Development of Airport Active Runway Vehicle Lighting

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16. Abstract

Runway incursions are a leading cause of airport ground accidents and usually result from the presence of unauthorized ground vehicles within the active runway area. In many cases, air traffic control personnel can become confused by the numerous flashing lights and various colors of lights on vehicles operating on the airport and because of this, are unable to distinguish which vehicles are on the runway and which are on a parallel taxiway or holding short of the runway. The purpose of this evaluation was to determine the feasibility of equipping airport ground vehicles with supplemental warning beacons that would be illuminated only when the vehicle was on an active runway, thus providing a visual cue to eliminate any confusion in regards to the location of the vehicle.

The objective of the research was to evaluate the various beacon features available, such as beacon colors, flash patterns, flash speeds, or beacon separation distances, to determine if there was a particular combination that would make the beacon unique enough to be used for this purpose. To investigate these features, an evaluation was conducted in which numerous vehicles were fitted with modified light beacons that enabled the project participants to observe the supplemental warning beacons in operation. The participants evaluated various beacon colors, flash patterns, flash speeds, and light bar arrays at various separations during the course of the evaluation. In addition, surveys were taken at various airports to determine which type of vehicle lighting was currently being used.

The supplemental warning beacon concept was not feasible for various reasons. It was determined that the available colors were not unique enough to identify the vehicles on the runway, because these colors are already being used for other functions in the airport environment. In addition, it was determined that adding another beacon of a different color to the standard amber beacon would require them to be spaced approximately 2 feet apart to ensure that the beacons did not blend when they flashed in unison. The beacons would also have to be mounted vertically, one above another, to make both of them visible from a 360 degree radius. For most vehicle applications, however, mounting beacons vertically or horizontally apart from each other is not acceptable.

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EXECUTIVE SUMMARY

The effort described in this technical note was accomplished in response to a research request memorandum from the Federal Aviation Administration (FAA) Office of Airport Safety and Standards, AAS-1, dated February 14, 2001. The purpose of this research effort was to develop and evaluate supplementary airport vehicular lighting that would readily identify ground vehicles cleared by air traffic control for operation within the active runway area. Such lighting would be displayed only during the period that the cleared vehicle is physically within the critical runway area.

An evaluation was conducted at the FAA William J. Hughes Technical Center, Atlantic City International Airport, New Jersey, in which numerous vehicles were fitted with modified light beacons that enabled the project participants to observe the supplemental warning beacons in operation. The participants evaluated various beacon colors, flash patterns, flash speeds, and light bar arrays during the course of the evaluation. In addition, surveys were taken at various airports to determine which type of vehicle lighting was currently being used.

Evaluators determined that the supplemental lighting concept, while very intriguing, was not feasible for implementation. It was determined that there were no color configurations unique enough to identify the vehicles on the runway, because all the colors available for vehicle lighting already have functions in the airport environment. In addition, it was determined that the two lights (amber and an added colored light) would need to be spaced approximately 2 feet apart to ensure that the lights did not blend when they flashed in unison. The lights would also have to be mounted vertically, one above another, to make both lights visible from a 360 degree radius.

This technical note provides a summary of the results found during this evaluation and suggests that the concept of using cleared vehicle lights not be pursued, due to the requirement for complex lighting devices and the potential problem caused by improper operation.

INTRODUCTION

PURPOSE.

The effort described in this technical note was accomplished in response to a research request memorandum from the Federal Aviation Administration (FAA) Office of Airport Safety and Standards, AAS-1. The purpose of this research effort was to determine the feasibility of developing supplementary airport vehicular lighting that would readily identify ground vehicles cleared by air traffic control (ATC) for operation within the active runway area. Such lighting would be displayed only during the period when the cleared vehicle is physically within the critical runway area.

OBJECTIVES.

The objective of this effort was to determine the feasibility of the supplemental ground lighting proposal, and then, if appropriate, recommend the type of lighting configuration best suited for the application. Yellow (amber), white, blue, red, and green lights in both rotating and strobe light fixtures were considered.

It was anticipated that in addition to finding a configuration of lights that would satisfy the vehicle on a runway identification requirement, it would also be necessary to address the following issues:

- Feasibility of the concept for active runway vehicle lights—The use of such lights will require active participation from ground vehicle operators and may require an added task for ATC to verbally command the vehicle to turn on or off the lights as part of the clearance message. Also of major concern is the question of what will happen if the vehicle operator forgets to switch the lights on or off.

- Recommended operating procedures—Considerable ATC input will be required in determining the circumstances under which this unique lighting must be displayed. Obviously, the workload on vehicle operators will be lessened if they are not required to activate the active runway vehicle lighting for relatively short runway occupancies (i.e., runway crossings). ATC participation in virtually all phases of this developmental effort is essential.

BACKGROUND.

Runway incursions, a leading cause of airport ground accidents, usually result from the presence of unauthorized ground vehicles within the presumed sterile active runway area. In many cases, ATC personnel can become confused by the numerous flashing lights affixed to vehicles operating on the airport and, therefore, unable to distinguish which vehicles are on the runway and which are on a parallel taxiway or holding short of the runway. There have been documented cases where ATC has erroneously cleared aircraft to land or takeoff on a runway that was occupied by a ground vehicle that visually blended in with surrounding flashing lights. It has been suggested that some unique configuration of vehicular lighting, supplementing the conventional yellow flashing warning lights, would serve to identify vehicles operating within the active runway area to the ATC as well as to aircraft and other ground vehicles operating within the area.

The initial survey of major airport operations groups revealed that a significant number of airports used the following available beacon colors.

- Yellow (Amber)—Used by virtually all airports on service, maintenance, and construction vehicles.

- Red—Used for fire operation vehicles and rescue vehicles at most airports. Red is also used on aircraft as anticollision beacons.

- Blue—Used for law enforcement and rescue vehicles at many airports.

- White—Used on aircraft as anticollision beacons and, at a few airports, on operations vehicles.

- Green—Used increasingly, with local airport authority authorization, for identifying incident command or public information officers at an accident scene.

Since these comprise the complete spectrum of colors available for use as airport vehicle beacons, it was immediately obvious that only a combination of colors might provide the distinctive signal required.

This concept, while it sounds simple, would require close attention by ground vehicle operators because they would be personally responsible for switching the supplemental lighting on or off as required. Failure to do so could result in a serious problem. There is also the question of whether the vehicle that is merely crossing the runway be required to operate the supplemental lights or whether only vehicles operating on the runway for a prolonged period of time be required to do so.

RELATED DOCUMENTS.

The FAA Advisory Circular (AC) 150/5210-5B, Painting, Marking, and Lighting of Vehicles Used on an Airport, July 11, 1986, provides guidance, specifications, and standards for lighting of vehicles operating in the airport operations area. It is the basic FAA document relating to lighting of airport vehicles. This AC also specifies what type of beacon should be used to identify the various types of ground vehicles operated on the airport.

The FAA Report FAA-RD-73-196, Evaluation of Identification Beacons for Airport Emergency Vehicles, January 1974, describes a research effort conducted to determine the effectiveness of several identification beacons for emergency vehicles. The results led to conclusions as to which signal characteristics are most effective for use within the aircraft movement areas of airports.

As far as can be determined, no previous investigations or evaluations pertinent to the specific concept of active runway vehicle lights have been conducted by the FAA.

DISCUSSION

METHOD.

It was determined that preliminary work on this project could be accomplished at the FAA William J. Hughes Technical Center, Atlantic City International Airport (ACY), New Jersey. Also anticipated was a subsequent expanded evaluation at an airport with a larger number of ground vehicles operating within the movement area. For the initial testing at ACY, the evaluation consisted of the following phases:

1. Operations personnel from several major airports were contacted to determine which vehicular beacon colors were used for designating specific use vehicles.

2. Various lighting configurations, designed to supplement the standard yellow flashing warning light, were temporarily attached to test vehicles at the FAA Technical Center for evaluation.

3. Carefully selected individuals, having considerable experience in the conduct and control of surface traffic on airports, were afforded the opportunity to view several proposed vehicular lighting (standard beacon plus the active runway vehicle light) configurations displayed on diverse types of moving vehicles. The subject evaluators were stationed in locations affording observation of the candidate lighting arrays from the most critical angles and aspects. These locations consisted of both ground level and elevated (control tower) viewpoints.

SUBJECTS.

Evaluators included ATC specialists, professional pilots, airport operations personnel, and visual guidance engineers.

DATA COLLECTION.

Subject evaluators were thoroughly briefed by project personnel prior to evaluation sessions and given limited information concerning the active runway vehicle lighting configurations to be presented.

Project representatives accompanied the evaluators to their observation locations to note comments and opinions expressed during the evaluation session.

During each session, the subjects were asked to complete a simple questionnaire. Since the sessions involved judging a considerable number of beacon configurations, the subjects were given the opportunity to fill out the questionnaires after observing each beacon set.

EVALUATION

Several vehicles were equipped with multiple beacon light configurations that allowed various color combinations to be viewed at the same time. In addition, both rotating incandescent and strobing condenser discharge type beacons were mounted for comparative testing. Figure A-1 in appendix A illustrates the light bar that was used to compare the rotating beacons. The commercially available light bar was reconfigured such that it permitted each vehicle operator to control each light individually through the use of dedicated switches inside the vehicle. In addition, the bar contained beacons that rotated at two different speeds. The center three beacons, as shown in figure A-2, rotated at 175 fpm, while the outer four (two on the left and two on the right) rotated much slower at 95 fpm. A supply of spare colored lenses was also kept on hand so that any combination of color, speed, and spacing could be evaluated. Figure A-3 illustrates the light bar that was fabricated to support both small- and large-strobe fixtures. A combination of two beacons having the same color (i.e., white and white or yellow and yellow) was not considered since many recent beacon designs incorporate rapidly repeated burst mode, same color flashes for added effectiveness.

Initially, all beacons on the test vehicles were mounted in the same horizontal plane, since it was anticipated that most future additions of beacons, assuming a suitable color combination could be achieved, would be done in such a manner (i.e., simply add an additional colored beacon next to the existing one on the vehicle roof).

Nighttime evaluation sessions were conducted with observers viewing test vehicles equipped with various color combination beacon sets moving at varying angles along taxiways at different distances. It was immediately obvious that while the vehicles made turns to follow selected routes, one colored beacon would frequently obscure or mask the second colored beacon and, thus, defeat any color combination identification feature. This same situation occurred with both rotating and strobe beacon installations. For only those times when vehicular orientation was such that both beacons were unobscured, the evaluators attempted to determine which combination of colors was most effective and acquisition most easily attained. Reference to the summary of responses (appendix B) will reveal that there was very little consensus as to the best color combination. The most favored combinations among participants, though not backed by the data, was the amber and blue combination, followed by the amber and white combination. The amber and blue combination appeared to be very eye-catching and provided sufficient contrast to identify the vehicle in the airport environment. The amber and white combination also provided an attention-getting signal but did not possess the eye-catching appearance presented by the amber and blue combination. The red and green combination was not found to be of sufficient contrast to perform the task. Unfortunately, airport police and rescue vehicles frequently use amber and blue colored lights, thus leaving amber and white as the only available combination.

Considering these initial results and recognizing that only a color combination configuration would suffice, a decision was made to separate the differently colored beacons vertically. To achieve this, the framework illustrated in figure A-3 was modified such that it would permit mounting several beacons, regardless of type, with a vertical separation of approximately 2 feet. Since most airport vehicles are already equipped with yellow-colored beacons, a decision was made to continue the testing only with a white and yellow color combination. The white and red combination had proven equally effective earlier but was rejected as a possible signal due to the fact that aircraft frequently display the same combination of colors as anticollision beacons.

The vehicle with the vertically mounted beacons was first observed from varying distances while stationary on the FAA ramp, with initially favorable results. Both the rotating incandescent and strobe beacon pairs were readily identifiable as a two-color signal and were particularly effective whenever the flash or strobe occurrences were exactly 180 degrees out of synchronization. The effect was considerably reduced, however, whenever the flashes occurred simultaneously.

Since the vertical separation appeared to render the combined color concept again possible, the decision was made to make further observations and evaluations from a greater distance and from a higher elevation. Observation activities were then transferred, once coordination had been achieved, from the field to the ACY control tower. It was understood that while the tower would provide an excellent observation platform, on-duty ATC personnel had normal control duties to perform and could not be asked to participate formally in the evaluation.

The test vehicle driver, as directed by the tower ground controller, drove the vehicle along runway 13/31 from the most distant point (approximately 1 1/2 miles) to a location closest to the tower (1/2 mile) while displaying both strobe (condenser discharge) and flashing (rotating) beacons, having a vertical separation of 2 feet. At the farther distance there was virtually no distinction between the two displayed colors, white and yellow, and they were not at all discernable as two separate beacons. At the closer range, while the truck was driven up and down the near runway, perpendicular to the observers, one could perceive that the signal was being projected by two separate beacons, but only when the flashes did not occur in unison. When flashing simultaneously, the two beacons appeared much more like a single-merged color signal.

The four project evaluation subjects (three pilots with considerable experience testing visual aids and one nonpilot who also had visual guidance experience) all agreed that the dual-beacon lighting displayed that evening left much to be desired.

Although vertical spacing in excess of the 2-foot dimension that was evaluated might eliminate the color and source merging at longer ranges, a beacon arrangement such as this on an airport vehicle would be prohibited due to building entrance clearance limits. Introduction of such a light bar would also weigh heavily on the major vehicle lighting manufacturers' willingness and ability to design and manufacture an entirely new line of product for this specific application, as nothing of this type is currently available.

It should be mentioned that during visits to major air carrier airports in connection with other projects, engineers participating in this effort made it a point to study the beacon installations typically used for operations, maintenance, and emergency vehicles. There appeared to be no standard beacon arrangement with regard to color, light source, mounting technique, etc. The arrays ran the gamut from single yellow-rotating incandescent beacons to sophisticated multicolor integrated units, providing a myriad of colors and operating modes. Figures A-4 and A-5 illustrate two such instances where airports have taken their own initiative to change the color of the lights on their vehicles. Figure A-4 shows an operations vehicle at Milwaukee General Mitchell International Airport. The light bar contains dimmable red strobe units that alternate in various patterns. There are no amber and yellow beacons on the vehicle. Figure A-5, which shows an operations vehicle from Chicago O'Hare International Airport, illustrates how numerous colors, beacon types, and flash speed and patterns are combined on a single vehicle. A large rotating light bar, with both white and amber lamps, is positioned on the roof, complemented with alternating amber strobe lights in both the back window and within the front grill, along with alternately flashing white reverse lights. These two vehicles are just two examples of how complex ground vehicle lighting has become. It seemed obvious that any attempt to bring order out of this proliferation of light beacon designs and styles, in an attempt to create a uniform active runway vehicle beacon identification, would involve considerable expense and retrofitting of vehicular lighting equipment.

TEST RESULTS

Results of the preliminary development and testing effort conducted at the William J. Hughes Technical Center can be summarized as follows:

1. Participants agreed that no particular color provided a truly unique pattern that they thought performed as required. Of the color combinations evaluated, participants favored the amber and blue and amber and white combinations. Participants indicated that the amber and blue combination was eye-catching and provided the contrast necessary to make the vehicle stand out in the airport environment. The amber and white combination was favored due to its use of nonemergency colors.

2. Multiple beacon installations, using combinations of colors, suffer from color merging and masking, especially when mounted on the vehicle at a common height.

3. Vertical spacing of dual beacons tends to reduce source and color merging, but cannot be carried to the extreme dimension required for complete signal separation.

4. Even with considerable vertical separation, synchronization of the flash or strobe rates must be attained to guarantee that each color would be seen as intended, without merging together.

5. Participating ATC personnel indicated that they did not believe the vehicle with the supplemental lighting would stand out during periods of heavy traffic, because the airfield becomes overcome with lights of various flashes, intensities, and color.

CONCLUSIONS

Based on the results of this study, the following conclusions were made.

1. A single color for use in this application, distinctive from others already used on airports, is not available. Color limitations for single beacons and the mutual signal interference of collocated dual-beacon installations, make it impossible to develop a unique lighting device (beacon) that will indicate the active runway status for vehicles operating on active runways.

2. An alternately flashing two-color, dual-beacon, would likely require replacement of all existing beacon installations with a new dual-beacon unit. It would further require custom wiring to permit the single beacon to flash while the vehicle is on the taxiway, and then permit the second lamp to turn on by a switch when the vehicle was on the runway surface.

3. If a two-color, dual-beacon system was installed, operation issue would be encountered with instances wherein the drivers of airport vehicles forgot to either activate or deactivate the special beacons. Such an occurrence would necessitate follow-up air traffic control radio communications on already crowded ground control frequencies and create distractions for the controllers.

APPENDIX A—PHOTOGRAPHS OF GROUND VEHICLE LIGHTING

FIGURE A-1. LIGHT BAR USED FOR ROTATING BEACON EVALUATION

FIGURE A-2. REAR VIEW OF ROTATING BEACON LIGHT BAR

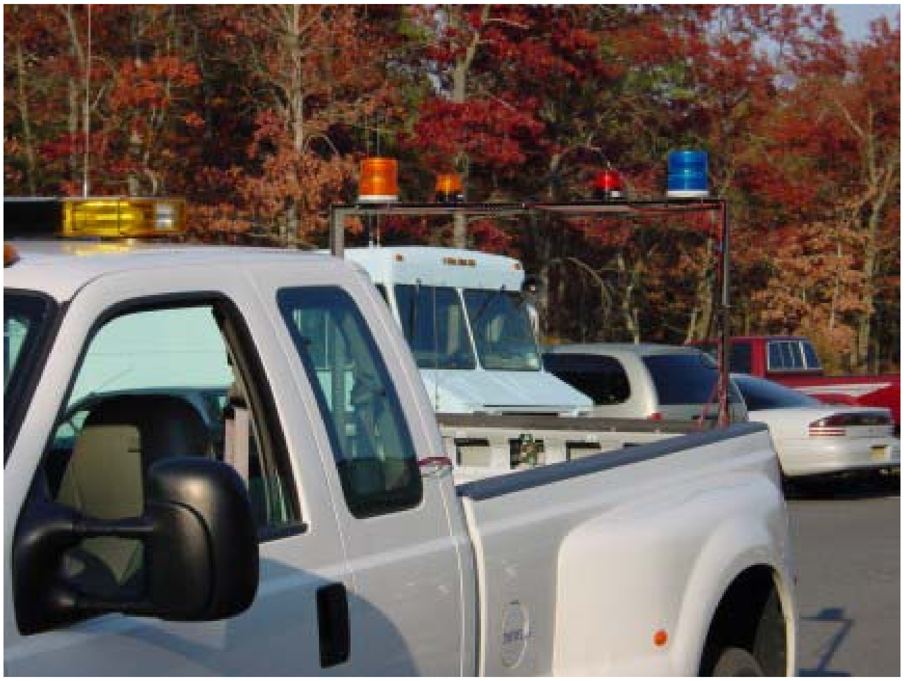

FIGURE A-3. LIGHT BAR USED FOR STROBE BEACON EVALUATION

FIGURE A-4. OPERATION VEHICLE AT MILWAUKEE INTERNATIONAL AIRPORT

FIGURE A-5. OPERATION VEHICLE AT CHICAGO O'HARE INTERNATIONAL AIRPORT

APPENDIX B—POSTSESSION QUESTIONAIRE

POSTSESSION QUESTIONNAIRE

Please complete this questionnaire after you have had the opportunity to observe and evaluate the respective Runway Occupancy Lighting (ROL) configurations. If you feel a decided preference for one or the other, we would like to have your reasons for the preference in the "comments" section.

Name:________________ Organization:________________ Date:_______________

With reference to each of the following color combinations you have seen in operation, please provide your opinion by placing a mark in the appropriate column.

1. Single Rotating Beacon, Amber, 95 fpm, on the vehicle, with a supplemental:

RED rotating, 95 fpm

I would rate the "acquisition" as:
Outstanding: 1 Relatively Good: 1 Poor: 3

I would rate the "uniqueness" as:
Outstanding: 0 Relatively Good: 0 Poor: 5

BLUE rotating, 95 fpm

I would rate the "acquisition" as:
Outstanding: 0 Relatively Good: 4 Poor: 1

I would rate the "uniqueness" as:
Outstanding: 0 Relatively Good: 3 Poor: 2

WHITE rotating, 95 fpm

I would rate the "acquisition" as:
Outstanding: 0 Relatively Good: 4 Poor: 1

I would rate the "uniqueness" as:
Outstanding: 1 Relatively Good: 1 Poor: 3

GREEN rotating, 95 fpm

I would rate the "acquisition" as:
Outstanding: 0 Relatively Good: 2 Poor: 3

I would rate the "uniqueness" as:
Outstanding: 0 Relatively Good: 2 Poor: 3

Please include any written comments on the back of this sheet

2. Single Rotating Beacon, Amber, 175 fpm, on the vehicle, with a supplemental:

RED rotating, 175 fpm

I would rate the "acquisition" as:
Outstanding: **0** Relatively Good: **3** Poor: **2**

I would rate the "uniqueness" as:
Outstanding: **0** Relatively Good: **1** Poor: **4**

BLUE rotating, 175 fpm

I would rate the "acquisition" as:
Outstanding: **1** Relatively Good: **4** Poor: **0**

I would rate the "uniqueness" as:
Outstanding: **2** Relatively Good: **2** Poor: **1**

WHITE rotating, 175 fpm

I would rate the "acquisition" as:
Outstanding: **1** Relatively Good: **1** Poor: **3**

I would rate the "uniqueness" as:
Outstanding: **0** Relatively Good: **1** Poor: **4**

GREEN rotating, 175 fpm

I would rate the "acquisition" as:
Outstanding: **1** Relatively Good: **2** Poor: **2**

I would rate the "uniqueness" as:

Outstanding: **1** Relatively Good: **2** Poor: **2**

Please include any written comments on the back of this sheet

3. Small Double Flash Strobe, Amber, 80 fpm, on the vehicle, with a supplemental:

RED double flash strobe, 80 fpm

I would rate the "acquisition" as:
Outstanding: **0** Relatively Good: **2** Poor: **2**

I would rate the "uniqueness" as:
Outstanding: **0** Relatively Good: **2** Poor: **2**

BLUE double flash strobe, 80 fpm

I would rate the "acquisition" as:
Outstanding: 0 Relatively Good: 4 Poor: 0

I would rate the "uniqueness" as:
Outstanding: 1 Relatively Good: 3 Poor: 0

WHITE double flash strobe, 80 fpm

I would rate the "acquisition" as:
Outstanding: 0 Relatively Good: 3 Poor: 1

I would rate the "uniqueness" as:
Outstanding: 0 Relatively Good: 2 Poor: 2

GREEN double flash strobe, 80 fpm

I would rate the "acquisition" as:
Outstanding: 0 Relatively Good: 3 Poor: 1

I would rate the "uniqueness" as:
Outstanding: 0 Relatively Good: 2 Poor: 2

Please include any written comments on the back of this sheet

4. Large Double Flash Strobe, Amber, 70 fpm, on the vehicle, with a supplemental:

RED double flash strobe, 70 fpm

THIS COLOR OPTION NOT TESTED

I would rate the "acquisition" as:
Outstanding:____ Relatively Good:_____ Poor:_____

I would rate the "uniqueness" as:
Outstanding:____ Relatively Good:_____ Poor:_____

BLUE double flash strobe, 70 fpm

I would rate the "acquisition" as:
Outstanding: 2 Relatively Good: 2 Poor: 0

I would rate the "uniqueness" as:
Outstanding: 2 Relatively Good: 2 Poor: 0

WHITE double flash strobe, 70 fpm

I would rate the "acquisition" as:

Outstanding: 1 Relatively Good: 0 Poor: 3

I would rate the "uniqueness" as:

Outstanding: 0 Relatively Good: 1 Poor: 3

GREEN double flash strobe, 70 fpm

I would rate the "acquisition" as:

Outstanding: 0 Relatively Good: 2 Poor: 2

I would rate the "uniqueness" as:

Outstanding: 0 Relatively Good: 1 Poor: 3

Please include any written comments on the back of this sheet

5. VEHICLE DRIVER/OPERATORS:

How would you consider the use of the ACTIVE RUNWAY VEHICLE LIGHTs while operating the vehicle:

Easy to get use to: 1 Hard to get use to: 0

Would you prefer to have a verbal reminder to turn on or off the lights?

Yes: 0 No: 1

My overall opinion of the physical use of ACTIVE RUNWAY VEHICLE LIGHTs:

Acceptable: 1 Unacceptable: 0

Please include any written comments on the back of this sheet

(Note: Only one driver/operator participated)