# Tests of Threshold Lighting Patterns

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### SUMMARY

This report describes the testing of a number of patterns of threshold lighting for the purpose of developing a pattern which will be more effective than the existing Air Force standard A number of arrangements and modifications were tried, most of which showed some improvement over the existing standard One pattern was evolved which incorporates the most effective improvements

### INTRODUCTION

Threshold lights have been used in aviation since the introduction of runway lighting The runway lighting defines the prepared landing area, the runway, and marks its edges and direction The threshold lights mark the ends of the runway and the limits within which the aircraft can safely operate when not airborne More specifically, the threshold lights at the approach end of the runway indicate to a pilot making a landing that he can touch down safely as soon as he has passed them At the exit end of the runway, the threshold lights warn the pilot of the end of the prepared surface

Threshold lighting evolved from the groups of range lights installed in the boundary circuit of all-way landing fields The range lights marked the ends of preferred landing paths, and they were coded by varying the numbers of lights marking the different landing paths Both ends of each path were equipped with the same number of lights, and each landing path had an individual number It was found that the groups of range lights were more effective if they were set in lines normal to the axis of the path When paved runways were introduced, lights were developed to mark the edges of the runways, and the range lights were moved to the ends of the runways where they became threshold lights Range lights were green to distinguish them from clear boundary lights, and threshold lights retain this color even on the exit end of runways As runway lights define the courses of the runways, the necessity for coding the green lights by number has disappeared and coding has been eliminated

A series of tests of various threshold lighting patterns, with several types of lighting equipment, was carried out at the CAA Technical Development Center, under a project sponsored by Wright Air Development Center These tests were made for the purpose of exploring the possibility of developing a threshold pattern which would be more effective than existing patterns

The tests consisted of forming experimental patterns on the north-south runway at Weir Cook Airport, Indianapolis, Indiana, and studying the effect of these patterns by means of ground and flight observations Comparisons were made on the basis of functional requirements

### REQUIREMENTS

The requirements for threshold lighting are simple and important They have been discussed in some detail in previous reports[1,2] but are summarized briefly here for convenient reference

On circling approaches it is necessary that a pilot be able to see 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 It is necessary that he be able to

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*Reprinted for general distribution from a limited distribution report dated August 1955

[1] Arthur T Tiedemann, "A Lighting Pattern for Runway Zone Identification," CAA Technical Development Report No 208, December 1954

[2] H J Cory Pearson, "Requirements of Threshold Lights," CAA Technical Development Report No 272, April 1955 (limited distribution report being printed for general distribution)

distinguish the threshold lighting from adjacent approach, overrun, and runway lighting, and identify it unmistakably as threshold lighting It is important that the threshold area be visible to the pilot for at least several seconds during straight-in approaches under conditions of restricted visibility so that he may not flash past it unknowingly if his attention should be diverted The lighting should not, in any case, 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

The exit threshold has a function essentially different from that of the approach threshold While both mark the ends of the paved runway, the approach threshold invites the pilot to land as soon as he has passed it The exit threshold, on the other hand, warns him to be airborne on a takeoff or to stop or turn off before he reaches it on a landing Because of this difference in function, the exit threshold lighting should be readily distinguishable from that of the approach threshold, and it should not depend wholly on the relationship of the pattern with the runway lighting to distinguish exit warning from approach invitation

Existing threshold marking in the United States employs the same pattern for entrance and exit thresholds This consists of a line of green lights normal to the runway axis and projecting into the extended runway area from the lines of the runway lights The entrance and exit thresholds are not differentiated Several countries in Europe use red lights for exit thresholds

Threshold lighting requirements, then, can be summarized as visibility, conspicuity, and recognizability

## PATTERNS

Six basic patterns of approach lights were tested in various combinations of units, both with and without various flashers

1 This pattern is the existing Air Force standard It consists of two bars of C-1 units with 200-watt series lamps and green filters The bars are normal to the runway axis and extend inward from the lines of runway lights The units are on 10-foot centers The gap between the bars is 136 feet

2 This pattern consisted of the bars in pattern No 1, extended outward beyond the runway lights to form T patterns instead of L patterns

3 This pattern was similar to No 2, with the bars extended further inward toward the runway centerline

4 This pattern also was similar to No 2, but included a line of ANL-9 flush lights connecting the two bars

5 In this pattern the bars had wings parallel to the runway axis and extending into the approach area

6 This was a pattern similar to No 5, but with the wings folded back along the lines of the runway lights instead of extending into the approach area

## LIGHTING UNITS

The lighting units employed in forming the pattern consisted of Air Force Type C-1 runway lighting units with 200-watt, 6 6-ampere series lamps, Air Force Type C-2 units with 500-watt, multiple, 120-volt lamps, and 6 6-ampere, 200-watt, PAR-56 lamps with spread lenses All units were fitted for red or green filters

The various flashing units consisted of·

1 Grimes aircraft warning lights with 100-watt spotlight lamps and motor-driven rotating reflectors These lamps were operated on 28 volts d-c, and were equipped with green dome filters

2 Rotating cluster lights using four 100-watt spotlight lamps under a green dome filter These lights also were operated on 28 volts d-c

3 A pair of synchronized counterrotating fixtures using 100-watt PAR lamps rotated by motors These units were operated on 120 volts a-c

4 A 400-watt PAR approach-light lamp undulated by periodic insertion of a similar lamp in series This lamp was operated on 120 volts a-c

5 A 100-watt, PAR-46 spotlight lamp rotated about a vertical axis and operated on 120 volts a-c

6 A group of four 200-watt, PAR, 6 6-ampere lamps set to cover different horizontal angles and flashed periodically in unison These were operated on a 6 6-ampere series circuit

7 A group of four 200-watt, PAR, 6 6-ampere lamps set to cover different horizontal angles and flashed progressively in sequence

All flashing light units were used with aviation green filters

## TESTING RESULTS

Pattern No 1 was tested with all-green filters and with split filters, with 180° green filters toward the approach and with 180° red filters toward the runway These two modifications were used essentially throughout the flight-testing of the runway zone-marking [3] The red filters used in this combination tended to merge with the red satellites, and they did not give adequate exit marking The consensus was that more adequate threshold marking is required

Pattern No 2 showed material improvement in conspicuity over No. 1 The bars extending beyond the lines of the runway lights formed T patterns and became much more conspicuous When used with red and green split filters, the red exit line was much more evident and did not appear to merge with the red satellites used in zone-marking

Various spacings of units were tried with this pattern Lights were tried on 10-, 5-, 3 1/2-, and 2 1/2-foot centers, and with C-1 and C-2 units alternating or installed with one type in each bar for comparison Bars also were set up with PAR lamps to check the effect of different distributions Various flashing units were substituted for the outermost unit of both bars or of the single bar toward the downwind leg The effects of these variations in spacing and of the flashing lights will be discussed later

Pattern No 3, with the transverse lines extended further inward, did not appear to be noticeably more effective than pattern No 2

Pattern No 4, with a continuous line across the end of the threshold, appeared to be an improvement over pattern No 2 This pattern should be given serious consideration as soon as serviceable flush lighting units become available None of the existing lighting units was structurally adequate to withstand propeller blast and jet blast from aircraft operation at the end of the runway

Pattern No 5 was developed to expand the threshold pattern from a line to an area in order to give the pilot a better visual target The extension consisted of either one pair, two pairs, or three pairs of green lights spaced 50 feet apart into the approach area and in line with the runway lights The testing showed a considerable improvment in the target pattern, particularly with three pairs of lights, but it also set up a possibility of the pilot's landing short of the actual threshold

Pattern No 6 was developed to avoid this feature It consisted of transverse bars extended outside the lines of runway lights, similar to pattern No 2, with the addition of lines of green lights extending back along the edges of the runway and spaced between the runway lights These lines formed a zone of threshold marking which started at the threshold and included the beginning of the runway as far as the first pairs of satellites, 400 feet along the runway This arrangement retains the advantage of depth and constitutes an improvement in the pattern The lines along the runway introduce difficulties where intersecting runways, taxiways, or turnouts interrupt the lines of the edges of the runways These extensions add enough improvement that they should be used wherever possible, even though only one side of the runway is available and even though zone lighting is not used

## DISCUSSION

Closer spacing of lights in the transverse bars tends to hold the bars together as the pilot comes closer to the threshold, and it adds conspicuity to the bars by providing greater

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[3] Tiedemann, op cit

brightness than the wider spacing It was found, however, that the use of five units on ten-foot spacing gives a fully adequate bar when the lights have proper spread and intensity Spacing closer than ten feet does not appear justified

Three types of light fixtures were tried in the bars The Type C-1 unit gives results as effective as those given by the Type C-2 units on the straight-in approach and on the final leg of a circling approach The Type C-1 unit, however, lacks the spread to cover the area occupied during the turn into final approach This area was better covered by the Type C-2 unit and by the 200-watt PAR lamp, but it also can be covered effectively by the more successful of the flashing units The 200-watt PAR lamp, while providing good coverage for a wider area than the Type C-1 unit, lacks any back light and does not provide for exit marking unless double units are installed The Type C-2 units with 200-watt series lamps provided very effective coverage and were comparable with the 200-watt PAR lamps

The seven different types of flashing lights were used at the outer ends of the threshold bars to serve two purposes The first was to provide a visible signal to areas where the threshold bar lights failed to penetrate, and the second was to add conspicuity to the bars

The Grimes lights provided clear sharp flashes and proved very effective for both purposes The lights were installed first on the outer ends of both approach bars, but as the flashes were not synchronized, they gave disturbing impressions of jumping movement to the lights An installation was made with these flashing lights at the four corners of the runway, and both pilots and observers commented favorably on having flashing lights at the upwind end of the runway as well as on the entrance threshold bars There appeared to be no difficulty with unsynchronized lights as far separated as the length of the runway, but for flashers as close as the width of the runway the lack of synchronization proved disturbing

In some tests, a single Grimes light was installed at the left end of the threshold bar without a corresponding flasher at the right end This light appeared to be essentially as effective as the pair of lights and eliminated the effect of nonsynchronization

It was found that the flashing light was much more effective if spaced out from the end of the threshold bar far enough to make it appear separate from the bar A minimum of 20 feet separation is recommended

Rotating cluster lights also were tried as flashing units These were not as effective as the Grimes lights

A pair of synchronized counterrotating beacons was installed at the outer ends of the threshold bars With these beacons the flashing lights appear synchronized to a pilot when he is on the axis of the approach system, if he is off course to either side, the lights appear to jump toward the axis and thereby give an added corrective indication These lights have possibilities of positive value

The 400-watt undulating light was very effective as a conspicuity marker to a pilot on final approach This would have to be duplicated in order to produce any signal to a pilot on the downwind leg or on the earlier part of the turn into final approach

The 100-watt rotating spotlight gave effective signal to all parts of the approach but lacked enough intensity to serve for marginal weather This unit could be masked for any part of the area where no signal is required

The group of four 200-watt PAR lamps flashed simultaneously gives the effect of a flashing signal over the angle covered by the spread of the projectors It has the disadvantage of imposing a large intermittent load on the circuit The use of four similar lamps flashed in sequence avoids this intermittent load and imposes the load of only one lamp on the circuit The effect produced is that of an undulating or flashing signal, depending on the alignment of the lamps This arrangement presents definite possibilities for the required service

The flashing signals share certain characteristics A rotating signal light presents full brightness at one point of the cycle, but the effectiveness is reduced by the short duration of the flash or by the long eclipse period between flashes if the speed of rotation is reduced This can be improved by using multiple projectors similar to flasher No 2 All of the rotating lights require constant power for the rotating element and for the light sources

The units employing lamps which are turned on and off all share the delays imposed by incandescence and nigrescence of the lamp The sequence-flashing group has an effective period equal to the total sum of the individual flashes

All flashing lamps and signals suffer great decrease of effectiveness if operated at less than full lamp voltage This is particularly marked in cases where the lamps are flashed on and off All flashing signals should be operated at 100 per cent voltage

In addition to use of separate flashing signals, the transverse bars were undulated in brightness to add conspicuity and were operated at one step higher brightness than the runway lights As an alternate to this, the outer unit of each bar was operated at one step higher brightness than the remainder of the bar

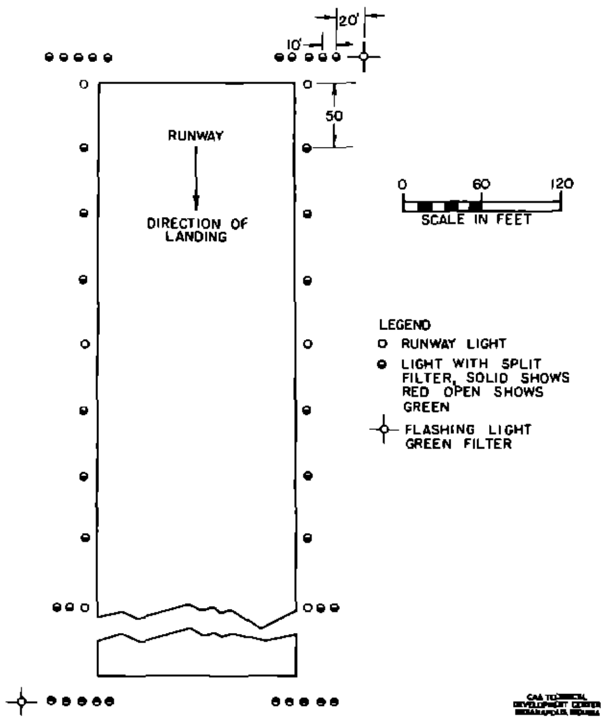


Fig 1 Diagram Showing Threshold Lighting Pattern for Counterclockwise Approaches

The increase in brightness resulted in increased conspicuity When applied to the entire bar, however, it could cause objectionable glare under certain conditions Also, the increase in brightness is impractical at the highest brightness step unless different units are employed for the brighter lights

The undulation of brightness in the entire bar improved the conspicuity, but the slow rate of incandescence and nigrescence required a cycle of not less than three seconds, which made the bar somewhat difficult to locate positively It is recommended that the bar remain at steady brightness and the conspicuity be provided by separate units

The most effective pattern, as judged from the long series of flight tests and ground observations, is that shown in Fig 1 This is the pattern previously listed as No 6 It includes 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

Split filters are recommended for all light units except the flashing lights which are provided with green filters The split filters show green to a landing pilot and red to a pilot approaching the exit end of the runway The red filters are recommended as exit filters in spite of the fact that pilots will have to accustom themselves to a change in the color of these lights This is considered to be of the utmost importance in enabling the pilots to differentiate between entrance threshold lights and exit threshold lights When operating minimums are lowered, the system will have to serve with the utmost certainty with only a short segment visible at one time