Guide to specifying visual signals

A visual signal is a luminous source within a coloured transparent enclosure and is used in many applications not least as reinforcement to an audible signal in the event of danger, warning or machine status / system process.

With the possible exception of status indicators, the purpose of the E2S visual signals range is to attract attention as compared with a luminaire or general purpose light which is intended to illuminate a given area and not necessarily attract attention. Therefore the effectiveness or the light intensity of a device as opposed to merely its capacity to illuminate is probably the important consideration. Different light sources may offer significantly different effective light intensity and ability to attract attention, particularly when flashing; however in contrast their ability to illuminate a given area may be fairly poor.

E2S provides information relating to the effectiveness of a visual signal based on **actual measurements** for each model within the E2S range. The information provided **IS NOT** based on rule of thumb assumptions and / or calculations alone. We therefore have confidence our measured light output values are meaningful and will better aid product selection.

There is a choice of luminous sources,

- Incandescent / Filament bulb – usually operated in conjunction with an additional circuit, both a steady output and more effective blinking output may be achieved. The filament light bulb gives adequate performance, at a relatively low cost, which may be enhanced with a freznel lens. It does however have quite a short life, and is further shortened when exposed to quite low levels of vibration.
- Halogen bulb – the filament of this bulb is enclosed in halogen gas and glows at a slightly higher temperature than a regular bulb. a more efficient light output and longer bulb life of up to three times that of a regular bulb. If a 40w bulb is considered, a halogen version may be expected to produce an increase of up to 80% in Luminous Efficiency (lumen per watts) when compared with a regular bulb.
- Xenon (strobe) tube – operating at high voltage generated by an inverter circuit, the xenon tube is ignited creating an instantaneous brilliant flash of light, which may further be enhanced when viewed through a freznel lens. The energy of the flash is a function of the tube size, the voltage across it and the capacitor discharging into it. The tube life is typically 5 to 8 million flashes with after which erosion of light output is experienced until the tube eventually fails.
- L.E.D (light Emitting Diode) - a semiconductor device, which unlike the filament bulb and the xenon tube emits only one frequency of light (i.e. one colour) dependent on its construction. L.E.D technology is developing and does not as yet offer as bright a solution as the xenon tube, it does however offer an extremely low current and very long life time, giving an effective solution where an indication or status is required.

How do E2S measure the light output

(Effective Candela – cd) of a Visual Signal?

A spectrometer is used for measuring the average effective luminous intensity of an entire beacon lens. This is then translated into an Effective Candela figure (cd).

In the case of a flashing beacon such as a xenon strobe the pulse duration as measured between the 10 % of peak amplitude for the leading and trailing edges of the pulse is measured. Light levels are collected during the pulse period, these are translated using the Blondel-Rey formula into an Effective Candela figure (cd). This is the intensity that would appear to an observer if the light were burning steadily.

The effective luminous intensity (*Ieff*), expressed in candela (cd), is calculated for each pulse measured using the following *Blondel-Rey* formula:

$$I_{eff} = \frac{\int_{f_1}^{f_2} I(t)dt}{a+(t_2 - t_1)}$$

Where,

I(t) is the instantaneous value in candela (cd);

a = visual time constant where either 0.2 (nigthtime) or 0.1 (daytime) constants are used in calculation.

t2 - t1 is the light pulse duration as measured between the 10 % of peak amplitude for the leading and trailing edges of the pulse.

Measured Effectiveness compared with Rule of thumb / calculated-only Effectiveness – Xenon Strobe Beacons

When evaluating or comparing output data of more than one visual signalling device, it is probably worth considering how the data has been established.

Rules of thumb and calculations based on the energy of the flash tube within a xenon strobe beacon have customarily been used to give an indication of effectiveness. However when comparing outputs derived by calculations based on energy alone, to measured outputs with a spectrometer or similar, the output is often over stated in terms of effective candela (candle power) and especially in terms of peak candle power. This can all too often be misleading and unless two devices have been measured for output then their effectiveness in terms of candela output cannot be accurately compared.

E2S state two measures of effective light output for all xenon strobe beacons both of which have been carried out and subjected to, a fully assembled, product fitted with a clear lens, these are,

Effective Candela (cd) – Measured: also known as *effective candle power*, this is the measured intensity that would appear to an observer if / when the light was burning steadily. This data which should be used when comparing two different visual signalling devices

Peak Candela (cd) – Measured: also known as *peak candle power*, this is the maximum intensity measured generated by a flashing device during its light pulse. – it is recommended the peak candela figure should not be used when comparing two different visual signals

In the case of xenon strobe visual signals E2S state calculated figures based on the energy rating of the flash tube, this type of information has customarily been used within the visual signalling industry to give a rule of thumb indication and is subject to many anomalies that give rise to inaccurate and over stated output figures. This may be due to differences in size and efficiency of lens, physical shape of the strobe lamp and arrangement relative to the lens and the efficiency of the strobe flash tube itself. Other factors, not least lens color influence light output and is dealt with later.

Below is a description of the calculated light output figures included for information only. The difference between these figures and actual measured outputs is demonstrated later.

Effective Candela (cd) – Calculated: also known as *effective candle power*, typically assumes 1 Joule of energy supplied to a flash tube assimilates 50 cd (candela)

Peak Candela (cd) – Calculated: also known as *peak candle power*, typically assumes 1 Joule of energy supplied to a flash tube assimilates 100,000 cd (candela) – it is recommended the peak candela figure should not be used when comparing two different visual signals.

An Example of Differences between Measured and Calculated Effective Candela data.

As stated before when comparing two visual signalling devices their measured effective candela should be compared as opposed to calculated effective candela. Peak candela should not be used for comparison purposes with respect to effectiveness.

The visual signals below are all 5 Joule energy rated xenon strobe beacons. They are physically different both in terms of enclosure and lens arrangement. Table 1, demonstrates the anomalies and assumptions which lead to inaccuracies if the effective candela is calculated and / or a rule of thumb is applied as opposed to being measured,

Table 1: Comparison of Measured effective candela with Calculated effective candela: Three different 5 Joule E2S beacons.

5 Joule Visual Signal Model Number	MEASURED Effective Candela (cd)	Warning Distance	
L101	200	22m	73ft
B300STR	125	18m	58ft
BExBG05D	105	16m	53ft
	CALCULATED Effective Candela (cd)	Warning Distance	
L101	250	112m	366ft
B300STR	250	112m	366ft
BExBG05D	250	112m	366ft

Beacon effectiveness & range

A common question as far as visual signalling is concerned is the range of a given device. The effective candela (or effective candle power) of a device may be used to determine the effective range using the following formula also referred to in EN54-23, and IES (Illuminating Engineering Society of North America (IES) Lighting Handbook, Fifth Edition);

The formula below may be used to convert effective candela into ***effective warning distance***, in other words, *alert* rather than *inform*.

$$d = \sqrt{\frac{Ieff(av)}{0.4}}$$

Where *Ieff(av)* = Effective Candela

d = Distance (m)

The formula below may be used to convert effective candela into ***viewing distance or range***, based on normal visibility in day time conditions.

$$d = \sqrt{\frac{Ieff(av)}{(6.37Lb+18.6)10^{-7}}}$$

Where *Ieff(av)* = Effective Candela

d = Distance (feet)

Lb = Foot-Lamberts background illuminance (normal day time conditions, Lb = 2919 ft-L)

From the above two formulas the table below gives an indication of both warning distance and range of a visual signal given an effective candela measurement.

Table 2: Indication of warning distance and range of a visual signal given an effective candela measurement.

Effective Candela cd	Warning Distance m	Warning Distance ft	Viewing Distance m	Viewing Distance ft
5	3.54	11.61	16	52
10	5.00	16.40	22	73
25	7.90	25.92	35	116
50	11.18	36.68	50	164
100	15.81	51.87	71	232
150	19.36	63.52	87	284
200	22.36	73.36	100	328
250	25.00	82.02	112	366
300	27.39	89.86	122	401
350	29.58	97.05	132	434
400	31.62	103.74	141	464
450	33.54	110.04	150	492
500	35.35	115.98	158	518
550	37.08	121.65	166	544
600	38.72	127.03	173	568

How much does lens colour effect the intensity of a light source?

The effect of lens colour on the intensity of the light source within an industrial environment may be expressed as follows,

Clear	Yellow	Amber	Red	Blue	Green
100%	93%	70%	23%	24%	25%

Please note all the above information is for guidance only and does NOT guarantee performance or coverage.

Siting of a visual signalling device

All round light dispersion should be the first consideration when installing a beacon, ensuring free air movement around the beacon enclosure and therefore preventing the build-up of heat from the light source emitted during the normal operation of the beacon. Vibration should be avoided particularly with filament bulb beacons. Light travels in straight lines, the beacon will be far more effective if positioned in the line of sight rather than relying on reflections. Where applicable audible signals should always be the primary warning with the beacon used as a secondary indication or status.

IEC 73 colours

These are the colours needed for lights and buttons to conform to the machine directive.

- RED – Danger Act Now.
  Danger of live or unguarded moving machinery or essential equipment in protected area.
- AMBER – Warning, Proceed with Care.
  Temperature or pressure different from normal level.
- GREEN – Safety Precaution: Go Ahead
  Checks complete, machine about to start.
- BLUE – Site Specified.
  Pre-set ready or remote control.
- CLEAR – No specific Meaning.
  Could confirm an earlier message.

Useful terms

Luminous intensity: symbol, I; unit, candela (cd). Measure of the power of a light source. Sometimes referred to as brightness.

Luminous flux: symbol, F; unit, lumen (lm). Measure of the flow or amount of light emitted from a source.

Illuminance: symbol, E; unit, lux (lx) or lm/m2. Measure of the amount of light falling on a surface. It is also referred to as illumination.

Luminous efficacy: symbol, K; unit, lumen per watt (lm/W). Ratio of luminous flux to electrical power input. It could be thought of as the 'efficiency' of the light source.

Coefficient of utilization (CU):
no unit. The amount of useful light will depend on the lamp output, the reflectors and/or diffusers, position, colour of walls and ceilings, etc. The lighting designer will combine all of these considerations to determine a figure for any lighting calculations.

Maintenance factor (MF): Because dirt and ageing can both cause loss of light, it's useful to take a maintenance factor into account. For example, a new 80W fluorescent lamp with a lumen output of 5700lm falls to 5200lm after 4 months, and remains at that level.

The light output has decreased by: 5200 / 5700 = 0.9

This value, 0.9, is the maintenance factor. It should not be allowed to fall below 0.8 by regular cleaning.