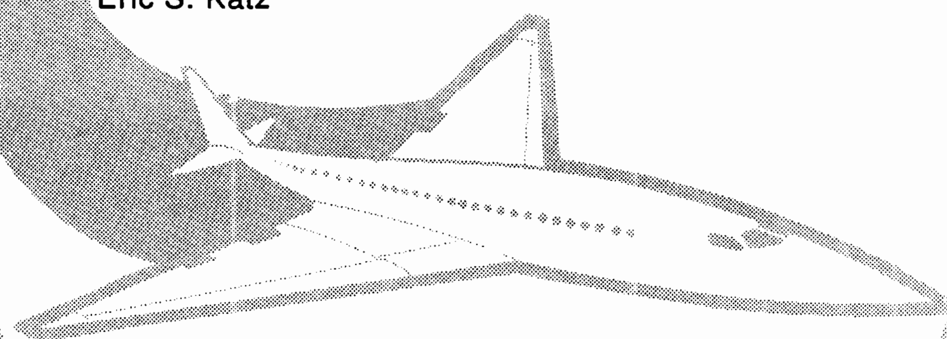
Evaluation of a Tritium Runway Lighting System

Eric S. Katz



April 1992

DOT/FAA/CT-TN92/15

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NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/CT-TN92/15		

4. Title and Subtitle	5. Report Date
EVALUATION OF A TRITIUM RUNWAY LIGHTING SYSTEM	April 1992
	6. Performing Organization Code
7. Author(s) Eric S. Katz	8. Performing Organization Report No. DOT/FAA/CT-TN92/15
9. Performing Organization Name and Address Federal Aviation Administration Technical Center Atlantic City International Airport, NJ 08405	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Technical Center Atlantic City International Airport, NJ 08405	13. Type of Report and Period Covered Technical Note 14. Sponsoring Agency Code ACD-110

15. Supplementary Notes

16. Abstract

A tritium powered runway lighting system was installed and evaluated at the Federal Aviation Administration (FAA) Technical Center. The purpose of this evaluation was to determine if the tritium runway lighting system would safely support Federal Aviation Regulations (FAR) Part 135 commercial operations, during nighttime visual flight rules (VFR) conditions at remote airports. Subject pilots having flight experience levels appropriate for pilots conducting FAR Part 135 air taxi operations were afforded the opportunity of flight testing the system. Results of the evaluation indicate that the tritium runway lighting system does not meet all of the minimum criteria necessary for FAA approval and, therefore, would not guarantee an acceptable level of safety.

17. Key Words	18. Distribution Statement
Tritium Runway Lighting System Remote Airports	Document is on file at the Technical Center Library, Atlantic City International Airport, New Jersey 08405

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	19	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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EXECUTIVE SUMMARY

The purpose of this evaluation was to determine the suitability of a tritium powered runway lighting system for providing nighttime visual guidance for approach and landing operations, under visual flight rules (VFR), to safely support FAR Part 135 commercial operations. The tritium lighting system is intended to be used only at remote landing sites where electrical power is not available and other approved lighting systems cannot be installed.

The tritium runway lighting system was evaluated at the Federal Aviation Administration (FAA) Technical Center and consisted of the following elements: runway edge lights, threshold lights, an airport identification beacon, and a lighted wind direction indicator.

The tritium lighting system was installed on a turf strip adjacent to runway 22. A total of eight subject pilots participated in the evaluation. Minimum flight crew included the subject pilot, a designated safety pilot, and a project observer/data recorder.

The results of the evaluation indicate that the tritium runway lighting system does not meet all of the minimum criteria necessary for FAA approval and, therefore, would not guarantee an acceptable level of safety.

INTRODUCTION

BACKGROUND.

Tritium lighting systems are currently being used in the state of Alaska for Federal Aviation Regulations (FAR) Part 91 operations (general operating and flight rules) at remote general aviation airports where electrical power is not available. The principal advantage of tritium lighting is that it is self-luminous and does not require an electrical power source. When tritium gas is injected into a phosphor-coated glass tube, Beta emission from the decaying tritium gas excites the phosphor to cause a continuous emission of visible green light. Having a half-life of 12.4 years, the tritium activated device is expected to provide light, without need for external power, for an extended period of time.

The state of Alaska has requested approval to use tritium lighting for FAR Part 135 commercial/air taxi operations. These operations involve flying for hire and, thus, require an approved lighting system.

An evaluation of a tritium lighting system was previously accomplished in Richland, Washington. Due to the lack of low visibility conditions encountered during the test period, the evaluation was conducted solely in visibilities of at least 12 miles. Although the tritium lighting system provided satisfactory visual guidance under those conditions, it was recommended that the tritium lighting system be evaluated further under weather representing the lower limits of visual flight rule (VFR) conditions (1,000-foot ceiling and 2- to 3-mile visibility). In response to this recommendation, the tritium lighting system evaluation was continued at the Federal Aviation Administration (FAA) Technical Center.

Three additional attempts were made by the FAA to evaluate the tritium lighting system. The first site was at Central, Alaska, in 1984. This location was not feasible for an in-service test due to its remote location and lack of subject pilots to conduct the evaluation. The second location was at Skwintna, Alaska, in 1985. No results were obtained due to the combination of the unavailability of FAA regional personnel to conduct test flights and the abnormal lack of appropriate weather (2 to 5 miles visibility) during the winter test period. The third attempt was at Fort Lewis, Washington, in 1990. It required 1 1/2 years to begin this test due to the requirements of having an approved environmental assessment and security plan. No data were obtained due to flight testing being abruptly terminated after 2 months, at the Army's request, due to the theft of some tritium units.

In addition, the state of Alaska has had tritium lighting systems installed at Council (near Nome), Chicken (near Fort Yukon) and Cold Foot (near Brooks Mountain Range). These locations are gravel village strips. No official state tests have been conducted in the lower ranges of the required weather conditions (2 to 5 miles). The FAA would be unable to conduct a test at these sites due to their remote locations and lack of subject pilots.

PURPOSE.

The purpose of continuing this evaluation was to determine the suitability of the tritium lighting system for providing nighttime visual guidance for approach, landing, and takeoff operations, under minimum visual meteorological conditions (VMC), to safely support FAR Part 135 commercial operations. Results of the evaluation will be considered for possible FAA approval to use the tritium lighting system for FAR Part 135 operations at remote landing sites.

OBJECTIVE.

This project was directed specifically toward determining if the tritium lighting system meets the following minimum criteria, as established by Flight Standards Service, in order to be accepted for FAA approval:

1. The tritium lighting system must be capable of providing an acceptable definition of the runway of sufficient brilliance on a full moonlit night and/or under minimum visibility conditions of 2 to 3 miles. The pilot must be able to immediately determine the aircraft's orientation relative to the runway while conducting normal aircraft maneuvering in the airport traffic pattern within a distance of 1.3 nautical miles without the assistance of other devices or aids. This would include maneuvering to crosswind, downwind, and base legs.

2. The system must include a low-powered airport identification beacon within 5,000 feet of the landing area and of sufficient intensity to identify the general runway location at a distance of 10 statute miles in visibility conditions equivalent to 10 statute miles or more.

3. The system must include an illuminated wind direction indicator capable of providing wind direction information to a pilot overflying the runway at pattern altitude.

TEST METHODOLOGY.

The tritium lighting system evaluation was accomplished through flight testing and data collection. The flight test sessions included three separate but related phases designed to determine if the tritium lighting system provided adequate visual guidance during the weather conditions encountered at the time of the test. Minimum flight crew included a subject pilot, a designated safety pilot, and a project observer/data recorder.

Upon completion of each flight test session, the subject pilot was asked to complete a pilot questionnaire. The recorded data were then analyzed to determine the extent to which the tritium lighting system met the established criteria.

SYSTEM EVALUATION

FACILITY, PILOT, AND EQUIPMENT REQUIREMENTS.

The tritium lighting system was installed at a test site mutually agreed upon by the FAA Technical Center and the U.S. Department of Energy. The test site landing strip had the following characteristics:

1. An adequate landing surface of 2100-foot length and 75-foot width, where the contrast between the landing surface and the adjacent area is such that the definition of the runway could not be determined without the aid of runway edge lights.

2. A location close to a major community from which the subject pilot and aircraft resources could be drawn.

3. An area with a relatively low concentration of ambient lighting. These conditions were simulated at the FAA Technical Center by de-energizing significant light sources that were located in the vicinity of the test air strip during each test session.

Subject pilots participating in the evaluation had, as a minimum, an experience level equal to that expected of pilots normally employed in the conduct of FAR Part 135 air-taxi operations. The tritium lighting system, as evaluated at the FAA Technical Center, consisted of the following equipment:

1. Runway Edge Lighting Units - intended to define the lateral limits of the available landing surface.

2. Threshold Lighting Units - intended to define the longitudinal limits of the available landing surface.

3. Airport Identification Beacon - intended to provide long range identification of the general airport/runway location.

4. Lighted Wind Direction Indicator - intended to provide wind direction information to pilots overflying the runway at pattern altitude.

The runway edge lighting unit (figure 1) consists of two tube holders that are attached at a 90 degree angle to allow omni-directional light visibility. (Note: Nighttime photographs have been visually enhanced for incorporation into this report.) Each tube holder measures 22 by 16 inches and contains six tritium filled phosphorized tubes to provide the green light source. The threshold lighting unit (figure 2) consists of two edge lighting units placed side by side at a distance of 2.5 feet.

The airport identification beacon (figure 3) consists of two low-powered battery-operated strobe lights which emit alternate green and white flashes at 1.5 second intervals. It does not contain any tritium lighting components, and it is located 325 feet from the edge of the tritium runway.

The lighted wind direction indicator (figure 4) consists of 10 tritium lighting fixtures, each containing six tritium tubes (three per side). The fixtures are installed to give the general appearance of a "T" shaped structure, which is free to turn into the direction of the prevailing wind. The "T" (intended to resemble a small airplane whose alignment with the runway indicates the required landing direction) is located 450 feet from the edge of the tritium runway.

A diagram of the configuration in which the various components are dispersed for the evaluation is shown in figure 5.

TEST PROCEDURES.

The tritium evaluation was conducted in three phases:

PHASE I: In order to determine the suitability of the tritium lighting system in providing the required visual guidance for pilots to safely conduct approach and landing maneuvers, three observation points were designated at a distance of approximately 1 nautical mile from the tritium runway as shown in figure 6. The safety pilot positioned the aircraft at each of these locations, and the project manager indicated to the subject pilot the direction and approximate distance in which to look in order to visually acquire the runway lighting system. From this position, the subject pilot was required to announce his relative orientation to the runway using one of the following three terms: centerline, downwind, or 45 degrees. This announcement had to be made within approximately 3 seconds after the runway direction was provided to the subject pilot to verify that the visual guidance provided by the tritium lighting system was self-apparent and unambiguous. The project observer noted the subject pilot's call, either as correct (C) or incorrect (I), on the appropriate location on the pilot questionnaire form.

PHASE II: In order to determine the effectiveness of the tritium lighting system in providing continuous visual guidance to the pilot while maneuvering in the traffic pattern, the safety pilot positioned the aircraft for entry into a downwind leg at a distance of approximately 1 nautical mile from the runway centerline. The subject pilot was then required to fly the aircraft through the downwind leg, base leg, and final approach portion of the traffic pattern to either a low approach or a full-stop landing. In flying the pattern, the subject was to use only the guidance provided by the tritium lighting system, without using guidance from onboard or ground-based devices other than night VFR flight instruments. In addition, all approaches and landings were made without using the landing light. This was done to simulate a landing light failure and to test the visual guidance provided by the tritium lighting system to a pilot on short final under these conditions. If the subject pilot was unable to maintain continuous orientation with the tritium runway, he was required to announce this condition to the project observer and safety pilot.

PHASE III: In order to determine the effectiveness of the combined components of the remote runway lighting system (i.e., the airport identification beacon, the tritium wind direction indicator, and the tritium runway lighting system), the subject pilot was required to execute an approach to the runway from a distance of 3-4 nautical miles using the strobe beacon for acquisition, determining the appropriate landing direction from the illuminated wind direction indicator, and executing the proper traffic pattern maneuvers to a low approach or landing. The safety pilot positioned the aircraft for initiation of this approach at a distance of 3-4 miles and an altitude of 1,000 feet above ground level (AGL).

If the subject pilot was unable to locate the airport, enter the proper landing pattern, and successfully complete a landing/low approach, or if the pilot lost visual guidance at any point in the maneuver, the tritium system was considered inadequate for that particular subject pilot.

Twenty subject pilots were determined to be an adequate sample size for this evaluation. In order to be acceptable, the tritium lighting system would have to have a 90 percent acceptance rate. If greater than 10 percent of the subject pilots rated the system as inadequate, the evaluation would be terminated early. These requirements were agreed to by Alaska's Department of Transportation, the Department of Energy at Richland, WA, and FAA's Flight Standards Service.

RESULTS

Eight subject pilots participated in the tritium light evaluation. Pilot experience ranged from 700 to 12,600 flight hours. Aircraft used for the evaluation included a Cessna-172, an Aero Commander-680E, a Piper Archer, and a T-34C.

Weather visibility conditions encountered during the test sessions ranged from 3 to 12 miles, with moon phases ranging from new to full. These VFR conditions largely agreed with the weather conditions as specified in criterion 1.

In addition to having been afforded a complete preflight briefing concerning the purpose and conduct of the evaluation, the subject pilots were given the opportunity to view the tritium lighting system components installed on the test runway at the FAA Technical Center. The purpose of this preview of system components was to insure that the subject pilots appreciated the difference in the appearance of the tritium lights as compared to conventional lighting system fixtures.

A summary of pilot questionnaire responses is shown in figure 7, and should be referred to during the test results discussion which follows. Pilot comments are summarized in appendix A.

PHASE I TEST RESULTS.

During the first run of phase I, six of the eight subject pilots were unable to determine their orientation with respect to the tritium runway from the centerline and 45-degree observation points. In addition, seven of the eight subject pilots were unable to determine their orientation from the downwind observation point. These results were acquired in a visibility range of 3 to 12 miles and during moon phases ranging from new to full. A second run of phase I could not be accomplished in four of the eight test sessions due to visibility deteriorating into instrument flight rules (IFR) conditions and, thus, not agreeing with the weather conditions as specified in criterion 1. During the second run of phase I, three of the four subject pilots were able to determine their orientation with respect to the tritium runway from the downwind and 45-degree positions, and two of the four subject pilots were able to determine their orientation from the centerline position. While the data from the second run do indicate some improvement in the subject pilot's ability to identify his relative position in the traffic pattern, it should be noted that the visibility ranged from 7 to 12 miles during these runs, which is well above the specified minimums. In addition, a number of the subject pilots stated that they estimated the aircraft's position in the traffic pattern by using visual references other than the tritium lights. For example, the stroboscopic beacon's relative position with respect to the aircraft became a significant clue to the subject pilot, which helped him determine his position in the pattern, even if he was unable to see the tritium lighting system.

PHASE II TEST RESULTS.

Phase II was not completed during one test session due to visibility deteriorating into IFR conditions. In answering questions 1 and 2, four of the seven subject pilots indicated that they were unable to judge the proper point at which to initiate the turn to base leg and final approach. In answering question 3, three of the seven subject pilots indicated that the tritium lighting system failed to adequately define the outline of the runway so as to permit them to maintain the proper glide path and alignment with the runway centerline. The responses to question 4 indicate that six of the seven subject pilots agree that the tritium lighting system provides sufficient runway definition for the flare, landing, and takeoff maneuvers.

PHASE III TEST RESULTS.

In response to question 1, all eight subject pilots indicated that the airport identification beacon provides an adequate indication of the airport location. In answering question 2, five of the eight pilots indicated that they were able to verify the runway orientation (direction) and most appropriate approach direction by reference to the tritium lighting system and the illuminated wind direction indicator.

The results of phases I and II indicate that the tritium lighting system does provide sufficient visual guidance during the flare, landing, and takeoff maneuvers. However, the majority of subject pilots were unable to determine the aircraft's orientation relative to the runway while conducting normal aircraft maneuvering in the airport traffic pattern. Therefore, criterion number 1 was not met.

The results of phase III indicate that the airport identification beacon provides an adequate indication of the airport location, thereby satisfying criterion number 2. Also indicated is the fact that three of the eight subject pilots were unable to determine the most appropriate approach direction by reference to the illuminated wind direction indicator. Consequently, criterion number 3 was not met.

In order to determine the relative differences with an existing standard, a comparison of acquisition distances was made between the tritium lighting system and an electrically-powered low intensity (40-watt) runway lighting system as installed at nearby Hammonton Airport (N81). The electrical runway edge lights are pilot-controlled and were designed to illuminate at a single intensity setting lower than full brightness. Approaches were made to both types of lighting systems from 90 degrees (perpendicular to the runway), 45 degrees, and extended centerline positions. When the lighting system was first identified, the acquisition distance, as determined by distance measuring equipment (DME), was recorded on a data sheet. The results of this comparison are shown in table 1.

TABLE 1. COMPARISON OF ACQUISITION DISTANCES

Weather: Clear, visibility 12, 3/4 moon.

HAMMONTON (N81)

Approaching Runway From:	Runway Lighting Acquisition Distance (Nautical Miles):
90 Degrees	1.5
45 Degrees	2.5
Extended C/L	8.0

TRITIUM TEST RUNWAY (ACY)

Approaching Runway From:	Runway Lighting Acquisition Distance (Nautical Miles):
90 Degrees	0.7
45 Degrees	0.7
Extended C/L	1.1

The acquisition distances shown in table 1 indicate that the light output from the low intensity electrical system is acquired at significantly greater distances than the output from the tritium system. Of particular significance is the fact that the tritium lighting system was not visually acquired until the aircraft was 0.7 nautical miles from the runway while approaching from the 90- and 45-degree positions. These results support the findings of both phase I and II, which were flown at distances of approximately 1 nautical mile from the runway.

CONCLUSION

Based on the results of this evaluation, it can be concluded that the tritium lighting system does not meet all of the minimums, as established by Flight Standards Service, that are necessary for Federal Aviation Administration (FAA) approval and, therefore, would not guarantee an acceptable level of safety. Specifically, only criterion number 2 was met for the use of a low-powered airport identification beacon of sufficient intensity to identify the general runway location.

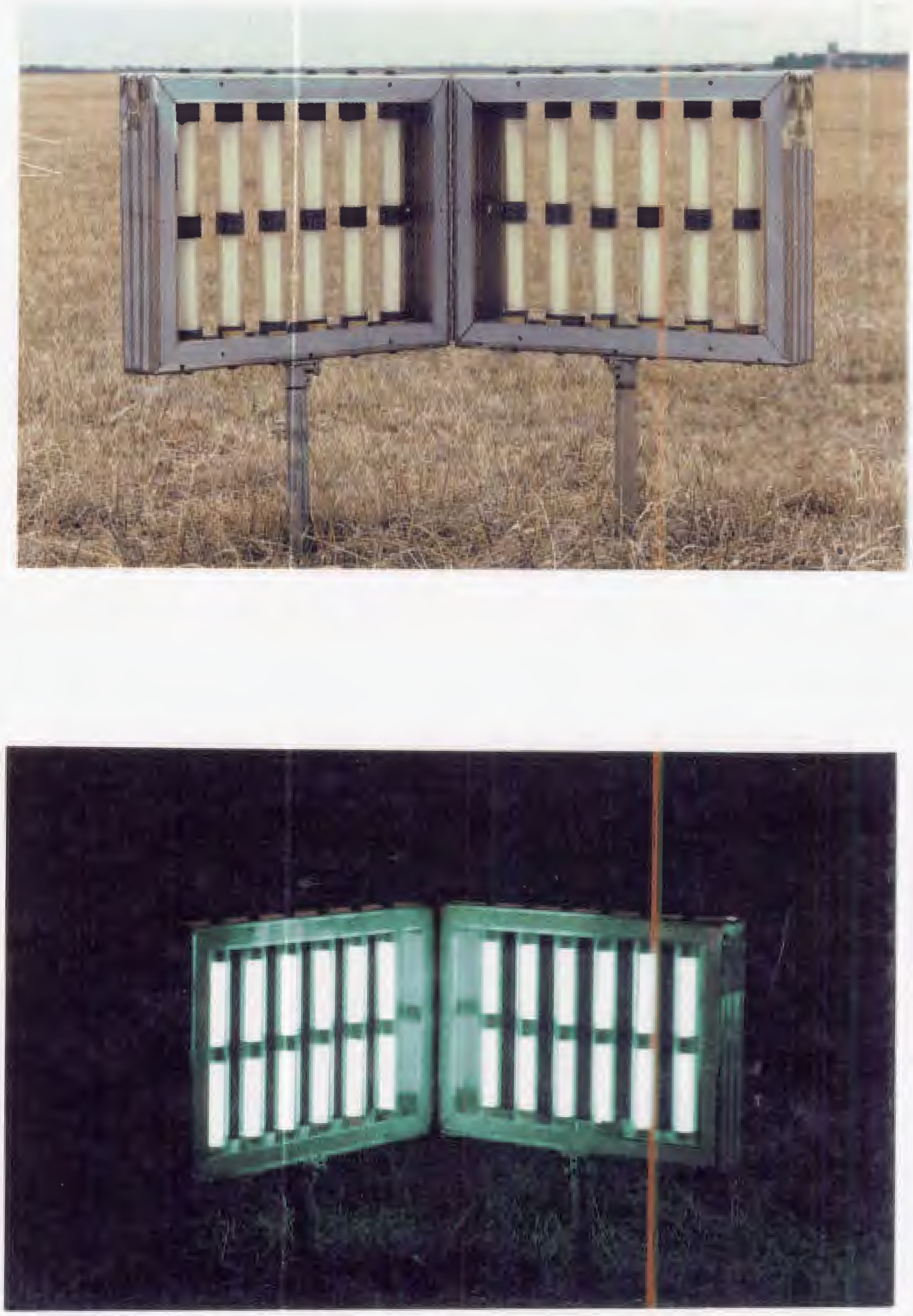

FIGURE 1. TRITIUM RUNWAY EDGE LIGHTING UNIT (DAY AND NIGHT)

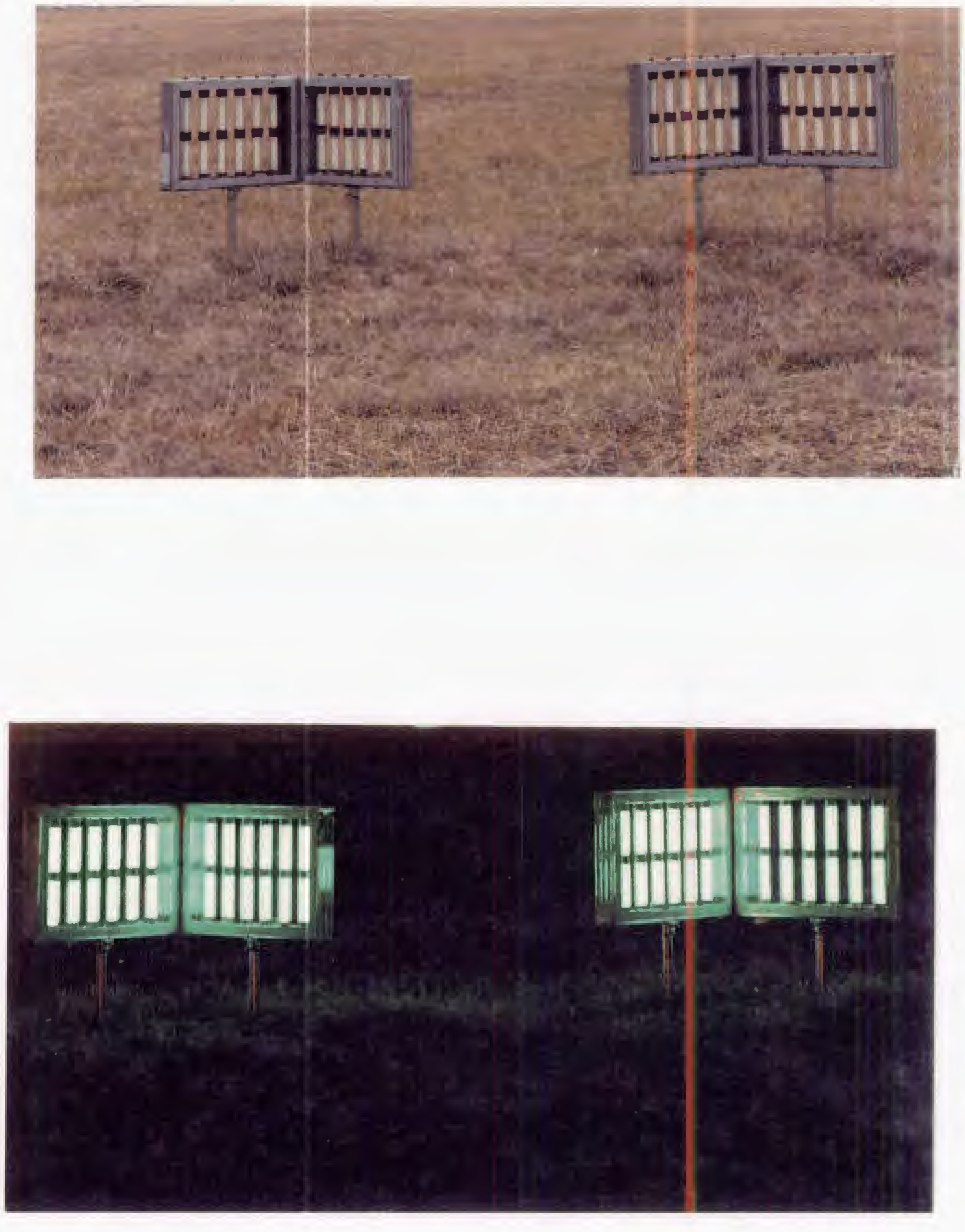

FIGURE 2. TRITIUM RUNWAY THRESHOLD LIGHTING UNIT (DAY AND NIGHT)

FIGURE 3. STROBOSCOPIC AIRPORT IDENTIFICATION BEACON

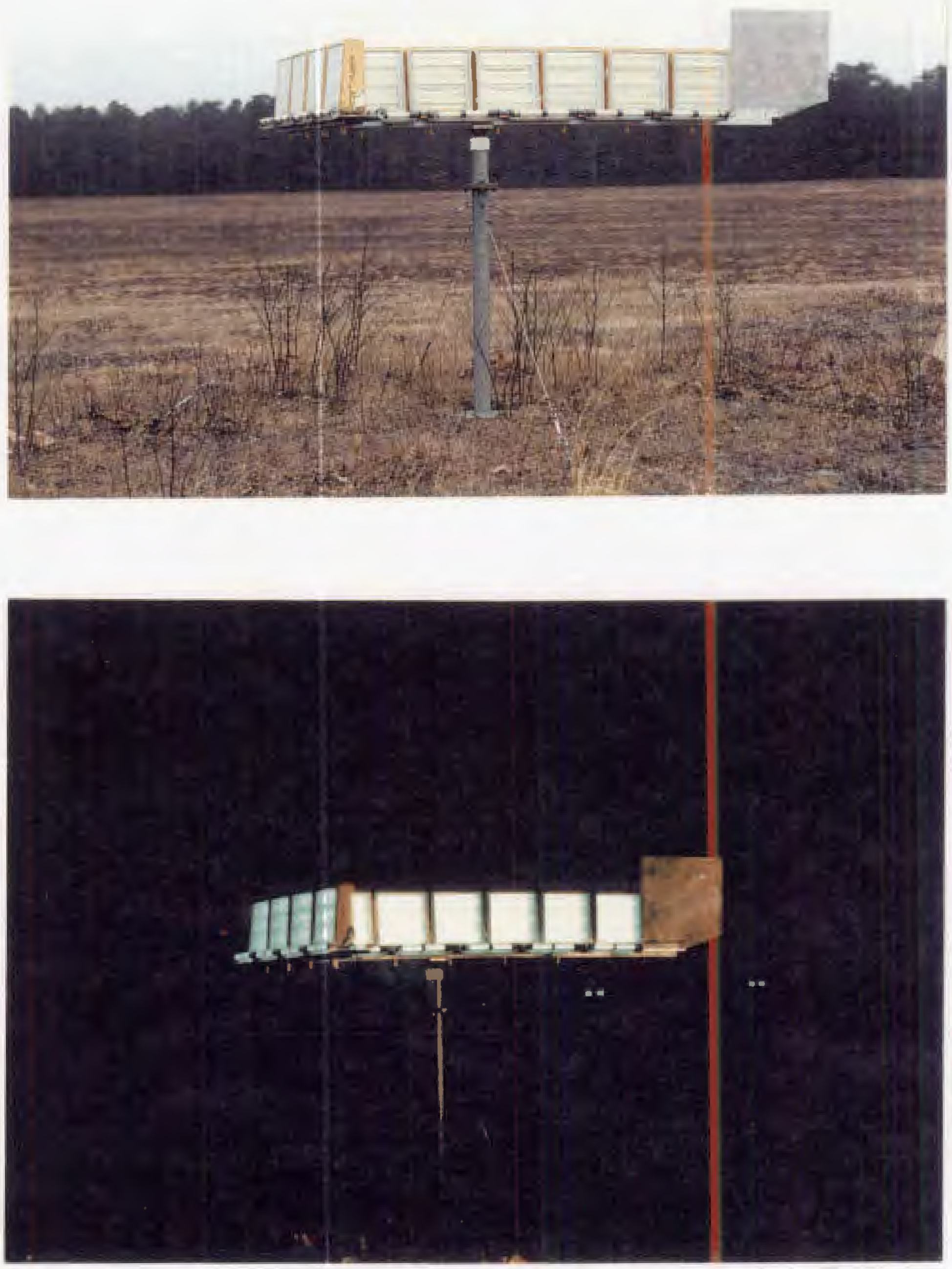

FIGURE 4. TRITIUM WIND DIRECTION INDICATOR (DAY AND NIGHT)

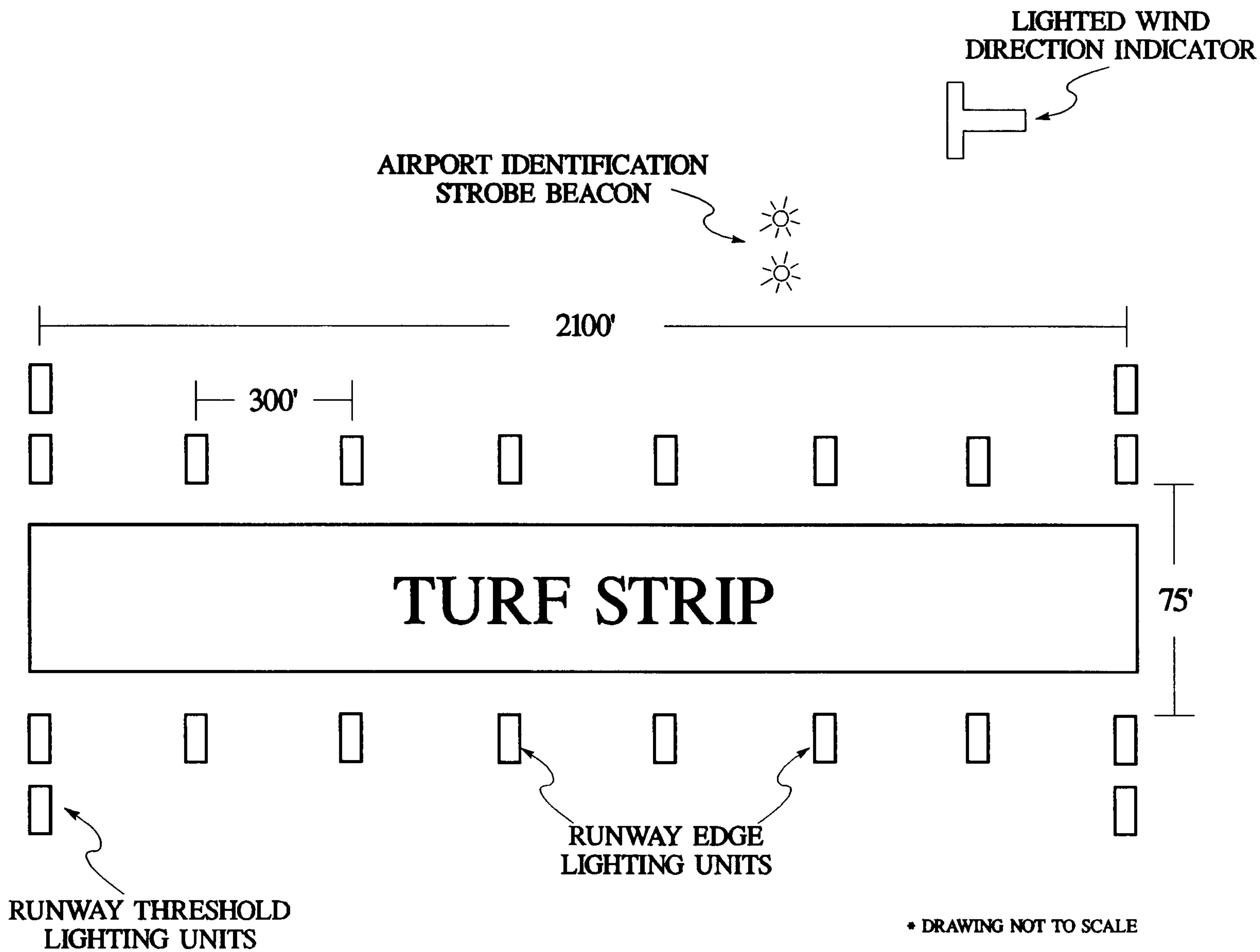

FIGURE 5. TRITIUM LIGHTING SYSTEM CONFIGURATION