assimilate instantly and instinctively in moments of mental stress. As a basis for the design of an AML system that will be most readily and easily interpreted, Calvert refers to the expansion pattern, or streamer pattern, theory of visual judgment. This theory is as follows:

> If an observer is in motion in a straight line towards a point X in a pattern, then all other points in the vicinity will appear to move radially away from X. It is thought that the pilot uses this phenomenon to maneuver the aircraft to a position where the lighting system appears to stream past him symmetrically, with the plane of symmetry through the pilot and extended runway centerline. When in this position, he stares fixedly ahead at the origin (point X) of the streamer pattern (as indicated by the stationary point about which the pattern expands) and notes consciously or subconsciously the rate of radial streamer velocity as a cue to his rate of descent. Streamer velocity at a given point in the visual field is inversely proportional to height, provided the forward velocity of the aircraft is maintained constant.

CONCLUSIONS AND/OR RECOMMENDATIONS:

On the basis of the expansion theory of visual perception, approach lighting patterns and flying patterns should be designed according to the following requirements:

The apex of the pattern should be at the selected touch-down point on the centerline of the runway.

The pattern should be symmetrical about the extended centerline of the runway. With such a pattern, the lights will appear to stream symmetrically along lines drawn through the selected touch-down point as long as the aircraft is moving along a path which intersects the runway at this point.

Flashing lights should not be used in the pattern to provide guidance because they break up the streamer pattern and make it difficult to observe or estimate streamer velocity. If flashing lights are used to help the pilot to identify the approach lighting system, they should provide the cues necessary for guidance. The number, spacing, and width of approach pattern crossbars designed to make streamer velocities more noticeable should be designed according to meteorological visibility conditions. Since these important visual judgments are based on parafoveal vision, the approach and runway lights, as well as marks, should be of large enough size to be maximally effective.

Lights or markings down the middle of the runway will be more effective as height indicators than lights or markings at the edges of the runway. This is because the vertical component of streamer velocity is inversely proportional to altitude, while the horizontal component of the streamer velocity is independent of height.

To avoid misjudgments due to changes of scale in the dimensions, runway, threshold, or approach marking and lighting system should be constant for all airports.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Calvert, E. S.
TITLE: The integration of the visual landing aids with particular reference to proposals submitted by Captain G. J. Malouin.
REFERENCE: Paper presented at the IATA Flight Technical Group, Fourth Meeting, New York, October, 1951.

SUMMARY:

In this paper, Calvert discusses the loss of guidance over the runway, and analyzes this loss in terms of the inadequacy of runway lighting as opposed to any inadequacy in the approach lighting pattern. He suggests that runway guidance patterns could be improved by a good system of white-painted markings in the daytime and flush centerline lights at night.

REMARKS:

This is an early discussion of the so-called "black hole" problem. The concept of integration is defined and discussed.

REQUIREMENTS AND/OR DISCUSSION:

An integrated system should have the following characteristics:

Easy transition from instrument to visual flight without uncertainty or illusions.

The runway guidance pattern should be good enough to enable the pilot to land safely once he has seen enough of the approach light pattern to make the transition from instrument to visual flight under poor visibility conditions.

The landing area should be unmistakably differentiated from the approach area.

Loss of guidance over the runway is not considered due to dazzle from the centerline approach lights.

The critical length at which the edge light runway guidance pattern begins to produce illusions and give insensitive directional indications is greater than the critical length for an approach lighting pattern. The first rule for seeing is to pick out a stable framework of the ground plane made up of horizontal and vertical lines and containing objects of known size to fix distances.

Ground plane means a visual indication of the attitude of the aircraft in pitch and roll, combined with an indication of its height.

The basic pattern of visual aids must be some form of regular grid which must be symmetrical about the centerline of the runway.

Directional runway edge lights are insensitive at low heights, and this is probably responsible for the "black hole" feeling. The loss of sensitivity at a given height is proportional to the square of the distance between the lines; thus, for a sensitive directional indication, double lines--if used at all--should be used in the outermost portions of the visual aids system.

The centerline runway lights will provide height indication by the apparent downward velocity of the lights as the aircraft passes over them.

CONCLUSIONS AND/OR RECOMMENDATIONS:

It was recommended that for adequate runway guidance, the following steps be taken:

A good system of white-painted markings for daytime use.

Centerline lights for night use.

Because putting centerline lights on existing runways is very costly, serious consideration should be given to the use of FIDO at airports and to bettering methods of measuring visibility.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Calvert, E. S.
TITLE: Visual judgments in motion.

REFERENCE: Journal of the Institute of Navigation, 1954, 7 (3), 233-250.

SUMMARY:

In this paper, Calvert discusses the judgments utilized by a pilot when landing an aircraft. The author discusses a number of aspects of the problem of providing artificial aids to the pilot which he can utilize as visual guidance in reduced visibility and how various systems of aids affect the general levels of landing success and safety. Displacements, rate of closure, and rate of change of closure judgments are discussed in terms of their utilization during approach and flareout and in terms of the visual indications utilized to make these judgments. The cockpit instrument used for presenting glide-path information is evaluated in terms of the type of information it provides, and its inadequacies are discussed. Recommendations are made for additional visual aids and runway markings consistent with the author's parafoveal streamer pattern theory of rate guidance.

REMARKS:

This article describes more of the fundamental human factors assumptions utilized by Calvert than are found in most of his other publications.

REQUIREMENTS AND/OR DISCUSSION:

<u>The visual field and the mental world</u>

The brain interprets the two-dimensional perspective image on the retina selecting the possible meaning it might have in light of all the other data available to it. If the wrong meaning is attached to the visual scene, then so-called illusions occur.

The most important features of the visual field are: the plane of the ground, and objects of known size on the surface. Without these two, humans can become disoriented and frightened.

Texture is considered the most common cue to the ground plane, followed closely by vertical and horizontal parallel lines.

The slope-line system of approach was not acceptable because it was contrary to the perspective of parallel lines.

<u>The transition from instrument to visual flight</u>

The pilot constructs a mental world as to his position and attitude from an integration of his flight instrument indications or GCA instructions.

Frequently, fatigue makes this integration difficult, and sometimes impossible.

Simulators might be quite useful in showing what the various pitfalls and errors are in making the transition from the mental world to the visual world.

The pilot's first act in the transition is to build up a visual reference plane or establish the ground plane. This means an impression of the distance of the plane of the ground from the aircraft with an impression of the inclination of this plane to the aircraft's longitudinal axis; it is an integrated impression of height, pitch, and bank.

Runway edge lights are not satisfactory because in bad visibility, three illusions can occur:

The lights appear to float in space.

The lights appear to swing from side to side.

During an overshoot, the pilot may have an impression that he is climbing more steeply than he is and may "level off" and fly into the ground.

Judgments during an approach.

In order to land, the pilot must close two planes - one vertical, and one horizontal.

The conditions for closing a plane are: displacement must be zero, rate of closure must be zero, and rate of change of closure must be zero.

The pilot must make nine judgments in all, as well as considering speed and many other things. This is because he satisfies six end conditions, three for each plane, by manipulating attitude in pitch and roll; heading is the ninth judgment.

Indications used in visual flight

At high speeds, pilots - as most humans will in similar positions - fixate straight ahead at a large distance.

The so-called "stare period" has led to the parafoveal streamer theory of motion judgments.

Rate information for an observer in motion is obtained from the apparent radiation of objects in the field of view from the point toward which he is moving.

Four conclusions derived from the parafoveal theory are of great importance:

The greater the speed of the aircraft, the smaller the heading changes needed to acquire a given displacement in a given time. Thus, the higher the speed, the more accurately must the point of impact be known. Thus, the higher the approach speed, the higher will be the minimum visual range for given levels of safety and approach success.

If there are no definite objects in the foreground, the point of impact cannot be found and the pilot runs the risk of flying into it.

Any fog-dispersal technique installations (e. g., FIDO) should extend into the approach as well as along the runway.

In order for the pilot to find his point of impact, accurately and quickly, the approach lighting pattern must extend laterally as well as longitudinally. The slope-line system only gave displacement information.

The use of rate information in a visual approach

The pilot satisfies his end conditions with respect to closing the planes by establishing a desired ground track, and establishing an acceptable descent path.

Instrument presentations for ILS approaches

The needles utilized for showing displacement from glide slope and localizer plane provide very little rate information.

With this type of information, the pilot has no power of anticipation.

Instruments which combine displacement and rate information are known as flight directors.

Effect of rate information on landing success

In general, the higher and more adequate the rate information given the pilot by both instruments and visual aids, the higher the probability of successful landings for given meteorological visibility and runway visual range.

Minimum visual range required for guidance

The minimum visual range required for guidance depends on the particular ground pattern and on the approach speeds utilized.

The visual range required for complete visual guidance at the end of the instrument approach is proportional to height.

Operating limits for the cross-bar system

If the visual range falls much below 1500 feet, the exposure time - the time from going contact to flareout - is very short. With an altitude of 50 feet and rate of descent at 10 feet per second, the pilot will have complete guidance for 7 seconds prior to that.

The author is convinced that however good the instrument aids, 1500 feet is below the visual range at which visual landings should be made in civil operations. This is because reductions below that deprive the pilot of too much exposure time below his critical height. If approach speeds continue to increase, it may be more desirable to cut out visual landing altogether and make the entire approach automatically.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Safety in landing can be increased by additional visual aids on the runway such as surface markings for day use and centerline lights and stub-bars for night use.

Accidents indicate that conditions which are marginal for circling approaches are also dangerous. Lead-in lighting calling for a string of lights is considered dangerous inasmuch as it does not provide ground plane.

Where the runway ends at the edge of the sea, or where approach lights cannot be installed, an angle of approach indicator should be installed.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Calvert, E. S.
TITLE: Visual aids and their effect on landing success and safety.

REFERENCE: Farnsborough, England: Royal Aircraft Establishment, 1955. (Report No. EL. 1486.)

SUMMARY:

Calvert discusses the approach and landing problem in terms of the pilot's task requirements, the visual guidance that the pilot requires, and the process by which the pilot obtains information (direction, roll) from his visual field.

REMARKS: None.

REQUIREMENTS AND/OR DISCUSSION:

During final approach, the pilot's task is to control his aircraft, so as to meet two general requirements:

> The aircraft's angle of approach must be within safety limits.
>
> The aircraft's alignment with respect to the extended runway centerline must be within safety limits.

Ideally, the pilot desires to follow a path in space defined by the intersection of two planes: the approach slope and the vertical plane through the extended runway centerline. In order to find and hold this path, the pilot must bring to zero at the same moment and subsequently hold on zero, six quantities. These are: his displacement from the plane, his rate of closure relative to the plane, and the rate of change of the rate of closure to the plane - for both the approach plane and the centerline vertical plane. Finally, when the aircraft has descended along this path, the pilot reduces his rate of descent which means that the six quantities he is controlling at zero must be continuously adjusted. The pilot's task includes two very basic judgments - the slope of his approach path, and the point at which this path intersects the runway.

A line of lights on the left side of the approach area is a widely-used pattern for an approach aid. An analysis of the visual guidance problem created by this configuration indicates that the pilot's task is to maintain a constant perspective angle between his position and the line of lights on the ground at some distance to his left. A problem is created, however, since the line will appear to the pilot to rotate with respect to the horizon for changes in altitude as well as for changes in lateral displacement so that he is left to guess the value of the angle which is correct for any given height. The position of the line of lights projected on the pilot's side wind screen will appear to move higher and higher as the pilot either increases his lateral displacement from that line or decreases his altitude with respect to the surface. Furthermore, in the absence of a defined external horizon, the same phenomena of the line of lights appearing to climb the left-hand window will occur as a function of roll. If the left-hand wing of the aircraft dips, the lights will appear to climb the left-hand wind screen. The usefulness of the left-hand line approach light is perhaps more of a hazard than a help, since this confusion between height, lateral error, and bank angle cannot be resolved through reference to the approach lights alone.

First, the extended runway centerline approach lighting system resolves the problem of confusion between changes in height and changes in lateral displacement, since the pilot's task as far as alignment is concerned is to hold the perspective angle at zero regardless of his altitude. Secondly, the use of transverse bars in combination with the centerline resolves the confusion between height, lateral error, and bank angle, since to the pilot looking along the centerline the bars always appear to be parallel to the horizon. In bad visibility, where the pilot has no reference to the actual horizon, his task is to keep the centerline perpendicular to the transverse bars, just as in good visibility he would keep the centerline perpendicular to the horizon.

The pilot's visual field is defined as an expansion pattern in which all objects in his field of view appear to move along paths which have the common property that at any moment the tangents of their paths meet at the point in the visual field towards which the aircraft is proceeding at that moment. This Point X is the center of the expansion pattern and is defined as a stationary or non-moving area, from which point all discriminable stimuli appear to be expanding.

Rate of closure with the ground is estimated on the basis of the angular distance of this Point X below the horizon.

Rate of closure with the vertical plane through the centerline is estimated on the basis of the angular distance of the Point X from the runway centerline.

A change in rate of change with respect to closure with the horizontal plane is estimated on the basis of the movement of the X point along the horizon.

Change in the rate of change with respect to closure with the vertical plane is estimated on the basis of the movement of the X point perpendicular to the horizon.

Factors affecting accuracy of rate judgments:

The expansion effect occurs only when the pilot looks along the centerline in a fixed direction in space. This is why pilots stare straight ahead during the final portion of their approach and during landing. Distractions of any kind which cause him to move his point of visual fixation will therefore reduce the accuracy of his rate judgments.

The second factor which affects the accuracy of these judgments is the nature of the terrain in the approach area and the degree of texturing in the presence or absence of markings on the runway. The accuracy of rate judgments is a function of the presence of definite objects in the foreground which permit an expansion pattern in sufficient detail.

Calvert claims that the cross-bar pattern not only resolves ambiguities between vertical displacement, lateral displacement, and angle of bank, but also provides sufficient patterning in the approach area to permit a more marked streamer effect than might occur under natural conditions or with a less-patterned approach configuration.

CONCLUSIONS AND/OR RECOMMENDATIONS:

As approach speeds increase, the pilot must more accurately and more quickly judge his track heading on final approach in order to keep his displacement within acceptable limits.

CONTRACT FAA/BRD-14
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Calvert, E. S.
TITLE: Visual aids for non-instrument runways.

REFERENCE: Paper attached to IATA Special Meeting, Amsterdam, November 14-22, 1955.

SUMMARY:

The point is made that an instrument runway is normally used in substantially the same way as a non-instrument runway, on the condition that the visibility is good enough for visual approaches to be possible. Therefore, non-instrument runways should be provided with high-intensity lights, not operated at full intensity, and the pattern utilized should be similar to instrument runway patterns, with at least one bar located near the threshold for an aiming point.

REMARKS:

Calvert makes a cogent plea for adequate and compatible lighting of non-instrument runways.

REQUIREMENTS AND/OR DISCUSSION:

The main requirement is for a distinctive land mark visible over a side angle.

The surface of the runway must be easily distinguished from its surroundings.

CONCLUSIONS AND/OR RECOMMENDATIONS:

A centerline pattern extending to a minimum distance of 1500 feet beyond the threshold, with omnidirectional low-intensity lights utilized, would permit the pilot to become accustomed to the pattern which he will have to use in bad visibility.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Calvert, E. S.
TITLE: The theory of visual judgments in motion and its application to the design of landing aids for aircraft.
REFERENCE: Paper presented at RAE Society, London, April, 1957.

SUMMARY:

This paper represents the latest (to date of this report) comprehensive review by the author of his thinking regarding airport marking and lighting. The principal points discussed are the need for better guidance in the vertical plane (height or elevation), the beam spreads of approach lights, and runway lighting. The paper itself is followed by an account of the discussion which occurred after the presentation. The account of the discussion also contains many interesting comments from both an operational and technical viewpoint.

REMARKS:

In this paper, the author does a very effective job of pin-pointing areas of controversy and areas in which more definitive knowledge would be most useful from an airport marking and lighting design standpoint.

REQUIREMENTS AND/OR DISCUSSION:

Although approach aids were originally developed for bad-weather landings, the accident statistics of the past 5 years indicate that they are required in visibility conditions above the minima originally intended.

The pilot's task consists of matching heading against displacement, so that at the moment when his displacement becomes zero, the relative track heading and the rate of turn have also become zero. This task occurs in 2 planes with the pilot controlling these 3 degrees of movement freedom with respect to each plane through rotation of his aircraft about its 3 axes. The information the pilot gets from his visual environment can be considered as feed-back information for his matching task.

Psychologists working on visual perception habitually discuss visual guidance in terms of about a dozen cues, failing to distinguish between those required for recognition and those required for guidance and control. Furthermore, they complicate the problem by misusing terms such as "parallax" and "orientation".

How information is obtained from the visual environment:

Displacement information is given by the shape of the perspective image in the horizontal plane. The perpendicularity of 90-degree bars provides this information. In the vertical plane, the displacement of the aiming point below the horizon provides the information.

Rate information is given from the position of the origin (X) of the streamer pattern in the perspective picture. Rate in the horizontal is the apparent distance between the apparent vanishing point of the centerline and a vertical line through X. In the vertical plane, rate is given by the apparent distance between X and the desired aiming point above 100 feet. At heights below 100 feet, the rate is obtained from the vertical distance of X below the horizon. In order to find X at all, there must be numerous objects in the field of view, and the streamer velocity within a certain angular distance from X must be above a certain value. In the real case, the pilot is always surrounded by a framework and is able to deduce where the aircraft is going by the relationship of this framework to the horizon, by his knowledge of the control configuration, and by readings of his instruments; thus, a horizontal cut-off line of the cockpit cowling is a useful framework structure.

Crossbars can replace the horizon for guidance in the horizontal plane, but not in the vertical plane. Thus, when the pilot leaves his instruments after he sees lights, he is without adequate guidance in the vertical plane for a much longer time than he should be. With the cross-bar pattern, if the aircraft is flying into the ground, the apparent decrease of the size intervals between the bars and the increase in streamer velocity warn the pilot of danger. This starts to be effective at a height of about 100 feet.

In very poor visibilities, the point X is difficult, if not impossible, to ascertain because of the lack of a definitive object.

The 2-unit angle of approach indicator will provide additional vertical guidance information instantly and instinctively.

The following additions to the ground pattern would be useful:

Marking the aiming point.

Establishing a minimum length, and interval separation for approach and runway patterns.

Defining a landing mat with flush lighting.

Research and development should be initiated for developing an optical setting device providing a transverse line and a dot which the pilot may use for vertical guidance. This was felt necessary because it is not believed that better rate information can possibly be obtained from any ground pattern.

The vertical beam spread of any steady approach lighting fixture should be wide enough and directed in a satisfactory direction so as to increase its conspicuity within the vertical region of guidance. The precise beam width required should be determined empirically.

The region of guidance in the horizontal plane is dependent upon two factors: lateral errors at the end of instrument portions of the approach and the latest point in the approach at which a visually-controlled maneuver must begin if the landing is to be accomplished safely.

The ICAO recommended region of guidance at 3000 feet from threshold of plus or minus 250 feet is somewhat narrower than would seem required for manual ILS with cross-pointer type approaches, assuming that a 95% success figure is an acceptable risk.

The length of the visual segment which the pilot must see is determined by visibility conditions; i.e., visual range, angle of cutoff, and the type of approach pattern used. In the United Kingdom, this is computed to be 800 feet at heights around 250 feet and is 1000 feet at heights around 120 feet.

In order to cover the region of guidance for manual ILS with cross-point needle type of approaches, the horizontal beam spread of approach light fittings in the approach pattern must have a uniform intensity over about plus or minus 15 degrees from centerline, falling to a few per cent of maximum intensity at an angle about plus or minus 26 degrees from the centerline. A side effect of this would be to improve guidance during turn in from a circling approach in moderate and better visibility conditions.

Circling lights positioned along the side of the runway for circling or "square-circuit" approaches should have a spread up to 170 degrees in azimuth, and be supplied from a separate circuit.

The author reports that Douglas, of the U. S. National Bureau of Standards, has suggested that with an angle in elevation of from 2-8 degrees, the intensity distribution in azimuth should vary between 5000 and 600 candles, varying on the azimuth values.

The British designed flush runway light is considered to give the same advantages as the Dutch Elfaka units at a tenth of the cost. The poor-beam spread of the Dutch Elfaka unit is considered unsatisfactory because roll and height guidance will be lost if the aircraft touches down with a very large lateral error, thus defeating the purpose of the whole mat.

Comments on discussion:

Captain Woodman describes the latter stages of an instrument approach in an impressive way, making the reader aware of the problems facing the pilot.

Captain Humphrey expressed interest in:

Doing something to enable the pilot to grasp the significance of the pattern more quickly.

Achieving a greater degree of standardization than at present.

Furthering the battle to eliminate extraneous lights.

Mr. Stallibrass suggested that the angle of approach indicator be named the "safe descent path indicator".

Mr. Holmes pointed out that the problem in providing for faster aircraft landings in misty daytime conditions by calling for bigger and brighter lights involves a logarithmic increase in intensity at a corresponding rate of increased expense. He points out that it doesn't look as if more than 10,000 candles are required if the light comes from the right place and is accurately controlled in the right directions.

Mr. Sparke commented that the weakness of visual guidance in the vertical plane compared with guidance in the horizontal plane is true in all visibilities, however good or bad, because in the vertical plane, the nominal glide path is not associated with any symmetry in the perspective image or in the streamer pattern, and the pilot must rely solely upon previous experience.

In his reply to these comments, one of the significant things that Mr. Calvert pointed out is that he is not in accord with the U. S. belief that sequence flashing lights have better guidance or fog penetrating quality. He also points out that a visual landing simulator would be useful in the U. S. as a means of checking new ideas quickly under controlled conditions. Mr. Calvert feels that the maximum intensity of approach lighting fittings should be 20,000 candles with a spread of 10 degrees vertically and 30 degrees horizontally. The author also commented that floodlighting of the runway creates pools of light and darkness inasmuch as the fittings cannot be put up high enough. Also, floodlighting consumes power enormously, compared with flush lighting. Mr. Calvert pointed out that the difference in vertical and horizontal guidance pin-pointed by Mr. Sparke is the major reason why visual guidance derived from a pattern can never be as good in the vertical plane as it is in the horizontal, even when the weather is perfect: thus, the need for an angle of approach indicator effective both day and night.

CONCLUSIONS AND/OR RECOMMENDATIONS:

See Requirements and/or Discussion.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Calvert, E. S.
TITLE: The possibilities of improving visual guidance during the approach, with particular reference to aircraft with poor downward views.
REFERENCE: Report prepared for meeting of NATO Airfield Standardization Committee, Paris, November, 1957.

SUMMARY:

The author reviews requirements placed on pilots by increased approach speed, low-speed handling characteristics, and reduced cockpit field-of-view, with each new generation of aircraft, particularly jet-propelled aircraft. It is pointed out that increasing the width of stub bars along the approach configuration will not significantly increase altitude guidance. On the basis of the rationale developed, the author established the need for a visual glide path indicator for use in moderate and good visibilities.

REMARKS:

There is certainly a firm view by the author that height guidance from centerline systems now in use, even with a number of crossbars, is somewhat less than adequate.

REQUIREMENTS AND/OR DISCUSSION:

Azimuth and height deviation indicators from the continuation of the ILS or GCA established glide path down to touchdown.

CONCLUSIONS AND/OR RECOMMENDATIONS:

With new types of aircraft, having instrument approach speeds as high as 180 knots and downward views as low as 5 degrees, the pilots will see little of the approach lighting pattern at heights below 300 feet even in good visibility. The visual guidance obtainable from the runway alone is poor, particularly in the vertical plane.

Adding stub bars, or increasing the width of crossbars to centerline systems would not significantly increase height guidance.

The limiting visual range will be increased by poor downward views inasmuch as the pilot must get lower to secure enough guidance to complete his landing.

The threshold is always visible within the limits of the limiting slant range required for the new generation of aircraft; therefore, a visual glide path indicator placed at that position giving vertical guidance will be visible in moderate and good visibility.

The 3- sector indicator suggested for use as a glide-path indicator has been found unsatisfactory because:

> The pilot sooner or later receives an indication that he is too high or too low when in fact he is not.
>
> The sectors tend to become amber due to condensation on the lens or diffusion in radiation fog. (Amber is a fly-down indication.)

The bi-color indicator satisfies the requirements for visual height guidance down to threshold and is not affected by condensation and diffusion in radiation fog.

The 2 units of the bi-color indicator give additional glide path information by virtue of the shape of the perspective interval between the bars.

The bi-color indicator is cheap, easy to maintain, and can be made to give any desired intensity.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Calvert, E. S.
TITLE: Safety in landing as affected by the weather minima and by the system used to provide visual guidance in the vertical plane, with particular reference to jet aircraft.
REFERENCE: Farnsborough, England: Royal Aircraft Establishment, 1958. (Technical Memorandum No. EL. 1827.)

SUMMARY:

The author reviews accident statistics from the viewpoint of specifying the special types of visual aids which might accomplish the best over-all benefit at the least expenditure. Inasmuch as about 80% of all approaches made in both Great Britain and the United States by civil aircraft are in visibilities above 2 miles, it is suggested that a visual glide-path indicator, giving improved guidance in vertical plane in these visibilities will have a significant effect on the accident rate. The extent to which such improved guidance in vertical plane might improve safety is illustrated. The author recommends that a long-term program of operational research be initiated with the objective of collecting the kind of data which would permit a more accurate assessment of the effects of expenditures for additional approach aids.

REMARKS:

A very convincing argument for the use of angle approach indicators in moderate and good visibility.

REQUIREMENTS AND/OR DISCUSSION:

About one-quarter of all military landing accidents in the USAF during 1953-54 were attributed to pilot error. The author considers that this sort of error needs to be analyzed and that the failures should be thought of as information-response failure.

The incidence of jet aircraft system failure was 7 1/2 times greater than for propeller-driven aircraft. Both of these points are based on the Directorate of Flight Safety Research Report, put out by the USAF.

In Great Britain and the United States, about 80% of the approaches made by civil aircraft are in visibility conditions above 2 miles.

Two suggestions for improving the general level of safety are:

The limiting Runway Visual Range should be related to the aircraft's critical height in such a way as to account for both the ground pattern and the types of marginal weather found at a particular airfield.

Methods of measuring and reporting marginal weather conditions should be utilized, based on the way in which the portion of the ground pattern seen by the pilot changes during the approach.

(The above two suggestions would affect only about 10% or so of the landings made in bad weather conditions.)

Runway Visual Range is the maximum distance along the runway, measured in the direction the aircraft will approach, at which markers or lights delineating the runway are visible.

The Critical Height is the height above airport elevation at which an approach to landing can be continued without visual reference to the ground.

Visual guidance in the vertical plane depends mainly on ground plane; i. e., on a combination of texture and horizon.

In the analysis conducted by the Directorate of Flight Safety Research, it was found that the probability of an accident due to a visual misjudgment was 2 1/2 times greater by night than by day.

The author suggests a re-definition of Critical Height so that it would require seeing at least one cross-bar of the ground guidance pattern.

The Instrument Control Loop is defined as: the electronic ground aid from which guidance is received, the method of computing the control movements required, the method of making these movements and response of the aircraft to these movements.

The combination of computation and control is known as the Coupler. Thus, the ICL is the electronic ground aid, the Coupler, and the aircraft.

Deviation from the optimal glide path for any particular control loop can be determined and drawn to include a given percentage of approaches. Allowing some clearance below this envelope, any object which penetrates this clearance surface is an Obstacle, and the surface can be called the "Obstacle Clearance Surface" for that particular Instrument Control Loop.

At some height, the Instrument Control Loop is discarded and the pilot goes to his Visual Control Loop. The height at which this change is made is called the Change-Over Height.

The poorer the visibility and the higher the Change-Over Height, the worse the vertical guidance that can be obtained from ground patterns by the Visual Control Loop.

During the correction of a lateral error, visual guidance in the vertical plane is virtually non-existent.

The accident rate in better visibilities will depend much more on the system of visual aids than on the visibility and even in marginal conditions, the visibility is not in itself a good measure of the difficulty of the pilot's task in the vertical plane.

A visual glide-path indicator which is effective down to a visibility of 2 miles would prevent about 75% of all accidents attributed to visual misjudgments.

It can be assumed that:

Beyond a certain point, raising the minima Runway Visual Range has no appreciable effect upon the overall accident rate.

If the limiting Runway Visual Range is correctly chosen, the accident rate for a given type of aircraft will be determined almost entirely by the total visual guidance available. In short, a poor system cannot be compensated for by raising visibility minima.

The author feels that the enthusiasm for sequence-flashing lights in the United States is due to the fact that the fixed-approach lights have very narrow beams and the beams are set far too high.

There are theoretical reasons for believing that sequence-flashing lights in the interior zone of the approach sector will interfere with the streamer pattern, and thereby impair visual rate information in the vertical plane. Thus, it may be probable that sequence-flashing lights would increase accident rates in marginal visibilities, particularly with jet-engine aircraft.

Any proposed glide-path indicator must be sufficiently sensitive at long ranges (over 5 miles) to deal with obstacles and have sufficient latitude at short ranges (less than 1 mile) to enable it to be used down to threshold. The author feels that only the RAE one-color indicator meets these requirements.

Length of the portion of ground-guidance pattern which is visible at any height is called the "Visual Segment" and that portion which is just sufficient to enable the average pilot to continue his approach and landing is called the "Minimum Visual Segment". Utilizing a Standard Visual Pilot (a statistical average), the length of the Minimum Visual Segment can be determined. The Minimum Slant Range required for an aircraft landing at 125 knots, using the Standard Visual Pilot as the determinant for the Minimum Visual Segment required, is in the following order:

Critical Height in feet	Minimum slant range in feet for 5-degree angle of approach		
	No approach pattern	Pattern 1500 ft. long with 2 bars	Pattern 3000 ft. long with 5 bars
200	4500	2500	1700*
250	5800	3550	1800*
300	7000	4600	2800
350	8300	5700	3900
400	9600	6900	5000

* Downward view 15 degrees

The table indicates that there is a large advantage in being able to achieve a critical height of the order of 250 feet, but not much advantage in going below this. At the Discontinuity Height, an increase in critical height means an increase in the minimum slant range required. Discontinuity Height is a function of:

cockpit cutoff,

angle of the glide path, and

the length of the pattern.

Shallow fog is dangerous because the change in the visual segment may be interpreted as a change in pitch in the nose-up sense in which case the pilot may steepen his rate of descent.

CONCLUSIONS AND/OR RECOMMENDATIONS:

The largest improvement in overall safety in landing can be obtained with the use of an effective glide path indicator. The author feels that only the RAE two-color indicator meets requirements.

On the relatively few occasions when landings are made in marginal conditions; safety will be increased by:

Relating limiting runway visual range to critical height so as to take account of both ground pattern and type of weather found at the particular airport, Using improved methods of classifying, measuring, and reporting weather conditions (the author suggests a four-category system).

A small standing group should be set up to make a yearly review of accident statistics and determine the amount by which the accident rates and regularity of the traffic would be affected by given expenditures on additional aids. This should be done on an international level.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Civil Aeronautics Administration, Office of Airports.
TITLE: Exit taxiways and holding aprons.

REFERENCE: Washington: Author, 1957. (Airport Engineering Bulletin No. 6.)

SUMMARY:

This report discusses considerations involved in the location, spacing, and configuration of exit taxiways and the location and configuration of holding aprons. The specific recommendations presented by this report are based upon prior studies and physical laws of motion. Factors considered were air frame stress and passenger discomfort in decelerating and negotiating a turn at various forward velocities and turn radii.

REMARKS:

Plan view diagrams are presented showing the location, spacing, and configuration of exit taxiways recommended in the report and the location and configuration of the holding aprons recommended. Graphs are presented showing the relationship between the taxi velocity and turn radii. Plots of the per cent of touchdowns at varying distances from the runway thresholds are included.

REQUIREMENTS AND/OR DISCUSSION:

The acceptance rate of a runway is one of the more critical elements affecting the ability of an airport to accommodate a given volume of their traffic. Rapid clearing of the runway and reduction in runway occupancy time will increase the runway's acceptance rate.

The location of runway exits will be a function of the distance from the threshold to the touchdown point and the distance from point of touchdown to the point of acceptable turnoff velocity.

When turns are to be made at relatively higher velocities, positive identification of the runway exits must be provided in sufficient time to alert the pilot to the presence of an exit. The problem is particularly critical under conditions of low visibility.

The size of the holding apron should be determined by the types of aircraft and the volume of traffic serviced by the holding apron.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Modern commercial propeller-drive aircraft can negotiate turns of approximately a 550-foot radius while travelling at 40 miles per hour.

Optimum locations for runway exits are 2500, 3500, and 4500 feet from the runway threshold based on the landing speeds, deceleration rates, and range of touch-down points characteristic of modern propeller-driven commercial aircraft.

Exit taxiways spaced at 5500 and 6000 feet from threshold should be installed at those airports which would be required to service the large jet-propelled airliners such as the Boeing 707.

Exit taxiways should be oriented at an angle of 30 degrees to the runway. This angle produces a turn radius of approximately 560 feet on a runway 150 feet wide.

Holding space requirements for aprons will vary from approximately 150 feet for a twin-engine aircraft to about 250 feet for a large 4-engine aircraft.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Douglas, C. A., et al.
TITLE: Development of optimum runway lights for jet aircraft. Interim Report No. 1.
REFERENCE: Washington: National Bureau of Standards, June, 1956. (Report No. 4741.)

SUMMARY:

This report is the first of a series describing NBS work on development of runway lights for jet aircraft. The report includes statements of the visual guidance requirements of a total visual landing aids system (excluding approach lights), noting that runway lights can not be considered independent of the total system. A summary of interviews with pilots, focused on the effects of jet aircraft on visual guidance requirements, is presented. Then, intensity distribution, beam width, and other specifications (as applicable) are discussed in light of the pilot interviews and visual guidance requirements for each of the following: beacons, runway identification lights, circling guidance lights, and threshold lighting.

REMARKS:

The report includes illustrations of intensity distribution requirements for circling guidance lights, regions of guidance of runway lights, and required beam spread of threshold lights. The report is thorough, proceeding from functional requirements to equipment specifications in all instances. It is the most definitive report available to date on the topics covered.

REQUIREMENTS AND/OR DISCUSSION:

Pilot information requirements

During initial penetration:

Location and identification of airport.

Location and identification of runway.

During a circling approach:

Distance from and direction of runway, so that the downwind leg can be flown parallel to and at desired distance from runway.

Location of and distance from threshold and direction of runway during turn from downwind leg to base leg, on base leg, and during turn from base leg to final leg of approach pattern.

On final leg:

Location of and distance from threshold.

Location of horizontal plane through threshold.

Location and direction of runway axis.

Height above runway or distance above or below a preferred glide path.

During flareout and touchdown:

Height above runway.

Direction of runway.

"Horizon".

Lateral boundaries of safe landing area.

During rollout:

Lateral boundaries of runway surface.

Direction of runway axis.

Location of turnoffs.

Distance from and location of upwind end of runway.

The report also states that during takeoff, visual guidance required of runway lights is essentially the same as the visual guidance required in the last phase of the approach and in the rollout.

It is impossible to annotate the discussions of the following topics without complete reproduction of the report. Thus, the interested reader is referred to the report for the following topics:

Summary of pilot interviews assessing current visual landing aids system in light of jet aircraft performance characteristics and operations.

Requirements for airport beacons.

Problems of location and identification of runway.

Specifications for runway identification lights:

- Beam spread.
- Intensity distribution.
- Flash frequency.

Specifications for circling guidance lights:

- Intensity distribution.
- Region of guidance.
- Intensity control.
- Spacing.

Specifications for threshold lights:

- Placement of bars.
- Beam spread.
- Spacing of light in bars.
- Length of bars.
- Color.
- Unidirectional vs. bidirectional.
- Recommended threshold lighting systems.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Twelve (12) conclusions and ten (10) recommendations are made in the report, covering all of the topics discussed. Abstraction of any would be unwise, because the conclusions and recommendations should be perused in the context of one another. The interested reader is referred to the report for the complete listing.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR:

TITLE: Final approach and landing.

REFERENCE: Record of discussions of factors affecting final approach and landing, held during Fifth IATA Technical Conference at Copenhagen, May, 1952.

SUMMARY:

This report summarizes the requirements placed upon airport visual aids in terms of the information they must provide the pilot.

REMARKS:

A fairly comprehensive summary of the 1952 thinking of a responsible operational group.

GA10

REQUIREMENTS:

General
Visual aids should be integrated. The runway guidance pattern should be developed within the context of the approach lighting pattern. Runway and approach lights should be developed so as to be compatible with the taxiway lighting system.

Approach Lighting
Requirements for beam widths of the individual units which comprise the approach system are guided by the following considerations:

The beam should be as narrow in its vertical and horizontal spread as consistent with the region of guidance so as not to produce an excess of light in the upward direction and, therefore, glare and reduction in the dark adaptation level of the pilot.

In the presence of fog, narrower beam lights are preferable to wide beam lights in terms of their ability to be visible through fog.

Wide beam units consume more electrical power than those of narrow beams of the same maximum intensity.

In order to specify precisely the requirements for units in the approach system, the following information needs to be generated:

The shape and dimensions of the region in space in which guidance from visual aids are required;

Characteristics of the aircraft on which guidance requirements are based should be the highest performance commercial aircraft to be serviced by the airport.

The width of the region of guidance should be sufficient for a maximum recovery maneuver "S" turn in the event the aircraft is laterally displaced off the centerline.

The height of the region of guidance should be based upon the maximum maneuver to the touch-down area.

In order to obtain guidance from the visual aids, slant range from the approach lights is required.

Runway Lighting
The problems in the current design of runway configurations are: insensitivity to changes in direction, and inadequate impression of the ground plane upon which judgments of proximity to ground and inclination of the flight path to the horizontal are estimated. It was recommended that pilots can be assisted in estimating height by accentuating or standardizing perspective angle performed by the edge lights, and by giving texture to the surface. The threshold in the touch-down area should be clearly defined, and accurate directional guidance in the horizontal plane should somehow be provided. It was recommended that a line of low intensity lights along the runway would be of value in assisting height judgments and providing directional guidance.

Taxiway Lighting
There is a requirement for adequate taxiway access lights.

Meteorological Information
The visual aid system should incorporate in its design a means of enabling the pilot to assess slant visual range.

CONCLUSIONS AND/OR RECOMMENDATIONS: See Requirements.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Gibson, J. J., et al.
TITLE: Parallax and perspective during aircraft landings.

REFERENCE: Amer. J. Psychol., 1955. 68, (3), 372-385.

SUMMARY:

The purpose of this study was to analytically examine the performance of successfully landing an airplane. Discussion proceeds from an examination of existing definitions of motion parallax to the formulation of a principle called motion perspective. The principle is then applied to the problem of perceiving the ground and one's relationship to it during landing. Formulae are presented for a mathematical analysis of motion perspective.

REMARKS:

The formulae presented should be most useful to any program of research in which motion perspective is to be considered an independent variable.

REQUIREMENTS AND/OR DISCUSSION:

Motion parallax is inadequate for drawing conclusions about the real distance of an object because the apparent angular velocity is not only inversely proportional to distance, but also varies with direction from the observer's line of movement (direction).

Diagrams of motion perspective occurring during straight and level flight and the landing glide are included to illustrate the expansion pattern and the zero expansion point.

With movement not parallel to a plane surface, the apparent velocity of visual elements not only diminish toward zero at the horizon of the surface, but also where the line of movement intercepts the surface.

Movement information can be found within the distribution of angular velocities in the sheaf of light rays reflected to the eyes.

There are two distinct characteristics of the flow of the visual field when in motion: gradients of amount of flow and radial patterns of direction of flow.

For landing an aircraft, the fundamental visual perception is that of approach to a surface. This perception specifies the observer's position, movement and direction as much as it specifies the location, slant and shape of the surface. The discriminable features of perception are probably altitude, speed, direction of glide, distance and time on the present path to the ground, and distance and time on any other path to the ground. In actual situations, the perspective of size and density of the visual field elements contains useful information.

CONCLUSIONS AND/OR RECOMMENDATIONS:

The formulation of monocular motion parallax as a cue to distance is insufficient.

A more general description of the phenomenon has been called motion perspective.

The variables of this flow pattern of motion perspective are specific not only to the depth of the surface, but also to the movement of the observer.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Gibson, J. J.
TITLE: The optical expansion-pattern in aerial locomotion.

REFERENCE: Amer. J. Psychol., 1955, 68, 480-484

SUMMARY:

The author reviews the general theory of the optical expansion pattern as containing information which the pilot may utilize for controlling his aerial movement. The aut suggests that the discrepancy at any time between what the pilot would like to achieve, and the state that he is in, represents the stimulus for his actions.

REMARKS:

Gibson points out the similarity of all locomotion control tasks to so-called tracking tasks, and notes that servo-systems operate on similar basic principles.

REQUIREMENTS AND/OR DISCUSSION:

Changing optical stimulation is governed by the principle of motion perspective.

Motion in the retinal image provides at once information about space and about the movements of the observer.

Pure expansion in the field of view is a sensory symptom of approach. It implies future contact.

Pure flow in field of view is a sensory symptom of progression, i.e., covering ground.

The ceasing of flow or expansion in the field of view is an indicator of coming to rest.

Focus of flow or expansion in the visual field is an indicator of direction of locomotion.

The continuous and symmetrical expansion of a shape in the field of view until it reaches a critical rate or until its size extends over a critical area of the visual field is an indicator of imminent collision.

Hypotheses accounting for the choice of certain pilot actions:

Control of the landing guide action to keep the optical focus of expansion at the point on the ground which the pilot wants to approach.

Leveling off: as imminent collision stimuli grow more intense, actions to move the optical focus of expansion from the ground to the horizon.

Helicopter landing: as imminent collision stimuli grow more intense, actions to cancel the expansion pattern.

Avoiding obstacles: actions to keep the focus of the expansion or flow away from the expanding shapes in the field of view, but between the area of expanding bounded shapes.

Pursuit of another aircraft: actions to keep the optical focus of expansion in coincidence with the shape of the object.

The statements above are all based on the assumption that movement is behavior with an end or purpose.

The discrepancy at any time between the desired spatial condition and the present spatial condition is the adequate stimulus for action control.

Actions tend to cancel discrepancies, i.e., they are compensatory in nature and cease when stimulation reaches a sort of equilibrium.

CONCLUSIONS AND/OR RECOMMENDATIONS:

See Requirements and/or Discussion.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Jenks, A. E.
TITLE: Report of the activities and findings of the high intensity approach light evaluation committee.
REFERENCE: Washington: U. S. Department of Commerce, Civil Aeronautics Administration, June, 1952.

SUMMARY:

This report presents an excellent and well-detailed discussion from an experienced pilot's viewpoint of pilot information requirements during visual approach and landing.

Five types of high-intensity approach lighting configurations presently in use in the United States were evaluated in terms of the degree to which they satisfy these requirements.

REMARKS:

An excellent, operationally-oriented discussion of the history of problems encountered in visually-controlled landings from 1930 to 1950 is included. These problems stem from the development of heavier, faster aircraft with higher landing speeds, wider turning radii, and the consequent changes in landing techniques and visual distance required by the pilot for safe landing.

The pilot's visual world is described as an inverted cone, with the pilot at the apex, carrying the cone with him through space.

The operational functions of ILS and GCA are defined and evaluated in terms of the pilot information requirements these devices satisfy, as well as those requirements not satisfied. (Continued on next page.)

An appendix to the report presents photographs of the light traces of 17 regularly-scheduled transport approaches to National Airport, Washington, D. C. The light trace data are analyzed to provide the following summary statistics:

Average descent angle (2. degrees).

Distance from threshold where stabilized approach occurred (1000 feet).

Distance from runway where alignment stabilized (2000 feet).

Refer to another study (Perreault, 1952) for subsequent reaction to this report.

REQUIREMENTS:

The following table summarizes pilot information requirements for successful approach and the elements of approach configurations most prominent in providing each requirement:

Requirements	Configuration Element
Positive identification	Distinct pattern of lights Flashing lights
Definition of extended runway centerline	Extended centerline lights
Roll guidance	Transverse bars
Distance from threshold	1000-foot bars
Height indication	Perspective angles in the pattern
Identification of threshold	Contrast in pattern and color

Approach configurations evaluated included the following:

Slope Line

French

Calvert

ALPA Centerline

Left Hand Row

Controlled experimentation and simulation were ruled out on the basis of time and runway restrictions. Consequently, perspective photoprints were prepared for each of the five systems. Seven views of each system were prepared from "on course and on path" positions beginning 3500 feet from threshold and successively closer by 500-foot intervals.

Pilots of multi-engined aircraft were shown each series of photoprints and asked to judge the adequacy of each system in providing the required items of information. The evaluations were made from on course and left and right of course viewing.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Approach lights should extend the runway centerline.

Configurations tested are equally usable under good visibility.

A flight simulator is required for practical, controlled evaluation of approach configurations.

Approach light systems should be compatible with runway lighting configurations.

Slope Line

This system provides the most complete information in good visibility, but is confusing and difficult to interpret under poor visibility, especially when only a few units of one row are visible.

Roll guidance is poor.

Left Hand Row

This system provides the greatest amount of erroneous information.

Alignment information is especially poor.

ALPA Centerline

This is the easiest system for a pilot to interpret and, therefore, least time consuming.

All items of required information are provided. Condenser discharge lights provide quick identification.

Calvert

All items of required information are obtainable quickly and unmistakably.

French

The left hand row feature of this system is distracting.

The center lights lack continuity.

Perspective is difficult to interpret.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Landing Aids Experiment Station.
TITLE: Operational requirements for airfield lighting and marking systems.
REFERENCE: Arcata: Author, 1948. (Memorandum Report No. 48-5.)

SUMMARY:

This report presents some information on photometric and operational requirements for marking and lighting systems. Requirements are specified for approach configurations, threshold configurations, runway configurations, and taxiway configurations. The requirements resulted from a preliminary evaluation of approximately 600 flight tests performed at the L. A. E. S., Arcata, California, from June through December, 1948.

REMARKS: None.

REQUIREMENTS:

General

Airport marking and lighting systems must meet requirements for straight-in as well as circling approaches.

The intensity of the lights must be sufficient to afford easy identification without excess of concentration on the part of the pilot, and at the same time shall not be so great as to be intolerable or glaring to the pilot.

The lighting equipment and fixtures must be designed so as not to be a general obstruction hazard to general flight requirements or to snow removal and other airport operations.

Approach Requirements

Pilot information.

The approach configuration should be promptly and unequivocally identifiable as approach lights and not confused with other airport configurations.

Position of the pilot relative to the desired glide path. The approach configuration should indicate to the pilot that he is to the left or right of the region of guidance, and if he is above or below the region of guidance and should, therefore, indicate to him direction to go toward the longitudinal axis of the runway.

Longitudinal distance of the aircraft from the threshold.

Direction of the track of the aircraft relative to the line of flight required.

The attitude of the aircraft with respect to the horizontal plane; that is, pitch and roll.

Photometric.

Approach configuration identification must be effective at the distance interval between the "far distance" at which meteorological obstruction to vision dims the lights (attenuates light signals below threshold), and the "near distance" where the lights disappear below the structural cut-off to downward vision of the aircraft's nose.

The information coded in the approach configuration should be visible to the pilot within the defined limits of the region of guidance for both straight-in and circling approaches. The region of guidance for straight-in approach is defined by the volume of air confined within the region 3500 feet from threshold between 2 and 10 degrees angle off the horizontal and about 500 feet horizontal width at the outer extremity. Region of guidance for circling approach is defined by radius extending out from the runway threshold 3/4 mile. The height of the region of guidance in this semi-circle is to be equal to the ceiling when the ceiling has a minimum of 1000 feet. The approach light system should be designed photometrically so as to afford guidance along any path approach within these defined regions of guidance.

Threshold requirements

The threshold configuration should provide identification of the location of the runway thresholds and should not be confused with other elements of the AML system.

Threshold lights shall be identifiable from any point outside and above the threshold within the region of guidance. The intensity of the threshold lighting system shall be sufficient in conditions of low visibility to be discriminable within 1200 feet of the threshold.

For circling approaches in limited visibility, the threshold should be identifiable within 3/4 mile from the threshold.

Runway requirements

Prompt and unequivocal identification of the runway so as not to be confused with other airport configurations.

Position on the longitudinal axis of the runway. The author suggests three sub-divisions: the first third of the runway to be designated as the safe touch-down zone; the second third of the runway should be designated as the central zone; and the remaining third of the runway to be designated as the terminal warning zone. The runway configuration shall afford information as to the vertical elevation of the pilot above the runway surface. The runway configuration shall provide adequate guidance as to the angle of bank to the aircraft with respect to the horizon and horizontal axis of the runway.

Runway configuration shall provide information relative to the direction of the course of the aircraft during terminal glide, flareout, touchdown, and rollout.

The runway configuration shall be discriminable from any point above the runway and within 200 feet of horizontal displacement from the runway centerline.

The intensity of the runway lights shall be equal to the approach lights. The runway configuration shall be designed so as not to expose the pilot to glare when the lights are set for maximum penetration.

For circling approaches the runway lights shall be visible from the point above the surface and at a distance of 3/4 mile.

As a braking consideration, runway markings shall be designed so as to provide the same coefficients of static and sliding friction as those of the surrounding runway surfaces.

Taxiway configurations

Taxiway configuration shall be promptly and unequivocally identified and not confused with other AML configurations.

The configuration shall provide direction in the ground plane at intersections, at taxipath turns, and within the central ramp area.

The taxiway configuration shall provide information as to the specific location of entrances and exits from runways.

The taxiway configuration shall be distinguishable at a minimum distance of 500 feet.

The taxiway system shall be circuited so as to provide a one-way path to the destination of each aircraft so that no intersecting taxipaths or intersecting runways and taxipaths are open for use simultaneously. Provisions should be made for "stop" or "hold" signals on all taxiways.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Studies should be undertaken to define the most desirable length of subdivisions along the longitudinal axis of the runway on the basis of a careful study of aircraft take-off and landing requirements.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Lane, J. C., & Cumming, R. W.
TITLE: The role of visual cues in final approach to landing.

REFERENCE: Melbourne, Australia: Aeronautical Research Laboratories, Research and Development Branch, 1956. (Human Engineering Note 1.)

SUMMARY:

Evidence is reviewed on the fact that errors in estimating range of the location of touch-down point in landing accounts for a substantial number of accidents to transport and military aircraft. The authors review the kinds of visual cues available for making the judgments required during this flight mode. Four cues are specified as being available for required judgments. These are: distance between landing lights; shape constancy of the outline of the runway; H distance (distance between aiming point and horizon); and center of expansion. The authors make a number of practical suggestions for training in the use of these cues and suggest that certain displays may deserve development to assist the pilot in his tracking task. The paper concludes with a suggested program of research designed to answer more definitively many of the questions raised in the paper.

REMARKS:

The rather unique feature of the Australian terrain; namely, relatively flat expanse, must be taken into account in appraisal of the report.

Most airports have very few urban areas around them;thus, the height judgments have always been a most critical factor in landings generally, in Australia.

The appendix contains an interesting reference to one of the reasons why a pilot, when he goes visual, undercuts the glide path he has been following on instruments. It is stated that he does this in order to get more ground guidance- and undercuts are considered dangerous.

REQUIREMENTS AND/OR DISCUSSION:

Approximately 10 1/2% of all aircraft accidents reviewed were due to the pilot's inability to establish and maintain a satisfactory glide path on final approach.

The task of the pilot is to position the aircraft in line with the extended center-line of the runway, close to a preferred height above runway level, within a fan of angles of elevation with the apex at the runway threshold. Position within this fan will vary depending upon such things as power settings, airspeeds, controllability, etc. Observations at Melbourne Airport indicate that this fan goes as low as 2 1/2 degrees and as high as 6 degrees, with an average of 4 degrees.

The selection of the starting point for final approach is considered more difficult for a straight-in approach than for a circling approach.

It is difficult to maintain a satisfactory approach because:

- The flight path is not coincident with the longitudinal axis of the aircraft.
- The task involves aiming in a vertical plane whereas all normal aiming by humans is in a horizontal plane. In short, heading and track do not coincide.

The so-called naturally available visual cues are:

- The apparent distance between successive runway lights (night only). Through size constancy, the perceived gap length between lights 1 and 2 appear not to change. If the aircraft is overshooting, the gap will seem to get bigger, if it is undershooting, the gap will seem to get smaller.
- The shape of the figure formed by the first 2 pairs of lights (night only). Shape will be perceived as constant, in terms of the height-width ratio of the trapezoid formed by the first 2 pairs of lights, if pilot is following correct glide path. If the aircraft is overshooting, the shape seems to get thicker; if the aircraft is undershooting, the shape seems to get thinner.
- The distance of the aiming point below the horizon (for both day and night). This is the so-called H distance. If the approach is constant and correct, the aiming point will stay at a constant distance from the horizon. If the aircraft is overshooting, the distance gets longer; if undershooting, shorter. The authors point out there is no evidence regarding its sensitivity. They point out that the sensitivity of the judgment might be quite good if the aiming point, which must be at the threshold, is "lined-up" on the windshield or other visible part of the aircraft, such as the radio antenna.
- The center of the expansion field. This refers to the point in the visual pattern that is apparently stationary, while all other parts of the pattern appear to move radially away from it.

The angular velocity of the desired aiming point for an overshoot or an undershoot varies inversely as the square of the distance to threshold, and thus increases very rapidly in the latter part of the approach path. In the earlier part, however, the velocity may be quite small. Assuming a threshold of perception of movement at somewhere between 2 and 4 minutes of arc per second, the movement of the threshold lights would not be perceptible for an overshoot or an undershoot until the pilot is somewhere between 3000 and 4500 feet from threshold.

The authors suggest that the H distance be used to select the angle of approach, to control tracking in the early part of the approach, with a transition to center of expansion cue as this becomes useful.

The authors believe that the aiming point in practice is often the runway threshold.

CONCLUSIONS AND/OR RECOMMENDATIONS:

It is recommended that:

Pilots be trained to make better use of available cues.

A final approach simulator be utilized.

Ground visual aids, such as a clearly-defined aiming point and angle of approach indicator (tri-color or Navy Mirror) be utilized.

Attention be given to airborne visual aids including an angle of depression sight and an aiming point sight.

The following research programs be carried on:

Survey present pilot beliefs and practices.

Laboratory studies to determine the sensitivity of various types of cues and their usefulness.

Development of a simple simulator for studying factors involved.

Development of a simulator for training.

Flight measurements of the last 5 miles of approach be made in order to get data on accuracy of aircraft aiming, width, and shape of error distribution about ideal flight path, proportion of incipient undershoots, reliability of pilot's angle of depression judgment.

Various studies to check out the suggestions for providing a visible aiming point and airborne aids and ground glide-path aids.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Malouin, G. J.
TITLE: Proposal for an integrated visual landing system.

REFERENCE: Paper attached to International Air Transport Association Special Meeting, Amsterdam, November 14-22, 1955.

SUMMARY:

The problem of landing in low-visibility ranges is analyzed by the author from a "cockpit" viewpoint, and requirements for visual aids specified. The object of this combined operational-technical study was to determine the major factors influencing various aspects of all-weather flying and to give design guidance to engineers for a wholly integrated visual aid system yielding continuous guidance and information.

REMARKS:

A drawing of the proposed integrated system is attached. This is an early paper from the operational viewpoint calling for an integration of airport marking and lighting.

REQUIREMENTS AND/OR DISCUSSION:

Some factors considered in the design of the proposed system were:

Maneuvering limitations of the most limited transport aircraft in a given stage of approach or landing procedure.

Guidance requirements need to be complementary among various guidance zones and have special compatible guidance features within particular zones.

Guidance zones specified: Zone A - maneuvering zone, Zone B - stabilizing zone, Zone C - landing zone, Zone D - deceleration zone.

Visual guidance common to all zones: identification, direction, and distance.

All zones shall be of basic equal dimensions with the exception of Zone D, in order to cater to the pilot's sense of timing, anticipation, and tempo.

Other factors considered were: threshold treatment, landing zone, visual comfort, apparent intensity, visual go-no go indications, intensity control, linear signal sources, integration with non-visual aids, capability of partial implementation, multi-purpose operational features system symmetry, allowance for development possibilities, and certain advance requirements.

CONCLUSIONS AND/OR RECOMMENDATIONS:

The system proposed is offered as one type of design that can result from incorporating integrating features. A system along this or similar lines is suggested as a basis for an approved standard for air lighting aids usable in all-weather operations.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR:
TITLE: Report of the AGA Study Group of the Flight Technical Group.
REFERENCE: Report presented at IATA Special Meeting, London, July, 1952.

SUMMARY:

This paper is a summary of the discussion and recommendations made by the study group on the "sculptured channel" concept. The concept, as developed by KLM for Constellation L749 aircraft was used as a basis from which an optimum shape was determined. The developed shape took into account performance and maneuverability of other relevant types of aircraft. Recommendations to IATA are made with respect to the channel developed.

REMARKS:

The maximum acceptable rates of descent utilized by the study group for defining the region of guidance between altitudes of 1000 feet and 50 feet were: 1200 feet per minute at 1000 feet; 600 feet per minute at 50 feet. The paper gives a good indication of the factors which this operational group considers critical in setting the "sculptured channel" or region of guidance.

REQUIREMENTS AND/OR DISCUSSION:

The solution to the problem of providing suitable lighting units, giving suitable guidance for visual approach and landing systems, involves:

- region of guidance
- performance and maneuvering limitations
- operating requirements for approach and overshoot
- pilot limitations and techniques
- runway and threshold design requirements.

The most practical way of determining the dimensions of the region in which visual aids are required would be to utilize the requirements posed by a typical modern large air transport aircraft in flying an advanced type of instrument approach system.

All lateral displacement errors should be resolved at a point in the approach path called the "zero error point". The "zero error point" should be located on the extended centerline of the runway at a distance 2000 feet from the ILS reference point or approximately 1000 feet from runway threshold.

The visual reference "portal" was considered to be at a distance of 3500 feet from the "zero error point".

The approach region of guidance should extend to a point 1000 feet beyond the reference point (down the runway).

The composite type aircraft used was as follows:

- approach speed: 140 miles per hour
- bank angle maximum: 12 degrees
- rate of descent, maximim 1200 feet per minute at 1000 feet down to 600 feet per minute at 50 feet.

A meteorological visibility of 300 meters (1000 feet) was assumed.

Variability of instrument approaches should be allowed for on the following order:

half-scale deflection on the deviation sensitivity indicator of the glide path,

a full-scale deflection on the deviation sensitivity indicator of the glide path.

Maximum displacements that can be corrected at distances of 2500 and 3500 feet from "zero error point" for varying approach speeds, bank angles, and infinite rates of roll were considered.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Region of guidance should be defined as follows:

Lateral Dimensions:

width at the portal: 275 feet on each side of the extended centerline,

width at the "zero error point" : 100 feet on both sides of the extended centerline.

Vertical Dimensions:

height at the portal of lower bounds: 300 feet above the airport elevation,

minimum height of lower bounds at a point on runway located 1000 feet beyond the ILS reference point 50 feet above the runway.

Cross-Section

The cross-section should be such as to encompass the lateral and vertical dimensions given in lateral and vertical above.

Minimum length of the continuously visible segment of the approach and runway areas should be at least 600 feet.

The tolerable lateral displacements of an aircraft from the approach beam, when 2500 feet from the point of "zero error", are 90 feet when the initial heading is parallel to the runway and 175 feet when the initial heading is towards the "zerc error point".

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR:
TITLE: Report of the Flight Technical Group - fourth meeting.

REFERENCE: New York: International Air Transport Association, October, 1951, 10-21. (DOC. OPS. 1096.)

SUMMARY:

This report examines requirements for pilot information to guide design of visual aids for approach, threshold, and runway areas and suggests designs to provide these information requirements.

REMARKS: None.

REQUIREMENTS:

Approach lighting

Positive identification.

Alignment and bank information.

Distance information.

Altitude.

Indication of the imminence of the threshold.

Photometric requirements in the approach

The system shall be visible through 360 degrees of azimuth.

The intensity of the approach, threshold, and runway lights shall be proportioned so as to provide the best possible visual balance between the elements of the system.

The intensity of the lights shall be capable of variation to permit adjustment to the variations and visibility conditions.

Runway lighting

The system must provide positive identification of the runway threshold itself.

The landing section of the runway should be well-defined, and distance information should be provided which defines the first and last 2000 feet of the runway.

Taxiways to which the pilot must turn off should be clearly defined in two ways:

An anticipated signal which warns the pilot of the temporal imminence of the turnoff.

The indication of the turn-off path itself.

CONCLUSIONS AND/OR RECOMMENDATIONS: None.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR:
TITLE: Report of study group meeting on runway lighting.

REFERENCE: IATA Meeting, Montreal, March 11-16, 1955.

SUMMARY:

This report summarizes the IATA study group recommendations regarding operational requirements and design principles which should be used for improved runway lighting. The major problem attacked in the meeting was the "black hole" problem. In addition to design requirements and principles, an example of application of the principles is given, and considerations lying behind the principles are discussed. At this point, the results of the study group were subject to IATA approval and were not official IATA policy.

REMARKS:

Graphs and illustrations are presented in appendices to the report to illustrate the principles involved. One interesting graph refers to the heights at which wide and narrow visual gauge runway lighting patterns give optimum height sensitivity.

REQUIREMENTS AND/OR DISCUSSION:

The flare zone must satisfy the following requirements:

- height guidance
- roll guidance
- alignment guidance
- distance interval information
- opportunity of assessing slant visual range.

Height guidance requirements should be met over a distance out from the ILS reference point, which is governed by:

- the performance of critical aircraft, including approach speed, length of flare, decelerating characterisitics, attitude change at flare, etc., and vertical deviation errors due to glide path and coupling deficiencies.

The following requirements must be satisfied by landing mats:

- height guidance, with signal continuity from approach lighting
- alignment guidance, with signal continuity from approach lighting
- distance interval information
- assessment of visual range.

Landing mat requirements should be met over a distance down the runway from the ILS reference point which is governed by:

- aircraft performance including approach and landing speed, decelerating characteristics, etc.
- operating minima and corresponding amount of exposure time available to the pilot
- human limitations, particularly the reaction time of the pilot.

It was considered necessary to provide a configuration change in the approach lighting pattern to give the pilot an imminence of flare signal at the appropriate stage.

Primary lines of guidance for runway lighting and marking are:

- a pair of longitudinal guidance lines 150 feet apart which define the width of the visual aid system,
- an additional pair of longitudinal guidance lines, 60 or 80 feet apart, symmetrically located relative to the pair of 150-foot lines,
- a longitudinal guidance line defining the center of the system, and
- transverse lines 500 feet apart which define the length of a "block" of the visual aids system, and
- additional transverse lines 100 feet apart within each "block".

When considered in an integrated form, these lines form a grid with established dimensions.

The principles utilized are designed to provide guidance for landings in visual ranges of 300 meters.

The only known method of providing good height guidance by visual aids is through a pair of parallel lines.

The optimum gauge of the parallel lines should not be influenced by runway width.

Flush-type lights in their existing state-of-art were considered to have certain limiting difficulties, such as :

- limited beaming characteristics,
- possibilities of snow obliteration,
- fuzziness of range,
- tire scuffing on grids, and
- lack of comprehensive dynamic strength testing results.

Flare zone and landing mat should be located relative to the path actually flown by aircraft under marginal weather conditions.

It was recommended that various components of the visual aids proposed might be installed in progressive or partial units where technical or economic considerations do not allow installation of the entire system.

CONCLUSIONS AND/OR RECOMMENDATIONS:

It was recommended that configurations conforming to the principles laid out be installed experimentally and their suitability flight-tested under representative operating conditions.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR:
TITLE: Visual aids to approach and landing.

REFERENCE: Montreal, Canada: International Air Transport Association. Unpublished report presented at a Special IATA Meeting, New York, 1955.

SUMMARY:

This paper is a brief summary of the Special IATA Meeting on final stages of approach and landing which was held in New York early in 1955. The paper briefly reviews the problems involved in the terminal flight modes and presents recommendations to ICAO for their consideration. These recommendations were termed by IATA at that time as representing operational advice based on the best available judgment.

REMARKS:

One of the attachments to the memorandum is the U. S. National Standard on lead-in lighting requirements.

REQUIREMENTS AND/OR DISCUSSION:

The following requirements apply specifically to other than instrument runways:

Impression of ground plane is necessary, in order to get guidance in both vertical and horizontal planes.

Approach and runway lights must overcome the false horizon frequently perceived because of other lights and objects in the area, particularly when there is no clear definition of the horizon in the vicinity of the threshold. This difficulty is accentuated in rain, partially through refraction.

Alignment and roll guidance are critical after circling approaches at night.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Pilot's tasks have grown progressively more difficult as evidenced by the number of serious accidents in recent years. Increased flight training can not entirely rectify this situation.

Factors increasing the difficulty of the pilot's tasks are:

Higher wing-loadings.
Increased approach speeds.
Poorer response to controls and power applications in high drag configurations.
Wind-screen obscuration of visibility.

For runways where it is impractical to install approach aids, the following should be added:

Threshold lighting bars.
Threshold warning bars.
Runway stub bars at 500, 1000, and 1500 feet from the runway threshold.
Threshold markings.
Centerline markings.
Day markers duplicating the stub bar lighting.

Visual aids recommended where some aids can be installed in the approach area:

Threshold lighting.
Threshold warning bar.
Lead-in lighting extending (if practical) for a distance of 3000 feet with crossbars of 150 feet at 500-foot intervals.
Stub bars.
Threshold markings.
Centerline markings.
Day markers duplicating the stub bars.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR:
TITLE: Visual aids to flare and landing.

REFERENCE: March Air Force Base, California: Director of Safety, Headquarters Fifteenth Air Force. (Date unspecified.)

SUMMARY:

This article reviews the requirements for all-weather operation. The paper represents an attempt to resolve the differences between civil and military requirements for overrun lighting and points out that Elfaka flush lighting units are the possible answer. It is a background paper for the March Air Force Base operational evaluations conducted in 1956. Appended to the article are two reprints (Jenks, 1955 & 1956); these are annotated separately in the present annotations.

REMARKS:

The extension of narrow-gauge lighting to the runway within a 3000-foot landing mat and its proposed testing at Dow Air Force Base are mentioned.

REQUIREMENTS AND/OR DISCUSSION:

The most critical demand upon the pilot's skill and attention is during transition from instrument to visual flying during low ceiling and restricted visibility.

Reaction to light patterns must be automatic and natural, requiring a minimum of effort and interpretation.

Guidance requirements are:

- Length of light pattern standardized.
- Centerline lights leading directly to the threshold.
- Lights of color and configuration so as not to be confusing with other lights.
- Lights to provide pilot reference and establish runway perception.
- Variable control intensity on bar lights.
- Sequence flashed condenser-discharge lights an essential part of a centerline system.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Implementation throughout the Air Force of the approach and runway lighting systems being suitability tested at March Air Force Base and Dow Air Force Base will be a major contribution to safer air operations, particularly under all-weather conditions.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Walter, C. E., & Roggeveen, V. J.
TITLE: Airport approach, runway and taxiway lighting systems.

REFERENCE: Journal of the Air Transport Division, June, 1958. (Paper 1659.)

SUMMARY:

The authors develop a set of airport lighting design criteria, based on principles of required pilot guidance, and evaluate the various systems of threshold, approach, runway, and taxiway lights which have been developed. The authors conclude with a plea for an integrated airport lighting system. By this, it is not meant that a system needs to be standardized, but only that it be integrated in the sense that a systems approach be used as a design basis.

REMARKS:

This is a well-written and concise analysis of approach and lighting systems including a bibliography of 63 articles and many informative diagrams. The interested reader is referred to the article inasmuch as annotation without complete reproduction would be most difficult. The design criteria utilized by the authors are generalized and thus not specific to unique requirements of the military, civil, or commercial.

REQUIREMENTS AND/OR DISCUSSION:

See report.

CONCLUSIONS AND/OR RECOMMENDATIONS:

The authors urge that a systems approach be used in the design of airport lighting.

It is recognized by the authors that the integrated airport lighting system which seems to be emerging in the U. S. will probably form a very expensive package and will not be installed on all airports. They suggest that a liberal policy be established so that the natural development of better approach systems will not be stifled due to "standardization".

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CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: McIntosh, B. B., & Burke, J. M.
TITLE: Non-emergency landing accidents.

REFERENCE: Norton Air Force Base, California: Directorate of Flight Safety Research, Office of the Inspector General March, 1957. (Publication No. 13-57.)

SUMMARY:

This report analyzes Air Force accident statistics in terms of pilot task requirements imposed by the perceptual problem of transition from cockpit to external visual signals, and from increasing demands on the pilot made by the characteristics of high-performance aircraft.

REMARKS: None.

REQUIREMENTS AND/OR DISCUSSION: None

CONCLUSIONS AND/OR RECOMMENDATIONS:

Rate of closure information must be provided in the ground visual aids configuration or should be presented on the wind screen of the aircraft so that the pilot's shift in attention can be facilitated. The author also discusses the higher approach speeds, faster sink rates, and increased lack of engine response to throttle: all of which tend to reduce the time available to the pilot for performing the required information-gathering, integrations, decisions, and reactions required to make a safe landing.

A large majority of non-emergency accidents occur under contact conditions and in 70% of these accidents pilot error was responsible for the accident. All unsafe acts committed by the pilot in the pattern and on the ground are primarily perceptual in nature. Present runway lighting does not adequately present the visual cues required for the pilot to make a judgment of rate of closure. This is especially critical at night and requires that the pilot shift his visual attention from the lighting pattern to his air-speed indicator. In a conventional type aircraft, it is found that during contact landings pilots made an average of 17 fixations per minute outside the cockpit and 15 per minute on the air-speed indicator. The mean length of outside fixation was 2.66 seconds and the mean length of fixation of the air-speed indicator was .69 second. Of the total time available to the pilot, 73% was spent looking outside the aircraft, 17% looking at the air-speed indicator, and only 10% attending to the remaining instruments.

CONTRACT FAA/BRD-18
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Moseley, H. G.
TITLE: An analysis of 2400 pilot error accidents.

REFERENCE: Presented at the 27th annual meeting of the Aero Medical Association, Chicago, 1956. (M-40-56.)

SUMMARY:

The author classified Air Force accidents into unsafe acts and unsafe conditions. He classified pilot error, maintenance error, and supervisory error under unsafe acts. Under unsafe conditions he lists material failure, airbase and airways, weather, and miscellaneous. Approximately 48% of all accidents, with known causes, were derived from pilot error. He then discusses the nature of pilot error in terms of various psychomotor requirements of the pilot, descriptive characteristics of the pilot such as age and experience, and aircraft type and phase of flight.

REMARKS: None.

REQUIREMENTS AND/OR DISCUSSION:

Successful flight requires that the pilot perceive his position, attitude, and velocity in space or on the runway. In every pilot error accident review, the requirement for perceiving, deciding, and reacting could be identified, and two areas of perceptual deficiency delineated:

Inadequate perception and interpretation of conditions outside the cockpit.

Inadequate perception and interpretation of conditions inside the cockpit.

Failure to perceive external conditions (more specifically, rate of closure with the surface) was a more frequent cause of aircraft accidents than failure to perceive conditions within the cockpit.

CONCLUSIONS AND/OR RECOMMENDATIONS: None

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Moseley, H. G.
TITLE: Human limitations and aircraft accidents.

REFERENCE: Presented at the Meeting of the NACA Subcommittee on Flight Safety, Air Force Missile Development Center, New Mexico, 15-16 October 1957. (M-22-57.)

SUMMARY:

Major Air Force aircraft accidents of 1956 are categorized as to the general source (cause) of the accident and the phase of flight in which the accident occurred. Interpretation of the underlying factors which contribute to errors is discussed.

REMARKS:

The primary cause of Air Force accidents is pilot error; approximately 45% of accidents are in this category of cause. In terms of flight modes, the landing and takeoff contain the highest proportion of pilot error accidents.

REQUIREMENTS AND/OR DISCUSSION: None.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Pilot-controlled flight is absolutely dependent upon the pilot's ability to:

Perceive the external world and the internal environment and recognize the meaning and significance of what he perceives.

To decide from such observations the course of action which will best guarantee successful flight.

To react in a manner which will implement those decisions.

The author discusses the question of the adequacy of the human to perform his complex task within the limits of time requirements imposed upon him as a function of higher landing speeds, faster sink rates, and increasing aerodynamic instability at low altitudes of high-performance military aircraft.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Zeller, A. F,
TITLE: Human factors in aircraft accidents.

REFERENCE: Data presented at Air Command Staff School, April, 1950.

SUMMARY:

The author discusses the human error component of aircraft accidents as a function of the fact that the pilot is placed in a situation in which he is unable to respond adequately to the time demands of the situation. He discusses the general inherent design limitations of the human in the light of the demands made on the pilot by advanced aircraft.

REMARKS: None.

REQUIREMENTS AND/OR DISCUSSION:

The human being has three basic design limitations which set requirements for aiding his performance. The first are his physical-sensory limitations; second, his physiological limitations; and third, his psychological limitations. The specific limitation on which the author focuses is response time characteristics of humans in terms of the response time requirements of landing operations. He states that the mechanical transmission of a light stimulus from the eye to the brain and the integrated response which results from interpretation of such a transmission is a time consuming process which can vitally affect the successful operation of an aircraft. The time lapse of this process is on the order of 30 milliseconds to three-tenths of a second. In terms of the importance of this delay to control of aircraft, the delay is translated into 8.8 feet of distance for an aircraft landing at 60 miles per hour. When speeds of 600 miles per hour are considered, such a time lag becomes of much more critical importance for during one-tenth of a second the aircraft travels 88 feet. This time delay of 30 milliseconds to three-tenths of a second describes the transmission of nerve impulse from eye to brain; we have in addition to this delay a recognition time of perhaps one-half second or more. Beyond recognition time, the information must be evaluated and interpreted and a decision reached as to the action to be taken. This additional delay may be on the order of a second or two seconds. Following the decision, response time requires, at a minimum, several tenths of a second. Two other time factors then have to be taken into consideration:

The time required for the aircraft to respond to the control input.

The time required for the aircraft to deviate from a given flight path once its control surfaces have been manipulated.

CONCLUSIONS AND/OR RECOMMENDATIONS: None.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Zeller, A. F.
TITLE: Human factors in selected multi-engine jet aircraft accidents.

REFERENCE: Paper presented at the Aero Medical Association Meeting, Denver, May 6-8, 1957.

SUMMARY:

The author presents summaries of accident data analyzed on 3 multi-jet aircraft types over a 4-year period. Accidents were analyzed according to phase of flight in which they occurred, causative factors, primary unsafe act, or acts, which precipitated the accident, and information as to pilot age and hours of experience.

REMARKS:

Graphs are presented which indicate the accelerating proportion of total aircraft flying time accounted for by multi-engine jet aircraft during the period 1948-1956. Multi-engine jet are compared with non-jet aircraft in terms of major accidents and in terms of fatalities. The graphs indicate the initial predominance of accidents and fatalities for multi-jet operations which then declined until the 1953-1954 period, during which the statistics for both aircraft types were essentially identical.

REQUIREMENTS AND/OR DISCUSSION:

The increase in aircraft performance has placed an increased requirement upon the human operator in terms of a reduced time for visual perception, analysis of the situation, and selection of an appropriate response. Generally, greater demands have been placed upon a human's perceptual-motor system. Particular requirements exist for an increased capability in estimating distance and making rate of closure judgments.

CONCLUSIONS AND/OR RECOMMENDATIONS:

The major proportion of accidents occur during landing and takeoff phases of aircraft operations.

Pilot error is a predominant source of aircraft accidents. Of the accidents reviewed, 44-45% are categorized as pilot error.

The most frequent unsafe act committed by pilots which contributes to accidents is poor technique in the landing pattern.

Poor landing technique is manifested primarily by stalling due to poor coordination of flight controls, misjudged distance, and excessive speeds.

No clear-cut trends existed in terms of the relationship between pilot age, experience, and accident rate.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Zeller, A. F.
TITLE: Search for human causes of aircraft accidents.

REFERENCE: Presented at the Air Force/ Aircraft Industry Conference at Santa Barbara, California, May, 1957.

SUMMARY:

This paper proposes a basic sequence of information gathering, decision making, and action as a framework for investigating sources of pilot error to which aircraft accidents can be attributed.

REMARKS:

The author has a great deal of practical familiarity with the accident records from which his paper stems.

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REQUIREMENTS:

Information Requirements

The pilot has a requirement for information from a variety of sources. Some of these sources are background in nature and derive from experience and training. This includes more recently experienced pre-flight information with respect to weather, flight requirements of the specific profile, and information regarding characteristics of the specific type aircraft. A second category of sources are in-flight derived. Information presented to the pilot during flight is integrated with the background information previously stored in the pilot's head. In-flight information is of several types:

One classification system is with respect to the cockpit - internal versus external to the cockpit.

Another classification is in terms of the nature rather than the sources of information. For example, the pilot receives information about the working condition of his aircraft, fuel supply, etc., and information about the position of his aircraft with respect to the earth's surface, and the nature of the change of that relationship through time. All of this information is required with respect to time considerations. He must receive, process, decide, and respond to information in time for the aircraft to accomplish the intent of the pilot as a function of his received information.

Decision Requirements

The author talks about decisions as judgments and stresses the human's inability to judge vertical distances and his inability to judge rate of closure. The fact that the time allotted for control decisions in the landing phase is so restricted, combined with the human's lack of precision in estimating vertical distance and rate of closure, is discussed as a primary source of accidents in the landing phase.

Action Requirements

The primary problem discussed in this section is the time delay from the initiation of control inputs by the pilot and the eventual reaction of the aircraft in space. In general, the author sees the pilot task requirement as:

Receiving and interpreting visual signals; integrating those interpretations with information previously stored in his head;

deciding upon an appropriate control input, initiating the control manipulation, after which aircraft aerodynamics determine additional "action" time required for aircraft response to control/input.

CONCLUSIONS AND/OR RECOMMENDATIONS:

See requirements.

SELECTED ADDITIONAL REFERENCES

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A9. Moseley, H. G. Aeromedical investigation of aircraft accidents. Norton Air Force Base, California, 1957. (Publication No. M-6-57.)

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CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Calvert, E. S., & Sparke, J. W.

TITLE: The effect on weather minima of approach speed, cockpit cut-off angle and type of approach coupler for a given landing success rate and level of safety.

REFERENCE: London, England: Ministry of Supply, 1957. (Technical Note No. El. 130.)

SUMMARY:

In this paper, the authors attempt to develop curves which will be useful to operational pilots for deciding whether or not to attempt a landing with a given slant range visibility and ceiling height. The curves indicate the minimum distance and altitude from the ILS reference point at which maneuvers designed to correct glide path errors of various sizes must be initiated if the aircraft is to be aligned with the runway safely. The effect of varying approach speeds and cockpit cut-off are taken into account, as well as the accuracy of the various types of instrument approach aids, including GCA and length of ground pattern available. The authors point out that their curves are only in the nature of worked examples, but they feel the approach used may be useful for determining minima under which landings can be attempted with an acceptable level of risk.

REMARKS:

The report has a fairly comprehensive set of graphs and curves.

From an approach and runway lighting design standpoint, the analytic attack on the problem utilized by Calvert and Sparke might be used by considering the intensity and positioning of approach lights as the dependent variables and figuring out the requirements they need meet for given values of the other factors involved.

REQUIREMENTS AND/OR DISCUSSION:

An operator needs to know the landing success in given meteorological conditions for an aircraft with a given cockpit cut-off angle, when this aircraft is landing at an airport with a given pattern of visual aids and width of runway.

Using the concept of Standard Visual Pilot, a family of curves can be generated, giving amount of pattern which the average operational pilot will be required to see at given heights in order to be able to make a final permissible maneuver.

The final maneuver permissible on landing approach seems to depend more on the psychological capabilities of the pilot in interpreting the visual aids and being able and willing to make the maneuver than the inherent maneuverability characteristics of the aircraft. This accounts for the fact that although studies have shown that automatic couplers have been assessed as giving an approach success of 100% at heights of about 100 feet, operational results show that this percentage does not occur until about 200 feet.

Flight tests illustrated that time taken to correct a given displacement was nearly the same for all types of aircraft tested (propeller driven). Although these had different approach speeds, maximum roll rates, maximum roll accelerations, etc., it would appear that the violence of the final maneuver is limited by what the pilot is prepared to do, rather than the capabilities of the aircraft.

The time-distance relationship for correcting maneuvers was found to as indicated in the table below:

Lateral Displacement feet	Time Taken To Correct seconds
0	0
40	10
100	12.5
200	15.0
330	17.5
500	20.0

Same track heading at end of maneuver as at beginning.

Wings level at beginning and end of maneuver.

Simulator tests indicated that the quality of visual guidance from the center-line cross-bar pattern was nearly perfect for azimuth, but very poor in elevation at all heights above 100 feet

Simulator tests also yielded the following conclusions:

The pilot must be skillful enough in instrument flying to be able to establish and hold a plane of descent close to or coincident with instrument glide paths.

The aircraft control system must be engineered to let the pilot, after he goes visual, know by feel of the elevator control that he is continuing the plane of descent previously established. This is due to the fact that critical heights below which landings are not to be attempted in civil operations are usually between 200 and 300 feet and that adequate visual guidance in the vertical plane does not become adequate until about 100 feet. The time interval between these two distances may be anywhere between 10 and 20 seconds.

This 100-foot altitude maneuver time is thought to be near the margin of safety for propeller-driven aircraft, but it may not be sufficient for future aircraft. Three reasons for this are:

Increased approach speeds and sinking speeds, thus requiring more height to stop the aircraft from sinking (height required is proportional to square of speed).

At speeds near stall, jets have less potential lift immediately available because of the absence of slipstream effect over the wing.

Plan forms, such as the pure delta, result in an increase in time taken to achieve a given increase in lift by means of elevator control.

For the above reasons, if guidance and procedures are not improved, the under shoot rate can be expected to go up.

The process of correcting errors in the horizontal plane impairs the pilot's capacity to judge the situation and make adjustments in the vertical plane.

It is assumed that the final maneuver should be completed at a height such that the aircraft is 6 seconds from the ground, with the normal sinking speed for the approach.

It is assumed that the pilot will attempt a landing if the aircraft is not less than 50 feet from the runway edge, with wings level, parallel tracking, and the runway is long enough so that he is satisfied to touch down near the aiming point.

Although the greater accuracy of flight directors and automatic couplers is advantageous at high speeds and with short approach lighting patterns, the main argument for their use rests on the fact that they enable two matching processes to be properly carried out without overloading the pilot. The processes are "nulling" vertical and horizontal displacement from glide path.

The "feel" elevator control is a matter which may require careful investigation in the near future.

It is suggested that after the pilot goes visual and the co-pilot turns over control to him, the co-pilot should continue to monitor the elevation from altimeters to about a 100-foot elevation.

For GCA landings, it is recommended that the pilot give the controller his critical height at the beginning of the talk-down. When he reaches this height, and thereafter, the controller should announce the fact and thereafter give glide path information only in terms of elevation. The pilot should have range and azimuth information from his visual contact; if he does not, he should not be going around. This procedure eliminates "noise" from the system, allows a more rapid rate of descent for the pilot, and eliminates the possibility of the controller making an error through changing back and forth from one scope to another.

It is recommended that pilots have periodic training on a landing simulator inasmuch as some long-haul pilots make, on the average, only one instrument let-down per year.

If approach speeds increase and/or downward views decrease, then the weather minima when using the less accurate couplers will rise.

When flying in rain, there may be a considerable difference in the maximum distance from which the ground pattern can be seen from the cockpit compared with the distance which it can be seen by a static observer.

CONCLUSIONS AND/OR RECOMMENDATIONS:

See Requirements and/or Discussion.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: de Boer, J. B.
TITLE: Visibility of approach and runway lights.

REFERENCE: Philips Research Reports, 1951, 6 (3), 224-239.

SUMMARY:

The author reviews relevant data collected by other investigations, and supplements these with data from some of his own experiments, all focused on the problem of luminous intensity and proper distribution in space required of approach and runway light configurations. Conclusions based on the data presented in the paper specify the lux needed at the pilots' eyes from a point source, with the additional modifications necessary because of "size", "shape", and "row" factors.

REMARKS:

The author's calculations are based on the least favorable pilot viewing condition (also verified by data) which is taken to be daytime in fog. He reported that the influence of color is negligible. Blackwell's data were utilized.

REQUIREMENTS:

The author considers the following factors as determinants of illumination on the observer's eyes (point light source).

- Background brightness
- Size of source
- Apparent shape of light-emitting surface
- Light sources in the neighborhood
- Color of light
- Character of light
- Time available for observing the light
- General conditions of observation (time-sharing, relative movement of visual field elements, visual search, etc.)

The formula for determining minimum eye-illumination used by the author was:

$$E_{min} = \frac{I}{r^2} \cdot t_v^{\,r}.$$

where E_{min} = minimum eye-illumination (in lux)

I = luminous intensity of light (cd)

r = distance from observer

t_v = transmission of the atmosphere.

CONCLUSIONS AND/OR RECOMMENDATIONS:

In daylight fog and the practical conditions of flight, a point source must produce 10^{-3} lux at the pilots' eye. This value needs to be multiplied by the "size" and "shape" factors derived by the author and presented in the report. For composite light configurations, the total candlepower of composite light sources determines their visibility. The influence of color of light is negligible.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: de Boer, J. B.
TITLE: Light-beacons to aid landing aircraft.

REFERENCE: Philips Technical Review, 1955, 16 (10), 273-286.

SUMMARY:

This article summarizes the history and function of approach, threshold, and runway lights. The required light distribution of each light is specified. Based on the review, lights designed by the Philips Company to fill these requirements are discussed.

REMARKS:

This article contains excellent data on the technical and visibility considerations of airport lighting. Candlepower distribution curves and cther useful diagrams and photographs (including the approach configuration at Schiphol Airport, Amsterdam) are included. An earlier and similar presentation of this information is contained in (de Boer, 1954).

REQUIREMENTS:

To make possible the provision of information to the pilot on his position in relation to the runway and the point at which he has to aim to make his touchdown, a sufficiently long segment of the approach and runway lights must be visible at any moment. This segment must not only be seen when the aircraft approaches the runway along the proper glide path, but also when, owing to inaccurate indicators of instruments which guide the aircraft, it follows a path that deviates from the proper one.

Aircraft must be enabled to land not only in day or night when visibility is good, but also in bad visibility at night and, most difficult of all, under conditions of mist or fog in the daytime. In these latter circumstances, it is impossible to make objects other than light sources visible at a sufficient distance.

The principal aims of the designer should be:

To reduce the peak luminous-intensity in beams as far as possible, and so limit glare.

To minimize the amount of light radiated outside the prescribed beam, since the light so "spilled" not only constitutes a loss in itself, but owing to fog or mist, increases the over-all background luminance and so produces a higher level of eye illumination. For the same reason, it is necessary to ensure that the amount of light radiated upwards is no larger than strictly necessary.

Proposed light beams were installed at Schiphol Airport for testing under actual flight conditions and for determination of their worth via pilot interviews.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Lights were designed to meet the specifications developed on the basis of the analysis presented in the report.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Douglas, C. A.
TITLE: Problems in the control of glare in approach- and runway-light systems.
REFERENCE: Washington: National Bureau of Standards, 1958. (Report No. 5747, Project No. 0201-20-2331.)

SUMMARY:

The author reviews current practices for controlling glare from approach and runway lights and points out that the use of light-beam restrictions and reduction of intensity lead to problems of reduction of region of guidance and effective visual range of the lights involved. Certain modifications of the systems were suggested. These were: the use of higher intensity and wider-beam lights in the "outer"regions of guidance, that is, further from threshold; and control settings for different relative intensity settings between inner and outer regions in conditions of restricted visibility. Suggestions also are made for improving control of intensity for varying visibility conditions.

REMARKS:

The relatively low cost involved argues for an experimental installation to operationally test the suggestions made. The report helps pinpoint one major factor in the "black hole" problem. Maximum useful intensity/viewing distance and visual range/intensity graphs are included.

REQUIREMENTS:

Maximum useful illumination to a pilot (just below glare) is considered to be about 2000-mile candles. Minimum useful illumination (just above threshold) is considered to be about .01 mile candles.

When viewing distance is small (50-100 feet) the maximum useful intensity is low, even in fog. However, maximum useful intensity increases quite rapidly as viewing distance is increased, e.g., 100 candles at 200 feet, 1000 candles at 3000 feet, both when visibility is rated at 400 feet. For 1000-foot visibility, the minimum useful intensity in the outer approach zone is about four times the maximum useful intensity in the inner approach zone.

Control of intensity setting requires first a knowledge of the suitable intensity and some means of insuring that the system is set at this intensity.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Use of highest beam intensity possible in outer regions consistent with required beam spread and permissible power consumption (color ruled out).

Use of lamps of different intensity and beam pattern in inner and outer regions.

Adjustment of two sets of lamps to different relative intensities in poor visibility.

Use of any one of a number of ways for improving setting of proper intensity.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Douglas, C. A.
TITLE: Some factors affecting the relation between reported visibility and visibility from aircraft.
REFERENCE: Washington: National Bureau of Standards, 1953. (Report No. 2715, Project No. 0201-20-2301.)

SUMMARY:

The author focused on analyzing the difficulties a pilot will have in predicting the slant visual range during landing under poor visibility conditions. Factors identified and discussed include: time and location variability in transmittance, cockpit cutoff, search time, effects of terrestrial background, aircraft flight path, and intensity distribution of lights used. Recommendations for practical steps to increase the accuracy of prediction are included, as well as for certain research and development projects aimed at the same objective.

REMARKS:

The analysis is supported by many graphs, formulae, and other visual aids illustrating the influence of the factors involved, including examples of their interactions.

REQUIREMENTS:

Visibilities reported to the pilot on the basis of ground weather observations should approximate, as nearly as possible, the pilot's actual visibility.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Choice of landing direction. The simple expedient of not landing in the up-sun direction under critical conditions can significantly increase the pilot's visibility.

Greater use of the lighting aids in hazy weather particularly when the sun is low.

Installation of high-intensity range lights to indicate the extended centerline of the runway.

Use of a sufficient number of lights in an approach-light system spread over a large enough area so that the time of search would be reduced.

Provision for runway markings of high contrast and of sufficient angular size which would be effective at distances as great as 3 miles.

Making visibility observations more representative in time and place.

Application of the visibility factors discussed in this report and of other significant visibility factors to the reported visibilities in order to obtain a measure of the visual guidance the pilot can expect.

An operational study on requirements for accuracy of measurement of visibility parameters.

Much greater emphasis be placed upon developing means of improving the guidance given the pilot than in the development of instruments which can do no more than tell how bad the visibility is.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Douglas, C. A.
TITLE: Some problems in approach lighting.

REFERENCE: Washington: National Bureau of Standards, 1958. (Report No. 5753, Project No. 0201-20-2331.)

SUMMARY:

The author discusses the following approach lighting problems: standardization, field testing, elevation guidance, and control of glare. The author concludes that compatibility of lighting systems appears a more feasible goal than standardization; service testing appears more satisfactory than flight testing; more sensitive elevation information will be required in the future; and glare in approach lights may be overcome by reducing the intensity of the lights in the inner zone.

REMARKS:

This is a competent review and evaluation of the general worth of past operational tests and offers valuable suggestions for future tests.

The conclusions are based on the author's personal observations and opinion.

REQUIREMENTS:

An integrated visual guidance system.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Standardization

Standardization of approach systems encounters several obstacles as follows:

Different views as to the relative importance of the different types of guidance to be supplied by the approach light configuration.

Differences in the accuracy of the coupling to the instrument landing system.

Differences in the capabilities of pilots and in the characteristics of aircraft.

Restrictions placed on the length of the system and on the permissible location of lights which are based on requirements other than guidance.

Differences in opinions as to the value of the various components which might be used to build a system.

The principle of compatibility should provide sufficient flexibility in the design of configurations in order that differences in operational requirements, differences in thinking, and limitations because of terrain can be met.

Field Testing

Past evaluations of approach systems have generally been based upon either pilot opinion or the application of arbitrary criteria as a measure of performance. Neither of these alternatives has been found to be entirely satisfactory. Other factors which have tended to invalidate or give misleading results in the testing are:

Failure to distinguish among relevant variables.

Use of special or highly homogeneous test crews.

Lack of suitable controls in the design of the experiment.

Extrapolation of results to conditions other than those in which the tests were made.

Deficiences in reporting such weather data as visibility and ceiling.

It would be highly desirable that a joint test facility, available to all agencies, be established. Such a facility could be equipped so that systems can be easily and cheaply installed for preliminary and operational suitability testing.

Elevation Guidance

The possibilities of systems of elevation guidance based upon new principles should be explored. The following factors should be considered:

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.

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.

Glare

The solution to this problem might 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.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Duerfeldt, C. H.
TITLE: Installation and test of automatic light intensity control system for approach and runway lights.
REFERENCE: Patuxent River, Maryland: Naval Air Test Center, 1954. (Report No. 2, Final Report.)

SUMMARY:

This report covers an automatic brightness control system and visibility indicator developed by the National Bureau of Standards, which was evaluated in connection with runway approach lights at Naval Air Station, Patuxent River. The system, responsive to horizontal visibility, provided good control of approach light intensity. Recommendations are made to improve the equipment from the standpoint of maintenance and to add a ceilometer to the system in order to obtain vertical transmissivity data.

REMARKS: None.

REQUIREMENTS:

The control of intensity of approach and runway lights and visibility information furnished pilots are important factors in effecting safe landings and takeoffs at airfields during low-visibility conditions.

The equipment was used to control the intensity of the lights of three approach systems under test for at least 100 of the 200 test flights, and pilots' comments were recorded. Also, recordings of day-by-day visibility were compiled and checked with aerology reports.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Results of tests indicated that use of transmissometers and associated intensity control equipment were an aid in supplying accurate visibility data and in controlling intensity of approach lights during low-visibility conditions.

Pilots' comments on intensity control, made during approach light evaluation, indicated that light intensity was much nearer an optimum setting when lamps were automatically controlled than when manually controlled. The only unfavorable comments were in connection with the lack of vertical transmissivity information.

A brightness control unit, modified to function with fast-acting voltage regulators, was recommended for incorporation in the system. A ceilometer was recommended so that vertical transmissivity information can be obtained for incorporation in intensity control.

Since the automatic intensity control system and visibility recorder tested showed promising results, further work along those lines was recommended.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Gill, J. F.
TITLE: Angle of foveal cone of vision under dynamic conditions.

REFERENCE: Report presented at the Flight Technical Group, IATA, Fourth Meeting, New York, 1951.

SUMMARY:

This paper reviews operational evidence which sets a requirement for determining the actual angle of foveal vision which can be utilized as a human capability in the design of airport marking and lighting systems.

REMARKS:

This paper would indicate that research had not been conducted at that date on the determination of the foveal vision of humans.

REQUIREMENTS AND/OR DISCUSSION:

Pilots depend upon direct acute foveal vision guidance from approach lights; therefore, evidence is needed regarding the limits of foveal vision under dynamic conditions.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Factual data are needed on the angular coverage of foveal vision under dynamic conditions of restricted visibility approaches and under the operational conditions involved in the pilot's task.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Haig, T. O., & Morton, W. C.
TITLE: An operational system to measure, compute, and present approach visibility information.
REFERENCE: Bedford, Massachusetts: Air Force Cambridge Research Center, Atmospheric Devices Laboratory, 1958. (Project 7694.)

SUMMARY:

This report covers modification to the equipment and methods utilized by Sperry in order to determine slant range visibility more economically. Derivation of information from this equipment, factors affecting it, and its utilization in military and civil air operations are discussed. Instructions for implementing the system on an interim basis are presented. Further research is recommended to bracket aircraft having smaller cockpit cut-off angles than were utilized in the aircraft participating in the study.

REMARKS:

The analytic basis used in this report is quite similar to that utilized in Great Britain by Calvert, in which more meaningful measures than ceiling and visibility are being sought.

REQUIREMENTS AND/OR DISCUSSION:

The equipment utilized by Sperry was used in determining values of threshold vision range as verified by threshold contact heights reported by pilots.

Operational experience at Newark indicated that the Sperry system, while giving satisfactory results, was much too cumbersome and expensive for general use.

Criteria for a simplified system were:

- the results must be just as good as the Sperry system,
- it must be applicable without extensive installation work to any airfield having instrument landing facilities,
- it must be compatible with civil and military aircraft operations,
- it must be economical, and require a minimum of manual attention, without requiring expensive or special equipment,

At the suggestion of Douglas at the National Bureau of Standards, the Sperry equations were simplified by assuming a homogeneous atmosphere below the base of the clouds, and using range computations based on sighting of light (Allard's law). These assumptions were verified by actual operational [illegible].

Factors involved in seeing:

- the target,
- the atmosphere,
- the observer.

Clouds were recorded in the study as an "effective ceiling" - a height determined so that 20% of the pilots gain visual contact above the level, and 80% below the level.

The equipment used in the interim system included:

- a cloud height set
- transmissometer
- illuminometer
- contact height tables.

Legal minima are established to maximize traffic flow and minimize accidents. The visual range of the pilot is the critical factor in determining landing success.

For establishing a legal minima runway visual range, two factors must be taken into account: safe rollout, and the acceptable percentage of pilots who must see the minimum distance.

For conventional commercial aircraft, and the crews that fly them, safe rollout takes anywhere from 1500 feet to as little as 700 feet. Allowing for a safety factor, 2000 feet might be used. It can then be determined, using a probability basis for a luminous threshold (the number of pilots who have a threshold equal to a less than a given empirically derived threshold) at what range pilots might expect to see the lights.

Determining the visual contact height minima is more complex and involves a statistical distribution of at least three factors which are not available. The distribution of lateral and vertical position of different type of aircraft using different type of instrument approach systems, varying distances from the runway aiming point, and different heights at break-out are required. Knowing these statistical distributions and the critical operating altitude of the aircraft, then a corresponding critical height can be established below which it would be unwise to attempt a landing. Again, this will have to be based on a probability basis, at an acceptable level of risk. In all instances, the pilot should be given the critical height and allowed to make his own decision as to whether or not he wishes to go around when he reaches it.

Jet aircraft pose special problems because of their high fuel consumption at low altitudes, and the frequent necessity for making a landing once committed from high altitudes.

Better measurement of visual range does not improve the pilot's ability to see; this is dependent upon adequate views from the cockpit and/or adequate approach light systems.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Visual contact heights and runway visual range better describe pilot visual range than do ceiling and visibility.

Pilot, cockpit, and airfield lighting system are inseparable components of the approach visibility problem. Maximum utilization of an airfield during instrument weather conditions depends, to a large extent, on ability to give the pilot direct and accurate visibility information.

It is possible to describe the pilot's visual range to an acceptable degree of accuracy by combining measurements of: target light intensity, cloud height, ground illuminance, atmospheric transmissivity, experimentally determined values of visual luminous threshold.

The visual range of an observer is a statistically distributed parameter.

The most useful form of slant visual range to a pilot is to give him height above ground on the instrument glide path at which he will obtain minima visual guidance.

There is a logical basis for determining the numerical value of a legal limit.

An adequate lighting system is required at all airfields handling instrument traffic inasmuch as visual range information is useful only if the pilot can receive adequate guidance from what he can see.

The interim system should be implemented at all airfields where an adequate lighting system is installed and where expected air traffic is composed of aircraft having a cut-off angle of 8 degrees or more.

Further studies should be made to determine how the system should be modified for aircraft with cut-off angle less than 8 degrees.

Legal minima for runway visual range should be determined following the procedures described in the report.

Further studies should be initiated to determine parameter values for establishing legal minima for visual contact height.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: National Bureau of Standards, Photometry and Colorimetry Section.
TITLE: Determination of the effective intensity and the visual range of flashing lights in restricted visibility.
REFERENCE: Washington: Author, 1958. (Report No. 5905, Project No. 0201-20-2327.)

SUMMARY:

Field tests, in fog conditions, of four types of flashing lights (compared to steady light) were conducted to assess their effective intensity and visual range. No significant deviations from the Blondel-Rey law resulted. The apparently greater visual range attributed by pilots to condenser-discharge lights over approach lights is discussed, and related to: differences in intensity (direction of view and settings), visual range of glow, and ease of identification.

REMARKS: None.

REQUIREMENTS:

The requirement underlying the present study is early contact with approach system lights.

Lighting units investigated in this study included the following:

- Westinghouse type FGL-1 krypton flash tube set for 40 flashes per minute.
- Sylvania type R4336 flash tube adjusted to 60 flashes per minute.
- Beacon consisting of six 120-volt, 300-watt, PAR-56 type lamps which provided a flash rate of 72 per minute.
- Beacon consisting of six 115-volt, 400-watt, PAR-56 type lamps which provided a flash rate of 72 per minute.

CONCLUSIONS AND/OR RECOMMENDATIONS:

The value of the constant <u>a</u> of the Blondel-Rey law was found to be 0.35 for night conditions and 0.15 for daylight conditions. The Blondel-Rey law is:

$$I_e = \frac{\int_{t_1}^{t_2} I \, dt}{a + (t_2 - t_1)} = \frac{E}{a + t}$$

Where:

I_e = effective intensity

E = energy per flash

a = visual response factor

t = flash time in seconds

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Sperry Gyroscope Company.
TITLE: A flight investigation of the performance of low ceiling/visibility meteorological equipment.
REFERENCE: Great Neck, New York: Author, December, 1954. (Report No. 5245-4059, Contract No. CCA 29773.)

SUMMARY:

This report describes the results of a flight test program to evaluate operationally the ceilometer-transmissometer system of measuring low ceiling/visibility weather for predicting what the pilot will see from the cockpit during actual weather approaches. It was concluded that the ceilometer-transmissometer system provided a sound method for remotely measuring weather in the runway approach zone. However, supplementary photometric data are required for the optimum interpretation of these weather observations.

REMARKS:

The test data are presented and analyzed in detail. The report is also very complete in supplying necessary photographs and diagrams of test equipment and facilities and in giving necessary background and discussion of all phases of the test program. Data are presented separately for each of the 468 flights. A summary report of this document is available (Sperry Gyroscope Company, 1954).

REQUIREMENTS:

The visual detection and/or recognition of objects, or patterns of objects, in the approach and landing areas of an airport are required as a basis for conduct of a visual contact landing. Visual reference with the runway threshold from the aircraft results from the recognition of one or more of the following visual configurations:

The runway proper as viewed against the background formed by the surrounding terrain.

Runway threshold lights against a terrestrial background.

Runway threshold markings against the runway surface background.

Under instrument flight conditions, detection range is a function of the following factors:

Meteorological constitution of the atmosphere affecting the transmission and scattering of luminous energy in the spatial region affecting the airport and the cockpit of the approaching aircraft.

Photometric distribution of sky luminance in the approach zone of the airport and the distribution of spatial luminances in all directions as viewed from the aircraft cockpit.

Geometric and photometric configuration of reflecting terrain and self-luminous sources in the approach and landing area.

Aircraft characteristics such as air speed, cockpit cut-off angle, and cockpit illumination.

Pilot visual characteristics such as illuminance thresholds and brightness contrast thresholds.

Special meteorological equipment was installed at the test sites as follows:

Transmissometer adjacent to the touch-down end of the instrument runway.

Ceilometer at the middle marker site and in the approach zone.

Terrain illuminometer at the threshold of runway.

Meteorological visibility targets and lamps used to determine day and night visibility.

Runway visibility markers to determine runway visual range during daylight.

Airborne instrumentation included cockpit motion picture camera to record the pilot's windshield view.

A visible terrain camera to record luminance measurements.

A photo theater to record aircraft outputs such as air speed, altitude, roll, pitch, heading, etc.

A NACA cloud detector.

Two airborne photometers to record luminances of the pilot's field of view and center of the visible terrain camera field.

A DC-3 aircraft was used for all flight tests and crews were drawn from five pilots, all employees of the Sperry Gyroscope Company, who held Airline Transport Pilot ratings.

During the test period January 1953 to February 1954, actual weather instrument approaches were flown. The tests emphasized weather below 500 feet ceiling and 1 mile visibility. Three significant points in the approach were reported by the pilot or co-pilot. These were vertical contact, approach light contact, and threshold contact.

When either the pilot or co-pilot first saw terrain below the aircraft, he stated it over radio communication. Similar statements were made upon obtaining visual reference with approach lights or other prominent terrain features in the approach zone and with the end of the runway. All of these observations were transmitted from the aircraft and recorded on the tape recorder located in the ground station.

CONCLUSIONS AND/OR RECOMMENDATIONS:

A program of field tests at scheduled airline terminals with participating airline aircraft should be implemented to check the ceilometer-transmissometer techniques for determining how well pilots can see from the cockpit, as developed in this project.

The following conclusions are based on a detailed statistical analysis of the data:

Transmissometer and rotating-beam ceilometer combination provided a sound method of remotely measuring weather in the runway approach zone.

Supplementary photometric data are required to interpret weather observations in terms of what the pilot will see from the cockpit.

The determination of what the pilot will see from the cockpit under weather and photometric conditions measured with a ceilometer-transmissometer system can be expressed only as a probability function.

The manner in which the weather is reported to the pilot should be modified if the performance of the ceilometer-transmissometer system is to be most useful to the pilot. This report could include the following predictions: vertical contact height, approach light contact height, threshold contact height, and runway visual range.

The ceilometer-transmissometer system requires a human observer to account for special weather conditions such as radiation fog and snow.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Sperry Gyroscope Company, Aeronautical Equipment Division.
TITLE: An operational flight evaluation of an approach zone slant visibility measuring system.
REFERENCE: Great Neck, New York: Author, May, 1957. (Report No. 3245-4080.)

SUMMARY:

Flight tests were conducted to determine the relationship between actual pilot observations of visual contact with threshold lights and cockpit visual range as computed by a ceilometer-transmissometer weather-measuring system.

REMARKS:

The report contains a complete breakdown of all flights on which data were collected. Graphical presentations of the data, subdivided according to day or night flights and brightness setting of approach lights, are given. The principal criterion utilized was initial runway threshold contact.

REQUIREMENTS:

During the terminal flight modes, the pilot needs to establish visual contact with the runway lights in sufficient time to conduct a safe landing. In low visibility conditions, the pilot can use information about the visual range he can expect to encounter in the approach zone as a basis for deciding whether or not he can carry out a safe approach and landing. An effective weather-measuring system, therefore, should translate its data into slant visual range information.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Slant visibility can be expressed only on a probability basis; therefore, a range of values should be provided to the pilot.

The intensity setting of an approach light system affects the illuminance threshold of the pilot and must be considered in determining slant visibility based on threshold lights.

A maximum of 58% and a minimum of 42% of the recorded approaches obtained threshold contact prior to reaching the altitudes predicted by the meteorological and photometric data.

The fog-smoke-haze weather condition at night produces a heterogeneous atmosphere in which the atmospheric slant transmission is not measured accurately by the transmissometer and ceilometer.

Displacement of the aircraft from the ILS glide slope on course introduces additional variability in the actual threshold contact height.

Aircraft type does not have any significant effect on slant visibility to the runway threshold during daylight approaches, but does at night.

Meteorological equipment for the direct measurement of slant transmission as a function of range should be developed to replace the ceilometer and transmissometer in the slant visibility measuring system.

Optimum slant visibility forecasting procedures require the direct prediction of the meteorological and photometric quantities involved as a function of time.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Stevens, N. B., et al.
TITLE: The determination of atmospheric transmissivity by backscatter from a pulsed-light system.
REFERENCE: Riverside, California: Motorola, Inc., Riverside Research Laboratory, 1957. (Contract No. AF 19(604)2213.)

SUMMARY:

The feasibility of determining visual range along the slant path by observation of light scattered by the atmosphere from a pulsed beam of transmitted light was investigated experimentally and theoretically. Three configurations were considered, in which the receiver and transmitter were coaxial, separated laterally, and separated in range. The experimental equipment did produce useful signals in the range of 1000-2000 feet. Although this range is not adequate, extrapolations of the data indicate the possibility of assembling a larger system as a means of covering larger ranges.

REMARKS:

Most of the text is quite theoretical. Much mathematical data and many diagrams are included.

REQUIREMENTS:

The fundamental requirement, basic to this project, was: pilot must recognize the runway lights while sufficient altitude remains to permit course correction. The research problem of this work concerns predicting, in hazy or foggy weather, at what altitude and range a pilot will see and recognize the approach lights.

This measurement was made by projecting a short (microsecond) duration pulse of visible light up the glide path, and measuring as a function of time, the light scattered from the beam. Accordingly, fundamental elements of the system (of whatever size or configuration) are the transmitter, consisting of pulsed-light source and optics, and the receiver, consisting of optics, fieldstop, and multiplier phototube.

The main aspect of interest was a relative comparison of pulse shapes at the source, and of resulting signal current pulse shapes at the receiving equipment. Because of the newness of the system, only limited experimental data were cited at date of report.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Coaxial arranged equipment yielded very little useful information. Using a separated transmitter and receiver, some information beyond 500 feet was received, but the useful range of such equipment was considered small. It was recommended that increased range capabilities be sought through continued work on light sources.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: U. S. Weather Bureau.
TITLE: Final approach visibility studies.

REFERENCE: Washington: Author, 1955.

SUMMARY:

This final report includes all pertinent material on a 3 1/2 year (1951-1955) project to determine ceiling and visibility factors which affect the operation and control of aircraft during final approach and landing, particularly under low ceiling and low visibility conditions. Equipment utilized included: transmissometer; fixed-beam ceilometer; rotating-beam ceilometer; pulsed-light cloud range meter; and television. The study was conducted partially in conjunction with the Sperry study on slant range visibility. A discussion and analysis of the problems involved are included, as well as certain conclusions and recommendations on the use of the equipment employed to measure visibility conditions.

REMARKS:

The report is most complete in supplying background, diagrams, and photographs of each item discussed. Graphic presentations of previous operational test results also are given. A very good report on the state of the art. See the Progress Reports on this project for additional discussion: (June, 1952, March, 1953; November, 1953; and January, 1954).

REQUIREMENTS:

Visual aids are required to assist pilots in locating their position and orienting their aircraft with respect to the duty runway.

Probability of finding and using a lighting system depends upon several factors such as:

Characteristics of the aircraft which determine cut-off angle, response lag.

Atmospheric transmissivities per elevation angles, and directions.

Intensities, designs, orientation of the airport lights.

Brightness contrast and texture contrast of runway with respect to the surround.

Background brightness which governs the adaptation level of the pilots' eyes.

Pilot characteristics: search procedure, decision and reaction time, and thresholds of brightness contrast.

The transmissometer used is illustrated in the text. The various instruments used in the rotating-beam ceilometer and the fixed-beam ceilometer also are shown in the text.

CONCLUSIONS AND/OR RECOMMENDATIONS:

In its present state of development, the rotating-beam ceilometer used offered several advantages over the fixed-beam type:

It was much faster in that it operates on a speed giving an indication every 6 seconds whereas the conventional fixed-beam ceilometer is designed to give two indications every 12 minutes. The fixed-beam ceilometer, because it scans at a relatively slow rate, does not give an indication of short term or random fluctuations in cloud height, whereas the rotating-beam presents discrete measurement of nearly all cloud fragments passing over the detector.

Because the alternate circuits are less complicated, the unit was a little less expensive, required less maintenance, and was more easily installed.

The power requirement is about 500 watts or one quarter that of the fixed-beam, thus showing more economical operation. A distinct disadvantage of the rotating-beam is that no permanent record is made of the cloud indications at the present time.

A scatter diagram of the results indicates that the two systems are comparable and compatible, in that there was no systematic difference between their measurements.

The conclusions reached in part with Sperry were:

The transmissometer-ceilometer combination provides a sound method for remotely measuring weather in the approach zone, but that optimum interpretation of the data requires supplementary photometric measurements.

Ceiling is usually a conservative estimate of vertical contact height.

When low clouds are present, reported visibility is usually greater than threshold contact range. In 91% of the cases this condition prevailed.

When radiation fog is present, threshold contact range and reported visibility agree fairly well in the average.

Comparisons showed that there is ample justification for the rather common belief that meteorological observations, as routinely made at present, do not accurately indicate conditions the pilot will experience if, as is frequently done, ceiling is interpreted as vertical contact height and visibility is interpreted as threshold contact range or other slant visibility.

Additional conclusions were:

The transmissometer and the rotating-beam ceilometer are serviceable instruments suitable for routine operational use.

A meter calibrated in visibility units is practical for control tower installations.

The pulse-light cloud range meter is not suitable for determining heights of low clouds or for determining slant and visual range.

Television enables an observer to determine visibility at remote locations fairly well in daytime, but not satisfactorily at night.

A field test be conducted, at a busy commercial or military airport, of the method of estimating slant visual range developed as a result of the MacArthur flight project.

Investigations be conducted with the view to developing new or improved methods of estimating slant visual range.

A research project directed toward precise, short period forecasts be inaugurated. Development work continue on various methods for displaying information obtained by the rotating-beam ceilometer. There is need for a simple, more easily interpreted, longer persistence display.

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CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Blatt, R. C.
TITLE: Are present lighting aids adequate for private flying?

REFERENCE: Paper presented at the National Technical Conference of the Illuminating Society, Washington, August, 1951.

SUMMARY:

The author presents the results of a survey he conducted assessing the adequacy of airport lighting, focusing on Class 1, the smaller type airport. He concludes that the lighting aids at that time were not adequate for private flying, and that the inadequacies are restricting utilization of private aircraft.

REMARKS:

One of the few analyses of the requirements of small private aircraft is in this report. Most students of airport marking and lighting have focused their attention on military and commercial carrier requirements.

REQUIREMENTS AND/OR DISCUSSION:

The opinions of 50 private pilots, each having considerable night flying experience, were solicited on questions concerning the following:

- airway beacons
- airport wind indicators
- airport lighting
- lighted directional taxiing signs
- aircraft lighting
- navigation lights
- cabin lights

The underlying assumption appears to have been that each of these were critical to private aircraft operations.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Lighting aids were not adequate for private flying, including airway lighting, airport lighting, and aircraft lighting.

The future of private flying depends on adequate lighting. This would bring about more utilities for private aircraft, more demand for private aircraft, and more business with increased profits for small airport operators.

Small lighted fields would aid national defense by providing Civil Air Patrol with round-the-clock flying facilities and the military service with emergency field facilities.

Airway beacons are helpful and are being used by most private flyers; therefore, they should not be removed.

While some of the private planes have radio equipment, it does not eliminate the need for adequate airway and airport lighting, including wind socks, tees, and tetrahedrons.

Wind socks are not adequately lighted or located.

Navigation lights should be flashing type.

There is a need for a low cost standard lighting system, perhaps $500 or less, for small or private operators unable to get government or local financial aid.

There is a definite lack of knowledge among private and commercial pilots of the meaning and identification of various lighting aids on the airways and airports.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Bressey, P. E.
TITLE: The undershoot problem.

REFERENCE: Paper attached to IATA Special Meeting, Amsterdam, November 14-22, 1955.

SUMMARY:

The author makes the point that a visible foreground is vital in order for the pilot to make the judgments required of him. He recommends that approach light systems be utilized even in good weather, or else that an angle of approach indicator, at least indicating a position below a safe angle of approach, be made available.

REMARKS:

The underlying implications of the author's remarks are that altitude, distance, motion parallax, and motion perspective judgments are much easier when the objects are closer to the pilots' eyes.

REQUIREMENTS AND/OR DISCUSSION:

A visible foreground, as close to the pilot as allowed by cockpit cutoff, needs to be provided in good visibility landings as well as in poor visibility landings.

CONCLUSIONS AND/OR RECOMMENDATIONS:

There is a general all-weather requirement for an approach light system and, if not feasible, at least a "dangerously low approach warning indicator".

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Cocquyt, P.
TITLE: Sensory illusions.

REFERENCE: Shell Aviation News, 1952. (No. 178.)

SUMMARY:

The author, an operational pilot, reviews the probable contribution of optical illusions to aircraft accidents as related to pilot error. The analysis is based upon his own experience in the air, his investigations of a number of accidents, and trigonometric analysis of landmarks or references to the position of aircraft in various roll and pitch attitudes. The author concludes that research on illusions is critical and that a training film illustrating such illusions should be prepared and distributed for showing to pilots to warn them against such illusions.

REMARKS:

A very good analysis of the kinds of problems that can arise in operations due to inadequate roll and pitch guidance.

REQUIREMENTS AND/OR DISCUSSION:

The pilot needs to orient himself in space with respect to his aircraft's position and its three degrees of rotational axes.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Misjudgment of height is very easy over a level surface or water.

A pilot frequently has the sensation of flying horizontally while in fact his aircraft is banked.

Illusions do not last long once the pilot has good visual stimuli of ground reference.

Many illusions arise with respect to the roll and pitch axes.

At night, when the ground plane is not easily visible, the pilot determines his relative height by estimation of the distance to a landmark, and the angle between the direction of the observation of his landmarks and his horizon. If his horizon is obscured, and he does not have a good perception of the ground plane (e. g., over water), errors in the assumed angle can account for roll and pitch errors and thus undershoots and flying into the ground.

Most optical illusions occur when the observed reference points are represented by objects without relief; i. e., elevation or height.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Eastburn, M. W.
TITLE: The black hole.

REFERENCE: New York: Flight Safety Foundation, 1955. (Pilot's Safety Exchange Bulletin 55-108.)

SUMMARY:

This paper highlights the "black hole" problem and reviews the evidence available for corrective procedures. The author concludes that a familiar vertical surface sticking out of the ground is required for visual landing.

REMARKS:

The author draws heavily upon the work at the U. S. Air Force School of Aviation Medicine for background materials.

REQUIREMENTS AND/OR DISCUSSION:

The approach area must provide adequate cues to orientation and space, namely, depth perception.

Motion parallax and size of familiar objects are the two most important requirements.

CONCLUSIONS AND/OR RECOMMENDATIONS:

L-shaped aids, one on each side of the runway, with the horizontal segment 90 degrees to the axis of the runway and pointing toward the runway will provide the motion parallax and familiar size objects needed for optimal pilot judgments.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Ellis, W. H. B., & Allan, R. M.
TITLE: Pilots' eye movements during visual approaches and landings.

REFERENCE: Royal New Zealand Air Force, Royal Air Force Institute of Aviation Medicine, September, 1954.

SUMMARY:

This study reports on an experiment conducted to analyze the pilot's eye movements during the latter stages of an approach. It was determined that the subjects spent on an average of 45 per cent of the last 30 seconds not looking outside the cockpit. Variations in blink rate, taken as a measure of visual concentration, are also discussed.

REMARKS:

The author quotes a figure of 2 seconds for focusing in and out of the cockpit, i.e., a complete cycle. This would seem to correlate with other evidence.

REQUIREMENTS AND/OR DISCUSSION:

It is important to know how pilots use their eyes during the approach, especially in view of ever-increasing approach speeds.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Approximately 45 per cent of the landing approach time was spent reading the airspeed indicator.

Evidence available shows that with an alternate method of airspeed presentation, such as an auditory one, the pilot spends almost 100% of his time looking out of the cockpit.

With the standard airspeed indicator, there is a disruption of normal blink rate. When the auditory channel is utilized, there is a near-normal blink rate.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Hochberg, J., & Smith, O.
TITLE: Landing strip markings and the "expansion pattern": I. Program, preliminary analysis, and apparatus.
REFERENCE: Perceptual and Motor Skills, 1955, 5, 81-92.

SUMMARY:

The problems faced by a pilot in approaching a carrier deck are analyzed theoretically on the basis of relative changes of positions and rates of movement of points in the perceptual field. The paper is an initial paper in a program c search focused on defining optimal landing strip markings. The general theory is discussed, terms are defined, laboratory apparatus described, and initial tasks in the research laid out.

REMARKS:

This paper represents the best application of a theory close to Gibson's to the operational problem of runway marking. The discussion is clear for the most part and makes important distinctions which need to be considered in a program of research of the sort contemplated. All in all, the study is a "must" for anyone preparing to do fundamental human factors research on airport marking and lighting design problems.

REQUIREMENTS AND/OR DISCUSSION:

A distinction needs to be made between the stimulation to which the observer responds; i.e., the proximal stimulation, and its source or reference, the target. The target is the physical object reflecting light energy to the eye of the observer. The proximal stimulus is the pattern of reflected light at the eye of the observer.

The proximal stimulus is a function of both the target and the relationship between the observer and the target, and as such is a potential source of information concerning both, although to start with, both are unknowns.

No analysis in terms of the proximal stimulus alone can correspond completely to what the observer does when faced with actions dependent upon depth judgment. Typically, one makes an environmentally-favored assumption about the nature of the target. This fixes one of the two unknowns, allowing information to be assessed regarding one's relationship to the target.

The entire expansion pattern may not be necessary for providing required information, but regions of maximal and minimal changes may be sufficient.

Factors which might limit the potential information available are: acuity, effectiveness, assumptions regarding the target, attention, set, and learning.

Visual acuity of several sorts may act as limiting factors, e.g., minimum separable stimuli, minimum motion acuity, minimum shape deformation acuity, and varying degrees of differential motion acuity thresholds (just noticeable differences).

Although the testing situation is designed to investigate specific psychological processes, it will--within limits--be conducted in conditions as similar as possible to the real situation.

CONCLUSIONS AND/OR RECOMMENDATIONS:

See Requirements and/or Discussion.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Jenks, A. E.
TITLE: Time concept of visual distance.

REFERENCE: Report presented at Flight Technical Group, Fourth Meeting, IATA, Montreal, 1951.

SUMMARY:

The author reviews the concept of reaction time and its importance in determining the positioning of airport runway and approach marks and lights.

REMARKS:

The author states that experience shows that 3 seconds is about the minimum normal reaction time that can be assumed in determining the position and intensity of approach lights.

REQUIREMENTS AND/OR DISCUSSION:

Normal minimum reaction time is defined to include:

- analysis and appraisal of corrective action required,
- the time to apply the control movements,
- time for the aircraft to respond,
- time to observe that the corrective force or action is taking place.

At the runway surface, the minimum visibility dimension, plus cockpit cutoff distance, approximates amount of runway surface used for visual reference under normal VFR conditions. This is used for texture and alignment appreciation during flare and touchdown--the so-called "stare period".

CONCLUSIONS AND/OR RECOMMENDATIONS:

The minimum distance concept for visual flight should be calculated on a 3-second basis at the approach speed employed. This amounts to 660 feet for an aircraft travelling at 150 miles per hour.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Jenks, A. E.
TITLE: Aircraft approach tolerances.

REFERENCE: Aeronautical Engineering Review, 1953, 12 (8).

SUMMARY:

The author discusses problems which the pilot faces during the last 3 minutes of a successful all-weather approach and landing. In the paper, he discusses the approach instruments utilized, the flight characteristics of straight-line flight, turn corrections in instrument approaches, the turn/time lag of modern aircraft both in fairly large and minute corrections, and the time factor in transitioning from instrument to visual flight. He offers a number of conclusions which would help remedy the problems facing the pilots.

REMARKS:

Of particular interest is the information regarding turn/time lag. The author quotes studies showing that from 4 1/2-7 seconds, depending upon the initial bank employed, are required for an aircraft to show a measurable departure from track after turn has been initiated. These turns were made by auto-pilot over a ground speed range of 129-171 miles per hour.

REQUIREMENTS AND/OR DISCUSSION:

Straight-in flight means the continual employment of minute corrective turns.

Bank amounts required for correcting displacements on an instrument approach must not place the wing tip lower than the landing gear in the extended position.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Turn/time lag measurement should be made for each type of "T" category aircraft.

Precision approach paths must be as straight as possible, particularly in the final stabilizing zone.

Heading instrumentation in the cockpit should be improved by reducing lag or lead.

Approach light lanes should be lengthened; otherwise, the runway space will be used for final corrections of the heavier and faster aircraft, and not for their intended purpose; i.e., landing and takeoff of aircraft.

When suitable means of knowing position on approach becomes available, pilot technique improvement will be in order after procedural change.

GCA controllers should be acquainted with the turn/time lag and allow for it in GCA procedures.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Jenks, A. E.
TITLE: The black hole.

REFERENCE: The Air Line Pilot, April, 1956.

SUMMARY:

The author reviews requirements for low visibility approach and landing with special attention to visual flight requirements and the capabilities of the human eye. On the basis of this kind of discussion, the advantages of narrow-gauge flush lighting for all-weather operations are reviewed.

REMARKS:

This is probably the most comprehensive analytic justification for the narrow-gauge runway lighting systems.

REQUIREMENTS AND/OR DISCUSSION:

Basic requirements for visual flight in the approach zone are: identification, alignment, roll guidance, flight guidance, distance, and positive threshold definition.

Basic requirements for visual flight for flare, touchdown, and landing roll are: identification, alignment, adequate definition of surface plane, (precise height sensitivity), roll guidance, and distance.

Runway lighting should not produce an abrupt change at the runway threshold, but should afford continuity of elements on which flight judgments are based.

Visual flight can be maintained with a minimum visual segment equivalent to 3 seconds of time at the aircraft's forward velocity, (i.e., 660 feet).

Difficulty is experienced on the runway in landing if the visual segment ahead of the aircraft is less than 1400-1900 feet, depending on runway width. This is equivalent to 6-9 seconds time.

Visual aids systems should be considered as only requiring 3 basic units: approach, threshold, and landing mat.

Instinctive interpretation, meaning that one of the units cannot be mistaken for the other whether visible or not, is vital.

Review of how requirements are met, with centerline approach system and runway edge lighting:

In lower visibilities, this change from approach area to runway area is noted by the transition from a solid visual reference (approach lights) to something vague and indefinite in lower visibility conditions (runway edge lights).

Alignment in good visibilities is obtained from the definition of the landing surface limits. In lower visibilities this is difficult because the runway centerline is not clear. Alignment must be gotten from the runway edge lighting.

For roll guidance in poor visibility, there is no simple horizon indication and the pilot must get this in secondary form from objects, or combinations of objects, that are visible. The height guidance is afforded by runway edge lighting and dynamic appearance of the runway surface texture below the aircraft. The eyes of the pilot during final flare and actual touch-down employ no saccadic movement but stare directly ahead. This is known as the "stare period".

Critical deficiencies inherent in present systems because of eye capabilities are:

The angular separation between the lights on the runway edge at the extreme visibility limits when the runway visual range is below 1400 feet is a little more than 5 degrees. The area of foveal vision when the eye is focused on infinity is 5 degrees or less.

There is no fixation point at the place where the pilot needs it; i. e., the runway centerline touch-down point.

The main visual assistance is derived from parafoveal streamer vision.

Under visual ranges of less than 2000 feet, the pilot may "go visual" while far out on the approach system, lose altitude until he obtains maximum height sensitivity from ground reference, and then check his flight path descent and fly his aircraft in over the tops of the lights. This is considered a perfectly safe procedure as long as cushions of speed or power are maintained.

Analysis of the proposed narrow-gauge lighting with respect to requirements:

Identification--the closely spaced double-bars are a clear configuration break from the approach system. The break is from positive to negative; i. e., the centerline is there in the approach, but is not there in the runway.

Alignment is obtained by estimating the middle of the two light rows.

Roll guidance--is provided by the horizon continuity formed by the paired light sources.

Runway surface plane--is defined in the area in which the pilot looks for height guidance.

The ending of the guidance elements (3000 feet from runway threshold)--avoids the use of added elements for pilot distance interpretation along the runway.

Limitations of the human eye:

There is only a very small area of sharp, clear vision, the foveal area, representing 3-5% of the entire field of vision, located in the center of the visual field when looking straight ahead.

Vision deteriorates rapidly in the remaining area to practically nothing at the extreme edge.

Vi''ion is founded on experience as much as anything else.

The brain may be considered a computer, taking visual information fed to it, analyzing it, and sending the appropriate muscle impulses out for required action.

CONCLUSIONS AND/OR RECOMMENDATIONS:

The proposed narrow-gauge configuration will provide visual aids in the foveal visual field down to visual ranges of less than 1300 feet. Below this, the system will provide strong and adequate signals in the parafoveal visual field and leave a dark spot for foveal vision fixation down to the lowest operational range.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Majendie, A. M. A.
TITLE: Seeing and believing.

REFERENCE: Paper attached to IATA Special Meeting, Amsterdam, November 14-22, 1955.

SUMMARY:

The author reviews the evidence bearing on interpretation of optical images of the external world impinging on the retina. The physiological and anatomical basis of the functioning and structure of the eye are reviewed, with areas of differential sensitivity pointed out. The author's most important point is that serious visual misjudgment can arise because the pilot can mistakenly judge what is being looked at.

REMARKS:

It appears that the author is calling for a reduncancy of information including an object of known size and shape to be included in visual aids.

REQUIREMENTS AND/OR DISCUSSION:

An accurate perception of what one sees.

CONCLUSIONS AND/OR RECOMMENDATIONS:

In the presence of limited visual information, it is quite possible for a pilot to build up an entirely mistaken belief of what it is that he is looking at, particularly if it is not a familiar visual object.

If a familiar object of known size and shape can be easily recognized or positioned, the possibility of a mistaken belief about what is being seen will be reduced.

A pilot's visual performance can be impaired by fatigue, in that he will not impose as much perceptual constancy on what he sees as he does in non-fatigued states.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Pearson, H. J. C., & Gilbert, M. S.
TITLE: Some considerations of high intensity approach lighting.

REFERENCE: Indianapolis: Civil Aeronautics Administration, Technical Development Center, 1948. (Report No. 60.)

SUMMARY:

The report discusses problems of high intensity approach lighting and various types and applications of lights that are being offered as solutions.

REMARKS: None.

REQUIREMENTS:

Region of guidance is that space within which it is essential that visual aids be sufficiently visible to the pilot to provide adequate guidance for safe approach and landing. At all points within this region the following requirements obtain:

Visible lights shall be immediately identifiable as part of the approach light system.

Lights on either side of the extended centerline 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.

Visible approach lights shall immediately indicate to the pilot that he is left or right, and if possible, above or below the region of guidance.

Sufficient lights shall be visible to indicate the location and direction of the extended runway centerline.

Location of the threshold shall be positively identified for a minimum distance of 500 feet.

Sufficient lights shall be visible to indicate the height above the runway or vertical departure from the glide path, the distance to the threshold, and the attitude of the aircraft with respect to the horizontal plane, both longitudinally and laterally.

The illumination visible at points on or above the level of the glide path shall not be excessive so as to produce glare.

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

CONCLUSIONS AND/OR RECOMMENDATIONS:

CAA Standard Neon Approach Light System

This approach light system is adequate at night under visibility conditions of 3/4 mile or better, but inadequate under conditions of more restricted visibility.

Present standard neon approach lights cannot be considered an example of adequate high-intensity approach lighting.

Bartow Lights

The candlepower distribution of these lights was designed so as to appear of equal brightness to a pilot on the correct approach path. However, on many occasions in bad weather, pilots missed seeing the approach lights entirely.

Single Row Approach Light Systems

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:

(1) 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

(2) to be able to see some lights or marks on the horizon for a reference; or

(3) to have one man watch for lights while the other stays on instruments and adjusts the attitude of the aircraft; or

(4) 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 alternatives, (1) involves a delay in eye adjustment at a very critical time; (2) is impossible in thick weather; and (3) while it is generally used, requires two men's attention and makes it difficult or hazardous for a single operator to land the aircraft. It would appear that (4) is the safest and most practical procedure if the lighting system is designed to furnish the necessary information.

AAF Funnel System

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.

Bartow Multi-Line System

This system is based on the concept of a lighted area as contrasted with a lighted channel. It provides a method of distinguishing one side of the path from the other by means of color and provides a greater degree of lateral tolerance in locating the approach path by virtue of the arrangement of the lights. However, the required multiplicity of lights and controls will increase the cost of an installation to a considerable degree.

NBS Path-Of-Flight System

The system is designed to provide the pilot with lighted paths leading to the runway from every section of the portal. Each line is designed to be sufficient guidance in itself, consisting of pairs of lights which provide the pilot with a horizon indication.

CAA Slope-Line System

The system is designed to indicate to the pilot position of his aircraft with respect to the glide path. 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 final solution to the problem requires the accumulation of sufficient successful experience under actual service conditions to warrant the pilot confidence in the system.

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.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Pfaffmann, C.
TITLE: Aircraft landings without binocular cues: A study based upon observations made in flight.
REFERENCE: Amer. J. Psychol., 1948, 61, 323-334.

SUMMARY:

The ability of experienced pilots to land with restricted binocular vision was studied. Especially prepared goggles were used to eliminate the binocular visual field. Decrements in performance were observed during circling, final approach, and flareout. It was concluded that experienced pilots utilized binocular vision in perceiving altitudes between 500-800 feet as well as for distance and depth judgments during final approach and landing.

REMARKS:

The study seems to indicate that cues to distance must be present in order for apparent size to operate as a distance judgment determinant. It should be noted that experience may be a large factor in the results. With more practice in landings with monocular vision, judgments may have returned to the binocular range--a different set of expectancies would be generated.

REQUIREMENTS AND/OR DISCUSSION:

Orientation and position judgments are involved in circling, final approach, and landing.

A number of subjects reported that the landing field seemed farther away when using monocular vision.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Removal of binocular cues produced:

A tendency to fly closer to the airfield than normal.

A tendency to approach and level off too high.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR:

TITLE: Problems of direct vision from aircraft.

REFERENCE: In P. M. Fitts (Ed.), Human engineering for an effective air-navigation and traffic-control system. Washington: National Research Council, Division of Anthropology and Psychology, 1951.

SUMMARY:

The following problems are discussed and human engineering data existing at that time brought to bear within each discussion: airport marking and lighting, including approach, runway and taxiway lighting and marking, aircraft lighting, adequacy of vision through the wind screen, measurement of visibility. Recommendations for research within these areas are made at the conclusion of the study.

REMARKS:

It is interesting to note that the authors of this study consider it most critical that research on problems of airport marking and lighting should be carried on chiefly in laboratories through the use of simulators, with carefully planned flight test work to check on the validity of the criteria employed in laboratory research.

REQUIREMENTS AND/OR DISCUSSION:

Approach Lighting

At least three levels of need may be delineated:

- contact landing on a clear night,
- shift to a contact landing as soon as the aircraft drops below an overcast,
- the use of ground cues as a check on electronic approach equipment.

The principal problems are in reduced visibilities inasmuch as the goal of approach way lighting is an ultimate reduction of weather minimums.

The approach lighting system should provide:

- orientation of the ground plane or horizontal
- direction to the threshold or touch-down point
- distance to the threshold or touch-down point
- identification of the threshold
- orientation of runway
- rate of travel or closure
- departure from the glide path.

Once the system is in view, there should be no greater need for referring back to instruments than during normal contact landings.

Approach light display and instrument displays must be compatible so that confusions during transitions from one to the other are reduced to a minimum.

The system must be positively and immediately identifiable and distinguishable from other lights, particularly the runway.

The luminous intensity of the system must be coordinated with that of the runway lights so that glare and dazzle are minimized.

Runway and Taxiway Lighting and Marking

The following information seems to be required:

- orientation of runway
- distance traveled along runway
- location of turn-off points.

CONCLUSIONS AND/OR DISCUSSION:

Systematic studies, chiefly through use of simulators, should be made on: cues most important for permitting orientation to runway from a pattern of lights, best way of locating position along the runway, investigation of factors influencing ability to shift quickly from instruments to ground display and vice versa, and interactions between approach light design and design of cockpit instruments.

Rectangles have strong shape constancy as reported in the work of others. This may account for the poor operational acceptability of the slope-line system and for chevron or arrow markings on runways. It is not known exactly how much ground information is needed for successful landing after break-through. In other words, we do not know what patterns best define a surface and which ones best allow orientation to the surface when the observer is moving relative to it.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Rose, H. W.
TITLE: Depth perception in flight training.

REFERENCE: Paper attached to IATA Special Meeting, Amsterdam, November 14-22, 1955.

SUMMARY:

In this paper the author reviews techniques which can be utilized in early flight training to achieve more efficient learning of landing in order to make the training safer and minimize the number of training failures. Techniques suggested include: a thorough indoctrination on the cues used for landing, training films illustrating the different kinds of depth perception, exercises in distance estimation (with one and with both eyes) from objects at known distance, conscious observation during early flights of motion parallax and size cues provided by the runway, and making deliberate est   es of depth (distance and altitude)during trainin

REMARKS:

The author refers to studies as a basis for asserting motion parallax and size cues as the important ones in landing. He discounts binocular parallax as being a significant factor along with other depth perception cues for fixed-wing aircraft, but points out that binocular parallax may be the most important cue in landing a helicopter.

REQUIREMENTS AND/OR DISCUSSION:

Perception of directions and depth perception.

Actual features of the airport provide the most useful size and motion parallax cues.

CONCLUSIONS AND/OR RECOMMENDATIONS:

The author suggests that the depth-perception training methods described may improve landing training.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Rose, H. W.
TITLE: Landing aids to facilitate orientation in space.

REFERENCE: Paper attached to IATA Special Meeting, Amsterdam, November 14-22, 1955.

SUMMARY:

A number of suggestions are made in this paper for increasing guidance provided by visual aids. These are based on the assumption that motion parallax and the apparent size of known objects are probably the two most essential cues for a conventional landing. The author covers all non-weather landing situations, including approaches over snow and water.

REMARKS:

The critical point made by the author is that we should not be too misled by trying to make our visual landing aids coordinate systems inasmuch as this requires conscious interpretation. He feels that distance may have to be consciously judged, but that landing aids should provide "immediate" cues for motion perspective, motion parallax, as well as objects of known size.

REQUIREMENTS AND/OR DISCUSSION:

Cues for motion parallax, perspective, and apparent size of known objects.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Simple bar patterns painted on the runway across the centerline separated universally at the same distance give a useful size cue.

For motion parallax, standard size markers extending vertically at 90 degrees to the axis of the runway, placed along the sides of the runway at standardized distance intervals: this would also provide a pattern for runway perspective.

For landing on snow, a bar pattern, of the sort suggested above. This can be improvised by a row of fir trees on one or both sides of the runway.

On aircraft carriers, vertical markers could be provided on the island, at the position of the LSO, and aft and directly below the landing deck.

On a glassy-smooth water surface, spars at standard intervals would provide cues.

For night, the two-coordinate runway outline has the effect of being 2-dimensional, and thus not very useful for motion parallax; thus, correctly-spaced runway lights could be used on both sides of the runway and extended into the approach zone, including floodlighting of the daytime vertical bars provided for motion parallax.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Rose, H. W.
TITLE: Monocular depth perception in flying.

REFERENCE: Journal Aviation Medicine, June, 1952, 23, 242-245.

SUMMARY:

Evidence bearing on the relative roles of binocular and monocular cues in flying is reviewed. The evidence clearly indicates that binocular parallax tests used either for selection or for continuing efficiency testing in no way is justified. The author suggests that two essential factors utilized by pilots, namely, motion parallax and size of retinal image, be tested and utilized as critical tests for selection, although the results should not be interpreted literally without consideration of other factors.

REMARKS:

The author mentions a portable motion parallax tester which was exhibited at the Aero Medical Association meeting in Denver, 1951.

REQUIREMENTS AND/OR DISCUSSION:

The pilot needs depth perception to obtain orientation in 3-dimensional space.

The same cues and factors are not effective in all situations.

CONCLUSIONS AND/OR RECOMMENDATIONS:

The author's study showed that the correlation between landing ability (ability to level off at proper attitude) and motion parallax test scores is statistically significant, although moderate in actual size. Binocular parallax measurements, on the other hand, do not correlate with success of landing in this or other studies.

During landing, the monocular cues of motion parallax and size of retinal image seem to be the limiting factors of efficiency.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Tiedemann, A. T.
TITLE: Lighting pattern distortion caused by rain on an airplane windshield.
REFERENCE: Indianapolis, Indiana: Civil Aeronautics Administration, Technical Development and Evaluation Center, 1953. (Report No. 189.)

SUMMARY:

This report describes a study of the effect of rainfall as a limiting factor in the effectiveness of airport signal lighting systems such as approach or runway lighting configurations. The major source of problems in this area is the interaction between rate of rainfall, the characteristics of the windshield, and the speed of the aircraft.

The effects of an anti-wetting agent are summarized.

REMARKS:

Photographs are included which were taken from a cockpit of aircraft approaching the slopeline lights at Indianapolis and Arcata under varying rates of rainfall. Other photographs are presented which demonstrate the effect of an anti-wetting agent applied to a windshield Slope-line approach lights are seen through treated and untreated windshields under rainfall rates varying from .6 to 2.4 inches per hour.

REQUIREMENTS AND/OR DISCUSSION:

During approach and landing phases, the pilot is dependent upon the pattern of lights which indicate the relationship of the pilot to the runway.

The general effect of water on the aircraft's windshield is to broaden the image of the signal lights, thus reducing the effectiveness of geometric patterns of lights and obscuring positional relationship with respect to critical elements of the airport. Rainfall between the windshield and the pattern of signal lights being viewed, on the other hand, caused some obscuration but little distortion.

Distortion results from water flow over a windshield where the water surface is of varying thickness across the windshield. The curvature of the water surface results in varying degrees of refraction of the light incidence on the windshield, and the image formed by this light is consequently distorted. This condition is magnified by a moving aircraft since its windshield will intercept a quantity of water that is approximately proportional to its forward velocity.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Rain in the atmosphere between aircraft and signal lights will reduce the visibility of the lights. In addition to attenuation in visual range, some halation may result.

Distortion in the pattern of the signal lights results from a non-uniform surface of water flowing over the windshield and is almost wholly a result of the quantity of water intercepted by the windshield. At approach speeds of 120 miles per hour, the signal light pattern would not be adversely affected in a rainfall rate of about .5 inches per hour or less on untreated windshields.

Windshields treated with an anti-wetting agent could tolerate a rainfall rate of 2-3 inches per hour without distorting the pattern of signal lights presented.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Warren, R. E.
TITLE: Perspective analysis of approach light patterns.

REFERENCE: Indianapolis: Civil Aeronautics Administration, Technical Development, 1949. (Report No. 96, and Supplement Report No. 133.)

SUMMARY:

This report presents perspective drawings of nine different approach lighting systems. The views are those which a pilot would see while letting down on a proper approach path and several erroneous paths. Four of the twelve views for each system assume unlimited visibility, while the remainder assume 1000-foot visibility only. Provisions for viewing the sketches with cockpit cutoff templates are provided.

REMARKS:

This is a good illustration of one kind of screening technique not requiring expensive apparatus that might be used for a proposed system. However, results always would have to be interpreted in terms of the dynamic conditions under which landings are made.

REQUIREMENTS AND/OR DISCUSSION:

The approach light pattern, which when seen from different positions or attitudes most quickly and accurately reflects these differences, will be the most useful to pilots.

CONCLUSIONS AND/OR RECOMMENDATIONS:

All of the systems analyzed were considered to provide adequate directional guidance provided attitude is level.

Those patterns which include satellites or cross-bars for horizontal reference are considered to furnish better directional guidance than those without a horizontal reference.

The slope-line system was considered to furnish the sharpest indication of direction.

None of the systems furnished an accurate indication of altitude except the slope-line system.

The horizontal cross-bar of the Calvert system and the 1000-foot marker on the ALPA system were considered to furnish the best indications of attitude.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Woodman, J.
TITLE: Approach success.

REFERENCE: Paper attached to IATA Special Meeting, Amsterdam, November 14-22, 1955.

SUMMARY:

The author reviews the developments of suitable approach light systems and makes a case for additional runway visual guidance to eliminate the "black hole" or "hold off and hope" area which has resulted.

REMARKS: None.

REQUIREMENTS AND/OR DISCUSSION:

Runway lighting comparable in effectiveness to the approach and threshold lighting systems developed.

CONCLUSIONS AND/OR RECOMMENDATIONS:

Full support should be given to development of a satisfactory landing lighting system.

A truly flush runway light has been developed and its evaluation program should be given the full support of IATA and ICAO.

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PROBLEM RELATED
HUMAN FACTORS STUDIES

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Cowper, M. C.
TITLE: An investigation into the perception of movement.

REFERENCE: Cambridge: Flying Personnel Research Committee, The Psychological Laboratory, 1947. (Report No. 683.)

SUMMARY:

This report presents the results of an experimental study which examined motion thresholds in the horizontal and vertical planes of 10 members of RAF air crews.

REMARKS:

The results of this study are related to the Calvert and Gibson theory of streamer velocities in the expansion pattern as cues to touch-down point and rate of closure.with the runway surface. The results also have implications for the design of cockpit instruments as it would appear that a needle indicator travelling from right to left would be more readily and accurately observed than movement in any other direction.

HUMAN CAPABILITY:

The ability to discriminate motion in four spatial directions - up, down, left, and right from a point of reference - was examined in this study.

INFLUENCING FACTOR(S) STUDIED:

The primary influencing factor studied was the direction with which the visual stimulus moved. Other variables examined were speed of movement and stimulus size.

CONTEXT CONDITIONS:

The study was conducted under laboratory conditions and the stimuli were presented tachistascopically.

RESULTS AND/OR CONCLUSIONS:

Considerable individual differences were found in velocity thresholds.

Motion thresholds varied significantly with the direction of movement. Horizontal motion thresholds were in the region of 1 minute of arc per second. Vertical motion thresholds were above 1 minute, 30 seconds of arc per second.

The ability to correctly judge motion of the four directions was in the following order: to the left, to the right, upward, downward.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Grindley, G. C.
TITLE: Notes on the perception of movement in relation to the problem of landing an aeroplane.
REFERENCE: Cambridge: The Flying Personnel Research Committee, 1941. (Report No. 426.)

SUMMARY:

This report presents a discussion of the problem of landing an aircraft on the basis of visual cues in the external environment. The rationale suggests that a pilot could safely perform a landing on the basis of velocity cues alone. During training the pilot has been shown the correct height for making control reactions involved in landing. If he can recognize the moment in which he reaches these heights on subsequent occasions, he can make appropriate control responses. The pilot's primary task is to correctly judge his absolute height above the surface.

A series of experiments was conducted to assess the capability of human observers in making absolute estimates of velocity, assumed to be the principal cue to height. The results indicate that, with practice, observers were able to judge velocity with sufficient accuracy to suggest the possibility that a pilot could learn to estimate height well enough to execute successful landing on the basis of velocity cues alone.

REMARKS:

The results of this report have important implications for the positioning of signal lights in approach and runway configurations, and for pilot selection and training.

Study findings indicate the potential advantage of using marks and lights to pattern those portions of the approach and landing area which appear near the periphery of the pilot's visual field. This patterning follows from the Calvert/Gibson analysis of the streamer velocity cues in the expansion pattern as cues to height and rate of closure, combined with the findings of the present study that velocity judgment accuracy is more accurate at high velocities. Those streamers near the periphery of the expansion pattern are of highest velocity.

Individual differences observed both in initial levels of ability to estimate velocity and in improvement in their ability through training, suggests the usefulness of velocity estimation as a selection device and training aid.

HUMAN CAPABILITY:

The principal ability studied in this work is the absolute judgment of velocity.

INFLUENCING FACTOR(S) STUDIED:

Conditions that were related to absolute judgment of velocity were the degrees per second velocity used as the standard, individual differences in initial abilities, and practice effects.

CONTEXT CONDITIONS:

The study was conducted with laboratory apparatus. The experimenter used a kymograph drum covered with a strip of green paper on which were placed a number of irregularly-placed ink spots averaging about 1/10 inch in diameter and about 5 per square inch. This drum was viewed monocularly through a 10-inch tube, 1 inch in diameter so that the observer had a 6-degree field of view. The experimenter accelerated the drum at a known rate from zero to a certain level of velocity designated as the standard. The observer was asked to remember what this velocity looked like, and after an exposure of about 10 seconds to this velocity, the experimenter stopped the kymograph drum. Then the experimenter gradually accelerated the drum from zero again, and on this trial the observer was asked to stop the experimenter when he thought that the standard velocity had been attained.

RESULTS AND/OR CONCLUSIONS:

Major conclusions of this study was that after only a small amount of practice, the subjects participating in this study achieved an accuracy of estimating absolute velocities on the order of about 5% error. This error level suggests the possibility that a pilot could learn to estimate his height and rate of closure well enough to conduct a successful landing on the basis of velocity cues only.

Substantial individual differences in initial ability to estimate absolute velocity as well as individual differences in learning to correctly estimate velocities were observed for this task.

There was a marked tendency for observers to improve with practice in their accuracy of estimation of any given velocity. The velocities used as the standard ranged from .4 degrees per second to 40.5 degrees per second.

Percentage error of estimation decreased with increasing velocities used as the standard. As the velocities increased from near threshold to a level where streakedness occurred, subjects were better able to match the standard on an absolute basis.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Gibson, J. J., & Carel, W.
TITLE: Does motion perspective independently produce the impression of a receding surface?
REFERENCE: J. exp. Psych., 1952, 44 (1), 16-18.

SUMMARY:

Subjects were exposed to a "spotted" (light dots) visual field which, when motionless, was thought to produce an impression of a surface on a frontal plane. When the spots move across the field, with the velocity decreasing upward from the bottom to the top, it was hypothesized that a perception of a receding surface, similar to that produced at night when looking out the window of an aircraft at the lights of a city, would be produced. No experience of slant, recession or increasing distance to a surface was reported by subjects. These results were interpreted in terms of the failure of the bank of light spots to have hardness or inpenetrability and thus no critical surface qualities. In this kind of situation, moving spots (motion perspective alone) will function truly only as clues, or cues, for distance rather than basic stimuli.

REMARKS:

The conditions under which the experiment was conducted, in which the spots on the visual field did not have gradients of increasing density or decreasing size, make the results useful as background information for the airport marking and lighting problem. The important conclusion is that it takes more than motion perspective to produce the impression of the receding surface.

HUMAN CAPABILITY:

The capability to perceive a moving receding surface.

INFLUENCING FACTOR(S) STUDIED:

The velocity of moving visual field elements was isolated as a single experimental condition.

CONTEXT CONDITIONS:

Not pertinent.

RESULTS AND/OR CONCLUSIONS:

No naive observers reported the experience of a receding surface but only reported that they saw the lights as a collection of discrete objects in empty space moving across the visual field. The conclusion is that the moving spots, and thus motion perspective, function as clues or cues for distance rather than as fundamental stimuli.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Gibson, J. J., et al.
TITLE: The relative accuracy of visual perception of motion during fixation and pursuit.
REFERENCE: Amer. J. Psych., 1957, 70, 64-68.

SUMMARY:

Subjects were tested on their ability to match the velocity of two moving surfaces under two different conditions: with eyes fixated on some stationary part of the visual field, and with pursuit by the eyes; that is, the eyes fixate on one part of the moving surface and follow it. No differences in the ability to match velocities of two moving surfaces were found under these conditions.

REMARKS:

Despite the fact that no differences in discrimination capabilities were determined, this experiment did not shake the reality of the Aubert-Fleischl paradox in which an observer gets an impression of velocity of a moving object when fixating on a stationary object, which impression is about twice as fast as his impression of velocity when he fixates the moving object (with pursuing eyes). In operational situations with which airport marking and lighting systems are concerned, observers will be responding on the basis of their perceptual impressions; thus their observations of the velocity of the moving object will depend upon whether they are fixating the object as moving or as some stationary part of the background or visual field.

HUMAN CAPABILITY:

The accuracy with which the speed of two moving surfaces can be matched: primarily a discriminative capability.

INFLUENCING FACTOR(S) STUDIED:

There were two different methods of operation: fixation of the eyes on a stationary part of the visual field and estimating the speed of a visual element in the field, and estimating the speed of the visual element when utilizing eye pursuit; that is, fixating on the moving element. For the matching judgment, both were used as standards in the experiment.

CONTEXT CONDITIONS:

No degradation of visibility conditions was studied. Observation of the moving surfaces was through two identical rectangular windows. Speed of the surfaces utilized was approximately 4.9 degrees per second angular velocity.

RESULTS AND/OR CONCLUSIONS:

No differences in the capability were obtained under the two modes of observation. However, there was a significant difference determined between the location of the standard; that is, the difference in the matching capability when the standard was in the right window, and when it was in the left window. No explanation of these significant results is offered by the authors.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Goldstein, A. G.
TITLE: Judgments of visual velocity as a function of length of observation time.
REFERENCE: Fort Knox, Kentucky: Army Medical Research Laboratory, Psychology Department, 1956. (Report No. 239.)

SUMMARY:

This study investigated the relationship between duration of prior exposure to a moving stimulus and observer judgments of the subjective or apparent velocity of movement of the stimulus. In general, the results show that there is a negative relationship between the duration of stimulus exposure time and judgments of velocity; the longer the exposure of observers to a moving stimulus, the greater the tendency for them to underestimate stimulus velocity.

REMARKS:

The results of this study indicate a tendency to underestimate velocity and are in apparent conflict with results reported by Grindley, whose subjects consistently overestimated velocities. The stimulus presentations involved in the two studies are considerably different, however, and of the two, the task conditions involved in Grindley's study more closely resemble those associated with the landing task.

HUMAN CAPABILITY:

The capability to estimate the velocity of a band of vertical stripes moving across the visual field at various rates.

INFLUENCING FACTOR(S) STUDIED:

Rate of movement of stimulus objects and duration of observation of the moving stimulus object.

CONTEXT CONDITIONS:

Subjects had better than 20/40 visual acuity and were partially light adapted. They were presented with a continuously moving band of black and white vertical stripes. The entire display was located frontoparallel to the subject.

RESULTS AND/OR CONCLUSIONS:

In general, the longer the period of observation of the stimulus, the slower the apparent velocity judgments. For every velocity level (2-14 centimeters per second), the maximum observation period (60 seconds), was associated with a slower velocity judgment than the minimum observation period (2 seconds).

The maximum decline in velocity judgment occurred during the 8-30 second observation period. Beyond exposure duration and up to 60 seconds, no further decline occurred.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Goldstein, A. G.
TITLE: Judgments of visual velocity as a function of the length of observation time of moving or non-moving stimuli.
REFERENCE: Fort Knox, Kentucky: Army Medical Research Laboratory, Psychology Department, January, 1957. (Report No. 258.)

SUMMARY:

This study was conducted to assess effects of prior experience of observing a non-moving stimulus or a moving stimulus on judging the velocity of a moving stimulus. The general function observed is that when the prior observation or surveillance duties involve moving stimuli, an inverse relationship between the judged or apparent velocity of a moving visual stimulus and the duration of observation of this stimulus obtains. However, this inverse relationship does not obtain if the subject was watching non-moving stimuli in prior observation. In other words, subjects over-judge the velocity of a moving stimulus to an extent directly in proportion to the length of time they observe the stimulus. This error was larger as observation time increased only if the subject had been watching other moving stimuli prior to the judgment.

REMARKS:

The results of this study suggest that pilots who have been watching cockpit visual displays for some time, and particularly when components of that display are moving, may be apt to over-estimate the velocity of what they see outside as a function of how long they look at the outside stimuli. While provocative, this suggestion must be interpreted cautiously. All judgments in the study were made of stimuli at a constant distance, whereas in the operational situation, the pilot is shifting between two distances--his cockpit panel and landmarks outside of the cockpit.

HUMAN CAPABILITY:

The capability to match the velocity of a moving stimulus object with the velocity of a stimulus directly under control of the subject. In short, a differential velocity threshold.

INFLUENCING FACTOR(S) STUDIED:

Duration of observation time, and duration of prior observation of movement and non-movement stimuli.

CONTEXT CONDITIONS:

Slight visibility degradation. (One-half reflecting screen.)

Dark-adapted eyes. Speed of moving stimuli was 14.28 centimeters per second on a screen 55 centimeters in front of the subject's eyes.

RESULTS AND/OR CONCLUSIONS:

Visual movement of stimuli in prior observation is necessary for the inverse relationship between length of observation time and over-judgments of velocity to obtain.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Johansson, G., et al.
TITLE: Studies on motion thresholds I.

REFERENCE: University of Uppsala, Sweden: The Psychological Laboratory, November, 1957. (Report No. 1.)

SUMMARY:

This study was focused on determining the length of motion track just detectable as a function of stimulus velocity. It was found that these threshold values decreased with increasing velocity and the relationship can be described by a power function.

REMARKS:

The judgment required in this task is very similar to the pilot's task of judging displacement from a visible centerline, the judgments required by the Navy Mirror System, and the two-bar angle of approach indicator.

HUMAN CAPABILITY:

The capability to perceive the shortest length of motion track of a visual stimulus.

INFLUENCING FACTOR(S) STUDIED:

Velocity of stimulus object.

CONTEXT CONDITIONS:

Observers were 57.3 centimeters from the screen. There was a slight dark-adaptation condition.

RESULTS AND/OR CONCLUSIONS:

The optimal displacement threshold was .18 minutes of visual angle which occurred when the test object had a velocity of 1.15 minutes per second of angular velocity. The threshold values seem to be fairly equivalent (about .20 minutes of visual angle) for angular velocities between .58 and 2.31 minutes per second. The parafunction which best describes the data is:

$$DT = .028 \times V^{-1.04} + .30$$

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HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Johansson, G., et al.
TITLE: Studies on motion thresholds II.

REFERENCE: University of Uppsala, Sweden: The Psychological Laboratory, November, 1957. (Report No. 2.)

SUMMARY:

This study was conducted to determine the relationship between the shortest perceptible length of motion track and distance of the visual stimulus from subject. The results show that the threshold of motion track, as expressed in angular velocity measure, is constant and independent of distance.

REMARKS:

This study has important implications if verified for a larger range of distances. Distance to the touch-down point, or runway threshold, would not have to be duplicated for experimenting with various patterns of lights. Rather, laboratory studies could proceed using angular velocity measures at smaller distances, and results would be expected to generalize to operational situations.

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HUMAN CAPABILITY:

Capability to detect the shortest length of motion track of a visual stimulus. (Displacement threshold.)

INFLUENCING FACTOR(S) STUDIED:

Distance between the observer and the visual stimulus.

CONTEXT CONDITIONS:

No degradation of visibility. Slight dark adaptation. Distances from the observer varied between 2.29 meters and 9.16 meters. Visual field was 45 minutes, vertical line was 34 minutes and diameter of the target 4.8 minutes, all of visual angle referent.

RESULTS AND/OR CONCLUSIONS:

The displacement threshold expressed in angular measure is constant and independent of distance from the display. Another interesting result was that when the displacement threshold was figured in terms of absolute size; that is, millimeters, it was related to distance in such a way that, if the total distance was split in half, the threshold was about half.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Leibowitz, H. W., & Lomont, J. F.
TITLE: The effect of luminance and exposure time upon perception of motion.
REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1954. (Technical Report No. 54-78.)

SUMMARY:

This report presents the results of a study to determine the minimum rate of target displacement required for the detection of movement at a constant rate of exposure. Velocity threshold values were obtained for a wide range of luminance values and durations of exposure.

REMARKS:

The results of this study indicate that both light intensity and viewing time are important variables to be considered in the specification of optimum stimulus conditions for motion perception. Motion discrimination was improved considerably more by increases in exposure time than by increased luminance. Such findings have potential application to considerations of approach light configuration length and intensity.

HUMAN CAPABILITY:

The human capability of concern in this study is the isochronal threshold velocity for foveal vision. **Isochronal threshold velocity** is defined as the minimum rate of displacement of a visual stimulus necessary for the perception of movement by the observer when the rate of stimulus displacement occurs at a constant exposure duration.

INFLUENCING FACTOR(S) STUDIED:

The isochronal threshold velocity in minutes of arc per second was determined as a function of two principal variables: luminance measured in millilamberts, and exposure duration measured in seconds. Thresholds were determined as a function of exposure duration with target luminances held constant and as a function of luminance with exposure durations held constant.

CONTEXT CONDITIONS:

This study was carried out with laboratory apparatus which simulated radarscope presentations. The viewing distance was approximately 90 inches and the visual stimulus consisted of white rectangular squares subtending a visual angle of 15 minutes of arc. The squares were pasted to a belt so that the angle between centers of adjacent squares was 45 minutes of arc. These visual stimuli appeared in the field of view of the subject on a circular frame subtending 3 degrees of arc.

RESULTS AND/OR CONCLUSIONS:

Considerable individual differences and intra-individual variability existed in the initial testing. This variability significantly reduced as a function of practice and thresholds were significantly lowered.

Threshold velocity decreased with increased luminance rapidly at first and then diminishing before reaching a limiting value after which further increases in luminance had little effect in lowering threshold. Increases in exposure duration, however, shift the functions to progressively lower values.

Increased exposure time not only lowers threshold velocities but permits motion discriminations to be made at progressively lower values of target luminance.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Leibowitz, H. W., & Lomont, J. F.
TITLE: The effect of grid lines in the field of view upon perception of motion.
REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1954. (Technical Report No. 54-201.)

SUMMARY:

An estimate of the range of individual differences in threshold of motion perception was obtained. Effects of luminance level, exposure duration of the visual stimulus, presence or absence of grid lines perpendicular to the line of motion of the visual stimulus, and practice were studied in terms of their influence on velocity thresholds.

REMARKS:

The variability of test subjects in motion perception thresholds and the significant reduction in thresholds brought about by practice has implications for pilot selection and training. The significant improvement in motion discrimination brought about by the presence of grid lines on the display perpendicular to the line of motion of the viewed object suggests a potential application to the design of aircraft wind screens, or sighting devices forward of the cockpit.

The results of this study are related to the theory developed by Calvert and Gibson that rate of closure with the ground plane can be estimated on the basis of differential velocities of the discriminable objects in the expansion pattern. It might be hypothesized on the basis of the results of this study that significant improvement on the part of pilots to estimate rate of closure and therefore a reduction in accident rates on landing may be affected by training techniques which stress the use of velocity cues as an indicant of rate of closure. It may be that the development of a gridded wind screen or sighting device may prove useful in improving rate of closure judgments.

HUMAN CAPABILITY:

The ability of the unaided eye to discriminate movement of a visual stimulus was investigated.

INFLUENCING FACTOR(S) STUDIED:

Velocity thresholds were determined under several levels of luminance and exposure duration of a constant sized visual stimulus and in the presence and absence of grid lines perpendicular to the line of target motion on the visual display.

CONTEXT CONDITIONS:

Subjects observed the stimulus conditions monocularly through a black tube 90 inches from the subject's eye. Subjects viewed a circular display (3 degrees of arc), upon which were square white targets, each subtending 15 minutes of arc and spaced 45 minutes of arc between centers of adjacent targets. Target velocity across the display was increased from a sublimimal speed to a speed at which motion was perceived by the subject twice in succession.

RESULTS AND/OR CONCLUSIONS:

Motion velocity thresholds are significantly reduced by: increased target luminance, increased target exposure durations, presence of grid lines perpendicular to the direction of target motion on the display, and practice of the subject.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Ludvigh, E.
TITLE: The visibility of moving objects.

REFERENCE: Science, 1948, 108 (2794), 63-64.

SUMMARY:

This study is concerned with derivation of formulae which allows determination of conditions necessary for maximum visibility. Formulae include diameter of the object, distance from the observer, and the angular velocity of the object. Visual acuity is expressed as a fraction of the observer's acuity at zero speed; that is, typical acuity measurements. As the angular velocity of the test object increases, as measured in degrees per second, the observer's visual acuity deteriorates rapidly.

REMARKS:

Although the formulae were focused on fixing the optimal altitude and air-speed for identification of objects of fixed sizes, the formulae should be useful in determining, with a given velocity and altitude, what size the objects on the ground should be. Also interesting is the static (zero speed) visibility threshold used by the author. It equals 2 minutes of arc or 033 degrees. He does not give any minimum dynamic visual acuity angies in this paper.

HUMAN CAPABILITY:

Recognition of the general form of an object when the observer or the object is moving.

INFLUENCING FACTOR(S) STUDIED:

Various angular velocities of the object.

CONTEXT CONDITIONS:

Not stated.

RESULTS AND/OR CONCLUSIONS:

Optical magnification otherwise unaided is not beneficial in increasing visual dynamic visual acuity and because of vibration, decreases in the field and other factors, would be detrimental. The magnification of size without loss of contrast and without increase in angular velocity would be helpful.for improving visual acuity.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Miller, J. W., & Ludvigh, E.
TITLE: The results of testing the dynamic visual acuity of 1000 Naval Aviation cadets.
REFERENCE: Pensacola, Florida: U. S. Naval School of Aviation Medicine, 1956. (Report No. 10, Project No. NM 001 110 501.)

SUMMARY:

Visual acuity tests on 1000 Naval Aviation cadets are presented. Variables considered are thresholds for angular velocities of 28 degrees per second and 110 degrees per second, and the A and B parameters which the authors utilized in determining dynamic visual acuity. Results are discussed in terms of the interrelationships of the parameters, the normality of the distributions, and the usefulness of distinguishable groups identified on the basis of measures of dynamic visual acuity.

REMARKS:

The author includes a brief summary of all dynamic visual acuity studies conducted by him and his associates prior to this study. The results reported on influence of training and the average values on dynamic visual acuity are in general accord with results determined by other investigators using different techniques.

HUMAN CAPABILITY:

The smallest resolvable critical detail of a moving object.

INFLUENCING FACTOR(S) STUDIED:

Individual differences among a large group of subjects.

CONTEXT CONDITIONS:

Landolt rings were used as the test subject.

Observers eyes were light adapted.

The illumination of the test objects was approximately 25 foot candles.

The optical distance from the test object to the observer's eye was 4 meters.

The reflection factor of the cardboard background was approximately 85%.

The observer's head and chin were rested in fixed positions and measures taken monoculary.

RESULTS AND/OR CONCLUSIONS:

The average threshold for the 110-degree velocity target was approximately 6.096 minutes of arc with a standard deviation of 3.229; for 20 degree per second movement, the average was 1.927 minutes of arc with a standard deviation of .703.

The distribution for all variables is markedly abnormal.

Individuals can be classified into groups on the basis of their dynamic visual acuity. This may be of considerable importance in future selection of pilots, if such a test is deemed useful.

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HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Pollock, W. T.
TITLE: The visibility of a target as a function of its speed of movement.

REFERENCE: J. exp. Psychol., 1953, 45 (6), 449-454.

SUMMARY:

The author studied detection thresholds of a moving target as a function of monocular luminance threshold, target speed, and direction of movement. The target speeds selected were those at which one might expect visual acuity to be reduced to zero.

REMARKS:

The conclusion that vertical target movement yields consistently lower thresholds than horizontal movement is an interesting one which apparently conflicts with conclusions reached by other investigators.

HUMAN CAPABILITY:

The ability to detect a moving spot of white light in an otherwise homogeneous field.

INFLUENCING FACTOR(S) STUDIED:

The luminance required for detection, as a function of speed of target and direction of movement.

CONTEXT CONDITIONS:

Subjects were dark adapted.

Targets were always presented so that the midpoint of target movement centered on the fovea.

RESULTS AND/OR CONCLUSIONS:

Threshold luminance increases systematically with increases in target speed. The function is best characterized as linear with a slope near unity when the threshold luminance and speed are plotted logarithmically.

Threshold luminance varied between .20 log millimicrolamberts at 50 degrees per second speed, to 3.5 log millimicrolamberts at 1600 degrees per second speed.

Vertical target movements yielded consistently lower luminance thresholds than horizontal movement.

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HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Smith, W. M.
TITLE: Effect of monocular and binocular vision, brightness, and apparent size on the sensitivity to apparent movement in depth.
REFERENCE: J. exp. Psych., 1955, 49 (5), 357-362.

SUMMARY:

The threshold for determining movement in depth was studied as a function of brightness, monocular and binocular vision, and apparent size. It was found that both brightness and mode of vision (monocular and binocular) affected sensitivity; sensitivity was greater with higher brightness and binocular vision. Brightness seemed to be the more important factor. There were interactions between subjects in both brightness and mode of viewing.

REMARKS:

At least within the realm of the experimental conditions considered here, apparent size of the stimulus did not affect sensitivity to movement. Thus, depending upon apparent size increases alone in the final approach may not provide adequate information.. Equally as important was the finding that sensitivity interacts with so-called internal behavioral factors (such as set, fatigue, attention, etc.) which are a part of the individual doing the observing.

HUMAN CAPABILITY:

Detection of apparent movement in depth of a non-familiar stimulus.

INFLUENCING FACTOR(S) STUDIED:

Brightness, monocular and binocular vision, and apparent size.

CONTEXT CONDITIONS:

No degradation of visibility.

Dark adaptation. Stimulus was 12 feet, 8 inches from observer's eyes. Angular velocity of stimulus was approximately 1.5 minutes per second.

RESULTS AND/OR CONCLUSIONS:

Brightness contrast decreases the reaction time to apparent movement in depth; it also decreases when binocular vision is used, as opposed to monocular. The effects of these factors varied from subject to subject. Apparent size of the test object did not affect these earlier conclusions and was not a factor in detecting movement in depth.

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VA20. Ludvigh, E., & Miller, J. W. Some effects on training on dynamic visual acuity. Pensacola, Florida: Naval Air Station, United States Naval School of Aviation Medicine, and the Kresge Eye Institute, Detroit, 1954. (Joint Project Report No. 6.)

VA21. Ludvigh, E., & Miller, J. W. The effects on dynamic visual acuity of practice at one angular velocity on the subsequent performance at a second angular velocity. Pensacola, Florida: Naval Air Station, United States Naval School of Aviation Medicine, and the Kresge Eye Institute, Detroit, 1955. (Joint Project Report No. 9.)

VA22. Miller, J. W. The effect of altered illumination on visual acuity measured during ocular pursuit. Pensacola, Florida: Naval Air Station, United States Naval School of Aviation Medicine, and the Kresge Eye Institute, Detroit, 1956. (Joint Project Report No. 12.)

VA23. Miller, J. W. The measurement of dynamic visual acuity while the observer is rotating. Pensacola, Florida: Naval Air Station, United States Naval school of Aviation Medicine, and the Kresge Eye Institute, Detroit, 1956. (Joint Project Report No. 11.)

VA24. Miller, J. W., & Ludvigh, E. A shortened procedure for the testing of dynamic visual acuity. Pensacola, Florida: Naval Air Station, United States Naval School of Aviation Medicine, and the Kresge Eye Insitute, Detroit, 1955. (Joint Project Report No. 8.)

VA25. Miller, J. W., & Ludvigh, E. An analysis of certain factors involved in the learning process of dynamic visual acuity for 1000 Naval Aviation cadets. Pensacola, Florida: Naval Air Station, United States Naval School of Aviation Medicine and the Kresge Eye Institute, Detroit, 1957. (Subtask 2, Report No. 13.)

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Bartlett, N. R., & Macleod, S.

TITLE: Effect of flash and field luminance upon human reaction time.

REFERENCE: J. opt. Soc. Amer., 1954, 44(4), 306-311.

SUMMARY:

This study reports two separate experiments dealing with the effects of varying conditions of signal flash and levels of background field luminance on visual reaction time at the fovea and retinal periphery. For both foveal and peripheral situations, reaction time decreases as flash luminance increases. The results also show that peripheral stimulation yields shorter reaction times for a dim flash, while foveal reaction times are shorter for brighter flashes.

REMARKS:

There apparently are combinations of field-stimulus levels that can be used to get equivalent reaction times in the event that "ideal" contrasts are not feasible.

HUMAN CAPABILITY:

Detection of a periodically presented light flash.

INFLUENCING FACTOR(S) STUDIED:

Locus of stimulation (fovea or periphery of retina).

Level of flash luminance and level of field luminance.

CONTEXT CONDITIONS:

Trained subjects. Dark adaptation, then light adapted to appropriate field illumination. Presentation rate varied from 1-3 flashes per minute, depending on flash luminance level.

RESULTS AND/OR CONCLUSIONS:

There is a negative relationship between reaction time and level of flash luminance for both peripheral and foveal stimulation.

There is a positive relationship between reaction time and level of field luminance, with sharpest increases in reaction time at higher levels for both foveal and peripheral stimulation. In addition, there is an interaction of field luminance and flash luminance such that increases in reaction time are a joint function of both level of field luminance and level of flash luminance.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Richards, W. J., et al.
TITLE: Reaction times in response to light stimuli.

REFERENCE: Fayetteville, Arkansas: University of Arkansas, 1953. (Technical Report No. 22, Contract DA-23-072-ORD-472, 59901-04.)

SUMMARY:

This study investigated the relationships between observer reaction time and the size and intensity of white and chromatic light stimuli. The data indicate the usefulness of reaction time as an indicant of the visibility of different wavelengths. Reaction times did not differ as a function of the size of the stimulus objects.

REMARKS:

While there is a relationship between intensity of the light source and reaction time, the greatest shortening occurs near the threshold of response--little effect is produced by intensity increases in normal intensity regions. In addition, sheer increases in size, at least within the values of the study, have no effect on reaction times. These data, coupled with the data on minimal increases in light transmission under poor visibility conditions, suggest the relative inefficiency of increases either in runway light intensities or in size of the light units beyond those currently employed.

HUMAN CAPABILITY:

Capability to detect onset of a stimulus light.

INFLUENCING FACTOR(S) STUDIED:

Light intensity.

Wavelength of light source.

Size of stimulus objects.

CONTEXT CONDITIONS:

Subjects were dark adapted and then light adapted to viewing field condition (.01 ml.).

Subjects were 6.5 inches from plane of the light disk. The target subtended a visual angle of 30 minutes.

RESULTS AND/OR CONCLUSIONS:

Reaction time shortens as the intensity of both achromatic and chromatic light increases. The major decline of reaction times occurs in the intensity area slightly above threshold. In general, the relationship of stimulus intensity to reaction times can be described by a hyperbolic function of the form $Y = aX^{-b} + C$.

Reaction time was found not to vary as a function of the size of the stimulus viewed.

Reaction time is not a function of wavelength as such, but depends precisely on effective intensity.

Reaction time varied from around 400 milliseconds at near threshold intensities to about 200 milliseconds at intensities well above threshold.

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HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Strughold, H.
TITLE: The human time factor in flight.

REFERENCE: Aviation Medicine, October, 1949, 300-307.

SUMMARY:

This review paper focuses on a discussion of the time lag in visual perception between the application of the stimulus to a receptor and the perception of the sensation. This span of time is called the perceptual latent period. Following a discussion of factors affecting the length of the perceptual latent period the author focuses on the implications of this time span for high speed flight. At supersonic speeds situations may occur where an object is not perceived until one has made contact with it, or even passed it by. This phenomena indicates the need for further research and for consideration of instrument design to provide information to the human which will help reduce this "blind" time.

REMARKS:

Time delays between onset of a visual signal and an appropriate control response to the signal become more critical as aircraft speeds increase. This time delay is a characteristic of the human which may eventually impose a limit on his usefulness as a monitor and controller of aircraft.

HUMAN CAPABILITY:

The capability focused on in the discussion is the detection of a stimulus object when either or both the stimulus object or the observer are moving at supersonic speeds. Minor focus is also placed on the recognition, comprehension, etc., of stimulus objects under high speed flight conditions.

INFLUENCING FACTOR(S) STUDIED:

A number of factors such as intensity of the stimulus, region of the retina stimulated, stage of dark adaptation of the eye were described as being related to the length of the perceptual latent period.

CONTEXT CONDITIONS: None.

RESULTS AND/OR CONCLUSIONS:

The fact that the latent perceptual period, the time between stimulation and perception, is present for all sense madalities and is a particular problem in visual perception at high speed flight, indicates the need for future research of the phenomena.

A review of existing literature indicates that the latent period has a maximum length of 150-300 milliseconds, and minimal length of 35-70 milliseconds.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Travis, R. C.
TITLE: Measurement of accommodation and convergence time as part of a complex visual adjustment.
REFERENCE: Wright-Patterson Air Force Base, Ohio: Air Materiel Command, 1947. (Report No. 2, Contract No. W33-038 ac-14559.)
SUMMARY:

In this study an attempt was made to determine the time required for accommodation and convergence functions to permit successful shifts in focus between near and far objects. The experiment was designed to duplicate the pilot's task of alternately focusing from the instrument panel to the landing strip and back again. Results showed that approximately 1.06 seconds were required for the shift. Practice in the task reduced the time required to successfully shift focus to approximately .6 seconds.

REMARKS:

These results are in general agreement with others which indicate that about two seconds are required to complete a cycle from near to far and back to near point of focus. These results do not include any requirement for changes in dark adaptation level of the eye which would exist in night landings. Therefore, the two-second estimate must be considered as a lower limit.

HUMAN CAPABILITY:

The ability to successively focus from near to far stimuli, including time for accommodation and convergence, eye movement time, perceptual speed, and reaction time in making an appropriate response was examined.

INFLUENCING FACTOR(S) STUDIED:

Major variable studied in relation to focus shift time requirements was the distance of the objects to be focused. Distances of 22 inches and 43 feet were used.

CONTEXT CONDITIONS:

Subjects were light adapted and this test was conducted under constant conditions of illumination. Test objects were of a size approximately equivalent to a 2 1/2-inch letter viewed at 20 feet.

RESULTS AND/OR CONCLUSIONS:

1.06 seconds are required by naive subjects to shift visual focus from near to far objects. This time reduced to .6 seconds after several daily practice sessions.

1.04 seconds are required for shifts in point of focus at equal observation distances.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Fry, G. A., & Alper, M.
TITLE: Effect of flashes of light on night visual acuity.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1951. (Technical Report No. 52-10, Part 1.)

SUMMARY:

This series of studies is concerned with the capability of the dark adapted eye following exposure to a flash of light or series of flashes. It was found that within the retinal area on which the image falls, the eye adapts to levels of luminance proportional to the product of the duration and intensity of the stimulation. Adaptation occurs within a 3-second interval for both continuous and intermittent stimulation. The effect of exposure to brightness in one part of the field of view on visual acuity in another part of the field of view is dependent upon the adaptation to stray light falling on the eye.

REMARKS:

These results imply that the intermittent stimulation produced by condenser discharge lights in the approach lighting configuration may affect dark adaptation to the same extent as steady stimulation of equal intensity and duration.

HUMAN CAPABILITY:

Dark adaptation characteristics of the eye was the principal capability of concern.

INFLUENCING FACTOR(S) STUDIED:

Effects of flashes of light of specified intensity and duration were examined.

CONTEXT CONDITIONS:

The subjects were tested under laboratory conditions. Viewing occurred monocularly from a fixed head position.

RESULTS AND/OR CONCLUSIONS:

The adaptation of any given part of the retina can be regarded as independent of other parts of the retina.

Total exposure, regardless of time and intensity, appears to be the important factor in adaptation up to a 3-second interval.

Stimuli applied to the central parts of the retina or points varying up to 35 degrees are equally effective in producing pupilary restriction.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Gallup, H. F., et al.
TITLE: The attention getting value of a steady light as a function of brightness, with respect to rapidity and reliability.
REFERENCE: Philadelphia: Naval Air Material Center, October, 1956. (Report No. NAMC-ACEL-301.)

SUMMARY:

The study compared the attention-getting values of steady, flashing, and alternating light signals. The results indicated no significant differences among the three types of lights when presented against a homogeneous background. When presented against a heterogeneous brightness background, both flashing and alternating lights were superior to the steady burning light, especially when onset of the signal occurred outside the principal visual field of the observer. The apparent movement of the alternating light provided greater attention-getting value than the on-off flashing light.

REMARKS:

These results appear to support the use of directionally flashing condenser discharge lights with the standard approach lighting configuration.

HUMAN CAPABILITY:

Reaction time latency from the onset of a light signal while observer is engaged in a tracking task.

INFLUENCING FACTOR(S) STUDIED:

Type of visual signal (flashing, alternating, or steady), brightness characteristics of the visual surround, and position of the signal in observers' visual field.

CONTEXT CONDITIONS:

Observer performed irrelevant tracking task in mockup of cockpit of F7U Cutlass. Stimulus light appeared on instrument panel.

RESULTS AND/OR CONCLUSIONS:

To be a reliable attention getter in a field illumination of 36.8 foot candles, the brightness of a steady light must be increased from 5 foot lamberts (the level at which flashing and alternating lights yielded 100% response) to at least 90 foot lamberts.

Under illumination levels of 5 foot lamberts, the brightness of a steady light must be increased up to at least 15-19 foot lamberts in order to be as reliable an attention getter as flashing lights which yield 100% detectability at 5 foot lamberts.

Under day conditions, reaction time latencies were least for alternating lights, greater for flashing lights, and greatest for steady lights. Moreover, the steady light resulted in 8% no responses at night, 53% no responses during day conditions.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Gerathewohl, S. J.
TITLE: Conspicuity of flashing and steady light signals, I. Variation of contrast.
REFERENCE: Randolph Field, Texas: USAF School of Aviation Medicine, April, 1951. (Special Report.)

SUMMARY:

Reaction time to intermittent and steady light signals were examined under four ratios of brightness contrast as follows: 100, 74, 52, and 33%. At the low levels of background contrast, the flashing light signals were significantly more conspicuous than the steady light signals in attracting the attention of observers engaged in the performance of a complex motor task.

REMARKS:

The results of this study lend experimental support to the use of condenser discharge lamps in the approach configuration of airport marking and lighting systems. Under operational conditions of low signal-to-background illumination contrast, the condenser discharge lights should be more quickly detected and responded to than the steady burning elements of the approach configuration.

HUMAN CAPABILITY:

Response time to steady vs. intermittent visual signals was recorded when the subject was engaged in the performance of a motor task and the visual signals were used as attention-getters.

INFLUENCING FACTOR(S) STUDIED:

The detectability of steady vs. intermittent signal lights is affected by numerous factors which include: luminance of the signals, contrast ratio, flash rate of the intermittent light stimulus, duration of the flash, color of the lights, size of the stimuli, location of the stimuli within the visual field, surface texture and characteristics of the background, kind of task which the observer is required to perform, etc. This study investigated only the effects on the conspicuity of intermittent light signals of brightness contrast (luminance relation of the signal and background) at four contrast ratios, 100, 74, 52, and 33%.

CONTEXT CONDITIONS:

The subjects' attention was diverted from the critical stimuli by an apparatus task, the Multiple Complex Reaction Test. The distance between the test signals were distributed vertically, 15 degrees 32 minutes, and horizontally, 10 degrees 30 minutes. Various types of signals were presented to the subject during the performance of the motor task and reaction latency to the visual signals was recorded.

RESULTS AND/OR CONCLUSIONS:

Response time is a function of brightness contrast. Response latency increases as the contrast ratio decreases.

Decrease in contrast ratio has a differential effect on steady and intermittent light signals. Under high contrast conditions, there is no observable difference in response time to the two types of visual signals. Under medium and low conditions of contrast luminance, latency to intermittent light signals is significantly shorter than response to steady signals.

Significant practice effects are produced. During the course of the experimental trials, reaction time to visual signals were substantially reduced.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Gerathewohl, S. J.
TITLE: Conspicuity of flashing and steady light signals, II. High contrasts.
REFERENCE: Randolph Field, Texas: USAF School of Aviation Medicine, 1952, (Report No. 2, Project No. 21-24-014.)

SUMMARY:

The report discusses an investigation of the conspicuity of steady light signals and intermittent light signals at contrast ratios higher than 1.00. Reaction time latencies were recorded under five levels of contrast conditions when observers were engaged in a complex motor task. Results indicated that steady light signals are more conspicuous than flashing light signals, especially when the subject is not familiar with the task. However, the data indicate that when the brightness threshold is surpassed significantly, no differences appear in the conspicuity of steady and intermittent signals. On the basis of both the numerical results and the observation of subjects, it was concluded that the conspicuity of signals is dependent on physical, physiological, and psychological factors which determine the conspicuity thresholds for the two types of lights.

REMARKS: None.

HUMAN CAPABILITY:

The capability to detect the presence of a light signal while performing a complex motor task. The capability to identify the type of light signal by making appropriate motor response while performing distracting tasks.

INFLUENCING FACTOR(S) STUDIED:

Steady burning vs. intermittent light signals and degree of brightness contrast between signal and background were studied in relation to response latency to the signal. Contrast ratios of 1031.6, 138.9, 19.0, 18.3, and 6.6 were used.

CONTEXT CONDITIONS:

Signals appeared at a distance of 90 inches from the subject at a visual angle of 15 degrees 30 minutes above the central line of sight. Stimulus brightness ranged from 16.7 to 2891.7 millilamberts and background brightness ranged from 2.2 to 2.8 millilamberts.

RESULTS AND/OR CONCLUSIONS:

At brightness contrast levels above 1,00,steady light signals are more conspicuous than flashing lights. However, at contrast levels above 19.0, little difference in reaction time to the two types of signals occurs.

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HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Gerathewohl, S. J.
TITLE: Conspicuity of flashing light signals: Effects of variation among frequency, duration, and contrast of the signals.
REFERENCE: Randolph Field, Texas: USAF School of Aviation Medicine, 1954. (Report No. 1, Project No. 21-1205-0012.)

SUMMARY:

Experiments were conducted to examine the conspicuity of flashing light signals (the ability of the light to attract attention) as a function of flash duration, flash frequency, and brightness contrast. A significant interaction was found between flash frequency and brightness contrast. At low contrast levels, conspicuity of the signal increased as frequency of the flash increased. The conspicuity of slow flash frequency signals increased as contrast increased. For practical application, the most conspicuous light signal is one flashing three times per second and at least twice as bright as its background.

REMARKS:

The results of this study appear to have relevance to the problem of flash frequency of condenser discharge lights in the approach lighting configuration. It would seem that the flash rate of the condenser discharge lights should be set differentially as a function of the background illumination condition. When the illumination contrast is relatively low the condenser discharge lights would be set to flash at a faster rate than under conditions of high contrast.

HUMAN CAPABILITY:

The response latency to light stimuli of varying characteristics was studied while the observer performed a complex motor task.

INFLUENCING FACTOR(S) STUDIED:

Response latency was studied as a function of various combinations of brightness contrast, flash frequency, and flash duration. Brightness contrast was varied at three levels: .16, .95, and 11.16. Three levels of frequency: one flash per 3 seconds, one flash per second, and three flashes per second; and two conditions of flash duration: .1 and .2 seconds were studied.

CONTEXT CONDITIONS:

This study was conducted under laboratory conditions with an observer seated about 6 feet from a white projection screen on which light signals appeared in a random sequence. The observer responded to these signals by operating a control.

RESULTS AND/OR CONCLUSIONS:

Response time generally decreases with increasing contrast.
Response time decreases with increasing flash frequency.
Response time decreases with increasing flash duration.
A significant interaction exists between contrast and flash frequency.
Substantial individual differences in response latency exist.
Significant practice effects occur.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Gerathewohl, S. J.
TITLE: Conspicuity of flashing light signals of different frequency and duration.
REFERENCE: J. exp. Psychol., 1954, 48 (4), 247-251.

SUMMARY:

This study examined the ability of observers to detect the presence of flashing light signals under varying conditions of flash frequency, flash duration, and brightness contrast between the visual stimulus signal and the background. Results indicated that short duration, rapidly-flashing signals were more effective attention-getters under conditions of low contrast. At the higher brightness contrast levels, however, all flash frequencies were seen with equal facility.

REMARKS:

The results of this work appear to have application to the problem of specifying temporal variables associated with the condenser discharge lights in the standard approach lighting configuration of airport marking and lighting systems. As an attention-getting device useful to pilots searching out the direction of the runway, it appears likely that a short- and fast-flashing series of signals will be more effective than a long- and slow-flashing series under conditions of low signal-to-background luminance contrast.

HUMAN CAPABILITY:

Capability to detect a flashing signal of various characteristics while performing a complex motor task was the focus of the present study.

INFUENCING FACTOR(S) STUDIED:

Detection capability was examined as a function of brightness contrast, duration of the individual signal flash, and frequency of occurrence of signal flashes. Brightness contrast ratios used were: high (74.2%), medium (1%), and low (.19%). Flash rates of 1, 2, and 4 flashes per second, and flash durations of 1/2, 1/4, and 1/8 seconds were studied as related variables.

CONTEXT CONDITIONS:

Laboratory apparatus was employed consisting of a complex psychomotor task to distract the subject from the test signals. The subject was seated before a visual display consisting of two vertically arranged screens. The test signals appeared as spots of light in the center of the upper screen. Signals used in the the complex psychomotor task appeared as colored or patterned dots on the lower screen. The subjects responded to these signals by moving handles attached to a control box.

RESULTS AND/OR CONCLUSIONS:

Significant individual differences in reaction time latencies were noted.

Significant practice effects occurred throughout the trials. Reaction time latencies to the visual signals of whatever characteristics consistently decreased.

Consistent decrease of reaction time latency occurred with increasing flash frequency. at the lowest brightness contrast condition.

At the medium and high contrast conditions, response latency appeared relatively unaffected by frequency variations.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Crannel, C. W., & Christensen, J. M.
TITLE: Expansion of the visual form field by perimeter training.

REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1955. (Technical Report 55-368.)

SUMMARY:

This study evaluated the extent to which identification of peripheral objects could be increased by systematic training. In general, the results show that perimeter training of various degrees did not result in positive transfer to identification of objects other than those on which the training occurred. These results held, regardless of the amount of training received.

REMARKS:

While it is probably not feasible to train pilots to be good general "out-of-the-corner-eyeballers", other evidence exists which indicates that they can be successfully trained to look for specific types of content while scanning.

HUMAN CAPABILITY:

The capability to identify various form objects presented in the periphery of the visual field.

INFLUENCING FACTOR(S) STUDIED:

Amount of perimeter training.

Type of stimuli to be identified.

CONTEXT CONDITIONS:

Light adaptation conditions were used. Illumination was 64 foot-candles. Exposures started at 24 degrees. Ferree-Rand perimeter was used as training device.

RESULTS AND/OR CONCLUSIONS:

There was no relation between amount of training and ability to identify unfamiliar objects.

There was increased accuracy of identifying the training stimuli as a function of amount of practice.

The latter results were interpreted as evidence for subjects learning to respond to reduced cues in the case of familiar stimulus objects.

It was concluded that little value can accrue from a training program devoted to the teaching of "form field expansion".

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Riopelle, A. J., & Bevan, W., Jr.
TITLE: The distribution of scotopic sensitivity in human vision.

REFERENCE: Amer. J. Psychol., 1953, 66 (1), 73-80.

SUMMARY:

This summary was designed to compare absolute scotopic thresholds in different parts of the retina, expressed in term of distance and direction from the fovea. In general, sensitivity contours are elliptical about the fovea with the major axis being in the horizontal dimension. The results also show maximal sensitivity on either side of the fovea on the horizontal meridian at approximately 20-30 degrees eccentricity. Further, sensitivity thresholds are generally lower for the upper as compared to the lower retina.

REMARKS:

Basic studies of the sensitivity contours of the retina may eventually provide a useful basis for design of lighting configurations. The results of the present study suggest that horizontally placed light arrays would be more easily perceived than vertically placed arrays.

HUMAN CAPABILITY:

The capability to detect light flashes.

INFLUENCING FACTOR(S) STUDIED:

Distance and direction of the light source from the fovea.

CONTEXT CONDITIONS:

Distance from observer to stimulus patch was 17 inches. Observers were dark adapted.

RESULTS AND/OR CONCLUSIONS:

Maximal retinal sensitivity is found on either side of the fovea on the horizontal meridian. Thresholds for the upper retina are lower than thresholds for the lower retina. Additional research is needed to ascertain the relationship between sensitivity data and anatomical structure, as well as to explore the problem of individual differences.

SELECTED ADDITIONAL REFERENCES

RS3. Brown, J. L. Review of the cone-to-rod efficiency ratio as a specification for lighting systems. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1957. (Technical Report No. 57-448.)

RS4. deGroot, Sybil G., et al. Factors in night vision sensitivity: III. The interrelation of size, brightness, and location. United States Submarine Base, Connecticut: Medical Research Laboratory, Bureau of Medicine and Surgery, Navy Department. (Report No. 234, Project NM 003 041. 09.05.)

RS5. Hillmann, B., et al. Brightness thresholds as a function of target contrast and retinal position. New London, Connecticut: Naval Medical Research Laboratory, 1955. (Report No. 266, Project No. NM 022 014. 09.04.)

RS6. Leibowitz, H. W., et al. Frequency of seeing and radial localization of single and multiple visual stimuli. J. exp. Psychol., 1955, 50 (6), 369-373.

RS7. Leibowitz, H. W., et al. Radial localization of a single stimulus as a function of luminance and duration of exposure. J. opt. Soc. Amer., 1955, 45 (2), 76-78.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Graybiel, et al.
TITLE: The law of the otolith organs.

REFERENCE: Paper presented at the 30th Annual Meeting of the Federation of American Societies for Experimental Biology. (Federation Proceedings issued in February, 1946, Baltimore.)

SUMMARY:

The paper reports the results of experiments on a human centrifuge directed toward distinguishing between the effects of angular acceleration on the semi-circular canals and of "g" on the otolith organs. The following law was determined: If, in the absence of visual orientation, a person is subjected to accelerated force, his perception of the vertical will eventually coincide with the resultant of the force introduced and the force of gravity.

REMARKS:

The law reported is essentially complementary to Gibson's viewpoint on the interactions of visual and proprioceptive forces in determining perception of the vertical. The third corollary suggests that if a slight "g", produced by a sudden displacement of the aircraft, coincides with an illusory perception of the ground plane, the pilot would be totally unaware of the true vertical.

HUMAN CAPABILITY:

Perception of postural vertical (perpendicular to earth's surface).

INFLUENCING FACTOR(S) STUDIED:

Amount of induced "g" forces, amount of bodily tilt, and various visual orientation stimuli.

CONTEXT CONDITIONS:

Utilization of human centrifuge (no other stimuli available).

RESULTS AND/OR CONCLUSIONS:

Additional corollaries to the law stated in the SUMMARY on the previous page:

An object in view which does not provide a clue to orientation to the earth will eventually be projected in space by the observer in accordance with the apparent vertical.

If objects in the visual field do provide clues for orientation, a conflict between visual and otolithic stimuli results and the resolution favors visual orientation to the earth.

If the body maintains a constant relationship to the direction of the resultant "g", one is not aware of any change from the true vertical position.

If the body maintains a constant relationship with the true vertical, one will be conscious of a tilt or rotation independent of a particular position of the body.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Mann, C. W.
TITLE: Visual factors in the perception of verticality.

REFERENCE: J. exp. Psychol., 1952, 44 (6), 460-464.

SUMMARY:

The study reported was concerned with the relative contribution of visual stimulation to perception of a vertical position of the body under varying conditions of proprioceptive stimulation. It is concluded that when visual stimulation is increased to the point at which a person can identify himself with the visual framework, his judgment of vertical will lie somewhere between the inclination of the visual field and the gravitational vertical if they are in conflict.

REMARKS:

These results support the argument for an immediately perceptible and strong inclination of the ground plane. Further, the importance of flying a smooth instrument flight path is reinforced.

HUMAN CAPABILITY:

Judgment of the gravitational vertical when visual and gravitational cues are in conflict.

INFLUENCING FACTOR(S) STUDIED:

Various tilt relationships between a visual background and the chair in which the observer sits.

CONTEXT CONDITIONS:

Light adaptation conditions were used. Subjects manipulated a visual target rod; thus eliminating verbal contamination of their responses.

RESULTS AND/OR CONCLUSIONS:

When visual stimulation is increased to the point at which a person can identify himself with a visual framework, there will be a conflict between the resultant visual stimulation and proprioceptive stimulation produced by gravitational force acting on the statocysts.

When this conflict occurs, a compromise judgment of verticality will be made, the judgment lying somewhere between the inclination of the visual field and the gravitational field force.

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PV3. Boring, R. O. The effect of visual stimulus variables upon the perception of the visual vertical. Pensacola, Florida: U. S. Naval School of Aviation Medicine, Aviation Psychology Laboratory, 1952. (Report No. 28, Project No. NM 001 063.01.28.)

PV4. Hermans, T. G., & Loucks, R. B. Annotated bibliography on the psychological aspects of orientation as they relate to aviation. Wright-Patterson Air Force Base, Ohio: Air Material Command, Aero Medical Laboratory, 1947. (Report No. 1, Contract No. W33-038-ac-15230.)

PV5. Mann, C. W. Studies in space perception. Pensacola, Florida: U. S. Naval School of Aviation Medicine, and the Tulane University of Louisiana, 1950. (Joint Project Report No. 18, Contract N7 onr-434 T. O. I.)

PV6. Mann, C. W., & Dauterive, H. J. The perception of the postural vertical. Report No. 1: The modification of non-labyrinthine cues. Pensacola, Florida: U. S. Naval School of Aviation Medicine and Research, and The Tulane University of Louisiana, 1949. (Joint Project Report No. 4, Contract N7 onr-434 T. O. I.)

PV7. Mann, C. W., & Graybiel, A. The perception of the postural vertical. Report No. 2: Visual factors. Pensacola, Florida: U. S. Naval School of Aviation Medicine and Research, and The Tulane University of Louisiana, 1949. (Joint Project Report No. 5, Contract N7 onr-434 T. O. I.)

PV8. Mann, C. W., & Passey, G. E. The perception of the vertical V. Adaptation effects. Pensacola, Florida: U. S. Naval School of Aviation Medicine and Research, and The Tulane University of Louisiana, 1949. (Joint Project Report No. 9, Contract N7 onr-434 T. O. I.)

PV9. Mann, C. W., & Passey, G. E. The perception of the vertical: VIII. Adjustment to the vertical as a function of the magnitude of tilt and the duration of exposure. Pensacola, Florida: U. S. Naval School of Aviation Medicine, and The Tulane University of Louisiana, 1950. (Joint Project Report No. 14, Contract N7 onr-434 T. O. I.)

PV10. Mann, C. W., & Ray, J. T. The perception of the vertical: XIII. An investigation of quadrant differences. Pensacola, Florida: U. S. Naval School of Aviation Medicine, and The Tulane University of Louisiana, 1956. (Joint Project Report No. 39, Contract NONR-475-05.)

PV11. Mann, C. W., & Ray, J. T. The perception of the vertical. XIV: The effect of rate of movement on the judgment of the vertical. Pensacola, Florida: U. S. Naval School of Aviation Medicine, and The Tulane University of Louisiana, 1956. (Joint Project Report No. 40, Contract NONR-475-05.)

PV12. Mann, C. W., et al. The perception of the vertical: I. Visual and non-labyrinthine cues. J. exp. Psychol., 1949, 39 (4), 538-547.

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CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Halsey, Rita M.
TITLE: The identification of signal lights: I., blue, green, white, and purple.
REFERENCE: New London, Connecticut: U. S. Naval Medical Research Laboratory, U. S. Naval Submarine Base. (Date not specified.)

SUMMARY:

This study investigated the ability of observers to accurately identify four test colors under varying levels of illumination. The data indicate large individual differences in color naming and poorer discrimination at lower illumination levels. With increased distance from the stimulus field, there is a tendency for the naming contours to shift toward green. There was a general tendency for observers to confuse blue and purple.

REMARKS:

This study suggests that because of individual differences and varying levels of illumination associated with operational conditions, the number of reliably discriminable colors is limited. If colors are to be used to distinguish stimulus objects, hues should be selected as far apart on the continuum as possible.

HUMAN CAPABILITY:

The ability of the observer to correctly identify colored signal lights.

INFLUENCING FACTOR(S) STUDIED:

Intensity of the light source, distance of subject from stimulus field, and individual differences among subjects are factors related to color discrimination.

CONTEXT CONDITIONS:

Observers of normal visual and color acuity were adapted to the illumination level of the test room and exposed to light stimuli of 2 seconds duration on a circular display 1/4 inch in diameter.

RESULTS AND/OR CONCLUSIONS:

The results showed highly consistent "green" responses, widely varying "blue" responses, some confusion between "yellow" and "white" and a large "purple" area. In addition, there was a repeated tendency to identify many supposedly blue colors as "purple".

Lowering the over-all illuminance level resulted in a notable decrease in color identification, particularly for the borderline or desaturated blues, greens, and purples.

While the magnitude is not great, color contours tend to shift toward green with increased distance.The results of this study indicate that the data obtained can be applied to the specification of boundaries for colored signals. With increased distance, there is a tendency for color contours to shift toward "green".

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Halsey, Rita M.
TITLE: The identification of signal lights: II. Elimination of the purple category.
REFERENCE: New London, Connecticut: U. S. Naval Medical Research Laboratory, U. S. Naval Submarine Base. (Date not specified.)

SUMMARY:

In this experiment, observers identified test colors in the violet-green-white region of the chromaticity diagram. The results showed that when the response "purple" is not permitted, there is improved identification of blue signals.

REMARKS:

Color naming contours (all frequencies judged to be the same) could be used as a basis for selecting highly discriminable colors for operational use in coding different airport facilities.

HUMAN CAPABILITY:

The capability to identify colored light sources under varying levels of illuminations.

INFLUENCING FACTOR(S) STUDIED:

Wave length of light source, distance from the stimulus, and intensity levels of the light sources were examined in relation to color idenfitication.

CONTEXT CONDITIONS:

Test colors appeared as spots of light subtending a visual angle of about 5 minutes. Light appeared for an exposure duration of 2 seconds.

RESULTS AND/OR CONCLUSIONS:

The data show improved identification of blue signals when observers are not permitted use of the response category "purple". There is a general confirmation of the previous finding that low illumination is associated with reduced accuracy of identification.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Halsey, Rita M., & Chapanis, A.
TITLE: On the number of absolutely identifiable spectral hues.

REFERENCE: J. opt. Soc. Amer., 1951, 41 (12), 1057-1058.

SUMMARY:

This study attempted to determine the absolutely identifiable number of spectral hues within the wavelength range of 430-642 millimicrons. The results indicated that 17 spectral hues are absolutely identifiable at an accuracy of 72% while 15 hues are identifiable at an accuracy of 95%. The authors interpret their results to indicate that the number of spectral hues we can be expected to identify to a high degree of accuracy in other than in a laboratory situation is quite small.

REMARKS:

The use of chromatic stimuli in situations where high accuracy of identification is critical necessitates employment of hues that are fairly far apart with respect to wavelength. It is only in the laboratory, where many ambient factors are controlled, that reliable identification can be expected on large numbers of hues. Furthermore, laboratory criteria of correct identification are often less restrictive than required in the operational situation where safety considerations weigh heavily.

HUMAN CAPABILITY:

The capability to identify (an absolute judgment) various spectral hues in the wavelength range 430-642 millimicrons was studied.

INFLUENCING FACTOR(S) STUDIED: None.

CONTEXT CONDITIONS:

Angular size of the test spots were 45 feet at viewing distance. Viewing field luminance was 2.4 candles per square meter. Wavelengths from 494 millimicrons to upper lengths were equated to a value of 2.8 candles per square meter. Those wavelengths below 494 millimicrons were of variable luminance. Subjects were light adapted and viewed hues against a gray background.

RESULTS AND/OR CONCLUSIONS:

The results of this study indicate that when observers are asked to identify the color of spectral hues in the wavelength interval 494-642 millimicrons, that they are able to identify a fairly limited number of hues accurately. The higher the criteria of accuracy, the lower the number of wavelengths that can be specified.

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CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Eriksen, C. W.
TITLE: Partitioning and saturation of the perceptual field and efficiency of visual search.
REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1954. (Technical Report No. 5 -161.)

SUMMARY:

This experiment was designed to investigate the effects of saturation, partitioning, and search area on visual search time. The results show that increased saturation of the display, i.e., the number of non-target stimuli in the display, leads to increased search time or identification of the relevant targets. Similarly, increased partitioning of the display matrix by means of grid lines degrades search time. No readily interpretable relationship between search time and search area was evident.

REMARKS:

The results suggest that redundant information may be a double-edged sword. Although it may improve some guidance factors (e.g., multiplicity of lights to define surface plane), it may interfere with other guidance factors (e.g., rapid identification of decision bar or threshold).

HUMAN CAPABILITY:

Identification of test targets among irrelevant objects.

INFLUENCING FACTOR(S) STUDIED:

Relative balance of target and irrelevant objects with respect to one another.

Relative number of partitions in visual field.

Total area of the display.

CONTEXT CONDITIONS:

Light adaptation.
Binocular vision.

RESULTS AND/OR CONCLUSIONS:

Search time increases both when the number of irrelevant signals is increased and when the number of partitions of the visual field is increased.

Visual search is most efficient when the search area is 18 or 32 inches square; least efficient when 24 inches square.

The results are explained in terms of the number of foveal fixations required for signal identification coupled with the use S's make of grid lines in their plan of search.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Fry, G. A., & Alpern, M.
TITLE: The effect of a peripheral glare source upon the apparent brightness of an object.
REFERENCE: J. opt. Soc. Amer., 1953, 43 (3), 189-195.

SUMMARY:

This study was designed to account for the decrease in apparent brightness of a foveally fixated object which is associated with a peripheral glare source. The results indicated that decreases in perceived brightness can be accounted for in terms of a veiling illuminance that is produced by stray light from the peripheral glare source which falls on the fovea.

REMARKS:

This result emphasizes the critical difference between increasing the physical intensity of airport lights and increasing their perceptual effectiveness. These are likely to be several areas within specific airport lighting systems where the perceived brightness of signal lights or illuminated surfaces could be increased by reducing stray light from peripheral glare sources more effectively than by increasing intensity.

MS2

HUMAN CAPABILITY:

The capability to match the apparent brightness of a standard object seen by one eye with that of a variable stimulus seen by the other eye. The test stimulus glare is varied by means of a patch of veiling illuminance.

The capability to match the brightness of two stimuli, where the glare source is varied by the distance of extraneous lights from the test stimulus. Adjustments are made by moving the distance of the glare sources from the test stimuli. One eye sees the test stimulus and one sees the standard stimulus.

Same matching task capability requirements as the first above, but with varied times of onset between standard and comparison stimuli.

INFLUENCING FACTOR(S) STUDIED:

Luminance of the patch of veiling illuminance.

Angle of separation of glare source from test stimulus.

Onset interval between test stimulus and comparison standard.

CONTEXT CONDITIONS:

Circular patch of veiling illuminance of 9.5 degrees was superimposed on the test object. Stimulus objects were retangular openings.

Two rectangular patterns were used as glare sources--these were placed on either side of test objects, which were also rectangular. Six values of distance between glare and test stimuli were used (3/4, 1, 1.5, 2.5, 3.5, and 4.5 degrees).

RESULTS AND/OR CONCLUSIONS:

The decrease in perceived brightness of a foveal test stimulus by a glare source is accounted for in terms of the veiling illuminance which is generated by stray light falling on the retina rather than by direct physiological retinal effect. This interpretation stems from the finding that the decreases in apparent brightness are produced by both peripheral glare sources and a patch of veiling illuminance. In addition, changes in perceived brightness that occur immediately following the onset and removal of a glare source can also be accounted for by the veiling illuminance generated by stray light.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Graham, C. H.
TITLE: Some factors that limit vision.

REFERENCE: Washington: Office of Naval Research, September, 1951. (Project No. NR 142-404.)

SUMMARY:

This paper presents a general discussion of a number of visual functions and factors that influence them.

REMARKS:

The relationships between characteristics of light and the basic human visual factors should be of general interest and value to the designer of airport lighting systems. The differential capability of the eye to discriminate greens and blues of equal intensity more effectively than red under low illumination conditions should be of specific interest.

HUMAN CAPABILITY:

Threshold sensitivity, differential sensitivity, grating acuity, vernier acuity, depth discrimination, and monocular movement parallax were the visual functions discussed.

INFLUENCING FACTOR(S) STUDIED:

Level of dark adaptation, stimulus intensity, stimulus area, and wavelength.

CONTEXT CONDITIONS: None.

RESULTS AND/OR CONCLUSIONS:

Threshold sensitivity

Greatest sensitivity exists for light of least energy in the visual periphery for the dark adapted eye. Sensitivity is increased as the stimulus covers a larger area, is of increased duration, and has a wavelength composition restricted to blue-green.

Differential sensitivity

Intensity discrimination is best with cone vision at high intensities. When two colors are equated for intensity, they provide a basis for equally good foveal discrimination. On the other hand, rod intensity discrimination at lower intensity levels is more effective for blue and green than for red. While duration and area of the background are fairly complex in their effects, there is a tendency for discrimination to be more effective with increases in duration and area.

Grating acuity

The same factors that influence intensity discrimination affect acuity. Acuity increases with intensity, duration and area increases. Acuity is equal for colors (matched in brightness) at the fovea, but in the periphery, the rod branch of the acuity is maximal for blue and green.

Vernier acuity

Coincidence acuity is affected to the same general extent by those factors which influence intensity discrimination.

Depth discrimination

Although precise data is not available, depth discrimination is influenced by intensity, area, and duration in somewhat the same way as the other acuity functions

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HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Morin, R. E., et al.
TITLE: Temporal predictions of motion inferred from intermittently viewed light stimuli.
REFERENCE: Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, 1954. (Technical Report No. 54-69, Contract No. AF 18(600)-54.)

SUMMARY:

This study was concerned with an examination of factors which affect judgments of when a moving object will reach a stationary object. Observers viewed the successive illumination of a number of lights under different stimulus conditions and were required to estimate the time remaining from the last illumination to impact with the stationary object. A major variable affecting this estimation was found to be the computed velocity of the imaginary moving object. The slower the actual velocity of the moving light source, the greater the degree of underestimation of arrival time. Another major factor affecting accuracy of estimation was the distance of the stationary light from the last cue light. The shorter the distance between the two, the greater the accuracy of estimation. In general, all serious errors of estimation of correct time were errors of underestimation.

REMARKS:

Experimental investigations of this sort have relevance to the operational marking and lighting problem involved in the design of angle of approach indicators which utilize the closing of two stimuli light bars to an aligned position or the centering of a variable position light between two aligned bars to indicate an optimal glide path.

This study provides some basis for estimating the extent to which rate judgments of changes in glide path displacements are possible from the rate of closure of the misaligned segments of the display. It would appear from the results of this work that a pilot's estimate of his rate of closure to or from a desired glide path will be most accurate when the misalignment is slight, and that, in general, his tendency will be to underestimate his rate of closure to, or rate of departure from, an ideal glide path.

HUMAN CAPABILITY: None.

INFLUENCING FACTOR(S) STUDIED:

The velocity of the moving object, interval between onsets of successive stimulus light, number of cue lights providing the projected path of the object, and distance of the target from the last cue light were found to be factors affecting accuracy of velocity estimation.

CONTEXT CONDITIONS:

The stimulus panel was 18 feet from the observers. Stimulus lights were 1/2-inch jeweled lamps. Cue lights were red, except for the final light indicating impact with target. Cue light remained on 1 second per light.

RESULTS AND/OR CONCLUSIONS:

For variations in velocity of the stimulus objects: errors of estimation were less than 10% for fast velocities (.10 feet per second), but were 25-53% at slower velocities (.05 feet per second) - in both cases, underestimates. For variations in distance between target and last cue light: the shorter the distance between the two, the greater the accuracy of estimation. Other results indicate that temporal estimations were more accurate for conditions involving increased numbers of stimulus lights.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Saltzman, Dorothy C., & Garner, W. R.
TITLE: Accuracy of visual estimation of azimuth position.

REFERENCE: J. Psychol., 1950, 29 (2nd half), 453-467.

SUMMARY:

A series of experiments were conducted to determine the accuracy with which human observers can estimate angular position of objects in the visual field. In all cases, a standard fixed reference light was used. Subjects were asked to: estimate the angular separation of the stimuli; adjust a light with respect to another to produce a specified angular deviation; and, in the latter instance, additional reference flights were introduced. Errors of estimation were analyzed in terms of direction and variability for the various conditions of measurement.

REMARKS:

The size of azimuth errors when the subject matched an adjustable figure to a specified angle was in the neighborhood of 1 degree. When subjects just estimated the angle, the average error averaged about 6 degrees.

HUMAN CAPABILITY:

The accuracy of estimating the angular position of one object from another object in the horizontal plane.

INFLUENCING FACTOR(S) STUDIED:

Method of measuring accuracy.

The effect of reference lights on accuracy.

CONTEXT CONDITIONS:

Slight dark adaptation.

Fixed head position.

Distance of the stimulus from the subject was 4 feet.

Size of the stimulus was 5/16 inch in diameter.

Reference marks were used at 10 degrees, 30 degrees, 45 degrees, and 90 degrees in the various experimental conditions.

RESULTS AND/OR CONCLUSIONS:

The method of measuring accuracy by adjustment was judged to more accurately reflect the nature of the perception than the method of estimation.

The presence of an additional reference light had little effect on constant errors, but reduced variable errors in the region of the reference angle and at one-half or twice the size of the reference angle. This latter effect was related to the accuracy with which a bisection judgment can be made compared to interpolations or extrapolations.

CONTRACT FAA/BRD-13
HSR PROJECT MARK
REPORT ANNOTATION

AUTHOR: Spencer, J.
TITLE: Judgment of height by the apparent obliquity of familiar ground outlines.
REFERENCE: Montreal, Canada: Royal Air Force, Institute of Aviation Medicine, March, 1953.

SUMMARY:

The experiments discussed in this paper did not involve actual judgments of heights, but rather the apparent slant of a circular spot whose orientation to, and distance from, the observer was changed. The effects of perceptual constancy (seeing a circle as a circle regardless of the angle of regard) were found to vary as a function of the actual obliqueness of the object, the general illumination of the object and its background.

REMARKS:

To the extend that a pilot uses the shape of the runway for judging the starting point for his approach, then the results here indicate that this choice will vary depending upon his entering altitude and whether or not he is flying at day or night.

HUMAN CAPABILITY:

Judging actual shape of a spot seen from an oblique angle (yielding an apparently distorted, or different shape)

INFLUENCING FACTOR(S) STUDIED:

Different angular subtense of the stimuli at the eyes and varying illumination levels with both monocular and binocular vision.

CONTEXT CONDITIONS:

Dark adaptation conditions were used. Target to background brightness contrast was 48%. Viewing heights of 10 inches, 23 inches, and 40 inches were employed. The diameter of stimuli was 3/8 inch, with angular subtense at the eye of 44 minutes, 30 minutes, and 24 minutes. Brightness ranges included 2.60 EFC (100%), 4.0%, and .0064%.

RESULTS AND/OR CONCLUSIONS:

Changes of illumination intensity affect the accuracy of matching judgments of obliquity.

Until more objective data from flight observation support the assumptions used in these studies, it is not considered worthwhile to further pursue the problem in the laboratory.

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