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ELECTROLUMINESCENT LIGHTING AND OTHER TECHNIQUES FOR IMPROVING NIGHT VISION GOGGLES COMPATIBILITY WITH COCKPIT DISPLAYS

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SUMMARY

Standard night lighting for most aircraft cockpits results in a lighting configuration that is not compatible with the use of night vision goggles. One specific example discussed in this paper is the US Air Force PAVE LOW III helicopter; a modified version of the HH-53H. Both wavelength and geometric light control techniques were developed and applied to this cockpit to make it compatible with the night vision goggles. A combination of light control film (3-M micro-louvre), color filters, infra-red blocking filters, electroluminescent light and anti-flare baffles were used to successfully retrofit the cockpit for night vision goggle use. In addition, some of the techniques are applicable to reducing windscreen reflection, thus, improving unaided night vision through the windscreen.

1. INTRODUCTION

The work described in this paper was done in support of the US Air Force PAVE LOW III helicopter. The PAVE LOW III is a modified version of the HH-53H helicopter (see Figure 1). The modifications included

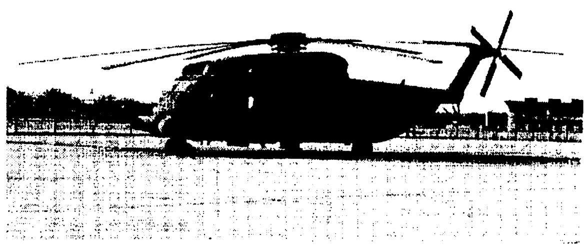

Figure 1. PAVE LOW III helicopter

a moveable infra-red imaging sensor mounted to the forward nose section and a radar altimeter to allow night and adverse weather low level flight. These and other modifications were done to facilitate the helicopter's night/day air rescue mission. After delivery of the initial aircraft, a decision was made to use night vision goggles to obtain lower night flying capability. Unfortunately, the cockpit lighting and displays were not originally designed for night vision goggle compatibility. The authors were requested to assist in developing techniques to reconfigure the cockpit lighting to alleviate this problem. The desired night flying configuration was for the pilot to wear the night vision goggles for piloting the aircraft while the copilot did not wear goggles so that he could monitor the aircraft instruments and the infra-red video display. In this configuration it was impossible to achieve sufficient lighting for the copilot to do his job while allowing the pilot to also do his job of viewing outside with the night vision goggles. Infra-red light from the incandescent lighting system and console displays caused reflections in the windscreen and other scattered light that made it impossible for the pilot to see outside with the goggles, even when the lights were turned so low that the copilot could barely see to do his job. The objective of this effort was to develop light control techniques that could be easily retrofit to the cockpit and would allow both crew members to do their assigned jobs.

2. LIGHT CONTROL TECHNIQUES

Basically, the light control techniques that were employed fell into two general categories: wavelength control and geometric control. The wavelength control techniques involve the judicious use of various filters to separate the visual sensitivity spectrum from the night vision goggle sensitivity spectrum. The geometric control involves the use of techniques to direct the light so that it only goes in desired directions.

2.1 Wavelength Control Techniques

The US Army AN/PVS-5 night vision goggles (NVGs) are sensitive to light in the spectral region from about 350nm to 900nm. This includes the visible wavelength region of '30nm to 700nm as well as a small portion of the near infra-red. Incandescent lighting normally used in aircraft cockpits for night operations emits considerable energy in this near infra-red band from 700nm to 900nm. The result is that reflections in the aircraft windscreen of instrument lights, that are annoying to the unaided eye, render the NVG's nearly useless.

The approach taken by the authors was to use electroluminescent lighting and color filters to separate the night lighting required for unaided vision from the sensitivity region of the modified NVGs. This was done by turning off all possible incandescent lamps and floodlighting the instrument panels with blue-green filtered electroluminescent light. Infra-red transmissive red filters were placed over the NVGs to reduce their sensitivity to the blue-green light. Since the electroluminescent light emits essentially no energy in the infra-red, it makes an ideal light source for the NVG compatibility. Figure 2 shows the emission spectrum of the electroluminescent light used before filtering (upper curve) and after a blue-green filter was used to "shape" its wavelength output. Similarly, Figure 3 shows the

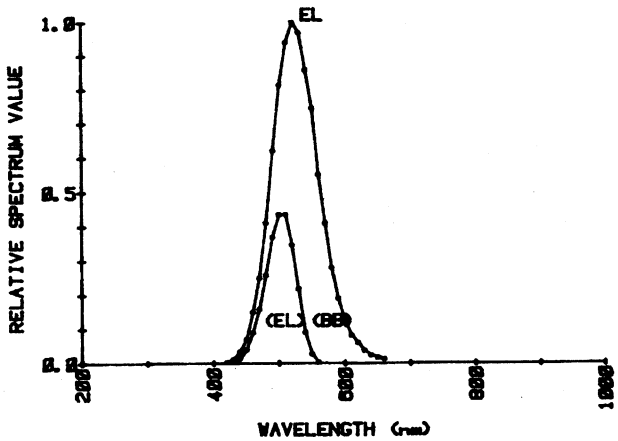

Figure 2. Emission spectrum of the yellow-green electroluminescent lights without blue-green filter (EL-upper curve) and with filter (EL-BB-lower curve).

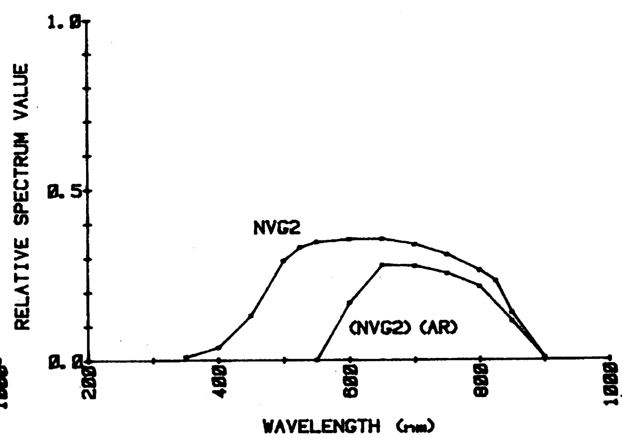

Figure 3. Relative sensitivity spectrum of the US Army second generation might vision goggles without filter (NVG2-upper curve) and with a red/infra-red transmissive filter (NVG2-AR-lower curve).

sensitivity of the so-called second generation NVGs before (upper curve) and after wavelength filtering. The result (see Figure 4) is that the two wavelength distributions have very little overlap.

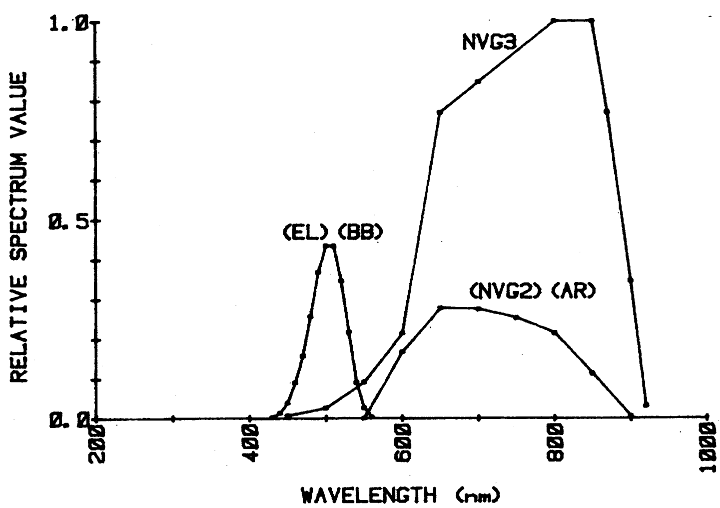

Figure 4. Comparison of emission and sensitivity spectra for the electroluminescent light with blue-green filter (EL-BB), the US Army second generation night vision goggles with red/infra-red filter (NVG2-AR) and the US Army third generation night vision goggles without filters (NVG3). Note that the spectra for the filtered EL light and the filtered NVG2s barely overlap.

This means that the NVGs can easily "see through" any spurious windscreen reflections that occur from the electroluminescent lighting.

The PAVE LOW III cockpit has two 5" by 7" video displays for presenting infra-red imagery (see Figure 5).

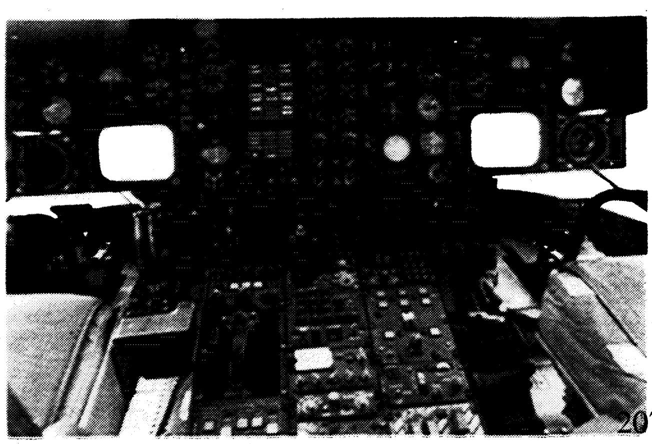

Figure 5. Front instrument panel and center console of the PAVE LOW III helicopter. Note the video displays located in front of the copilot seats. Light switches and instruments on the center console are a major source of windscreen reflections.

These displays use a P-4 white phosphor and are normally covered with a red filter for night flying. This results in incompatibility with the use of the NVG's since the red filtered displays are filling the cockpit with red light to which the NVGs are sensitive. Figure 6 shows the overlap with wavelength distributions for the display (P-4) and the unfiltered NVGs. By using the same combination of blue-green filters

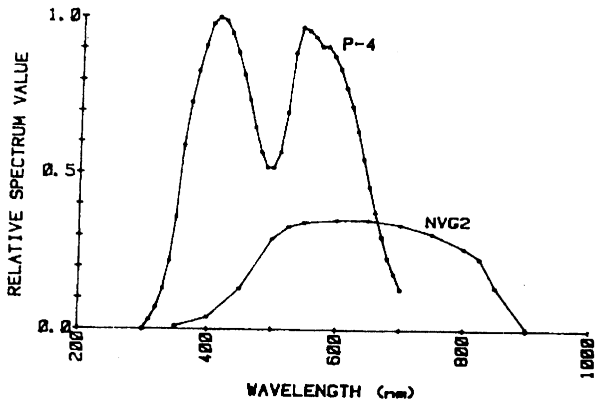

Figure 6. Comparison of the emission spectrum of the P-4 phosphor on the video displays and the sensitivity spectrum of the night vision goggles (NVG2). Note the considerable overlap of these two curves out to and including the red region of the spectrum (600-700nm) used for conventional red light lighting.

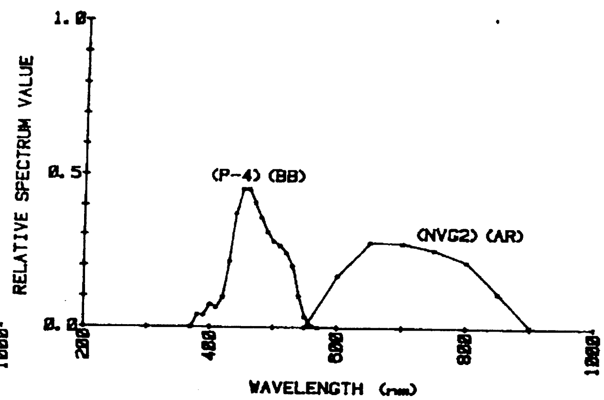

Figure 7. Comparison of the same two spectra described in Figure 6 but with appropriate filters placed over the display and the NVGs. Note that there is very little overlap between the two distributions.

described previously, it is possible to separate these two wavelength distributions as shown in Figure 7.

There has been some concern expressed about using blue-green lighting and blue-green filters over the display from the standpoint of its effect on the dark adaptation state of the crew members. It should be noted that the crew members that are not wearing the goggles are focussing their attention on the displays and instruments inside the cockpit. It is, therefore, not necesaary for them to be absolutely dark adapted.

Some instrument lights in the cockpit cannot be turned off. The incandescent infra-red light from several of these lights located in the center console (see Figure 5) resulted in direct reflections in the windscreens. To reduce this adverse effect, these lights were covered with an infra-red blocking material that transmitted most of the visible light. This thin plastic material was originally developed for laser safety goggles but worked very well for this application.

2.2 Geometric Control Techniques

Geometric control was accomplished by simply devising means to direct the instrument lighting in desired directions and blocking it from going in undesired directions.

Many instrument lights consist of an incandescent lamp with a diffusing (sometimes colored) filter over the top with a printed legend on it. This diffusing filter distributes the light in all directions, including toward the windscreen. This results in unwanted reflections of these lights in the windscreen. To combat this problem, a product developed by 3-M Corporation called micro-louvre was used to direct the light away from the windscreen. The micro-louvre is a relatively thin plastic material with extremely small slats or louvres imbedded within. It is available with different slat spacing and orientation. It acts very similarly to a miniature venetian blind.

By selecting the appropriate angle of micro-louvre, it is possible to direct the instrument lights toward the aircrew members and away from the windscreen. This allows full viewability of the instruments and displays by the aircrew members but prevents the light from reaching the windscreen and causing a reflection. Figure 8 shows a laboratory example of this effect for visible light. A back illuminated lettered text in the lower portion of Figure 8 was positioned so that a reflection of it could be seen in a thin piece of clear plastic (windscreen) in the upper portion of Figure 8. A small section of micro-louvre set for a 30^{o} angle was placed on the lettered text so that it directs the light toward the louvres and away from the windscreen. Note that it is difficult to see through the windscreen in the area of the reflection except for the rectangular area covered by the micro-louvre. This technique was used considerably throughout the PAVE LOW III cockpit.

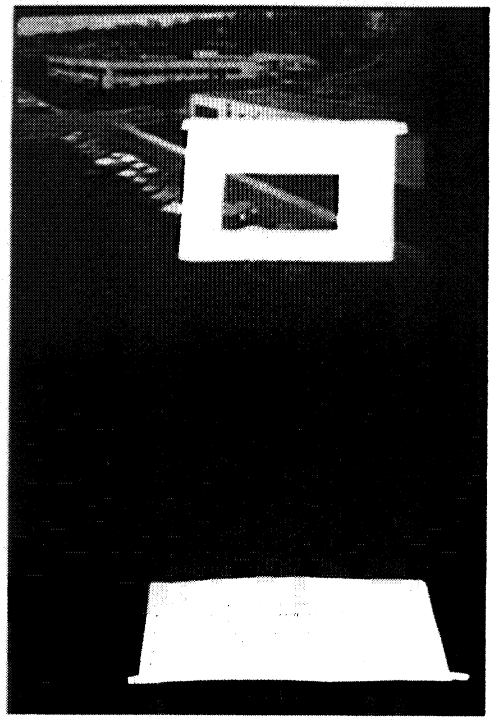

Figure 8. Laboratory example of the effectiveness of the 3-M Corporation micro-louvre in directing the light from display screens. The lower part of the photograph shows a back illuminated screen with a rectangular piece of micro-louvre placed over the center of the text. The upper part of the photograph shows the reflection of the text in a sheet of plastic simulating a windscreen. A background scene consisting of buildings and cars in a parking area is easily visible except for where the display reflection washes it out. But the area of the text display covered by the micro-louvre does not reflect in the windscreen, permitting easy visibility of the outside scene. Note also that there is no detrimental effect caused by the micro-louvre in reading the text display in the lower portion of the photograph.

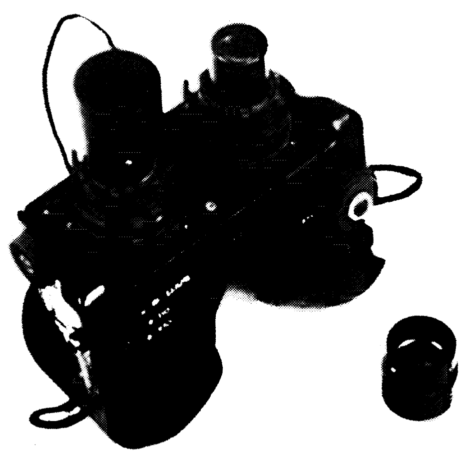

Figure 9. US Army second generation night vision goggles with anti-flare baffle (lower right).

A second geometric control technique was to attach a small flare baffle to the objective lens housing of the night vision goggles. These baffles (see Figure 9) reduced the flare produced in the objective lens caused by relatively bright light sources outside of the field of view of the goggles. The baffles also made a convenient mounting location for the red/infra-red filters previously mentioned.

The final light control technique was a recommendation that the flight crews wear black or dark infra-red absorbing clothing and, to a maximum degree, the interior of the cockpit be painted with a black-matte finish. The geometry of the cockpit was such that the pilot and copilot could see a reflection of their knees in the windscreen. In other cockpit configurations, i.e., C-130 aircraft, many of which have a cream colored control column, the light colored objects are clearly reflected in the windscreen at low (one quarter foot-Lambert) ambient light conditions. By reducing the stray light in the cockpit and minimizing the reflectance coefficient of the clothing, this reflection source was considerably reduced.

3.0 EVALUATION OF LIGHT CONTROL TECHNIQUES IN THE PAVE LOW III HELICOPTER COCKPIT

All of the previously discussed light control techniques were installed in the cockpit of a PAVE LOW III helicopter for evaluation. Several instructor pilots viewed the modified cockpit and provided a critical assessment. In general, the comments concerning the modifications were extremely positive. Reflections in the windscreen were greatly reduced, even for the visible spectrum, which improved outside visibility for both the copilot (without the goggles) and the pilot (with the goggles). It was not possible to make photometric measurements of the improvements because of the relatively low light levels involved. However, photographs were taken to document the improvements. Figure 10 shows a picture taken through the night vision goggles of the forward field of view of an unmodified cockpit. The lower row of lights are runway lights seen outside. The collection of lights in the upper portion of the picture is from reflections

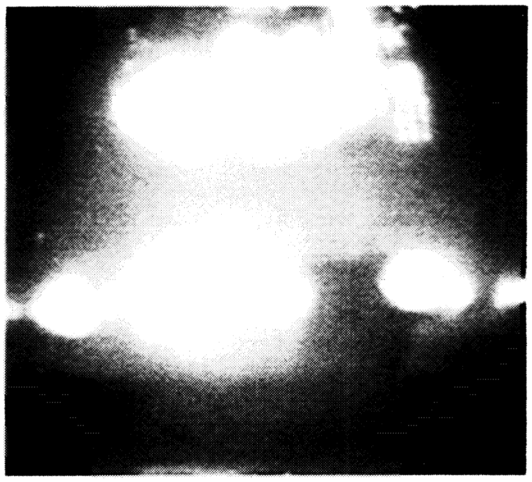

Figure 10. Photograph taken through the night vision goggles of the forward field of view seen from an unmodified PAVE LOW III cockpit. The lower row of lights are runway lights from a nearby airstrip The upper secton of lights are reflections in the windscreen from the center console. Note that some of the reflections are as intense as some of the runway lights.

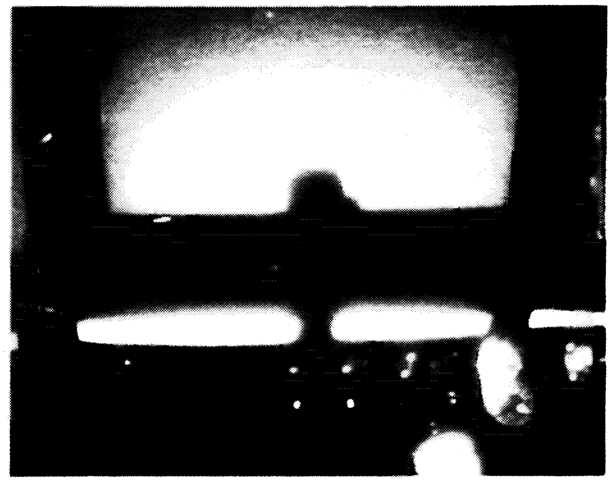

Figure 11. Photograph taken through the night vision goggles of the light control modified cockpit Note the absence of reflections except for two minor light leaks reflected from the center console. The rectangular strips of light toward the lower part of the photograph are the electroluminescent lights mounted under the glare shield to illuminate the forward instrument panel.

of center console instruments in the windscreen. Note that the intensity of some of these reflections is comparable to the outside runway lights. For comparison, Figure 11 shows the forward view out of a helicopter cockpit that was modified with the light control techniques. Except for two small reflections caused by inadequately covered instrument lights, the view is clear of unwanted reflections. With the reflections gone, the night vision goggles' gain was increased to a level that it was possible to see the sky glow of a nearby city that was masked in the view from the unmodified cockpit.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The light control concepts discussed in this paper were quite successful in providing lighting conditions compatible with the use of night vision goggles. However, several problems still exist in developing materials and installation techniques that will be suitable for aircraft retrofit. It is extremely difficult to locate electroluminescent floodlighting to adequately illuminate all areas requiring illumination without involving expensive modifications to the cockpit lighting. It is considerably easier to provide for electroluminescent lighting when designing the original cockpit than to devise acceptable ways to retrofit this lighting in the cockpit. The micro-louvre does an excellent job of directing the light as desired but it is unfortunately cast in a relatively soft plastic that is susceptible to both warping from heat and loss of effectiveness from scratching and wear. It would be highly desirable to develop a tougher version of the micro-louvre, but as of this writing, there are no known efforts in effect to do this. The laser safety material used for blocking the infra-red radiation from critical incandescent instrument lights needs to be improved to pass more visible light in the red region (630nm) and to block the light better toward the far red and infra-red region (650nm to 900nm). Use of the material over red warning lights reduced the visible level to a degree which rendered them unsatisfactory for daytime use in the helicopter. With the indicated needed improvements, this problem should be alleviated.

Even with these shortcomings from the materials standpoint, interest and work in this light control area for night vision goggle compatibility is progressing rapidly. Other USAF aircraft that have been modified and tested with these light control techniques are the UH-1N and HH-53C rotary wing aircraft for MAC/AARS (Air Rescue and Recovery Service) and two special mission C-130E/H fixed wing aircraft for TAC. In all cases, the wavelength separation and light control techniques were pursued, as appropriate to the individual cockpit configuration and aircraft mission, with very good to excellent results through ground evaluation and flight test.

Yet to be tested is an all electroluminescent lighting system for the interior and exterior of six A-10 single seat attack aircraft for TAC. NVG compatibility is not a requirement with these ten aircraft, rather, a complete emphasis on unaided night visibility inside the cockpit and through the transparencies and improved lighting for formation flying and night refueling is needed.

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