Electroluminescent Lighting Applications

By Chesley S. Pieroway
Major, USAF

PRAM Program Office
Aeronautical Systems Division
Wright-Patterson AFB OH 45433

Presented to Illuminating Engineering Society of North America
Aviation Lighting Committee

Electroluminescent Lighting Applications

Air Force tactical airlift, tactical fighter aircraft, and special mission areas place increased emphasis on the ability to fly and conduct operations at night. Most aircraft support systems use incandescent lighting as the primary source for illumination of flight data systems. Incandescent lights cause hot spots, glare, uneven lighting, canopy reflection, have relatively short life, increase equipment heat loads, and are not compatible with night vision and night vision devices. The Productivity, Reliability, Availability, and Maintainability (PRAM) Program office, in conjunction with the Air Force Material Laboratory and the Air Force Aerospace Medical Research Laboratory, is testing the use of electroluminescent (EL) lighting on austere runways and in aircraft cockpits to increase operational readiness, system reliability, reduce operational and support costs, and to eliminate some of the aforementioned problems.

The electroluminescent effect of phosphor was first noted in 1936 by De Striau and has been in limited use for many years. The major obstacles to effective use of EL in the past have been:

- Low light input
- Susceptible to moisture and ultraviolet
- Color shift
- Cost effective manufacture
- Short life

In the past several years many improvements have been made in the manufacture of EL lamps that have caused an increased emphasis on its use in military and commercial systems. Today we have:

- Higher output, long life phosphors
- Micro-encapsulation to prevent degradation by moisture
- Ultraviolet absorbers
- Controlling of color shifts – dye conversion
- Efficient, lightweight power source of 400Hz and above
- Expanding technology

EL lighting has several advantages over incandescence which makes it a prime candidate to replace incandescent lighting in the nighttime environment. It provides improved night vision capability because it:

- Has no infrared radiation emission
- Has no ultraviolet emission
- Emits in narrow bandwidths
- Is compatible with Night Vision Goggles (NVG)
- Provides excellent scene contrast
- Does not fail catastrophically

Being an area light, it:

- Helps eliminate glare
- Improves contrast and visibility
- Is flexible/durable
- More reliable, low maintenance
- Low power consumption and cool

The average emittance of a green EL light is 15 to 25 FL at 115 Volt 400Hz at a wavelength of 530 nanometers. Most lighting systems are designed around brightness, but it is becoming increasingly clear that brightness is not necessarily the optimum design point. Besides the problems associated with night vision, incandescent light systems consume large amounts of energy, produce heat, are bulky, and of lower reliability. EL lighting is being evaluated as a supplemental light source and as replacement lighting on several Air Force Systems.

Runway Lights

Air Force airlift presently uses a combination of 6 volt battery operated lights (Elco or "Bean Bag" lights), and a centrally powered hardwire system, "Harvest Eagle", to meet the requirement for rapidly deployable, portable light for austere Landing Zones (LZs) and by poor light emission, size, weight, reliability, power supplies and illusions or disorientation caused by dim or flickering lights when seen through smoke, haze, dust, and other atmospheric aberrations. The Elco lights are used to define an austere field and have an acquisition range of 1.0 to 1.5 miles, depending on the weather. If it is a lengthy operation, they may be replaced by a Harvest Eagle Light System.

In April 1980, in response to a Military Airlift Command (MAC) runway lighting defiance report, an EL runway lighting system was assembled and installed in Holland LZ, a 3,000 foot LZ located at Pope Air Force Base, NC. Green, white, red, and blue 8 inch by 10 inch EL panels mounted between Plexiglas were connected with 20 gauge field communication wire, and powered by 115 Volt-400Hz source. The Elco lights were also installed so that a direct comparison could be made between the two systems. C-130 aircraft made assault landings, first with both sides Elco, then one side of the field Elco, the other EL, then both sides EL. The results of the test were:

a) The EL lights were acquired at 5 to 6 miles versus 1 to 1.5 for the Elco
b) Acquisition range of EL lights was not noticeably reduced during dust and haze conditions.
c) The EL did not glare, which eliminated pilot blinking during round-out and touchdown.
d) EL was seen through dust caused by reversing prop pitch after landing, the Elco was not.
e) EL provides a good tunnel effect
f) EL approach lights provided an excellent roll bar.

g) EL did not flicker or give the indication of motion.
h) EL lights did not have a halo.
i) Elco exceeded EL in brightness when under a mile.
j) Several Elco lights were damaged when they blown away by C-130 prop wash.

Additional tests were accomplished with different frequencies and smaller EL lights to determine the effect of size reduction on acquisition range. Lights as small as 4 inches by 8 inches were used with no appreciable reduction in acquisition range. As a result of these tests, MAC stated EL could satisfy their LZ and DZ lighting requirements and requested development of a lightweight, self-contained, remotely controlled EL runway light to replace Elco light. The EL was subsequently tested in Alaska during January 1981 as the primary lighting system for BRIM FROST 81. The results paralleled those at Pope AFB, with the systems being acquired at more than 3.5 miles during blowing snow, tundra and ice fog. The field was only closed once when the ceiling was reduced to 150 feet (ceiling limit for safety), even trough the air crews had a good runway presentation.

Electroluminescent Lighting Application

Test Analysis

Many questions have been raised as to why EL lights are seen better than incandescent lights, considering the fact that EL produces less light (photometric measurement) than incandescent. This fact, more than anything else, has slowed the use of EL, since it is believed by some designers that high levels of brightness are necessary to see when in fact under certain conditions the opposite is true.

Runways

The Elco lights use a 3 watt bulb (6 volts. 0.5 amps) radiating through a clear plastic lens-like structure. The green EL panels used in the first set of tests were 80in², consumed 14 watts (115 volt, 0.125amps), and emitted 18FL. In order to find what the systems were like at equivalent watts, frequency to the EL was reduced to 60Hz, which has the effect of reducing the light output to about one-fifth or 4FL. Acquisition range was still 2.5 to 3 miles. Subsequent tests were conducted using 32in² of EL, 6 watts and 18 FL. Acquisition range was 5+ miles. In fact, during one test, the approach to the field was obscured with heavy smoke from a local forest fire, but acquisition range was still 4 miles.

If we look at the emission of the light rays only, the typical light output of a standard incandescent source is about 14 to 20 lumens per watt whereas EL is 2 to 3 lumens per watt. Although the incandescent source emits more light per watt, it emits the light from a point source whereas EL emits the light over a large area. If a true comparison of the light source is to be attempted, a point source would have to be made into an area source, which would require the use of diffusers, lenses and/or reflectors, which makes for a larger, heavier light system versus the flat, thin EL lamp.

Tests have been conducted to measure the light emission intensity of EL versus the present Elco lens and a lens design utilizing a continuous horizontal band. Test subjects viewing the different systems indicated that incandescent systems were brighter than EL at one-half mile. This observation was verified by pilots at Pope AFB, that once inside one mile, the brightness of the EL and Elco were equal, with the Elco brightness increasing with decreasing range. Neutral density filters were then placed in front of the incandescent source to reduce intensity until the source were photometrically the same. The viewing subjects were evenly divided as to which source was brighter.

These tests and the field testing indicate that the visual system (eye) perceives the EL light differently than photometric measurement predicts. The reason for this

perception difference is unknown at this time, but it is believed that the self-induced phosphorescence at a different frequency and wavelength, not measurable, and the fact that EL is in effect being switched on and off by the alternating electrical field, may cause effects on the eye that are not presently clearly understood.

EL has a distinct advantage over incandescence in that it is less susceptible to scintillation effects caused by atmospheric aberrations. This is the single most critical problem facing flight crews. The design of the incandescent light can be changed to increase acquisition range by projecting a different pattern of light or increasing lamp output to project a brighter beam, but it cannot correct the basic problem of point of source lights, i.e, halos, flickering, depth perception, etc. Note that the incandescent image starts small at near distances but continues to enlarge due to haloing effects as you proceed down the field, causing depth perception problems, but the EL starts large and progressively gets smaller, thus providing the proper perspective for depth perception. Due to improved perception of depth and distance provided by EL, pilots made repeated night landings touching down at the same spot on the runway each time.

Of equal importance is that EL lights do not flicker as do incandescent lights, which gives the incandescent lights an appearance of motion. The EL light presented a stable image through many types of atmospheric conditions, i.e., haze, fog, dust, snow, ice fog, and smoke. This is due to EL being an area light (non-coherent) versus a point source (coherent). With a point source, the atmosphere will bend or distort the single beam of light (one for each crystal of phosphor), hence not all the beams can be bent out of the viewing angle of the eye. Since the lights do not flicker or give the sensation of apparent motion, they present to the pilot a more stable reference plane. This was noticed in the test results as a good tunnel effect and a good roll bar. Also, since EL lights is a non-coherent source any deviation right or left of runway centerline on approach, the pilot perceives a difference in brightness between the two sided of the runway marker lights.