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PAVE LOW III: Interior Lighting Reconfiguration for Night Lighting and Night Vision Goggle Compatibility

H. L. TASK and L. L. GRIFFIN

Human Engineering Division, Aerospace Medical Research Laboratory, Wright-Patterson AFB, Ohio

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The PAVE LOW III aircraft is a modified HH-53H helicopter that has a low altitude—below 30.48 m (100 ft)—night/day rescue mission. The desired night flying configuration is for the pilot to wear night vision goggles (NVGs) to fly the aircraft while the copilot, without NVGs, observes the video display and monitors the aircraft instruments. The problems of NVG incompatibility in the cockpit were successfully countered using several light control techniques. The light control modifications were evaluated on the ground in the PAVE LOW III helicopter at Kirtland AFB in April, 1980, by PAVE LOW instructor pilots. The evaluation results were extremely positive.

THE PAVE LOW III aircraft is a modified version of the HH-53H helicopter. Its primary mission is day/night air rescue. The mission profile of this aircraft is to fly extremely low for day/night search and rescue of downed pilots. The original PAVE LOW III modifications included a forward-looking infrared (FLIR) imaging sensor mounted on a moveable gimbal at the forward section of the aircraft. This FLIR provided night, infrared imagery via two 5 × 7 in cathode ray tubes (CRTs) mounted in the instrument panel in front of the pilot and copilot. Additionally, to support night and adverse weather navigation, a radar altimeter and terrain avoidance/terrain following radar was installed. However, as the PAVE LOW III aircraft was undergoing acceptance testing and required participation in Red Flag '79 tactical air combat exercise, the requirement for low-altitude flight was extended beyond the design capabilities of the radar. It was felt by those familiar with the helicopter that lower altitudes could be achieved at night if the pilot used the U.S. Army developed, second-generation night vision goggles (NVGs).

In initial tests with the night vision goggles, it was determined that the interior lighting for night flight interfered severely with their useful operation. The night illumination, even adjusted to a low level, emits considerable energy in the near infrared, where the NVGs are most sensitive. A first attempt to reduce this problem was conducted by the PRAM (Productibility, Reliability, Availability, Maintainability) PO (Program Office) at Wright-Patterson AFB in cooperation with the Military Airlift Command (MAC) and the Air Rescue and Recovery Service (ARRS). This initial test involved turning off all possible interior lights and floodlighting the instrument panel with yellow-green electro-luminescent lighting. Electro-luminescent (E-L) light emits almost all of its energy in the visible region and, essentially, none in the infrared. This "cold light" effect makes the E-L light much more compatible with the use of NVGs than the traditional incandescent lighting.

At a meeting late in 1979, the authors were asked by PRAM and MAC to address the problem of making the interior lighting of the PAVE LOW III helicopter compatible with the use of the NVGs. The desired operating condition was for the pilot to wear the NVGs to fly the helicopter while observing the outside world, and for the copilot to monitor the FLIR video display and the aircraft instruments. Thus the fundamental problem was to design a means of lighting such that the copilot had sufficient light to monitor the cockpit instruments but insure that the lighting did not interfere with the pilot's NVGs. A review of the aircraft interior lighting and the windscreen/instrument geometry revealed two sources of lighting difficulty. First, several illuminated instruments on the center and overhead console reflected directly in the windscreen from the pilot's and copilot's

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eye positions as well as the flight engineer's nominal eye position. This problem makes night flight, even without the NVGs, difficult and distracting and almost totally disallowed the use of NVGs. Second, the stray light in the cockpit illuminated other surfaces (like the pilot's knees and hands) such that their reflections in the windscreen were highly visible and distracting when using the NVGs. To improve the NVG utility, it was necessary to eliminate the direct reflecting sources and reduce or control the scattered light.

APPROACH

Several lighting and light control techniques were recommended to alleviate the NVG incompatibility problem:

1. Use blue-green E-L flood-lighting and turn off all possible incandescent lamp sources.
2. Use blue filters, instead of red, over the CRT display and place a red filter over the NVGs.
3. Use light baffles to control stray light.
4. Use anti-flare baffles on NVGs to reduce flare.
5. Use flat-black flight clothing and helmets to reduce stray light and reflections.

As a result of the meeting with MAC and PRAM, the authors were requested to implement the above recommendations on a PAVE LOW III helicopter for a full-up ground evaluation. The following sections describe each of these recommendations in detail.

Electro-Luminescent Flood Lighting: The main reason for using E-L light is that, unlike incandescent lighting, it emits little or no light in the near infrared region (4). The NVGs are highly sensitive to light from about 450-850 mm wavelength (1,2). By limiting the interior lighting to blue-green visible wavelengths only, considerable adverse interaction between the lighting system and the NVGs was eliminated.

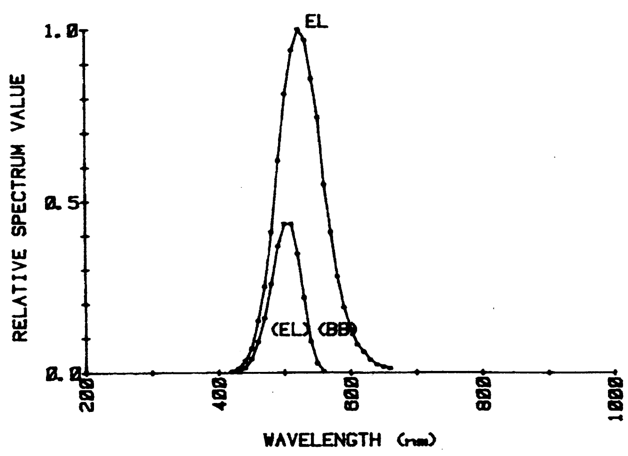

Fig. 1. Wavelength emission spectrum of the electro-luminescent lamp without filter (E-L) and with a blue filter (BB).

Fig. 1 shows the emission spectrum of the E-L lamps used. The upper curve is the E-L lamp without filter and the lower curve shows the lamp with a blue filter (BB) used to shift the peak of the emission spectrum further into the blue region.

The E-L lamps were placed under the glare shield to illuminate the front instrument panel and center console. They were also placed on the backs of the pilot's and copilot's seats, directed upwards, to illuminate the overhead panels. It was not possible under the constraints placed on this retrofit (no holes drilled or permanent modifications allowed) to properly illuminate the far forward section of the overhead panels or the rear section of the center console. Thus to provide a means of "portable" illumination, and E-L light wand was provided that the copilot could use for map reading or close-up instrument tasks, such as setting radio frequencies. In an ideal situation, these areas would be locally illuminated with E-L light built into the instrument or its immediate surround.

Blue/Red Filters: The CRT FLIR displays on the helicopter use a P-4 white phosphor. Although this emits no infrared light, it does emit over the full visible region. The standard night operation required the white CRT screen to be covered with a red filter. This left a display emission spectrum in the visible region from about 600-650 nm. This spectrum is in the center of the sensitivity region of the NVGs. Fig. 2 shows the relative sensitivity

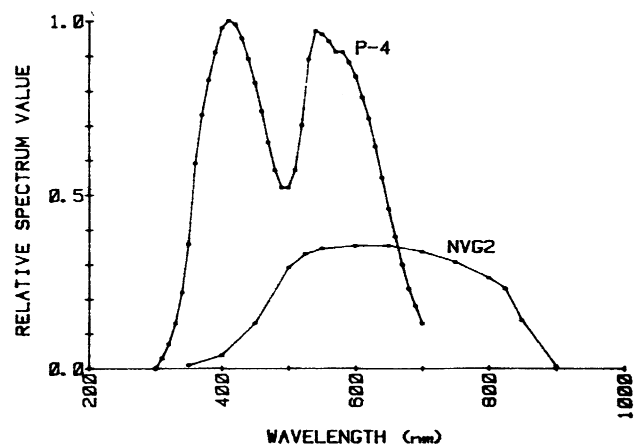

Fig. 2. Composition of the display P-4 phosphor spectrum and the night vision goggle (NVG 2) sensitivity curves.

of the second generation night visions goggles (NVG2) compared with the emission spectrum of the P-4 phosphor.

By using a blue filter (BB) over the P-4 phosphur screen, it is possible to shift the peak of the emission spectrum toward the blue, where the NVG is not quite as sensitive. This still results in considerable overlap. To reduce the overlap still further, a red plastic filter that was also highly transmissive in the near infra-red was placed over the NVGs. This resulted in the curves shown in Fig. 3. Under these conditions, the emission of the display and the sensitivity of the NVG have almost no overlap, thus effectively eliminating the interference of the display with proper operation of the NVGs (3). The red/infrared filter over the NVGs also significantly reduced the sensitivity of the NVG to the blue-green E-L, thereby eliminating that source of interference.

The red/infrared filter reduces the overall sensitivity of the NVGs. However, since most of the natural night illumination is in the near infrared i.e. 800-1000 nm, the effective reduction in night sensitivity is relatively small.

Baffles for Light Control: It is not possible to turn off all incandescent lights in the cockpit since some are

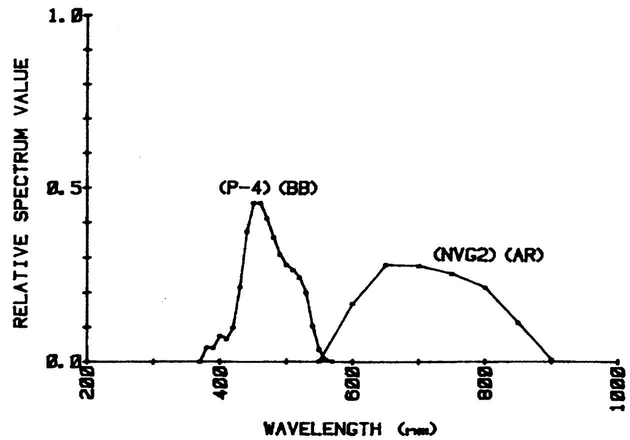

Fig. 3. Comparison of P-4 phosphor with blue filter and night vision goggle sensitivity with red filter. Note lack of overlap.

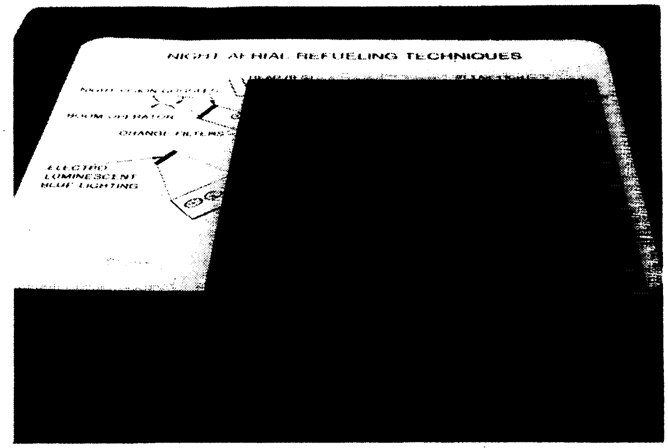
Fig. 5. The 48° fan, 0° tilt micro-louver viewed from an angle of about 60°.

required instrument status lights. Several such lights were, unfortunately, located in the center console. Most of the center console was directly visible in the windscreen due to the reflection geometry. To control these reflections, a material developed by 3-M Corp. was applied wherever possible. This material, called Micro-Louver (ML), is like a miniature venetian blind cast in a thin plastic layer. It is about 1/16-in. thick and can be obtained in various configurations. By varying the "slat" spacing and tilt, the fan of light that is allowed through the material can be controlled. The material comes in three "fan widths" of 48°, 60°, and 90°; and several tilt angles: 0°, 18°, 30°, and 45°. The tilt angle refers to the direction with respect to the vertical. Thus a 48° fan at 0° tilt results in a 48° light distribution spread that is emitted vertically, with respect to surface of material.

By placing appropriately chosen ML sections over the lights and displays, the light can be directed away from the windscreen toward the pilot, copilot, and flight engineer. This reduces or eliminates the direct reflection of instruments in the windscreen. Fig. 4 shows a section of ML that is a 48° fan, 0° tilt mounted over a vugraph. Note the clarity of the vugraph beneath the ML. Fig. 5 shows this same vugraph and material, but from a different angle. The vugraph light has been directed in a fan upward.

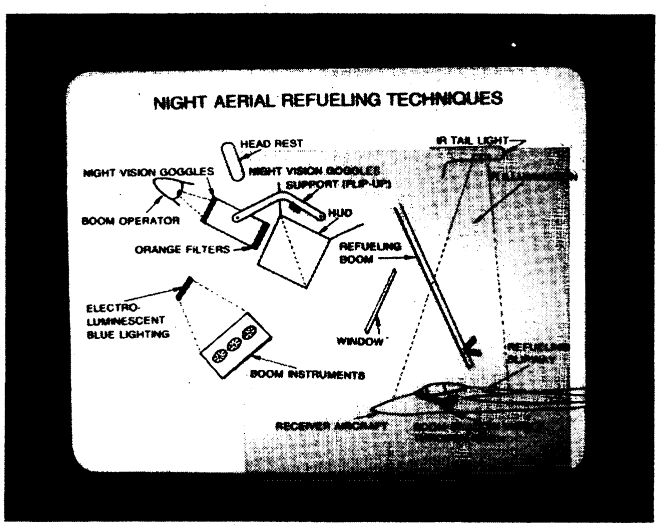

Fig. 4. The 48° fan, 0° tilt micro-louver viewed directly.

This technique of using ML baffles was successfully employed over several indicator lamps and displays including the incandescent lamp illuminated moving map display located in the center console. The ML was oriented to provide a horizontal fan of light directed away from the forward windscreen toward the pilot, copilot, and flight engineer positions.

Although this technique was highly successful for the visible light reflections, it was not totally successful with the IR reflections. The ML plastic was partially transmissive in the IR, and IR from the lamps was so strong that it caused scattering within the ML material. To combat this problem, a thin, plastic material was borrowed from the laser safety industry. The original purpose of this material was to provide laser safety and protection at the near IR wavelengths. Thus the material passed a large portion of the visible spectrum but absorbed light in the near IR. This IR-blocking material (IRBM) was used in conjunction with the ML material to provide fairly effective control of both visible and IR radiation. The IRBM was a "Glendale Green" filter material obtained from Glendale Optical Co. The published photopic transmissivity of the IRBM is about 45%. It does have a definite green tint and affects the red end of the visible radiation much more severely than the green.

Anti-Flare Baffles on NVG: Another source of stray light that can affect the NVG operation is caused by flare. The NVGs have a 40° field of view (FOV), 1:1 optical imaging system. However, bright light sources just outside of this FOV can still illuminate the objective lens of the NVG. Although this illumination is not imaged through the optical system, since it is outside the FOV, it still scatters in the lens causing a veiling luminance at the image plane that reduces contrast. This condition can be partly alleviated by providing an antiflare baffle outside of the objective lens. The baffle "shades" the objective lens from bright light sources outside the FOV and provides a housing to mount the red/IR filters to the NVGs.

Black Flight Clothing: To further reduce stray light, it was recommended that the flight crew wear dark clothing to absorb any stray light instead of reemitting it. Due to the geometry of the windscreen and pilot/copilot seats, the knees and hands of the pilot/copilot were reflected and highly visible in the windscreen to the NVG wearer. By wearing dark clothing, the intensity of the reflections was greatly reduced.

GROUND EVALUATION RESULTS

All of the light control techniques herein described were applied to the PAVE LOW III aircraft and evaluated by several instructor pilots during a day/night ground evaluation. Overall, the evaluation results were extremely good. The copilot had sufficient light to do his job, but the lighting did not adversely affect the pilot's NVGs. Several specific problems were identified by the evaluating instructor pilots.

In general, the use of the IRBM tended to make some of the indicator lights too dim to the unaided eye in daytime. In particular, the moving navigation map display was only marginally acceptable in daytime when sufficient IRBM was applied to block the IR emissions for night use. During the night evaluation, several other sources of incandescent or neon light IR emissions were identified as requiring applications of the light control techniques. These sources were not identified originally because the other sources totally masked their light. However, with the original problem lights effectively controlled, these "secondary" sources of light control problems became evident.

What need to be solved before these techniques can be applied are the long-term materials problems associated with the ML and the IRBM. The ML is a soft plastic; it is susceptible to scratching and can be warped by the heat of incandescent lamps. These same concerns apply to the IRBM as well.

If an aircraft cockpit used E-L panel lighting instead of incandescent, then the heat problem associated with the ML application would be solved. Also, this would eliminate the need for the IRBM since the E-L emits no IR.

An additional bonus of an all E-L cockpit light system or application of the techniques described is that the emission of IR from the cockpit is greatly reduced or eliminated. This should make the craft less visible and vulnerable to IR sensing and seeking devices.

CONCLUSIONS

The light control techniques described were successfully applied to the PAVE LOW III helicopter to make the interior lighting system compatible with the use of night vision goggles. From the ground evaluation, it is evident that these techniques provide a simple, inexpensive, and useful means to improve night visibility looking out of the cockpit with or without night vision goggles. The materials problems encountered should be addressed, and these techniques should be considered in the design of new cockpit layouts for interior night lighting.

Since this effort, similar efforts have begun for light control of the C-130 and UH-1 aircrafts.

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