# Lighting for clinical observation of cyanosis

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## Background

Clinical observation has always been an important part of medical diagnosis. One important aspect of clinical observation is the reliable detection of cyanosis, that is, the bluish discoloration in the skin and mucous membranes, which indicates that oxygen levels in the blood are dangerously depleted. While pulse oximeters are used in operating rooms and recovery areas, there are areas within hospitals where these are not universally used and there are some medical conditions, for example where patients have poor peripheral circulation, which can make their use unreliable.[1] In these instances the ability of medical staff to reliably detect the onset of cyanosis by visual observation may be critical to a patient's well being.

## Clinical observation

We observe colour by reflection of light from objects. In simple terms an object is blue because it absorbs all the non blue light and reflects the blue light back to our eyes. If the light source in the area has no blue component in its spectrum then we will not detect the blue colour. A formerly common example of this was the lack of colour definition provided by low pressure sodium street lights—which is one reason why they are no longer used despite their efficacy and long life.

Work by Dain and Hood[1] has suggested that light sources, which will allow the reliable detection of cyanosis, should have an appropriate power output in the red part of the visible spectrum, particularly around 660 nm where the maximum difference in spectral transmittance between oxyhaemoglobin

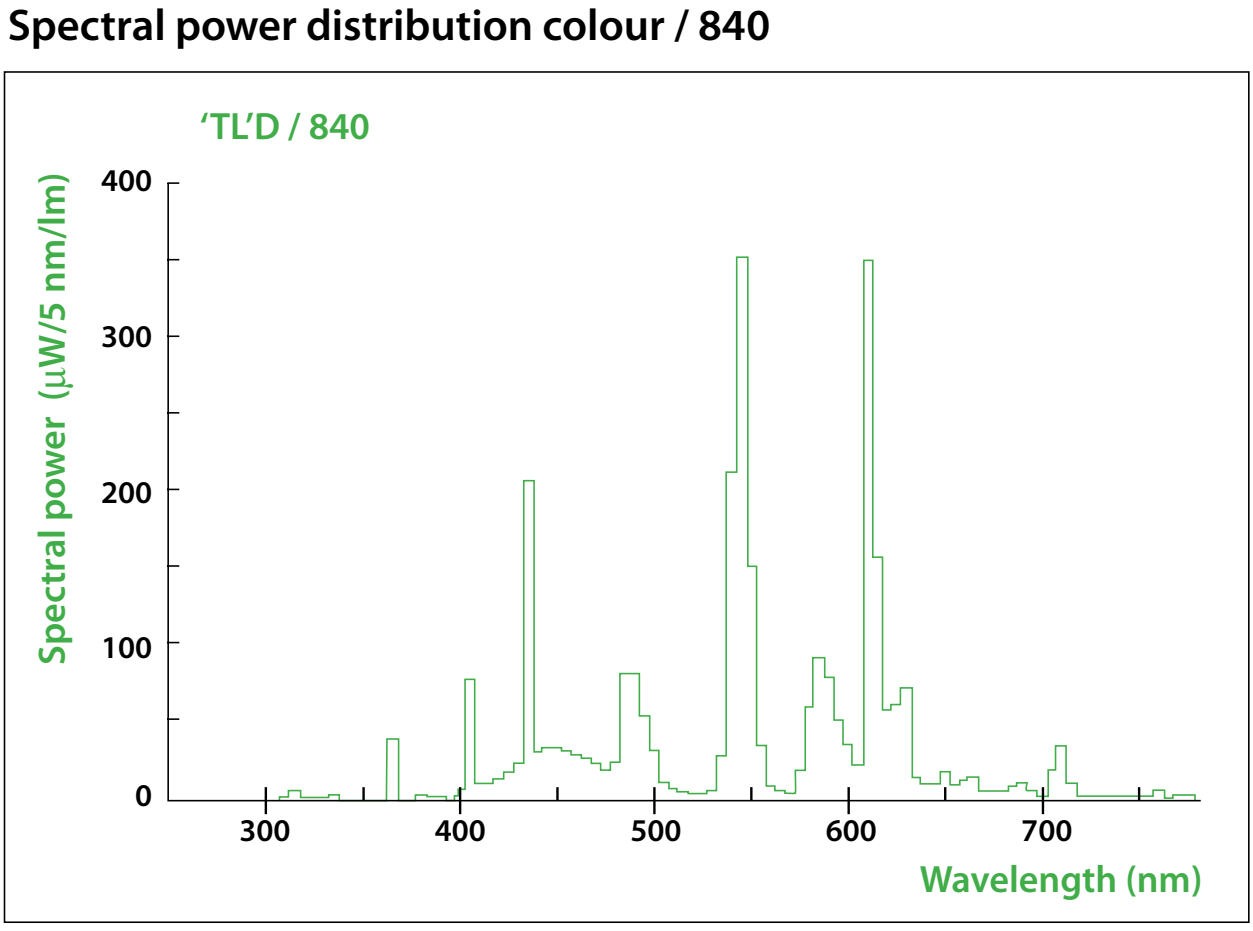


*Figure 1: Spectral power output for a high efficacy triphosphor lamp*

## Spectral power distribution colour / 940

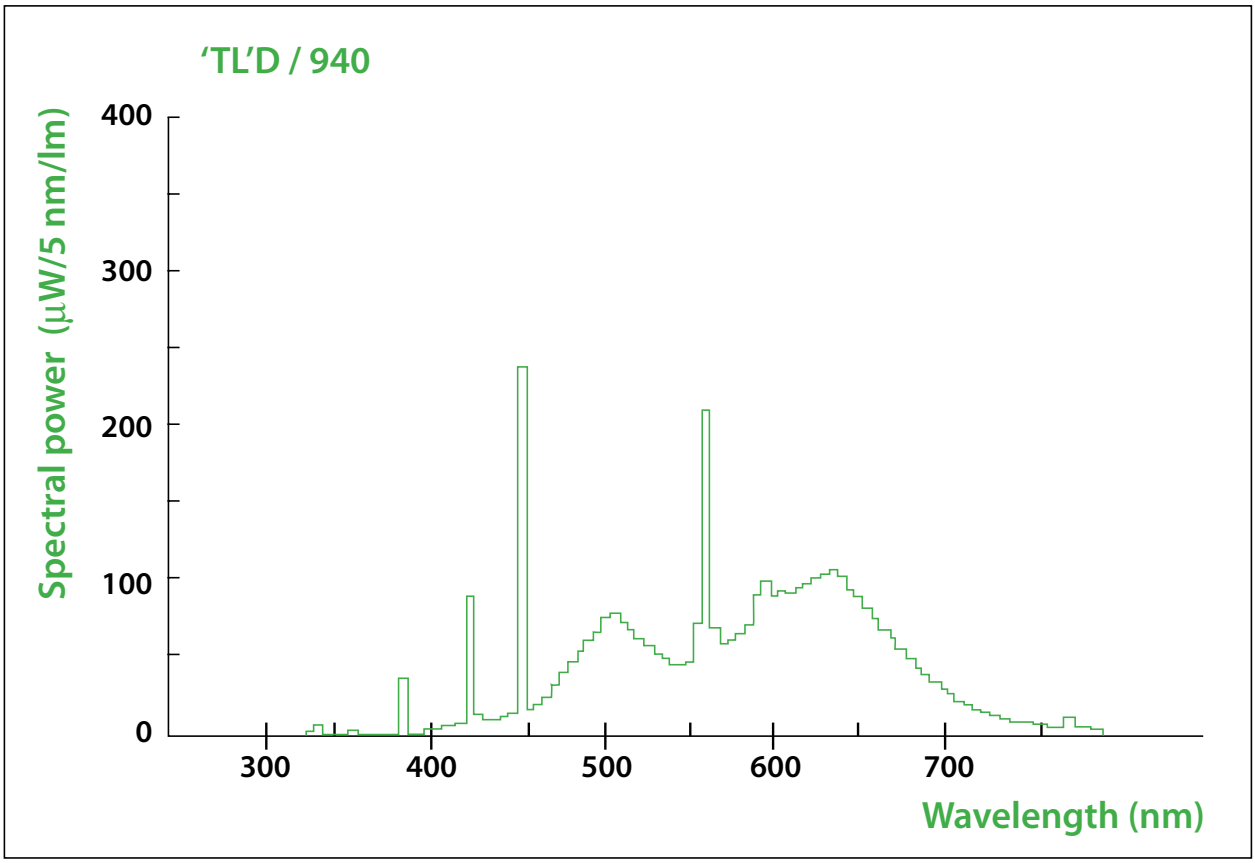


*Figure 2: Spectral power output for a 900 Series triphosphor lamp*

and reduced haemoglobin occurs. If the output is too low a patient's skin colour may appear darker and he/she may be diagnosed as cyanosed when this is not the case. Conversely, if the output is too high it may mask the cyanosis and it may not be diagnosed when it is present. The end result is that clinical staff cannot rely on visual detection.

It has also been found that lamps suitable for the reliable detection of cyanosis should have a correlated colour temperature (CCT) between 3200 K and 5500 K.[2] In general it would be expected that non complying lamps with CCTs above 3200 K would provide false positive diagnoses and that lamps with CCTs below 3200 K would result in failure to detect cyanosis. It should be noted that, while cyanosis is defined as a bluish discoloration, 660 nm lies in the red end of the colour spectrum.

Low pressure mercury (fluorescent) lamps commonly in use may not have a continuous spectrum. Modern triphosphor type lamps have three phosphor coatings and have significant power output in only three regions of the visible spectrum based around wavelengths at 440 nm (blue), 540 nm (green and 610 nm (orange/light red) and may not have any significant output in the 660 nm region.

Figure 1 shows the spectral power distribution of a typical 4000 K triphosphor lamp and clearly shows the lack of output in the 660 nm region.

### Basis for the Australian Standard

Extensive clinical trials carried out at Royal Prince Alfred Hospital in Sydney in the early 1970s identified a number of lamps that were suitable for reliable diagnosis of cyanosis. This led to the publication of *AS 1765:1975*[2] which included a graphical method of determining which lamps were suitable based on colour temperature and the colour rendering indices $R_a$ and $R_{13}$. An outline of the method can be found in *AS/NZS 1680.2.5:1997* Appendix H.[3]

The lamps identified in the 1970s used halophosphor technology and generally had a continuous spectrum. In the 1980s, however, triphosphor lamps entered the market and over a period of time have replaced halophosphor lamps except for special purposes. Triphosphor lamps provide major efficacy and life benefits.

As part of a review of *AS 1680* in the 1990s, Standards Australia Committee LG/1, Interior Lighting, revisited hospital lighting. Resources were not available to carry out the large scale trials of the 1970s, which had established the original cyanosis observation criteria. However, using the data from the first trials and the known reflective properties of blood, a methodology for calculating a Cyanosis Observation Index (COI) was established and published in *AS 1680.2.5:1997.*[3]

The COI is a dimensionless number and is calculated from the spectral power distribution of a lamp. The methodology calculates the colour difference between blood viewed under the test lamp and when viewed under the reference lamp (a 4000 K Planckian source) for 50% and 100% oxygen saturation and averages the results. To comply with *AS 1680.2.5* requirements for the reliable diagnosis of cyanosis, the COI should be 3.3 or lower and the lamp correlated colour temperature should be between 3300 K and 5500 K.

During the development of the COI method and leading up to the publication of *AS 1680.2.5:1997* a number of different lamps were assessed. At this time no triphosphor lamps or triphosphor based lamps were found to comply.[1,4] It should also be noted that normal tungsten (incandescent) or tungsten halogen lamps generally do not meet the *AS/NZS 1680.2.5:1997* criteria although some special high colour temperature or filtered light sources will comply.

## Lamp types

Phosphors are materials used to coat discharge lamps and which convert ultraviolet radiation to visible light. The original phosphor used was calcium halophosphate which when suitably treated with different impurities produced a range of fluorescent lamps of varying colour temperatures. These lamps did not render colours accurately nor were they very efficient. When modified to provide improved colour rendering they became even less efficient.

Modern lamps use rare earth-based phosphors which provide better colour rendering and provide more light output. Triphosphor based lamps generally come in two types. These are the 800 Series and 900 Series lamps where the first number indicates the colour rendering index range and the second and third numbers relate to the correlated colour temperature of the lamp in kelvins. 800 Series lamps have three phosphor coatings and have a colour rendering index ($R_a$) of between 80% and 89%. The 900 Series lamps have an additional two or three phosphor coatings and have colour rendering indices ($R_a$) above 90%.

For the most commonly used lamp, a 36 W linear fluorescent, the current typical efficacy of an 800 Series lamp is 93 lumen/watt (lm/W) while for a 900 Series lamp it is between 60 and 65 lm/W, although lamps with efficacies of 75–80 lm/W have recently become available. The lower efficacies of the 900 Series lamps are due to the additional phosphor coating which, while providing a wider range of spectral power output, also absorbs some of that output. The spectral power distribution of a typical 900 Series lamp is shown in Figure 2.

## Clinical observation revisited

Since 1997, based on the work carried out prior to the publication of *AS/NZS 1680.2.5:1997*, it has generally been believed that no triphosphor-based lamps in current production meet the COI requirements in *AS/NZS 1680.2.5*.[1,4]

After the publication of *AS 1765:1975*, the Philips Colour 37 lamp was the commonly used lamp in hospitals; however this lamp had an efficacy of only 43 lm/W. Since the publication of the 1997 Australian Standard the NEC Hospital Cool White lamp, which is based on halophosphor technology, has become the standard lamp used in medical areas when compliance with *AS/NZS 1680.2.5* is required.

Calculations carried out in 2004 by the authors using the methodology in *AS/NZS 1680.2.5* show that the Osram 940 lamp has a COI of <2.5 and therefore also complies with AS 1680.2.5 requirements. While a range of 900 Series lamps were tested as part of the trials carried out in the development of *AS/NZS 1680.2.5:1997* (including a 940 type lamp), the Osram 940 does not appear to have been included in the trials.

Understanding that similar colour temperature lamps may vary between manufacturers, the authors also carried out calculations for 900 Series lamps from Osram and Philips to see if any other lamps might have compliant clinical observation indices.

In the meantime, in 2005, Philips announced the introduction of a new range of hospital lamps designed to meet *AS/NZS 1680.2.5:1997* requirements.

## Lamps for clinical observation

The data in Table 1 are based on calculations carried out in accordance with *AS/NZS 1680.2.5:1997* and on data provided by lamp manufacturers.

| Lamp | Observation Index | Efficacy (lm/W) | Life (hours) | CCT | Comments |
|---|---|---|---|---|---|
| NEC Hospital Cool White | < 1.5 | 61 | 12 000 | 4200 | Passes COI and CCT range |
| Osram 840 | 15.2 | 93 | 20 000 | | Fails COI |
| Osram 940 | 2.3 | 80 | 20 000 | 3800 | Passes COI and CCT range |
| Osram 954 | 5.9 | 79 | 20 000 | 5400 | Fails COI and CCT range |
| Philips 930 | 4 | 62 | 20 000 | 3020 | Fails COI and CCT range |
| Philips 940 | 3.5 | 66 | 20 000 | 3870 | Fails COI |
| Philips 950 | 4.4 | 62 | 20 000 | 5190 | Fails COI |
| Philips Master 940 | <3 | 78 | 20 000 | 4000 | Passes COI and CCT range |
| Philips Master 950 | <3 | 78 | 20 000 | 5300 | Passes COI and CCT range |

*Table 1: Lamp data*

**Notes:**

1. Efficacy is based on a 36/37 W lamp.
2. Life is based on 50% mortality on electronic control gear.
3. COIs for NEC and Philips Master lamps are based on manufacturers' statements.
4. Because it is a dimensionless number the observation index will apply to all members of a lamp family regardless of wattage, provided that the spectral power distribution is unchanged.
5. Sylvania does not have 900 Series lamps in its range in Australia.

As can be seen from Table 1, with the exception of the Osram 940 and the new Philips medical lamps all of the triphosphor based lamps fail to meet the 3.3 COI criterion.

The outcome however is that we now have a choice of four lamp types for compliance with *AS 1680.2.5:1997* COI requirements.

An interesting point about the Osram 940 is that it is available as a compact lamp and will also be available as a T5. While there is some loss in efficacy for the compact lamp there are some applications where a complying compact lamp is useful. The use of a T5 lamp in clinical areas of a hospital would be limited due to the relatively high lamp brightness.

### Selection criteria for lamps for clinical observation

The following selection criteria should be taken into account when selecting lamps for the reliable diagnosis of cyanosis:

- COI of 3.3 or lower[2]
- colour temperature between 3300 K and 5300 K[2]
- lamp price

- lamp availability
- lamp life
- lamp efficacy
- lumen maintenance
- lamp range

Lamp efficacy has a varying impact on lighting design. Many recommended lighting levels in hospitals are generally in the 160–240 lx range and these are readily achieved by lower-efficacy lamps at practical spacings. For larger areas and higher recommended illuminance areas, higher efficacy can be an advantage.

*Lamp prices will vary, with costs to a hospital for complying lamps expected to be about 3 times the cost of a non-complying 800 Series triphosphor.*

### Conclusion

There are now at least four lamp types available in Australia that meet the COI and colour temperature requirements of *AS/NZS 1680.2.5:1997.* These are the NEC Hospital Cool White, the Osram 940 range and the Philips Master TL/D 940 and 950. Both the Philips and the new version of the Osram lamps have improved efficacy over previous high colour rendering lamps and when combined with high frequency ballasts the Philips and Osram lamps have an average life of 20 000 hours.

### References:


1. Dain SJ, Hood JW. Lighting for cyanosis identification, Conference Proceedings IES Convention, 1997.
2. AS 1765:1975, Artificial lighting for clinical observation, Standards Australia, 1975.
3. AS/NZS 1680.2.5:1997, Interior lighting, Part 2.5: Hospital and medical tasks, Standards Australia, 1997.
4. LightLab International. Why tri-phosphor lamps are unsuitable for hospital lighting, Lab Notes Issue 4.