Flashing Aircraft Beacons using LEDs

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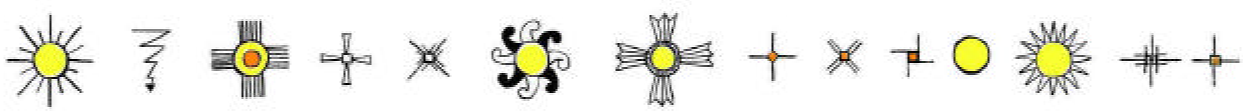
Rev 24JAN2004



[Native American Symbols for Various Lights]

So let's get right to it and see what the FAA wants---[My comments in brackets]

Sec. 23.1401 - Anticollision light system.

(a) General. The airplane must have an anticollision light system that:

(1) Consists of one or more approved anticollision lights located so that their light will not impair the flight crewmembers' vision or [nor] detract from the conspicuity of the position lights; and

(2) Meets the requirements of paragraphs (b) through (f) of this section.

(b) Field of coverage. The system must consist of enough lights to illuminate the vital areas around the airplane, considering the physical configuration and flight characteristics of the airplane. The field of coverage must extend in each direction within at least 75 degrees above and 75 degrees below the horizontal plane of the airplane, except that there may be solid angles of obstructed visibility totaling not more than 0.5 steradians. [So a strut or other part of the airplane is not an issue.]

(c) Flashing characteristics. The arrangement of the system, that is, the number of light sources, beam width, speed of rotation, and other characteristics, must give an effective flash frequency of not less than 40, nor more than 100, cycles per minute. The effective flash frequency is the frequency at which the airplane's complete anticollision light system is observed from a distance, and applies to each sector of light including any overlaps that exist when the system consists of more than one light source. In overlaps, flash frequencies may exceed 100, but not 180, cycles per minute.

(d) Color. Each anticollision light must be either aviation red or aviation white and must meet the applicable requirements of §23.1397. [For a number of reasons, go with red LEDs.]

(e) Light intensity. The minimum light intensities in any vertical plane, measured with the red filter (if used) and expressed in terms of "effective" intensities, must meet the requirements of paragraph (f) of this section. The following relation must be assumed:

$$I_e = \frac{\int_{t1}^{t2} I(t)\,dt}{0.2+(t2-t1)}$$

where:

Ie =effective intensity (candles).

I(t) =instantaneous intensity as a function of time.

t2   t1 =flash time interval (seconds)."

Normally, the maximum value of effective intensity is obtained when t2 and t1 are chosen so that the effective intensity is equal to the instantaneous intensity at t2 and t1. [I have no idea what this means, do you? But it seems parenthetical, so I'm not scared.]

(f) Minimum effective intensities for anticollision lights. Each anticollision light effective intensity must equal or exceed the applicable values in the following table.

Angle above or below the horizontal plane	Effective intensity (candles) [candelas]
0 deg. to 5 deg...	400
5 deg. to 10 deg..	240
10 deg. to 20 deg...	80
20 deg. to 30 deg...	40
30 deg. to 75 deg...	20

[Doc. No. 4080, 29 FR 17955, Dec. 18, 1964, as amended by Amdt. 23-11, 36 FR 12972, July 10, 1971; Amdt. 23-20, 42 FR 36969, July 18, 1977; Amdt. 23-49, 61 FR 5169, Feb. 9, 1996]

Let's look at the scariest part of this thing:

The FAA says--"The following relation must be assumed:

$$I_e = \frac{\int_{t1}^{t2} I(t)dt}{0.2+(t2-t1)}$$

where:

I_e =effective intensity (candles).

I(t) =instantaneous intensity as a function of time.

t2   t1 =flash time interval (seconds)."[This is easy to confuse with frequency.]

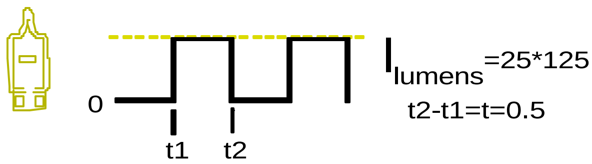
So you didn't think you would have to re-learn Calculus just to put lights on your airplane? Remember that the FAA hired smart people to do this section and they had families to feed. But what does this equation really mean?

Well, the I_e is "Effective Intensity" the FAA says is equal to the intensity integrated over the flash ON time. If you slept through Isaac Newton's greatest mathematical triumph, you can just assume the Effective Intensity is the Peak Intensity times the pulse width. (This is perfectly true only for square waves…but that's what we're going to make with the LEDs).

Now what about the bottom half? It is really a way to express the curious fact that a 200 millisecond bright flash is generally the shortest bright flash you can see; or rather, it takes 200 milliseconds for the eye to process a bright flash. Furthermore, since this is true, a very short bright flash is 5X more visible (in terms of power) than continuous light of the same brightness. This is shown by setting t2-t1=0; then the denominator becomes simply 0.200 second. This is called the *Blondel-Ray Law*. (A bright light >5 Hz cannot be seen to pulse although its dimmer reflection can.)

So to minimally comply with FAR sec. 23.1401, let's see what we need to get 400 candelas effective intensity out of a lamp—First let's see what the manufacturers do—

For the Cessna flashing halogen, 1 second frequency, pulse width 0.5 seconds. 125 Watt lamp.

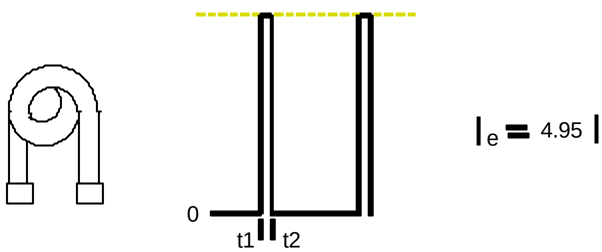


For halogens 25 lumens/watt
is typical so we have 25*125*0.5
divided by 0.2 +0.5=2188 lumen seconds
is the Effective Intensity. For isotopic candelas
2188 lumen seconds times 1/(4*Pi)=174 cande

I have not included the effect of a red cover on the beacon. The red cover certainly cuts the light by half. (Whelen says it reduces the light by up to 82%).

Cessna also used the older standard (says Whelen)—100 candelas. These are isotopic candelas (spread in all directions), so even if we put a mirror at the base of the lamp, we'd almost double it, and a little optics to squeeze the beam horizontally will make up for the rest--or if the peak intensity is more than the 125 watts would indicate (and it is because of the cold filament when the lamp turns on) then the Effective Intensity could easily put them beyond the mark—at least the old 100 candela mark, pretty easily.

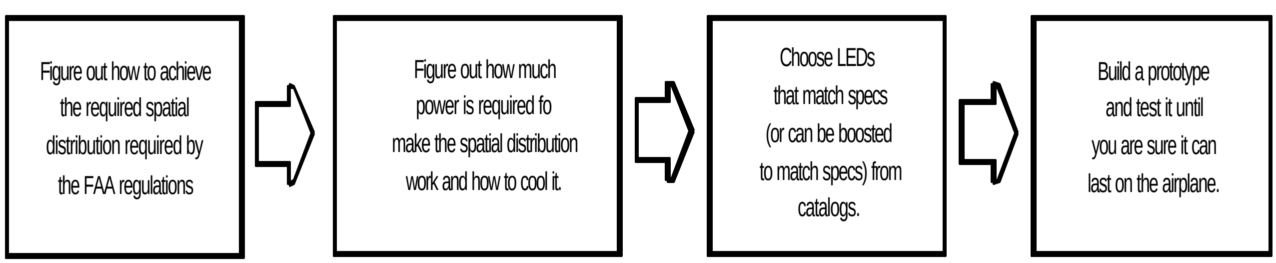
Let's look at a xenon flash beacon typical of aircraft—xenon flashtubes make short pulses at high current:



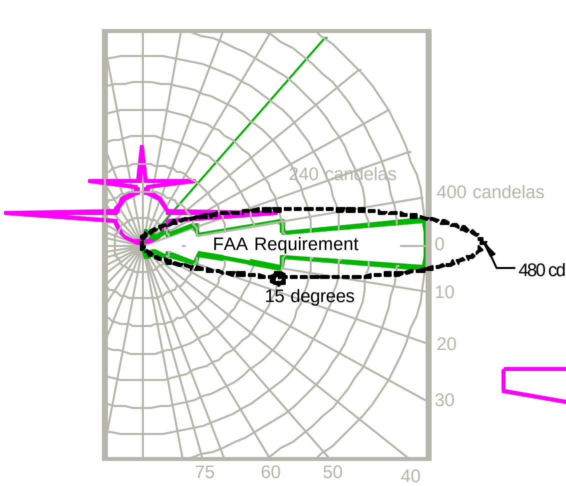
For xenon flash tubes 50 lumens/watt
is typical so for a 20 watt second flash tube we have
4.95 times 20 times 50 lumen seconds =4950 lumen seconds
is the Effective Intensity. For Isotopic canelas
4950 lumen seconds times 1/(4*Pi)=394

So we're real close! Again these are isotopic candelas so a little rear reflection would easily put us far over the minimums, besides, we made several estimations that are probably a little off.

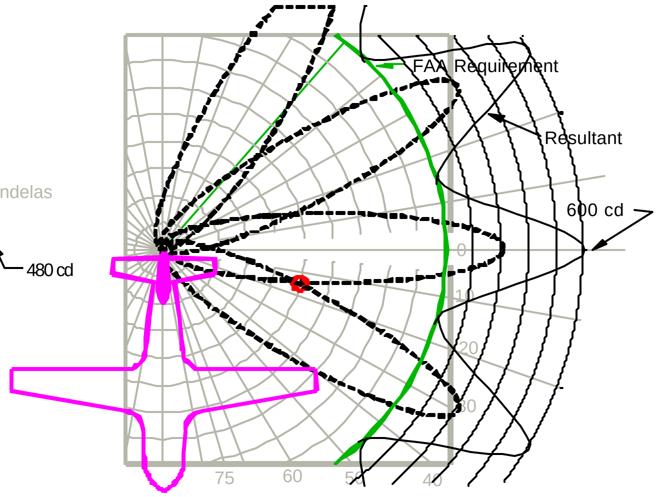
So what about LEDs? What's the first step? I have mentioned before that it might seem that choosing a REALLY bright LED would be a good place to start. But this would be entirely backwards. Do it like this--



And be careful. You need to understand that bright LEDs are usually narrow and wide LEDs are usually not bright. Compromise is the art of the possible.



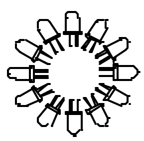
Spatial Distribution in Any Vertical Plane

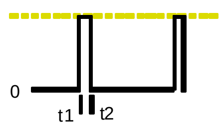


Spatial Distribution in Any Horizontal Plane
12 LEDs each 30 degrees

Now let’s work this equation backwards.

$$I_e = \frac{\int_{t1}^{t2} I(t)\,dt}{0.2+(t2-t1)}$$





For LEDs 25 lumens/watt is now typical (soon they will be 100 lumens/watt!) so for a "Daisy" of 12 LEDs, we can consider them one lamp at 10 ms pulsewidth operated at 5X normal current times 12 LEDs. Let's use 18 cd LED (at 30 mA). We boost them to 90 cd each at 150 mA for 0.1 second. Thus we have 3.33 times 90 times 0.1 sec =30 candelas effective intensity.

Notice we didn’t need to figure in the luminous efficacy of the LEDs, since candelas were used. Nor did we figure in the 50% horizontal overlap. Regardless, this is NOT a close result and adding a few more LEDs or making some small adjustments would NOT do the job.

How about Luxeons? Well, optics would have to be added, and the drive requirements of Luxeon Emitters do not allow more than about 75% overdrive.

So what do we do? Well, we could use a whole lot of LEDs—even assuming we add in the 50% horizontal overlap, we still need about nine times as many LEDs as used in our “daisy” array example. In fact, since I chose an almost unobtainable LED (18 CD! 30 degrees!). We would need a “daisy” of a couple hundred LEDs.

What if we use the Cessna method but use Luxeons? Cessna has a couple thousand lumens at their disposal. This is 20 Luxeons. This is a $400 deal just for LEDs. And you need a couple beacons at least.

So my recommendation is---Just wait until LEDs are brighter and cheaper. And you won’t have to wait very long.

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