ANALYSIS - FAA / DOT PUBLICATIONS

HELIPORT LIGHTING FOR THE NEXT MILLENIUM

RESULTS OF FAA / DOT RESEARCH 1991-1998

Introduction

Between 1996-1998 the U.S. Federal Aviation Administration, funded by a Congressional grant, sponsored a series of research studies to identify the newest and best lighting technologies for landing helicopters in the next millenium. Newer commercial helicopter designs feature larger aircraft with significantly increased load capacity, requiring changes in traditional heliport design to accommodate the new take off and landing capabilities heretofore available only to military customers.

Invitations were extended to multiple manufacturers, both within and outside of the U.S., to provide the newest lighting technologies for study, with the goal of improving and/or replacing existing incandescent landing lights for heliports.

Many research studies have been published by the FAA with regard to helicopter pilot activities during night landing operations. The definitive studies of the newest lighting technologies for use during helicopter night landing operations were published in a series of research papers published in 1998.

Summarized below are the results of the seminal research papers on this topic, as well as additional information that has since become available as the result of continuing research and development by Litebeams Corporation.

1. Guidelines for Integrating Helicopter Assets into Emergency Planning, DOT/FAA/RD-90/11, July, 1991, NTIS No. AD-A241479. (FAA Vertical Flight Program ARD-30)

During the decade 1980-1990, the use of helicopters in civilian and commercial operations expanded rapidly. One of the new uses for the helicopters was a greatly expanded Emergency Medical Services [EMS] base, nationwide. This guideline was the first coordinated attempt to consider all aspects of helicopter operations when responding to emergency situations. These guidelines contain "recommendations on how to best integrate helicopters into existing emergency planning in order to provide maximum protection and life saving services in the community."

On p.43 of the Guidelines, the subject of lighting is addressed. The subject, while of utmost importance, was given little attention. The entire statement regarding lighting is as follows:

"Lighting systems are necessary to support night operations, but they are usually only practical to install at permanent heliports. Portable lighting systems are commercially available and can be used at temporary facilities. Flares, vehicle lights, and other light sources are acceptable field expedients as long as they are deployed by trained personnel."

Comments

While extensive descriptions regarding the administrative and practical aspects of responding to an emergency with helicopter support are explored thoroughly, little or nothing is said regarding lighting requirements for night landing operations. A key statement used in this guideline is the permission granted, by this FAA sponsored study, to use "expedient" light sources, all of which have been used for many years. Use of "expedient" light sources, all of which contain a "point source" of light, are capable of inducing spatial disorientation in the pilot. This fact was not scientifically studied prior to 1991. Litebeams, Inc., through its R&D activities first introduced this concept to the Vertical Flight Program of the FAA in 1993-1994.

Additionally, the statement that "portable lighting systems are commercially available," while well-intended, did not mention that none of these lighting sources meet any reasonable standard for landing light effectiveness or safety. The primary reason for this lack of information was due to the fact definitive studies on helicopter landing lights had never been attempted. No information was available, and the researchers had no new information to report, other than what was being used, and had been used by helicopter operators, fire and police departments, etc., for many years.

2. Integrating Helicopter and Tiltrotor Assets Into Disaster Relief Planning, AC No. 00-59, November 13, 1998. (FAA Vertical Flight Program AND-710)

Due to the continuing increase in the use of helicopters in the U.S. and the introduction of the tiltrotor models, the FAA once again visited the subject of integration of the helicopter into emergency situations. The use of the helicopter, including larger aircraft with longer flight capabilities, significantly increased load capacities, improved take off and landing capabilities, and the ability to service multiple communities from a single location, made the updating and reissuing of these guidelines necessary.

The stated purpose of the new AC, "provides general guidance on integrating helicopters and tiltrotor aircraft into disaster relief planning efforts" is basically unchanged from the previous guidelines issued in 1991. There are many more additions to the original paper, presenting multiple administrative and management tools, including guidelines for community involvement.

In Chapter 5, Helicopter and Tiltrotor Landing Areas, Section 51 b. Safety Perspective, the statement is made "Safety is Paramount." Included in this chapter is Section 50 i, "Lighting." Once again the paragraph addressing this key issue is brief, however, it now contains a significant shift from the FAA's previous position as stated in the 1991 report above. The new statement is as follows:

"Lighting systems are necessary to support night operations, but usually, the installation of permanent lighting systems is only practical at permanent landing sites. Portable lighting systems are commercially available and can be used at temporary facilities. Flares, vehicle lights, and other light sources may be acceptable field expedients if trained personnel deploy them under very carefully controlled circumstances. To avoid the temporary destruction of the pilot's "night vision," special care must be taken in the placement and orientation of lighting."

Comments

The FAA, acting under newly published scientific information[1], for the first time has accepted the concept that a pilot's "night vision" can and will be affected by flares, vehicle lights and "other light sources." Current research has verified the fact that a "point source" of light, which emanates from a single intense origin such as an incandescent filament or a road flare, will physiologically affect the retina of the pilot looking at it by causing the appearance of an "after image" in the field of vision, a normal physiologic response to a bright or intense light. The "after image," a phenomenon experienced by all helicopter pilots, has been identified as a cause for the induction of spatial disorientation in helicopter pilots.[1]

In this document it is noted the FAA states expedient light sources can be used by "trained personnel." There is no reference to what "training" is involved, nor how such training can prevent the phenomenon of the occurrence of an "after image" in the helicopter pilot during night landing operations. The apparent disclaimer at the end of the paragraph, "To avoid the temporary destruction of the pilot's "night vision," special care must be taken in the placement and orientation of lighting." is incorrect in that it is not possible to use these light sources in any manner as to completely avoid the creation of an "after image" in the pilot's retina while using these lighting sources during night landing operations. By placement of this statement in the publication, it appears the FAA now openly embraces the concept of the ability of a "point source" of light to cause an after image, and possibly induce spatial disorientation in helicopter pilots.

Listed in Appendix B, "Outline of Elements for a Typical Helicopter and Tiltrotor Integration Plan" are multiple topics. Of interest to this review under section I (one) Establish Goals, subsection A "Guideline Goals," includes (1) save lives. In Section V (five) Landing Areas, subsection A "Selection criteria, no. 8 is "lighting." The FAA clearly recognizes the importance of including proper lighting at the temporary or emergency helicopter landing zone (HLZ).

While the FAA's position has shifted significantly since 1991, mention of the use of cold cathode lighting to completely avoid this problem was not included in this publication. This AC was issued by FAA's AND-710, and published concurrently with four additional research papers supported by AND-710. These four papers are reviewed below.

Heliport Lighting Research Conducted by the Science Applications International Corporation (SAIC) for FAA's AND-710

The following four papers were generated as a result of a research grant to the FAA's General Aviation and Vertical Flight Program under the sponsorship of AND-710, and whose office has since been reorganized. These research reports document the initial phase of an FAA/Industry effort to develop a cost-effective heliport lighting system for Global Positioning System (GPS) helicopter approaches. The reports include new technologies that could be employed in both the civilian as well as the military sectors. The research results add significant information and support for the use of cold cathode lighting technology for use at heliports, and airports as well.

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[1] Schmidt, Reynold T., M.D., Reduce Risk of Inducing Spatial Disorientation Using Physiologically Compatible Ground Lighting, J. Aviation, Space, and Environmental Medicine, Vol. 70, No. 6, June, 1999, pp. 598-603.

3. Evaluation of a Heliport Lighting Design During Operation Heli-STAR, FAA / ND-97/20, June, 1998

The FAA was evaluating different lighting systems that could support precision instrument approaches to heliports using the Differential Global Position System (DGPS). Previous lighting systems developed by the FAA were determined not to be able to be installed at many heliports because of the lack of real estate available.

A prototype lighting system was developed and tested by the University of Tennessee Space institute, and after limited evaluation, was subjected to further evaluation as part of "Operation Heli-STAR," a demonstration helicopter transportation system established in Atlanta, GA during the 1996 Olympic Games. The prototype system used a 20-foot light pipe, green cold cathode lights, and electroluminescent panels.

As part of the heliport approach lighting requirements, "during the course of an instrument approach, the pilot had to perform a series of tasks. At or before the decision waypoint (DWP) the pilot will have to visually acquire the landing environment, transition to a visual scan, and proceed to a safe hover and landing." "The required visual cues are:

- visual acquisition of landing environment
- horizontal reference (horizon)
- lineup
- closure rate
- glideslope
  - relative altitude
  - obstacle clearance
- touchdown."

The results of the study revealed that cold cathode lights provide sufficient illumination of the heliport, making installation of incandescent flood lights unnecessary. The electroluminescent lights did not provide useful acquisition, closure rate, or lineup cues.

Conclusions of the study included:

- The lights appeared to be suitable for VFR and perhaps IFR as well. They appeared to be cost effective and could be arranged to fit typical heliport sites.

- The acquisition cues provided by the prototype lighting system are very strong and appeared to be suitable for most heliports. The color characteristics of the lights were unique to the well-lit city environment and they were easily identified in the midst of a variety of typical city lights. Their unique characteristics also improved the ease with which the pilot maintained visual contact with the heliport environment and significantly increased the amount of information provided to the pilot as compared to conventional incandescent heliport lights.

- In clear weather the cold cathode lights provide ample translational cues to support the transition to a hover, the hover itself, and land tasks, without the use of additional floodlights. (No data were available in anything other than clear weather.)

In the section "Some Recommendations for Further Work" key statements included the following comments:

- Light Pipe

  There were numerous concerns listed including what would be the proper height of the pipe, the proper distance from helipad to place the light pipe, the necessity to have two light pipes, the proper angle of approach and the correct placement of the light pipe to provide useful line-up cues, the concern that improperly installed the light pipe may pose a risk to flight operations. These concerns resulted in the conclusion that use of a light pipe would be very limited, if used at all.

- Electroluminescent Panels

  These units were judged not to be significant enough to warrant any additional research.

- Cold Cathode Lights

  The potential value of the cold cathode light was recognized immediately. The following points were posed as considerations for further study:

  - What is the optimum and minimum number of lights required for proper heliport lighting?
  - Can cold cathode lights be used to provide easily identifiable "lead-in" lights to lead the pilot to the heliport from a point that is farther away from the heliport than the existing visibility? If so, what is the best configuration for these lead-in lights?
  - Can a line of cold cathode lights spaced at specific intervals be used as close rate cue?
  - How well does the light from the cold cathode lights penetrate weather? Is it equal to, better than, or worse than conventional incandescent light?
  - How well do the cold cathode lights perform in the presence of snow, ice and frost? These lights are more efficient (than incandescent lights) because they do not "waste" energy in the generation of heat. This may be a serious disadvantage in cold climates. Will temperature-activated heaters be required? Should these lights only be used in mild climates?

At the end of this limited study, the prototype system was moved to Washington, D.C. for further evaluation. This was carried out at the United States Park Police Heliport in Washington, D.C.

Comments

During this demonstration, the cold cathode lights performed very well, and were unanimously recommended to be considered for further study by all pilots and other FAA personnel involved with this project. The questions posed in this demonstration project Operation Heli-STAR regarding the usefulness of employing cold cathode lights at heliports were answered in subsequent FAA demonstrations and further research conducted by the Litebeams Corporation.

4. Heliport Lighting - Technology Research, FAA / ND-98-1, November, 1998.

This report documents an initial part of a comprehensive program to develop a cost-effective lighting system to support GPS instrument approaches to heliports. This report specifically identifies lighting technologies suitable for use now and those for potential future systems.

The report states the problem to be stated in this manner: "In addition to the constraints of location, the approach lighting array must provide for the following items:

1. Acquisition of the heliport after breaking out of the weather. Although designed for a precision approach, the array should also permit acquisition of the heliport after breaking out from a non-precision approach as well as during visual conditions.
2. Safe Lineup and vertical guidance to the hover point over the helipad.
3. Spatial orientation during the visual segment to include:
   a. Depth perception of the pilot.
   b. Vertical orientation to prevent pilot vertigo.
4. Closure rate on the helipad.
5. Visual cues for final flare and touchdown.

In Section 3, Lighting Technologies, the researchers state in part: "By considering (and taking advantage of) the physiology of the human vision system, effective designs that provide an improvement over the present state-of-the-art can be produced. Perceptions of brightness, movement, color, contrast, and depth should all be involved to the greatest "scientific" extent possible in developing a suitable lighting system."

The following lighting systems technologies were evaluated, and their advantages and disadvantages summarized:

- Electroluminescent Lighting
- Visible Lasers
- Light Pipe or Light Bar
- Strobe Lights
- High Intensity Strobe Beacon for Acquisition
- Flush Surface Lights
- Flood Lights - Surface Mounting
- Perimeter Lights
- Pulse Light Approach Slope Indicator (PLASI)
- Cold Cathode Lights

While many of the above technologies offered valuable advantages, most had inherent disadvantages that outweighed their usefulness for wide deployment. The comments on cold cathode lights appeared quite promising:

"Advantages:

- Low initial cost
- Can operate using battery power
- Portable installation

- Does not degrade the pilot's night vision

Disadvantages:

- Low intensity"

In Section 5, Conclusions (Criteria for Test), an in-depth discussion of the key factors necessary to include if additional testing is carried out included the following factors:

- Acquisition
- Approach (line-up)
- Approach (glideslope)
- Closure (rate)
- Landing (flare, hover and touchdown)

Two specific final recommendations were made by the researchers:

1. "The possibility of enhancing the proposed lighting systems with the application of color should be explored.

2. In order to enhance the closure rate cues, the possibility for emphasizing pad texture by special marking (that is compatible with the installed lighting system) should be explored."

Comments

For the first time in its history the U.S. FAA officially addressed the physiology of the human visual factors which are of key importance for the helicopter pilot's operational requirements. The statement "By considering (and taking advantage of) the physiology of the human vision system," indicates that Litebeams' research contribution to the study and understanding of one cause of spatial disorientation (a "point source of light") was accepted as a valid percept / concept.

A second major point made by Litebeams research efforts focused on the "color" (nanometer range) of the light required to offer superior performance in night landing operations. The recommendation to explore the "color" of the landing light represents a significant step forward by the U.S. FAA in reaching the goal of developing the proper helicopter landing light. This recommendation supported the independent research conducted by Litebeams Corporation regarding this important physiologic factor of human visual requirements during night operations.

The second recommendation regarding targeting a light source which may emphasize helipad texture was another important feature that was successfully addressed by Litebeams cold cathode lights in a later project in this series.

5. Heliport Lighting - Configuration Research, FAA ND-98-2, November, 1998.

This report develops a methodology for researching and designing heliport lighting systems with particular emphasis on lighting system configurations. The report also catalogs lighting system components, subsystems, and systems identified to date. The main objective of this effort was to develop a basis from which to form a more efficient lighting system for instrument approaches to heliports using the Global Positioning System (GPS).

Review of existing heliports revealed that heliports of many different designs are found in a large variety of environments and simplification is very difficult. In addition, this study showed that the environment can have a significant effect on the relative importance of each lighting cue. Under clear daylight conditions, all the required visual cues were generally available. Under reduced visibility conditions, including darkness, the availability of the required cues varied with the environment. In the absence of a natural horizon, often encountered in approaches to very dark areas, the horizon cue may be the most critical for the designer to supplement. In an urban environment, the large number of lights provides a relatively high ambient light level and a strong natural horizon. In urban environments, obstacles may mean that glideslope cue is the critical lighting cue.

For purposes of this study, heliports were grouped into one of three groups:

- Rooftop
- Ground-Level / Off-Airport
- Ground-Level / On-Airport

Required lighting cues were identified as follows:

- Visual acquisition of the landing environment to include:
  - Identification as a heliport
  - Early acquisition in conditions of reduced visibility
- Lineup
- Closure rate
- Horizontal reference (horizon)
- Glideslope, that provides:
  - Relative altitude
  - Obstacle clearance
- Touchdown, which includes:
  - Transition to hover and hover position cues
  - Hover altitude and hover altitude rate cues

The report reviewed present conventional lighting and found that visual cues can be provided by a variety of methods. The research revealed lighting systems often provide multiple cues. Some of these cues are weak and may not be sufficient to fully satisfy a specific requirement. Also, some of these lighting systems may have undesirable attributes, such as poor maintainability, high life-cycle costs, a requirement for excessive real estate, interference with other lighting systems, interference with pilots' night vision, a tendency to cause pilot disorientation, or they may introduce a potential obstruction hazard. A detailed analysis is provided in Table 1, p.14 of the report.

- Qualitative characteristics of heliport lighting were examined carefully. The key qualitative aspects were summarized as follows:

  - Discrimination: the range at which the display can be discriminated from other displays
  - Intelligibility: can the display be understood?
  - Interpretability:
    - How difficult is the display to use?
    - Does the pilot have to interpret the displayed information or is it intuitive?
  - Responsiveness: is there time lag in the displayed information?
  - Simplicity
  - Visual Compatibility:
    - Is the display compatible with other aspects of the pilot's total visual task?
    - Is it much brighter or dimmer than ambient lighting conditions?
    - Is the display compatible with each segment of the approach?
  - Based upon the results of research to date, workload is a qualitative characteristic that should be included in the evaluation of a lighting system or display. Workload is dependent on some of the quantitative measures, such as resolution and sensitivity, as well as some of the qualitative measures, such as interpretability and intelligibility. There are measures to quantify workload, but a typical pilot response to high workload is fixation on one display or task, or the dropping of one display or task from the pilot's scan.

"Most lighting systems used to date have employed incandescent lights in one form or another. Two exceptions that come to mind are Xenon flash tubes and electroluminescent (EL) lighting, although there may be others. The lighting at aviation landing sites has been primarily incandescent. Recent research efforts have attempted to review alternative lighting technologies. Some have been around for years and have not previously been used in the aviation field, and some are relatively new technologies that have only recently become cost effective. A number of these alternative technologies show promise as potential components of heliport and vertiport lighting systems."

It was not possible for the researchers to thoroughly evaluate all of the lighting components and subsystems identified in the report. The lighting technologies were grouped into three major groups: (1) point source lights, (2) diffused lighting technologies, and (3) retroreflective markers.

- Point Source Lights

  "Point source lights are characterized by a very bright point of light typically generated by a glowing filament or arc. These lights are most often shielded from direct view by a pilot because of the negative impact on night vision adaptation and because of the "after-image" effect. If a bright light is viewed directly, it often leaves an after-image on the retina that continues to be seen for several seconds or longer. If incandescent lights are not shielded, they are typically filtered with color lenses, or directed away from the pilot. Exceptions to this are approach lighting systems where hundreds of 300-watt incandescent lights are aimed at the pilots of approaching aircraft."

Point Source Lights reviewed included:

- Light emitting diodes
- Lasers

- Diffused Lighting Technologies

  Diffused lighting technologies reviewed included:

  - Light Pipe
  - Cold Cathode Lights
  - Electroluminescent (EL) Lights
  - Fiber Optics

- Retroreflective Markers

Each type of light source was described briefly. The description of cold cathode lights was very complete, and is as follows:

"Cold cathode lights also provided a light that is very different from the incandescent "point source" lights found in urban environments and from those commonly used in aviation lighting. These lights use a gas filament that tends to disperse the light instead of a hot metal filament that burns an after-image onto the retina. Consequently, the lights leave very little, if any, after-image even after looking directly at the lights. The cold cathode lights are effectively monochromatic, and the lights tested in a prototype heliport lighting system had a greenish hue with a predominant wavelength of 512 nanometers. This wavelength (color) was selected to maximize the efficiency of the eyes' rods and cones at the low light levels encountered in nighttime aviation (reference 6). Since these lights can be viewed directly without adverse effects on pilot vision, they were used to outline the perimeter of the landing pad and to provide illumination of the landing surface. The cold cathode lights had an added advantage in that they did not require dimming as the pilot got closer to touchdown. Thus, the same light intensity setting was used to provide long-range acquisition cues and touchdown cues.

The cold cathode lights have advantages in power consumption and reliability. The cold cathode lights convert 65 percent of their power to light while 35 percent is lost to heat. Incandescent lights convert only 5 percent of their energy to light and 95 percent is lost to heat. This is an efficiency factor increase of 13. The cold cathode lights also have a considerable maintenance advantage over conventional incandescent lights. The cold cathode lights have an approximate lifetime of 20,000 to 40,000 hours compared to a lifetime of about 2,000 hours for the incandescent lights."

- Lighting Configurations

Lighting configurations were explored in great detail. An listing of the considerations reviewed is as follows:

- Acquisition
  - Acquisition Cues
  - Acquisition Design Considerations

- Line-up
  - Line-up Cues
  - Line-up Design Considerations
- Glideslope
  - Glideslope Cues
  - Glideslope Design Considerations
  - Horizon
  - Horizon Cues
  - Horizon Design Considerations
- Closure Rate
  - Optical Expansion Rate
  - Optical Flow Rate
  - Optical Edge Rate
  - Use of a Glideslope Indicator to Interpret Closure Rate Cues
  - Alternative Closure Rate Cues
  - Closure Rate Design Considerations
- Touchdown
  - Touchdown Cues
  - Touchdown Design Considerations

In the discussion of Touchdown Cues, Section 7.6.1 in the report, the following paragraph is of importance:

"Point source lights, used to outline the perimeter of a landing pad, do not adequately illuminate the texture of the landing surface. If point source lights are made bright enough to provide useful approach cues, they are too bright to be useful as a hover aid. The brightness of the point source prevents the pilot from seeing the surrounding texture and leaves an annoying and often disorienting "after image" in the pilot's view. Radio control of lighting intensity is often used to mitigate this problem although it adds to the pilot workload. (Cold cathode lights have also shown promise in solving this problem)."

In Section 8.0 Heliport Lighting Systems, Section 8.2 Operation Heli-STAR was discussed, and a summary of key elements which were learned and published previously in a report by these researchers in June, 1998, were restated. It is significant that the researchers felt compelled to repeat, to re-emphasize, and to add some information not published previously in the June, 1998 report. Important statements include the following excerpts:

- "<u>Acquisition</u>. The prototype system provides easy acquisition of the landing environment at ranges out to 20 miles in clear weather. Identification of the heliport is provided by the unique color (green) and the unique character of the cold cathode lights and light pipe. The same intensity setting that provides acquisition cues out to 20 miles does not adversely affect pilot vision in a hover over the pad. No dimming is required."

- "<u>Closure Rate</u>. In clear weather, the high ambient light levels and the well-defined landing zone provided adequate closure rate cues."

- "Touchdown. In clear weather, the cold cathode lights provided ample translational cues to support the transition to a hover, to hover itself, and landing tasks, without the use of additional flood lights."

The report concluded that the most promising candidate lighting components and lighting systems should be tested in a variety of operational environments and under a variety of different weather conditions at different times of the year. The report states also that "if possible, test locations should be chosen that allow a wide variety of industry helicopter pilots to participate in this flight testing."

Comments

This report provides an extensive analysis of the factors a design engineer is required to analyze when configuring a heliport. It is evident that multiple, complex issues have to be carefully considered and planned for. The report clearly emphasizes the reality that all heliports are not the same, and that each to has to be configured in its own setting for proper planning purposes.

What this report does do is to review the existing heliport lighting systems and to compare them to selected newer lighting technologies, weighing their advantages and disadvantages regarding the complexity of issues facing the design engineers.

Taking the information provided by this report in its totality, cold cathode lighting is very favorably reviewed, and key features of the cold cathode lighting technology are advanced for consideration. These features include:

- Not a "point source" of light - a critical safety factor for prevention of pilot disorientation. The cold cathode lights were determined to be able to be viewed "directly" by the pilot without adverse effects on pilot vision.

- No Dimming Requirement - the lights have a major advantage in that they do not have to be dimmed (decrease the brightness) for the pilot during landing operations. The same light setting (light intensity/brightness) can be used for both long-range acquisition cues as well as for touchdown cues, in contrast to incandescent lights.

- Cost effectiveness - when compared to the incandescent light the cold cathode lamp is truly superior in this aspect.

- Visibility - the pilot is able to "acquire" or view the cold cathode light from at least 20 miles in clear weather, a major accomplishment. This was stated to be due to the "unique green color" within the nanometer range of 512 nm. Litebeams researched and developed this light for this specific purpose.

- Closure Rate - in clear weather conditions the light provided excellent ambient light levels that defined the HLZ clearly and provided "adequate closure rate cues," a very significant necessity for safe approach and landing operations.

- Touchdown - in clear weather the cold cathode light provided "ample translational cues" which allowed the pilot to safely transition from flight to hover, from hover to landing "without the use of additional flood lights." Thus, the cold cathode lights illuminated the helipad to such an extent they allowed for safe operating procedures without the necessity for supplying auxiliary lighting, i.e., floodlights.

None of the other lighting sources reviewed possessed all of these characteristics in a single light source.

6. Heliport Lighting - U.S. Park Police Demonstration, FAA ND-98-4, November, 1998.

This report reviews a second demonstration project in the initial phase of an FAA/Industry effort to develop a cost-effective heliport lighting system for Global Positioning System (GPS) helicopter approaches. This demonstration utilizes new technologies that could be of use as part of a heliport lighting system as well as military lighting systems that could be useful if optimized for civil heliport applications. This report also documents previous research that has attempted to determine what helicopter pilots need in the way of visual cues for heliport approaches at night or in poor weather.

- Background

  "This demonstration/evaluation of prototype heliport lighting system components was part of a larger effort to research the requirements for lighting systems to support precision approaches to heliports. The heliport/vertiport precision instrument approach lighting system must provide or enhance the visual cues necessary to safely acquire the landing environment, decelerate, and land during the visual (final) segment of an IFR precision approach. This visual segment of a helicopter instrument approach is very different from a fixed-wing visual segment. The major difference is the requirement for the helicopter pilot to decelerate to a stop while maintaining a constant glide path.

  The lighting system, in addition to providing or enhancing cues for heliport acquisition, lineup, horizon, glideslope, and touchdown, must provide the pilot with strong closure rate cues. In comparison with airport lighting systems, all of this must be accomplished by lighting equipment located in a very limited physical space. Based on the success of a VFR prototype system demonstrated in conjunction with Operation Heli-STAR, it was decided to continue the demonstration/evaluation at the United States (U.S.) Park Police Heliport in Washington, D.C. "

  The report states in part: "Well-designed lighting systems (at heliports) can provide "credits" that reduce required visibility minimums for instrument flight rules (IFR) approaches. The approach lighting system should "reach out" from the landing area, assuring the pilot that a landing site is ahead, and visually guide a pilot to this landing site."

  "Flight tests conducted for the Federal Aviation Administration (FAA) by the University of Tennessee Space Institute (UTSI) and Science Applications International Corporation (SAIC) identified new technology lighting systems with great potential to meet the requirements for IFR approaches to heliports. Initially, these lights were briefly evaluated in a downtown environment.

The color characteristics of the cold cathode lights were so unique to the well-lit city environment that they were easily identified in the midst of a variety of traditional city lights. These unique characteristics also improved the ease with which the pilot maintained visual contact with the heliport environment (simulated during these tests) and significantly increased the amount of information provided to the pilot as compared to conventional incandescent heliport lights. These tests were sufficiently promising that the FAA decided to evaluate these lights in an operational city environment. The system was modified slightly and installed at the United States (U.S.) Park Police Eagles' Nest Heliport in Washington, D.C."

- U.S. Park Police Aviation Section - Eagles' Nest Heliport, Washington, D.C.

  "The U.S. Park Police Aviation Section is currently the only public service aviation provider within the District of Columbia. Its missions include aviation support for law enforcement, medical evacuation, search and rescue, high-risk prisoner transport, and Presidential and dignitary security. The U.S. Park Police have provided accident-free aviation services to our Nation's Capital for over 25 years."

- Components of Prototype System Installed at U.S. Park Police Heliport

  The prototype system that was installed at the U.S. Park Police Eagles' Nest Heliport (not all at the same time) are listed below:

  - laser guidance
  - high intensity strobe beacon
  - light pipe and cold cathode lighting system
  - glideslope indicator that used the "alignment of elements" concept

At the Eagles' Nest Heliport of the items surveyed prior to testing included the following items: acquisition, line-up, glideslope, horizon, closure rate, and touchdown. "By far the largest challenge in operations in the Washington DC area is the visual acquisition of the heliport. No rotating beacon is installed at the heliport. The amber perimeter lights are difficult to separate from the variety of amber and white lights in the city environment. Typically, the heliport is identified and then the perimeter lights are located in relation to the entire heliport."

- Lighting Technologies Evaluated

  The lighting technologies evaluated were similar to those evaluated at Operation Heli-STAR, described above, and included the following:

  - Point Light Sources
    - Lasers
    - High Intensity Strobe Beacon
  - Diffused Lights
    - Light Pipe
    - Cold Cathode Lights

Each of the above technologies was reviewed in respect to their (1) statistics; (2) advantages; (3) disadvantages; (4) current applications, and (5) potential aviation applications. While the information presented appeared to contain more factual information than in previous publications, the conclusions that could be reached from the data listed in this report were similar, if not identical to those which could be made from previous reports. While some of the descriptions contained additional factual material, the section on cold cathode lighting was expanded significantly in Section 5.2.2 Cold Cathode Lights. Due to the importance of this information, it is reproduced as stated in this report below:

- Cold Cathode Lights

"Manufactured by Litebeams, Incorporated, Burbank, CA, cold cathode lights are not new technology. they have been used as obstruction lights for 30 years. The lights work on the same principle as a neon sign. The lights generate an arc in an inert gas in a glass tube coated with metal compounds. Mercury is used to help initiate and sustain the arc. The combination of gas and metal coating determines the color. cold cathode lights produce a more uniform light output than the high intensity concentration that is typical of an incandescent light. consequently, cold cathode lights leave no after image on the retina, even after looking directly at the light. An after image is created by the slow recovery of the retinal neurons (rods and cones) following exposure to concentrated light. Since the light emitted from a cold cathode light is more evenly distributed across the retina, the retina recovers more quickly. This is important in aviation applications, especially for helicopter operations, because the cold cathode lights allow the pilot to see the ground around the light and not just the light itself.

Statistics:

Power: 25 watts (sized to match light output of standard 69-watt incandescent aviation lamp

Efficiency: approx. 65 percent of energy converted to light, 35 percent lost to heat (compared to 95 percent to heat and 5 percent to light for a typical incandescent lamp)

Color: color can be controlled without the use of filters

Life: 20,000 to 40,000 hours (compared to 2,000 hours for a typical incandescent lamp

Operating Temperatures: Lamp burns cool; electrodes reach 3000 degrees F.

Advantages:

Monochromatic in a wide variety of colors
Does not leave an after image on the retina
Low initial cost
Long life
Low power consumption
Operates on battery or 120 VAC power
Compatible with night vision devices
Can be operated as a strobe or steady burning light

Disadvantages:

Medium to Low intensity only
Requires special intensity level controls (cannot vary intensity by varying input voltage)
Requires a ballast to condition input power

Ability to melt ice and snow in winter has not yet been demonstrated
Current Applications:
Obstacle lighting
Potential Aviation Applications:
Runway lighting
Taxiway lighting
Heliport lighting (acquisition, line-up and approach applications)"

- Additional Comments - Cold Cathode Lights

  - "The cold cathode lights illuminate the surround ground providing the pilot with "texture" cues required to sense movement of the helicopter."

  - Section 6.3.4 Human Factors - "The distinctive blue-green color of the cold cathode lights is very easily identified. The color was selected by UTSI (University of Tennessee Space Institute) because it maximizes the ability of the eye to detect the light. This is because the blue-green wavelength (512 nanometers) is equidistant between the best frequency for the rods and the best frequency for the cones in the eye. Additionally, the cold cathode lights use a gas filament that tends to disperse the light leaving no after image on the retina. By comparison, the hot burning metal filament (point-source light) of an incandescent light will burn an after image onto the retina that causes a reduction in night vision. the pilot can see the cold cathode lights from miles away in good weather and then view the lights directly while at a hover without any loss of night vision and without an dimming required."

  - Section 7.3.2 Evaluation of Results - "the cold cathode lights could also be easily seen and identified at ranges of at least 3 miles yet did not need to be dimmed during an approach or in a hover over the lights. The pilots particularly liked the distinctive blue-green color of the cold cathode lights. this color was very distinctive when contrasted with the surrounding city lights. The cold cathode lights provided adequate illumination of the heliport surface. This illumination of the ground provided microtexture to the pilot, which allowed the pilot to control altitude and hover."

- Conclusions

  One conclusion stated in this report was: "As an indication of the positive impression of the prototype lights, the U.S. Park Police helicopter unit is interested in a permanent installation of cold cathode lights at their heliport."[2]

Comments

- This demonstration project was the most extensive and thorough of the demonstration projects conducted during this testing sequence by the U.S. Federal Aviation Administration in cooperation with the University of Tennessee's Space Institute and private industry.

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[2] Subsequent to this demonstration and issuing of the report, the U.S. Park Police did purchase and install permanent cold cathode lights identical to those in used in the demonstration project.

- The information gained from this demonstration project fully and completely supported the usefulness of cold cathode lights for use at heliports.

- The information presented from the efforts of this project were similar, if not identical to the data collected from Operation Heli-STAR demonstration project conducted six months previous to this study.

- While other light systems had their positive attributes, i.e., lasers, high intensity strobe beacon, light pipe, LED's, and fiber optic light systems, the cold cathode light system emerged as the most cost effective, practical new technology to replace the incandescent lighting now in use.

- The cold cathode's unique blue-green light was proven superior in all tests for pilot acquisition, hover and landing operations. The light provided pilots with visual contact with the helipad surface allowing discrimination of the microtexture providing the pilot with the appropriate visual cues for translational movement and proper evaluation of the helipad for safe landing maneuvers.

- It is not necessary to alter the brightness (intensity) of the cold cathode light during approach and landing operations. No visual distortion or spatial disorientation is induced in the pilot by visual contact with the cold cathode light. The light aids the pilot during the final seconds of the landing process by providing an excellent soft illumination of the helipad or helicopter landing zone (HLZ) surface while allowing the pilot to detect simultaneously unwanted obstacles/hazards at or around the HLZ.

- While this research paper indicates the cold cathode light is only being used for obstacle lighting, this information is incomplete. Litebeams Corporation has its entire line of cold cathode portable aircraft landing lights being used for temporary runway, taxiway, and heliport lights by customers, world wide. The users include civilian and military units. The lights meet the specifications of the FAA's AC 150/5345-50 Specification for Portable Runway and Taxiway Edge Lights.[i]

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[i] **Since completion of this series of demonstrations, Litebeams Corporation has conducted additional research and development to improve the performance of its cold cathode aviation light product lines. Litebeams cold cathode lights recently have been tested to 98-100 candelas, and hence qualify as high intensity lights. In addition, recent testing has demonstrated excellent operation of the lights between -10^{o}F to -20^{o}F. Lower operating temperatures will be achieved shortly due to innovations in Litebeams technology. To date, collection of snow and ice on the lens during winter conditions has not been a problem.**