GRID

# *Handbook on Quality Control for Street Lighting Projects of EESL*

August 2017

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# List of Abbreviations and Acronyms

| | |
|---|---|
| *AC* | Alternate Current |
| *AQL* | Acceptable Quality Level |
| *BEE* | Bureau of energy efficiency |
| *BIS* | Bureau of Indian Standards |
| *CCT* | Correlated Color Temperature |
| *CFL* | Compact Fluorescent Lamp |
| *CIE* | Commission Internationale de l'Eclairage |
| *CRI* | Color Rendering Index |
| *CRS* | Compulsory Registration Scheme |
| *DC* | Direct Current |
| *DeITY* | Department of Electronics and Information Technology |
| *EE* | Energy efficiency |
| *EESL* | Energy efficiency services limited |
| *EMC* | Electromagnetic Compatibility |
| *ESCO* | Energy service company |
| *HV* | High Voltage |
| *IEC* | International Electrotechnical Commission |
| *IESNA* | Illuminating Engineering Society of North America |
| *ILAC* | International Laboratory Accreditation Cooperation |
| *IR* | Insulation Resistance |
| *ISTMT* | In Situ Temperature Measurement Test |
| *KOLAS* | Korea Laboratory Accreditation Scheme |
| *LED* | Light Emitting Diode |
| *MRA* | Mutual Recognition Agreement |
| *NABL* | National Accreditation Board for Testing and Calibration Laboratories |
| *NMEEE* | National Mission for Enhanced Energy Efficiency |
| *PF* | Power Factor |
| *SI* | International System of Units |
| *SMD* | Surface Mounted Device |

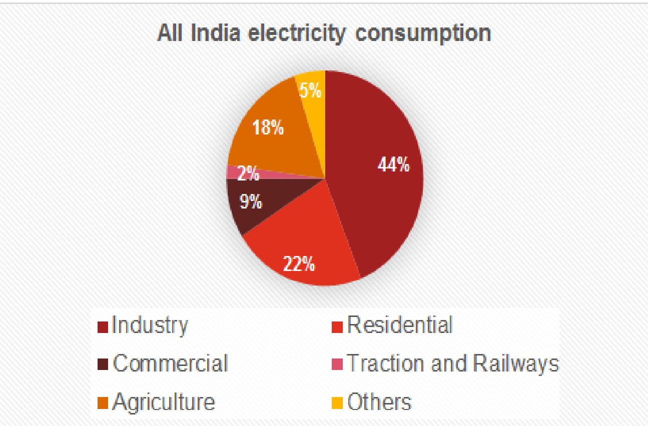
# 1. Introduction

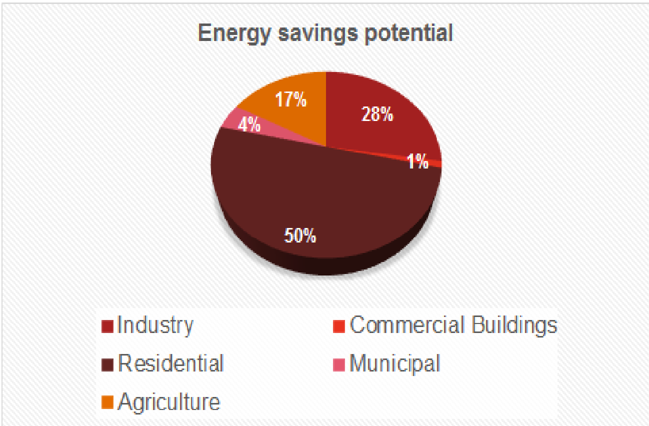
## 1.1. Background

India has huge potential of energy conservation /efficiency in different sectors of the economy. The potential available in different sectors along with the investment required to tap that potential is given below:

| Sector | DSEE Investment potential (INR crore) | Energy savings (million TOE) |
|---|---|---|
| Industry | 19,949 | 9.45 |
| Residential | 74,237 | 5.95 |
| Commercial Buildings | 1,139 | 0.30 |
| **Municipal Street lights** | **25,200** | **0.72** |
| Agriculture | 30,000 | 2.58 |
| ***Total*** | ***150,525*** | ***19.01*** |

Energy efficiency market potential in India has been studied by various financial and research institutions in different contexts[1] in the past. In 2010, the 'National Mission for Enhanced Energy Efficiency' (NMEEE), has indicated INR 74,000 crore of investment potential for energy efficiency and conservation (EE&C). The government has then revised this investment estimate for energy efficient electrical equipment to around Rs.150000 crore in about six years following the success of the LED lamps distribution program[2] by EESL. The sector wise energy consumption and saving potential is shared below:




[1] The Asian Development Bank (ADB), in 2005, puts the 'energy performance contract (EPC)' market in India at INR 14,000 crore. The Climate Group report on 'India's Clean Revolution', in 2011, has predicted energy efficiency as the most valuable low carbon development strategy for India, worth USD 477 billion by 2020. The HSBC report on 'Sizing India's Climate Economy' expects a fivefold increase in the energy efficiency market size by 2020 to USD 77 billion.

[2] EESL Managing Director told ET

The government and stakeholders are pushing market based approaches to unlock energy efficiency opportunities in India. These approaches can be applied for EE projects across multiple sectors and across equipment categories like lighting, appliance etc. Most of the EE projects are implemented by Energy Service Companies (ESCO) provide attractive options in this field. However, the prevalent reach of these ESCO are limited and large-scale implementation of energy efficiency is constrained by a number of important regulatory, institutional and financing barriers. EESL seeks to create a market for a greater involvement of ESCO by overcoming these barriers and by implementing innovative business models which can be replicated. However, such models carry considerable performance risk.

This handbook intends to act as a guide to mitigate the risks related to performance of the product being used in SLNP scheme i.e. LED lamps.

## 1.2. Objective

The objective of this handbook is to act as a comprehensive guide in designing and implementing quality control plan for EE projects involving LED lamps. It is aimed at creating an understanding of the accepted international and national quality standards for LED lamps, the various methods available for comparing the product features with the quality standard and finally, provide an action plan to ensure quality standards are adhered to.

## 1.3. Need

Performance based contracting is an integral part of EE projects. Under this form of contracting, the revenue generated by a project of an ESCO is directly related to the energy savings achieved. With respect to EE projects in lighting, the energy savings achieved is directly related to the performance of the lighting equipment being used. To that extent, quality control of the lighting equipment to be installed is of paramount importance to address performance risks.

For an organization engaging in performance contracting, a knowledge repository which assists in developing and implementing a quality control plan as well as provide a framework for vendor quality management is essential to deliver the EE project objectives.

## 1.4. Flow of topics

This document is divided into 3 phases based on the flow of processes involved in a standard quality control plan:


*Figure 1: Key phases of Quality Control Plan*

### *Establish performance goals*

This section gives an understanding of LED Lamps and the parameters which are measured to assess quality. The established international and national quality standards are laid down with respect to these parameters and finally, performance goals for LED Lamps are established based on the standards.

### *Evaluation of actual performance*

Performance evaluation is determined through tests of the product at different phases of the project lifecycle. The processes involved in these tests are explained in this section.

### *Compliance and Action taken*

This section discusses the action to be taken in case there is a difference in the results of the performance tests and the performance goals.

A **<u>Quality Control Flowchart</u>** has been prepared. This flowchart will give a broad level understanding and correlation between the phases, processes and the role of the stakeholders in each of the processes. The flowchart is shared in **Appendix.**

# 2. Establish Performance Goals

## 2.1. About LED

### 2.1.1. Introduction

LED or light emitting diode is a 2 lead semiconductor light source. Light is emitted when voltage is applied across the leads through the process of electroluminescence. First created in 1927, LEDs were started to be used in practical electronic components in 1962. Most of the usage was limited to display purposes in the electronic equipment. Subsequent advancement in semiconductor technologies, optics and material science, resulted in an exponential increase in the light output of LEDs. This led to development of LED lamps and luminaries which can be packaged into commercial products and be used for general illumination purposes. Since the prevalent light sources i.e. incandescent/CFL bulb consumed more energy than these LED based products for similar illumination properties, replacement of conventional light sources with LEDs started gaining ground.

### 2.1.2. Components of Street Lighting

All streetlights in India need to confirm to the National Lighting Code, where the minimum intensity of light on various kinds of roads has been defined. The roads have been categorized based on traffic density. All public lighting infrastructure must conform to these standards. Based on the lighting requirements as well as the age of the existing lighting infrastructure a decision is made on whether a new design and installation is required or objectives could be met by retrofitting the existing lighting system.

The components of a lighting system are classified based on their functions. They are generally described as:

- ✓ **Structural systems**: consisting of poles and pole bases (foundations)
- ✓ **Optical systems**: which consists of the luminaires
- ✓ **Electrical systems**: consisting of lamps, ballasts and service cabinets (fuse box)

During designing, these systems should be designed as per the road requirements in a way to achieve minimum life-cycle cost, while meeting lighting requirements. To achieve an effective energy-efficient design, it is essential to select the proper lamp/ballast combination that produces high lumens per watt together with fixtures that meet design requirements and minimize glare, light trespass and light pollution.

1. ***Structural Systems – Poles:*** Based on the purpose and lighting requirement of the roadway, as well as the age of existing lighting infrastructure, decisions have to be taken upon whether new designs and installations of street lighting is required or whether project goals can be accomplished by retrofitting the existing lighting system. To retrofit the existing system, it must be determined whether existing poles can be used with replacement of only luminaires, or if the ground needs to be dug up for laying cables. In case of new installation, exact location and number of poles needs to be decided.

2. ***Optical Systems – Luminaires:*** Lighting EE is a function of both the light source (the light "bulb" or lamp) and the fixture, including necessary controls, power supplies, other electronics, and optical elements. A luminaire is defined as a complete unit consisting of a lamp, together with the parts designed to distribute the light, to position and protect the lamp, and to connect the lamp to the power supply. Components that make up a luminaire include the reflector, the refractor, and the housing. These are important to ensure luminaire efficiency and cut-off and glare control, to guarantee the right level of lighting while avoiding light pollution. The Indian BIS standards provide specifications for selection of street lighting luminaires. Luminaires are classified into three categories according to the degree of glare (BIS 1981).

***Cut-off luminaire:*** A luminaire whose light distribution is characterized by rapid reduction of luminous intensity in the region between about 80° and the horizontal. The direction of maximum intensity may vary but should be below 65°. The principal advantage of the cut-off system is the reduction of glare.

***Semi–cut-off luminaire:*** A luminaire whose light distribution is characterized by a less severe reduction in the intensity in the region of 80° to 90°. The direction of maximum intensity may vary but should be below 75°. The principal advantage of the semi-cut-off system is a greater flexibility in siting.

***Non–cut-off luminaire:*** A luminaire where there is no limitation on light distribution at any angle. This luminaire is permissible when a certain amount of glare may be accepted (when daytime appearance of the street is important) and when the luminaires are large and have reduced brightness.

3. ***Electrical Systems – Lamps and Ballasts:***

    a. ***Lamps:*** The most important component of any street lighting system is its light source. It is the principal determinant of the visual quality, cost, and EE aspects of the illumination system. An electric light source is a device, which transforms electrical energy, or power (in watts), into visible electromagnetic radiation, or light (lumens). The rate of converting electrical energy into visible light is called “luminous efficacy” and is measured in lumens per watt. Today, street lighting commonly uses high-intensity discharge lamps, often HPSV lamps. However, lamp technologies have greatly evolved over the years, with increasing EE potential. Details on types of lamp technologies along with their selection will be discussed in upcoming sections in the manual.

    b. ***Ballasts:*** Ballasts are required for all HID and fluorescent lamps. The ballast generally serves three functions. First, it provides the proper open circuit voltage to start the lamp. Second, it keeps the lamp operating within its design parameters. Third, it adapts the lamp to any one of the line voltages commonly available. Sodium vapor and metal halide lamps require an igniter to initiate the arc in the lamps. High frequency electronic ballasts are recommended for tubular fluorescent lamps in street lighting in order to optimize energy use and to avoid flickering during low voltage conditions at peak traffic hours. Another useful technology to save energy in HPSV and MH lamps is the new dimmable electronic ballast that enables both constant wattage and variable illumination. The advantage of this ballast is the maintenance of desired lux level (illumination level) during low and high voltage periods at night, which helps ensure good visibility for road users during peak traffic hours. In addition, capacitors and igniters are not required when using this technology, which brings down the maintenance costs.

## 2.2. Features of Effective Street Lighting Systems

In order to properly design new lighting schemes, it is important to consider the appropriateness and effectiveness of the various energy-efficient street lighting technologies and systems for different situations. Street lighting technology and design decisions should be based on meeting local lighting requirements and design as well as technical specifications of the NLC, while achieving maximum EE. Parameters, such as the lamp efficacy, CRI, power factor, and operating temperature, also play an important role and should be taken into consideration while taking decisions about the lighting system.

Table below[3] lists the important features to consider when designing and procuring an energy-efficient street lighting system.

*Table 1: Key Features of Effective Energy-Efficient Street Lighting Systems*

| S. No. | Features | Benefits |
|---|---|---|
| 1 | Proper pole height and spacing | • Provides uniform light distribution, which improves appearance for safety and security<br>• Meets recommended light levels<br>• Minimizes the number of poles, reducing energy and maintenance costs |
| 2 | Proper luminaire aesthetics | Blends in with the surroundings |
| 3 | High lamp efficacy and luminaire efficiency | Minimizes energy cost |
| 4 | Life of the luminaire and other components | Reduces lamp replacement costs |
| 5 | Cost effectiveness | Lowers operating cost |
| 6 | High lumen maintenance | Reduces lamp replacement costs |
| 7 | Good color rendering | • Helps object appear more natural and pleasing to the public<br>• Allows better recognition of the environment, improves security |
| 8 | Short lamp restrike | Allows the lamp to quickly come back after a power interruption |
| 9 | Proper light distribution | Provides required light on the roads and walkways |
| 10 | Proper cut-off | Provides adequate optical control to minimize light pollution |
| 11 | Minimizing light pollution and glare | Reduces energy use |
| 12 | Automatic shutoff | Saves energy and maintenance costs by turning lamps off when not needed |

## 2.3. Parameters for performance measurement

For any commercially available LED lamp, performance is measured based on photometric tests, which measure visible light in units that are weighted according to the sensitivity of the human eye.

The photometric parameters used for performance measurement of LED luminaries are:

1. ***Total Luminous Flux***

   It is the measure of the total energy radiated from a light source in all directions, taking into account the varying sensitivity of the human eye to different wavelengths of light. SI Unit of luminous flux is lumen. It serves as the basis for calculating other parameters and can be used for comparing different light sources.

2. ***Luminous intensity***

   It is the measure of the luminous flux emanating from a point source within a solid angle of 1 steradian. The SI unit is Candela i.e. lumens per steradian.

3. ***Luminous Efficacy***

[3] Source: New York State Energy Research and Development Authority

It is the measure of luminous flux with respect to the energy consumed to produce it i.e. it is the ratio of luminous flux to power. The SI unit is lumens per watt. Luminous efficacy gives an understanding of the energy consumption by the LED to produce a certain level of illumination.

4. ***Chromaticity Coordinates***

Chromaticity is an objective specification of the quality of color emitted by a luminary source i.e. hue and saturation. Hue is the attribute of by which the light is discernible into its dominant wavelength or color. Saturation determined by a combination of light intensity and the distribution of the intensity across the spectrum of different wavelengths.

As the human eye has 3 type of color sensors, the full plot of all visible colors is a 3 dimensional area with 3 tristimulus value: Luminance or brightness, hue and saturation. Chromaticity coordinates are determined by projecting the values in the tristimulus coordinate space into coordinates in chromaticity space through mathematical conversion.

5. ***Correlated Color Temperature (CCT)***

A measure of the color of a light source relative to a black body at a particular temperature. It is based on the Kelvin Color Temperature Scale and is measured in degrees Kelvin (K). The figure below gives the range of color temperature for different color of the light source.

Usually, incandescent lights have a low color temperature of approx. 2800K while white LED Lamps have a color temperature value between 2700-3500K. Color temperatures over 5000K are considered cool colors i.e. bluish white while lower temperatures around 2700-3000K are called warm colors i.e. yellowish white through red.

6. ***Color rendering index (CRI)***

It gives measure of the light source's ability to reveal colors of an object realistically or naturally with respect to a natural or an ideal light source. CRI is measured by the international standard CIE $R_a$. Numerically, the highest value is 100 for standardized daylight or a black body. Typical LEDs have CIE $R_a$ values of around 80-85.

## *2.4. Performance Measurement Standards*

### *2.4.1. International Standards*

The Commission Internationale de l'Eclairage (CIE) is one of the main international entities providing standards and guidelines for street and outdoor lighting, particularly roadway lighting. Standard CIE 115-1995 highlights the importance and purpose of street and outdoor lighting in:

Allowing users of vehicles to proceed safely, leading to fewer accidents and fatalities

- Facilitate high visibility among pedestrians so they can commute safely
- Substantial reduction of criminal activities, leading to a sense of security among residential communities.

Above factors have largely affected the design and installation standards in outdoor lighting since 1976. Examples of international standards and guidelines applicable for street and outdoor lighting and traffic lighting include:

- CIE 31-1976—Glare and Uniformity in Road Lightings Installations
- CIE 22-1977—Depreciation of Installation and their Maintenance (in Road Lighting)
- CIE 47-1979—Road Lighting for Wet Conditions
- CIE 48-1980—Light Signals for Road Traffic Control

- CIE 66-1984—Road Surfaces and Lighting (Joint Technical Report CIE/PIARC)
- CIE 93-1992—Road Lighting as an Accident Countermeasure
- CIE 132-1999: Design Methods for Lighting of Roads CIE 140-2000: Road Lighting Calculations
- CIE 136-2000: Guide to the Lighting of Urban Areas
- CIE 144-2001: Road Surface and Road Marking Reflection Characteristics
- CIE 115-2007: Recommendations for the Lighting of Motorized Traffic (updated)
- CIE 180-2007: Technical Report: Road Transport Lighting for Developing Countries
- CIE 115-2010: Lighting of Roads for Motor and Pedestrian Traffic
- CIE 119-2010: Recommended System for Mesopic Photometry Based on Visual Performance

Other International/Economy-Wide Standards of reference include:

- CEN/TR 13201-1: Road Lighting—Part 1: Selection of Lighting Classes
- EN 13201-2 Road: Lighting—Part 2: Performance Requirements
- ANSI/IESNA RP-8-00: American National Standard Practice for Roadway
- ANSI C136.37: Solid-State Light Sources Used in Roadway and Area Lighting
- AS/NZS 1158.1/1-1997: Road Lighting—Vehicular Traffic Lighting AS 1158.2-1971: Standards Association of Australia (SSA) Public Lighting Code—Lighting of Minor Streets
- AS CA19-1939: Australian Standard Rules for Street Lighting

ANSI C136.37 is the only international standard focusing exclusively on LED Street and outdoor lighting. The standard specifies a number of requirements for LED luminaires based on existing regional and international LED standards such as operating temperature, correlated color temperature, mounting provisions, dimming, ingress protection, wiring and grounding. The standard aims at providing recommendations and guidance to utilities and manufacturers. The People's Republic of China, Chinese Taipei, Republic of Korea and the United States are the only APEC member economies with economy-wide standards covering specifically LED street and outdoor lighting applications.

#### *2.4.1.1. LM 79-08*

The default global test standard is LM 79-08 developed by Illuminating Engineering Society of North America (IESNA). It provides the environmental conditions for testing, how to operate and stabilize LED sources during testing, the methods of measurements and type of instruments to be used. It captures aspects of performance which includes photometric and electrical properties. The photometric properties include the following:

1. Luminous flux
2. Luminous efficacy
3. Luminous Intensity Distribution
4. Chromaticity Coordinates
5. CCT
6. CRI

#### *2.4.1.2. CIE S 025/E:2015*

Since IESNA LM79-08 was developed by a regional organization, many national standards could not adopt this. Hence in March 2015, CIE S 025/E:2015 was published by International Commission on Illumination or Commission Internationale de l'Eclairage (CIE) based on global representation. CIE S025 draws on experience of LM-79 and is more comprehensive, covers more measurement instruments and has greater depth. It covers measurement of:

1. Total luminous flux
2. Partial luminous flux (useful lumens)
3. Centre beam and beam angles
4. Electrical measurements
5. Luminous efficacy (efficiency)
6. Luminous intensity distribution
7. Chromaticity coordinates
8. CCT
9. Distance from Planckian locus
10. CRI
11. Angular color uniformity

It also specifies standard test conditions and also accounts for uncertainty of instrument measurement by specifying tolerance interval and acceptance interval.

#### *2.4.1.3. In Situ Temperature Measurement Test (ISTMT)*

It is the measure of the LED source temperature within the LED system. It is used to check whether the temperature of the luminaire is within the temperature of the LM 80-08 report and it forms the basis for determination of LED lifetime based on TM 21-11 or any other method.

#### *2.4.1.4. LM 80-08*

Developed by IESNA it is used to measure lumen maintenance of LED light sources. The report provides luminous flux for a given current over a 6000 hour period. It is conducted for 3 different LED case temperatures: 55°C, 85°C and a 3rd temperature selected by the manufacturer.

#### *2.4.1.5. TM 21-11*

TM 21-11 is the approved method by IESNA for taking LM-80 data and make useful lifetime projections for LED luminaries.

### *2.4.2. Indian Standards*

In order to ensure the citizens' safety and provide guidance to the public lighting authorities the Bureau of Indian Standards (BIS) has established standards (IS 1944) for lighting levels for street light. The Indian Standard (BIS 1981) has classified the roads based on traffic density of the road (Table 2). BIS also provides specifications for Street Lighting Poles (Table 3) and recommends mounting height of luminaires and levels of illumination (Table 4).

*Table 2: Classification of the Roads*

| Group | Description |
|---|---|
| **A1** | For very important routes with rapid and dense traffic where the only considerations are the safety and speed of the traffic and the comfort of drivers |
| **A2** | For main roads with considerable mixed traffic like main city streets, arterial roads, and thoroughfares |
| **B1** | For secondary roads with considerable traffic such as local traffic routes, and shopping streets |
| **B2** | For secondary roads with light traffic |
| **C** | For residential and unclassified roads not included in the previous groups |
| **D** | For bridges and flyovers |
| **E** | For towns and city centers |
| **F** | For roads with special requirements such as roads near airports, and railways |

Source: BIS 1981

*Table 3: Specifications for Street Lighting Poles*

| Section | Overall length 11 m + 25 mm (base plate) | | | Overall length 9.5 m +25 mm (base plate) | | |
|---|---|---|---|---|---|---|
| | Outside Diameter (mm) | Thickness (mm) | Length (mm) Outside D | Outside Diameter (mm) | Thickness (mm) | Length (mm) Outside D |
| Bottom section | 139.7 | 4.85 | 5600 | 165.1 | 4.85 | 5000 |
| Middle section | 114.3 | 4.5 | 2700 | 139.7 | 4.5 | 2250 |
| Top section | 88.9 | 3.25 | 2700 | 114.3 | 3.65 | 2250 |
| Planting depth | 1800 mm | | | 1800 mm | | |
| Nominal weight of the pole | 160 kg | | | 147 kg | | |
| Tolerance on mean weight for bulk supply is 7.5 %<br>Tolerance for single pole weight is 10% | | | | | | |

Source: BIS 1981

*Table 4: Recommended Levels of Illumination and Mounting Height of Luminaires*

| Type of Road | Road Characteristics | Average Level of Illumination on Road Surface in Lux | Ratio of Minimum/Average Illumination | Type of Luminaire Preferred | Min: Max (%) | Mounting Height of Luminaires |
|---|---|---|---|---|---|---|
| **A1** | Important traffic routes carrying fast traffic | 30 | 0.4 | Cut-off | 33 | 9 to 10 meters |
| **A2** | Main roads carrying mixed traffic like city main roads/streets, arterial roads, throughways | 15 | 0.4 | Cut-off | 33 | 9 to 10 meters |
| **B1** | Secondary roads with considerable traffic like local traffic routes, shopping streets | 8 | 0.3 | Cut-off or semi-cut-off | 20 | 7.5 to 9 meters |
| **B2** | Secondary roads with light traffic | 4 | 0.3 | Cut-off or semi-cut-off | 20 | 7.5 to 9 meters |

Source: BIS 1981

In 2012, the Bureau of Energy Efficiency (BEE) and Bureau of Indian Standards (BIS) introduced 10 comprehensive performance, safety, and quality standards for the LED lighting (Table 5) as part of the Government of India (GoI) initiative to introduce and promote energy-efficient street lighting in the country and to introduce the concept of sustainability in the ULBs, although these standards are not specific to the street lighting standards. Thus, Table 5 refers to general lighting standards.

In addition, BIS has also issued a National Building Code 2010, as a guidebook on comprehensive source for lighting projects for various applications in the country. The guidebook has specific sections on Road Lighting and Energy-Efficient Lighting Systems. The ULBs and project design consultant may refer to the code, for reference with respect to the project design of street or public lighting system.

*Table 5: List of LED Standards of BIS*

| S. No. | IS No. | Equivalent International Standard No. | Title |
|---|---|---|---|
| 1. | 16101 : 2012 | IEC 62504 TS | General Lighting – LEDs and LED Modules – Terms & Definition |
| 2. | 16102 (Part 1) : 2012 | IEC 62560 | Self – ballasted LED lamps for General Lighting Services<br>Part 1 – Safety Requirements |
| 3. | 16102 (Part 2) : 2012 | IEC 62612 | Self – ballasted LED lamps for General Lighting Services<br>Part 2 – Performance Requirements |
| 4. | 16103 (Part 1) : 2012 | IEC 62031 | Led Modules for General Lighting<br>Part 1 - Safety Requirements |
| 5. | 16103 (Part 2) : 2012 | IEC 62717 | Led Modules for General Lighting<br>Part 2 - Performance Requirements |
| 6. | 15885 (Part2/Sec13) : 2012 | IEC 61347-2-13, Ed 1 2006-05 | Safety of Lamp Control Gear<br>Part 2 - Particular Requirements<br>Section 13 - DC or AC Supplied Electronic Control gear for Led Modules |
| 7. | 16104 : 2012 | IEC 62384 | DC or AC Supplied Electronic Control Gear for LED Modules<br>Performance Requirements |
| 8. | 16105 : 2012 | LM 80/ | Method of Measurement of Lumen Maintenance of Solid State Light (LED) Sources |
| 9. | 16106 : 2012 | LM 79/<br>IEC 60598 | Method of Electrical and Photometric Measurements of Solid-State Lighting (LED) Products |
| 10. | 16107 (Part 1) : 2012 | 34D/950/NP | Luminaries Performance<br>Part 1 – General Requirements |
| 11. | 16107 (Part 2) : 2012 | 34D/977/DC | Luminaires Performance<br>Part 2 - Particular Requirements |
| 12. | 16108 : 2012 | IEC 62471 | Photo-biological Safety of Lamps and Lamp Systems |

The Department of Electronics & Information Technology (DeITY) issued "Electronics and Information Technology Goods (Requirement for Compulsory Registration) Order, 2012" on 3rd October 2012 and a notification on 13th November 2014 which subjected 30 categories of electronics products to Compulsory Registration Scheme (CRS). From the 30 categories mentioned, the following standards for LED lamps are covered by the Order:

1. IS 15885 (Part2/Sec13) : 2012
2. IS 16102 (Part 1) : 2012

As per the Order, no person is allowed to manufacture or store for sale, import, sell or distribute goods which do not conform to the Indian standard specified in the order. It mandates manufacturers of these products to get their product tested from BIS recognized labs and subsequently apply for registration from BIS. Once the manufacturer is registered by BIS under its registration scheme, the manufacturer is permitted to declare that their articles conform to the Indian Standards and put the Standard Mark notified by the Bureau.

## *2.4.3. Accepted Standards*

Based on the BIS standards, following can be the minimum technical requirements for the acceptance of an LED lamp:

*Table 6: Accepted Quality Standards for LED Lamps*

| Sr. No. | Parameters | Requirements | Applicable IS |
|---|---|---|---|
| 1. | Light source | SMD LED chip | LM80/ IS:16106 |
| 2. | Make | Nichia, Cree, Osram, Philip Lumiled | LM80/IS:16106 |
| 3. | LED Lamp Wattage | LED wattage is based on the existing old lamp | As per the old luminaries |
| 4. | CCT | 5000K and 5700K | As per ANSI |
| 5. | CRI | Minimum 70 | IS:16102-2 and IS:16106 |
| 6. | LED Chip Wattage | 1 W to 3 W | At operating current(design) |
| 7. | Estimated Life Span | 50,000 hrs | At operating current(design) - Ref 1.b Case Temperature of 105 deg C w.r.t Lumen maintenance of 70%, refer Clause 4 and 10.2 of IS:16103 |
| 8. | System Efficacy | >=110 lumen/watt | IS:16106:2012 |
| 9. | LED driver efficiency | 85% | |
| 10. | Junction temp | Maximum 85°C | IS:16102-1 |
| 11. | Harmonics | Maximum 10% | Method of Test as per IS:16102-2:2012 and IEC 61000-3-2 |
| 12. | PF | Minimum 0.95 | IS:16102-2 |
| 13. | Frequency | 50Hz ± 3% | LM-79 report |
| 14. | Operating Voltage | 110 V – 320 V | LM-79 report |
| 15. | Operating Current | >=350 mA<1000 mA | LM-79 report |
| 16. | Surge Voltage | > 4 kV | LM-79 report |
| 17. | Ambient Temp | -10 to 50 deg C | LM-79 report |
| 18. | Working Humidity | 10% - 90% RH | |
| 19. | Degree of protection | IP-66 | IS: 10322 |
| 20. | Luminaire Body Temp | should not exceed 30 deg. C from ambient (45 deg. C) with tolerance of 10 deg C after 24 Hrs | |
| 21. | Lens/ Lens module for LEDs | LED Lights shall be provided with Lenses/Lens modules.<br>Lens should be of material resistant to de-gradation during service, due | |

| | | | |
|---|---|---|---|
| | | to atmospheric components, to avoid adverse impact on light output. Lens shall be bolted (and not pasted - However, bolted AND pasted is acceptable) on to the MCPCB above the chips and the lens should be minimum IK07 impact resistant if it is also used as a lens cover. | |
| 22. | Cover Glass / Lens Cover | Glass - Distortion free, clear, heat resistant, toughened, UV stabilized glass; Lens Cover - Lens should be of material non-degradable during service, due to atmospheric components, to avoid adverse impact on light output. | |
| 23. | Cover Frame | Polycarbonate/ Al alloy cover fixed to the housing means of stainless steel screws. | |
| 24. | Heat Dissipation/ Heat Sink | INSITU/Thermal Test will cover this parameter. Manufacture must submit design/ drawing indicating maximum temperature point on LED array. This value shall not exceed junction temperature of Tj - 85 deg C | |
| 25. | Impact Resistance | The Street Light shall be built in such a way that it can withstand wind speed of 150 Kmph. | IEC/ES: 62262:2002 |

# 3. Measurement of Actual Performance

## 3.1. Introduction

For any EE project involving LED lamp, the actual performance can be measured by the following process:

1. ***Document verification*** i.e. Confirmation or declaration via certificates and checklists. Certificates issued are based on lab reports and all lab test reports submitted by the vendor should have NABL accreditation.
2. ***Physical or actual verification via testing***. It includes 4 types of tests which can be conducted in an EE project involving LED lamps:
    - ✓ *Type Test*
    - ✓ *Routine Test*
    - ✓ *Acceptance Test*
    - ✓ *Verification Test*

With reference to any EE project involving LED lamps, a combination of both Document verification and Testing should be used across the project lifecycle. To get a better understanding of the quality control processes employed in an EE project, the project lifecycle is divided into following 3 phases:

- Phase 1 – Bid Evaluation
- Phase 2 – Production/Pre-Delivery
- Phase 3 – Post-Delivery

A detailed approach to quality control method to be adopted in these 3 phases is elaborated below.

## 3.2. Phase I – Bidding

Bidders shall submit typical Quality Assurance and Inspection Plan, including the details of in-process testing and Pre-dispatch Inspection, along with the technical bid. The Pre-dispatch Inspection Plan and Types Tests proposed to be carried out shall comply with the requirements under IS: 16107 (Part 2/Sec1) and the other test requirements covered under IS: 16017 read along with other IS Standards referred to within IS: 16107. Types Tests and Acceptance Tests, as applicable under IS: 15885 (Part 2/Sec13) and IS: 16014 shall also be included.

- Pre-dispatch Inspection Plan shall be finalized within 1 week of placement of order in consultation with and duly approved by, EESL.
- Based on the survey results the pre-dispatch inspection plan shall be accordingly revised and approved from M/s EESL subjected to meet the project timelines as per LoA.
- The activities namely – survey, the Pre-dispatch inspection and subsequent installations shall be performed as a parallel activity in a Sector/Ward wise fashion; to enable faster installation
- If PDI fails then, one more chance shall be given to the bidder within 10 days after that if it again fails then it may be given to other party at risk and cost of vendor.

From a quality control perspective, during the bidding phase, the pre-qualification of any vendor is tested on the basis of verification of the documents and certificates submitted by the bidder. The tests conducted at this stage involves the following:

### 3.2.1. Type Test

Type Test is conducted for the purpose of checking compliance of the design of a given product with the requirements of the relevant standard and general quality/design features of the unit. In case of any change in any design parameter, the complete type test is repeated.

The quality standards considered for compliance are IS16102 (Part 1): 2012 and IS16102 (Part 2): 2012. The parameters that are to be measured according to the standards mentioned are as follows:

*Table 7: Type test parameters*

| TYPE TEST | | | |
|---|---|---|---|
| **No.** | **Safety (IS:16102-1)** | **No.** | **Performance (IS: 16102-2)** |
| 1 | Marking | 1 | Marking |
| 2 | Interchangeability | 2 | Dimensions |
| 3 | Protection against electric shock | 3 | Lamp Power |
| 4 | IR and electric strength after humidity treatment | 4 | Central Beam Intensity |
| 5 | Mechanical strength | 5 | Beam Angle |
| 6 | Cap Temperature Rise Test | 6 | Color quantities viz. CCT, Chromaticity Coordinates, CRI |
| 7 | Resistance to Heat | 7 | Lamp life, Lumen Maintenance and Endurance test for built-in Electronic Ballast |
| 8 | Resistance to flame & ignition | 8 | Harmonics and Power factor |
| 9 | Fault Condition | 9 | Emission (Radiated and Conducted) of radio frequency disturbances |
| 10 | Clearance and Creepage Distance | 10 | Luminous Flux |

The above set of tests are to be conducted by the vendor in NABL Certified Labs only and the results recorded in corresponding Test Reports. While LM79 Test Report captures the performance parameters like luminous flux, color quantities etc., LM80/TM 21 Test Reports records Lamp Life. For all other parameters under the safety and performance requirements, vendor should have Detailed Test Certificate from NABL Certified Labs. As detailed in the following section, these Test Reports along with other documents need to be submitted by vendor during bid submission to be considered for evaluation.

*EESL can select one number sample for each of the wattages and to send the same for Type Test at an independent NABL Accredited Laboratory. In case LED Chip/Design is changed, during the course of execution, from the LOA Specifications, EESL can carry out Type Tests on such Luminaries and the charges for the same shall be borne by the Successful Bidder.*

### 3.2.2. Document Verification

The following gives the checklist of documents required for verification at the bidding stage:

*Table 8: Documents required to be submitted by vendor at bidding stage*

| No. | Confirmation & Declaration of Quality |
|---|---|
| 1 | BIS Certification |
| 2 | LM80 report from reputed LED Chip supplier |
| 3 | Letter from Chip supplier assuring supply support to Bidder |
| 4 | Accreditation of ILAC/MRA/KOLAS/EPA International Certifying Package Agencies for LM80 test reports |
| 5 | LM79 Test report from NABL Certified Lab |
| 6 | Detailed Test Certificate from NABL Certified Lab for parameters not covered under LM-79 'Technical Specifications' |
| 7 | Sample copy of batch test report (specifying which tests will be reported with each bulb consignment) |
| 8 | Warranty certificate for performance |

A detailed inspection of the submitted documents is essential to ensure the verity of the documents and that there is no data manipulation. This inspection should be conducted by EESL to check for compliance and decide on the action to be taken.

## 3.3. Phase II – Production/Pre-Delivery

EESL conducts Pre-dispatch Inspection (PDI) at their works either on their own or through their authorized representative for any or all the lots of LED Luminaries to be supplied under subject LOA, as per Inspection Plan approved by EESL. All the requirements under this clause shall be applicable in case of each of the manufacturers from whom successful bidder may outsources the LED lights.

Intimation for PDI should contain the details of Batch Number and Serial Number of Lights along with wattage of Lights offered for inspection. All the Test Reports should contain Batch number as well as Serial Number. The Inspection call should be accompanied by a statement of the details of Make/Order Code/Part Number and Serial Numbers of LED Chips used in the Luminaires offered for inspection (Luminaire wattage-wise) along with the copies of documents in support of purchase/receipt of LED Chips (Invoice, etc.).

PDI should include review of Internal Test Reports, which should contain details of LED Chips used in the batch of Luminaires under inspection (Order Code/Part Number and Serial Numbers of LED Chips for each wattage rating of Luminaires). Internal Test Reports as well as PDI Test Reports shall be submitted for all Lights.

EESL can collect samples from Field or from the lot offered for inspection at manufacturer's works for testing as per IS: 16107 in a NABL Accredited Lab. Charges for Type Tests carried out at NABL Accredited Laboratory shall be borne by the successful bidder for one number of Luminaire of each wattage/design. EESL reserves the right to reject the entire lot in case of failure of the sample.

Type of sealing/marking of Luminaires cleared for dispatch – to be specified and the same are to be recorded during receipt inspection at site.

Variation in Driver output (Voltage and Current) at 140V and 270V w.r.t value at rated Voltage of 240V shall be within permissible limits as per IS: 16104 (CI: 7.2).

During the production stage there can be 2 types of quality check routines:

1. Routine Test
2. Acceptance Test

### 3.3.1. Routine Test

Routine Test comprise a set of tests performed by vendor on each complete unit of the same type. This is done to check whether the final product complies with the relevant standard. The vendor should maintain the records and test results with traceability. The test results are to be submitted to EESL before the product is being offered for acceptance.

The parameters that must be present in Test report are as follows:

*Table 9: Routine Test parameters*

| ROUTINE TEST | | | |
|---|---|---|---|
| **No.** | **Safety (IS:16102-1)** | **No.** | **Performance (IS:16102-2)** |
| 1 | Marking | 1 | Marking |
| 2 | Interchangeability | | |
| 3 | Protection against electric shock | | |
| 4 | IR and HV after humidity treatment | | |
| 5 | Mechanical strength | | |
| 6 | Resistance to Heat | | |

Sampling for the test will be conducted in accordance with the Quality Assurance Plan of the vendor. EESL can review of Quality Assurance Plan for reviewing the procedure. The Routine Test results, provided by the vendor should be verified by EESL.

### 3.3.2. Acceptance Test

This set of tests is conducted on samples taken from the lot which has successfully completed Type & Routine Tests. This helps in verifying whether the lamps produced by the vendor matches the EESL's technical requirements and hence, to decide whether it can be accepted or not. Acceptance Tests helps capture any quality lapses that may arise post production and prior to delivery.

The parameters that are verified at this stage are as follows:

*Table 10: Acceptance test parameters*

| ACCEPTANCE TEST | | | |
|---|---|---|---|
| **No.** | **Safety (IS:16102-1)** | **No.** | **Performance (IS:16102-2)** |
| 1 | Marking | 1 | Marking |
| 2 | Interchangeability | 2 | Dimensions |
| 3 | Protection against electric shock | 3 | Lamp Power |
| 4 | IR and HV after humidity treatment | 4 | Luminous flux |
| 5 | Mechanical strength | 5 | Central Beam Intensity |

| | | | |
|---|---|---|---|
| 6 | Cap Temperature Rise | 6 | Beam Angle |
| | | 7 | Chromaticity Coordinates, CRI |

To ensure the quality of products being delivered, acceptance test should be performed on each lot based on the following sampling plan:

*Table 11: Sampling plan for Acceptance Test*

| **Sampling Plan** | | |
|---|---|---|
| | **Safety (Part 1)** | **Performance (Part 2)** |
| Sample size as per IS 16102 | 25 (for all parameters except Cap Temperature Rise)<br><br>5 (for Cap Temperature Rise) | 15 |

The sample size indicated here is the minimum of sample to be selected, regardless of lot size. Depending on lot size, the sample size may be higher. The procedure to determine the sample size in case of larger lot size is discussed in Sampling Technique section.

Samples should be selected at random to ensure proper representation of a lot. The method employed for random selection should be in compliance with IS 4905:1968 (R2001) standard and is discussed in detail in Sampling Technique section.

For Acceptance Test, set of Safety tests are conducted first. Based on the test results, samples are selected from the lot which has passed the Safety Test for Performance Tests.

Considering the technical requirements of these set of tests, a Third Party Inspecting Agency can be employed for inspect the samples and generate Test Reports. Post inspection, the Test Reports generated can be verified by EESL for compliance.

## 3.4. Phase III – Post – Delivery

### 3.4.1. Verification Test

This set of tests are conducted before deployment of the product as a final verification of the important design parameters. Although not mandated by the relevant standards i.e. IS16102 (Part 1 & 2), Verification Test is a vital cross check mechanism, post-delivery, to ensure quality products reach the end users/consumers. While the performance checking is essential at this stage, safety test is optional. The following are the parameters which are to be tested:

*Table 12: Parameters for Verification Test*

| **VERIFICATION TEST** | |
|---|---|
| **No.** | **Performance (IS:16102-2)** |
| 1 | Lamp Power |
| 2 | Luminous flux |
| 3 | Central Beam Intensity |
| 4 | Beam Angle |
| 5 | Chromaticity Coordinates, CRI |

The following sampling plan should be followed for the verification tests:

*Table 13: Sampling Plan for Verification Test*

| **Sampling Plan** | |
|---|---|
| **Verification Test** | **Performance** |
| Sample size as per IS 16102 Part 2 | 15 |

The sample size indicated here is the minimum of sample to be selected, regardless of lot size. Depending on lot size, the sample size may be higher. The procedure to determine the sample size in case of larger lot size is discussed in Sampling Technique section.

Samples should be selected at random to ensure proper representation of a lot. The method employed for random selection should be in compliance with IS 4905:1968 (R2001) standard and is and is discussed in detail in Sampling Technique section.

A Third Party Inspecting Agency should be considered for these set of tests for measuring technical parameters. Post inspection, the Test Reports generated can be verified by EESL for compliance.

## 3.5. Summary of Test Schedule

*Table 14: Consolidated list of parameters for each test*

| No. | | Test Description | Type Test | Routine Test | Acceptance Test | Verification Test |
|---|---|---|---|---|---|---|
| 1 | | Proof of procurement of LEDs | Y | Y | Y | Y |
| 2 | | Safety Test (IS : 16102-1) | | | | |
| | a | Marking | Y | Y | Y | - |
| | b | Interchangeability | Y | Y | Y | - |
| | c | Protection against electric shock | Y | Y | Y | - |
| | d | IR & HV test after humidity treatment | Y | Y | Y | - |
| | e | Mechanical strength | Y | Y | Y | - |
| | f | Cap temperature rise test | Y | - | Y | - |
| | g | Resistance to heat | Y | Y | - | - |
| | h | Resistance to flame & ignition | Y | - | - | - |
| | i | Fault condition | Y | - | - | - |
| | j | Creepage distance & clearance | Y | - | - | - |
| 3 | | Performance and reliability tests (IS : 16102 – 2) | | | | |
| | a | Marking | Y | Y | Y | - |
| | b | Dimension | Y | - | Y | - |
| | c | Lamp power | Y | - | Y | Y |
| | d | Luminous flux | - | - | Y | Y |
| | e | Centre beam intensity | Y | - | Y | Y |

| | | | | | | |
|---|---|---|---|---|---|---|
| | f | Beam angle | Y | - | Y | Y |
| | g | CCT, Chromaticity coordinates, CRI | Y | - | Y | Y |
| | h | Lamp life, Lumen maintenance & Endurance test for built in electronic ballast | Y | - | - | - |
| | i | Harmonics and power factor | Y | - | - | - |
| | j | Test for emission (Radiated and Conducted) | Y | - | - | - |

# 4. Compliance and Action taken

This stage involves comparison of the test results/parameters given in documents with the established performance standards. On the basis of compliance or non-compliance to accepted standards given IS16102: Part 1 & IS16102: Part 2, the tested lot will be accepted or rejected.

Compliance is determined by the Acceptance Level i.e. maximum number of non-conforming items allowed in a sample for a lot to be accepted. An item is considered non-conforming when the tested value of the attributes are inconsistent with those specified in the Accepted Standards. Another term, Acceptable Quality Level (AQL) can be calculated from Acceptance Level. AQL is the Acceptance Level expressed as percentage of the sample size. The use of AQL is explained in the following section on Sampling Technique.

The compliance standards and actions to be taken at different phases is given below:

### *Phase I – Bid Evaluation*

The parameters of the documents submitted as Confirmation & Declaration of Quality should comply with the established performance and safety parameters. In case of non-compliance in any of the parameter, the bid should be rejected.

### *Phase II – Production/Pre-Delivery*

***Routine Test:*** The lot which is non-compliant to any performance or safety parameters is rejected. Only those lots which pass Routine Test proceed to Acceptance Test.

***Acceptance Test:*** The lot from which sample is selected is considered compliant if it follows the following Compliance scheme:

*Table 15: Compliance parameters for Acceptance Test*

| **Compliance** | | | | | |
|---|---|---|---|---|---|
| **Safety Requirements** | | | **Performance Requirements** | | |
| **Test Parameter** | **Acceptance Level** | **AQL** | **Test Parameter** | **Acceptance Level** | **AQL** |
| Marking | 2 | 8% | Marking | 2 | 13% |
| Interchangeability | 2 | 8% | Dimension | 2 | 13% |
| Protection against electric shock | 2 | 8% | Lamp wattage | 4 | 27% |
| Insulation resistance after humidity treatment | 2 | 8% | Luminous Flux | 4 | 27% |
| Electric strength after humidity treatment | 2 | 8% | Centre Beam Intensity | 2 | 13% |
| Mechanical strength | 2 | 8% | Beam Angle | 2 | 13% |
| Cap temperature rise | 1 | 20% | CCT, Chromaticity & CRI | 2 | 13% |
| All parameters combined | 4 | 16% | All parameters combined | 5 | 33% |

In case of performance testing, compliance is considered if 'Marking, Dimension, Centre Beam Intensity and Beam Angle' requirements are met. During testing, if any one or more sample fails, remaining LED lamps shall be tested from which not more than one shall fail.

### *Phase III – Post Delivery*

The performance compliance standards given in IS16102: Part 2 is considered in this section. The lot from which sample is selected is considered compliant if it follows the following Compliance scheme:

*Table 16: Compliance parameters for Verification Test*

| **Compliance:** | | |
|---|---|---|
| **Performance Requirements** | | |
| **Test Parameter** | **Acceptance Level** | **AQL** |
| Lamp wattage | 4 | 27% |
| Luminous Flux | 4 | 27% |
| Centre Beam Intensity | 2 | 13% |
| Beam Angle | 2 | 13% |
| CCT, Chromaticity & CRI | 2 | 13% |
| All parameters combined | 5 | 33% |

The qualifying limits discussed here are on the basis of the minimum sample size laid down in IS16102 (Part 1 & 2). As mentioned earlier, the sample size may increase based on the lot size. For sample size larger than that mentioned above is will be inspected according to the procedure given in IS2500:1965 (Part 2), elaborated in the following section.

# 5. Sampling Technique

## 5.1. Introduction

This section details the method employed to choose samples for testing. The information given in this section is in accordance with the following Indian Standards:

1. IS 16102 (Part I & II) – Self Ballasted LED Lamps for General Lighting Services (Safety & Performance Requirements)

2. IS 4905:1968 (R2001) – Methods for Random Sampling

3. IS 2500:1965 (Part 2) – Inspection by Variables for Percent Defective

The minimum sample size as mandated by IS16102 for safety & performance tests are 25 and 15 respectively. Based on the information in IS2500:1965 (Part 2), the corresponding lot size for the minimum sample size is 500, considering the recommended Inspection Level (Level IV) in the standard. For lot sizes greater than 500, the procedure given in IS2500:1965 (Part 2) is applied to determine sample size. It is assumed that lot variability is not known beforehand and hence, the Variability Unknown – Range Method is considered. The following section details the procedure to determine sample size for lot sizes greater than 500, according to the Variability Unknown – Range method.

## 5.2. Procedure for determining sample size

According to the specified method, the procedure for determining sample size is as follows:

1. Refer Table 1 of the IS document and determine the sample size code letter for Inspection Level IV and the given lot size.

2. Refer Table 4 of the IS document to identify sample size for the Sample size Code Letter determined in the previous step.

The next section elaborates on the sample selection procedure after the sample size has been determined.

## 5.3. Procedure for sample selection

As discussed in the document, sampling is required by EESL/TPIA in two test types:

1. Acceptance Test

2. Verification Test

For Acceptance Test, the sampling process will be conducted at 2 levels:

1. For testing safety requirements

    a. Up to and including 20 containers per batch

       Out of every container an equal number of lamps (or as near to equal as possible) shall be selected through Simple Random Sampling to obtain the designated number of lamps in the sample size.

    b. Over 20 containers per batch

A method of Systematic Sampling is conducted to select 20 containers from the total container lot. Simple Random sampling is adopted to select the designated number of lamps as given in the previous step.

2. For testing performance requirements

   Sample selection is conducted for those set of lamps which conform to the compliance requirements of safety inspection tests. Similar to testing for safety requirements, there can be 2 cases during sample selection for testing performance:

   a. Up to and including 20 containers per batch

      Out of every container an equal number of lamps (or as near to equal as possible) shall be selected through Simple Random Sampling to obtain the designated number of lamps from the sample size.

   b. Over 20 containers per batch

      A method of Systematic Sampling is conducted to select 20 containers from the total container lot. Simple Random sampling is adopted to select the designated number of lamps as given in the previous step.

For Verification Test, sampling process will be conducted at 1 level only:

1. For testing performance requirements

   The procedure would be same as followed in case of Acceptance Test.

The procedure for Simple Random Sampling and Systematic Sampling are given below:

1. Systematic sampling:

   This method consists of first selecting a single sample item from the population of *N* items and thereafter selecting items at a sampling interval *r* to make up the desired sample of size *n*. The sampling interval is determined by the formula, $r=N/n$. In case of a fraction, the integral part of *r* is taken as the interval and then the items are counted in one order. Every $r^{th}$ item thus counted is withdrawn until the sample of required size is obtained. In this approach, progression through the list is treated in a circular manner where there is a return to the top once the end of list is reached. This circular approach is continued until the sample size is selected.

2. Simple Random Sampling:

   In this method, sample size *n* is selected from the lot size *N* such that while selecting the item the chance for any item of the lot being included in the sample is the same. Also, an item once drawn, will not be placed back in the lot.

   To ensure that equal chance of selection of any item, *n* random numbers are required. The random numbers can be obtained from the Random Number Table (as given in Appendix B of IS 4905:1968 (R2001)). The procedure of the usage of the Random Number Table is given in the same IS document. Once the random numbers are available, the selection is conducted. Starting from any item in the lot and counting them in one order, the items corresponding to the random numbers noted down are withdrawn to constitute the required sample size *n*.

# 5.4. Analysis of Test data

## 5.4.1. Introduction

Once the sample has been selected, tests are conducted the safety and performance parameters. The procedure for analysis of test data for compliance with accepted standards is given in IS 2500:1965 (Part 2). In order to elaborate the procedure an understanding of the following terms are required:

1. Mean ($\bar{x}$) – The sum of the observations divided by the number of observations
2. Range (R) – The difference between the largest and the smallest observations in a sample
3. Variability Range ($\bar{R}$) – The mean of set of ranges calculated for sub-groups of five observations in a sample.
4. Sample Standard Deviation (s) – It quantifies the amount of variation in a set of data values.
5. Sample size (n) – The number of items in a given sample
6. Range factor (k) – Factor determined from Table 4 of the IS document based on Sample Size and AQL
7. Confidence Level – It gives the probability that test results will fall within a specified range of values. For any confidence level, an interval is defined, giving the upper and lower confidence level.
8. Upper & lower confidence level – This parameter gives the upper and lower limit of the range of values specified for a specific confidence level. The Upper and Lower confidence level is used in case of certain performance parameters as given in IS 19102:2001 (Part 2) viz. Lamp Power, Luminous Flux, Centre Beam Intensity and Beam Angle along with the Upper and Lower Specification Limit, as may be applicable.
9. Upper (U) & Lower (L) Specification Limit – Based on the accepted standards, the upper limit or the lower limit of the test value for any parameter will be specified. In case either of the two is specified, it is called a One-sided specification Limit, In case both are specified, it is called Two-sided Specification Limit. The specifications are available from the Accepted Standards section above. The limit to the specification are specified in IS16102 (Parts 1 & 2)
10. Limit factor (a): Maximum value, according to Table 6 of IS2500 (Part 2), for a particular combination of chosen AQL and sample size code letter.

## 5.4.2. Procedure

The procedure for Inspection according to Variability Unknown – Range Method is outlined below:

1. From table 4, the Range factor (k) is identified for the sample size and the AQL. The AQL for each parameter is defined in the previous section. In case the AQL defined is beyond that given in the table, a value in the table closest to the defined AQL is chosen, subject to the agreement between the parties concerned.
2. The mean ($\bar{x}$) and variability range ($\bar{R}$) is recorded for the test values of each sample for each safety and performance parameter.
3. The condition for compatibility is considered on the basis of the following:
    a. For one-sided specification limits:
        i. When U is defined, $(\bar{x}+k\bar{R}) \leq U$
        ii. When L is defined, $(\bar{x}-k\bar{R}) \geq L$

b. For two-sided specification limits:

   i. $\overline{R}/(U-L) \leq a$

   ii. $(\bar{x}+k\overline{R}) \leq U$

   iii. $(\bar{x}-k\overline{R}) \geq L$

   For compatibility, all the 3 conditions should be fulfilled.

c. For confidence level:

   The upper and lower limit for determining confidence level is calculated by the formulae given in IS16102: 2001 (Part 2):

   i. Upper Confidence Level: $\bar{x} + 1.96\ (s/\sqrt{n})$

   ii. Lower Confidence Level: $\bar{x} - 1.96\ (s/\sqrt{n})$

   According to the IS document, the appropriate formula is used for the specified parameters. The compatibility, the results should comply with both the specification limit and the confidence level criteria.

4. Based on the compatibility with the above criteria, as applicable, the test result for each parameter is considered as “Accepted” or “Rejected”.

5. For parameters (viz. Interchangeability, Lamp Power, Luminous Flux, Centre Beam Intensity and Beam Angle) having multiple compatibility criteria, the results are “Accepted” only if compatibility is established for all the criteria. Rejection in any one criteria will lead to rejection of the sample for that specific parameter.

6. For the consolidated results, the parameters for which acceptance will be at the discretion of EESL.

As discussed earlier, in case of Acceptance Test, tests for performance are conducted only for those samples which comply with the Safety requirements. For Verification Test, only the Performance Requirements will be tested for those samples which have passed the Acceptance Test.

# 6. Third Party Inspection Agency (TPIA)

## 6.1. Need for TPIA

As discussed, there are multiple parameters require to be tested to ensure quality control of LED lamps. These tests require controlled environment with specialized equipment as well as qualified personnel. Although for any EE project the quality of the product supplied by the vendor is of paramount importance, quality control is seldom the core function of an ESCO, in this case, EESL. A greater advantage can be leveraged by outsourcing the function of conducting the test to a TPIA. Such agencies provide the following advantages:

1. There are no commercial biases, unlike the tests conducted by the manufacturer. The test reports have more credibility
2. Due to specialization of the independent laboratory, the turnaround time for test activity is reduced drastically
3. Independent organizations often have specialized facilities with current calibration
4. Personnel often have excellent experience, credentials, certifications, and accreditations which will be an additional cost function if in-house quality testing is conducted

While it does provide certain advantages, precaution must be taken to ensure close co-ordination between TPIA, vendor and EESL. This will prevent any delay that might adversely affect the schedule of the project.

## 6.2. Selection of TPIA

Selection of TPIA shall be on the basis of the following:

1. Technical Criteria
2. Financial Criteria

The Technical Criteria falls under the purview of this document and is discussed in detail.

### 6.2.1. Technical Criteria

NABL has published documents delineating the specific criteria for the set of laboratories on the basis of area of testing. These Specific Criteria documents must be used in conjunction with ISO/IEC 17025:2005 (General Requirements for the competence of Testing and Calibration Laboratories). The Specific Criteria documents provide an interpretation of the latter document and describes specific requirements for those clauses of ISO/IEC 17025:2005 which are general in nature. The laboratories are required to comply with all the requirements listed in the international standard ISO/IEC 17025:2005. Further, the Laboratory shall follow the national, regional and local laws and regulations as applicable.

Accreditation is normally granted for the test facilities for which the laboratory is properly equipped and has demonstrated its capability. The scope of accreditation, hence, varies with the range of work performed, the scope and complexity of the tests involved, the competence of laboratory staff and the capability of equipment available. The accreditation is accorded to a laboratory for the entire test facilities or a part of facilities. When the facility is accredited for testing of one product and it is required to test another product where the same facility can be used, the laboratory can perform the test and issue test report. However this test will need to be evaluated by NABL during subsequent surveillance so that the scope can be appropriately amended

Following are the specific criteria documents that are referred to for NABL accreditation for testing LED Lamps:

1. Specific Criteria for Electrical Testing Laboratories (Reference Document No: NABL 104)

2. Specific Criteria for Photometry Testing Laboratories (Reference Document No: NABL 109)

Apart from the requirements specified in ISO/IEC 17025:2005, these documents focus specifically on:

1. Management Requirement to ensure operation and effectiveness of the quality management system within the laboratory

2. Technical Requirement to take care of factors which determine correctness and reliability of tests and calibrations performed in the laboratory

3. Safety Requirements to address workplace safety related issues

## *6.3. Scope of Work*

As discussed, TPIA can be employed at the Production/Pre-delivery and Post Delivery stages of project lifecycle. The details of the TPIA's function at each stage is described below:

### *6.3.1. Production/Pre-Delivery Stage*

1. Perform sampling at the vendor's product storage area based on the Sampling Plan stated earlier. TPIA is expected to arrange for the equipment and personnel required for the process. EESL will supervise the process and clarify process related queries, if required.

2. Take handover of the bulbs selected after sampling. Any damage caused due to improper handling of the samples after taking handover the vendor will be the responsibility of the TPIA. The costs which arise due the damage will be borne by the TPIA.

3. Undertake transportation of the samples from the vendor's warehouse to the TPIA's Testing Facilities ensuring proper packaging.

4. Conduct requisite tests in accordance with the statutory guidelines using own facilities, equipment and personnel.

5. Submit detailed test reports to EESL which records the following parameters:

    a. Date and time of conducting test
    b. Manufacturer's name and designation of the lamp under test
    c. List of quantities to be measured
    d. Total operating time of the product for measurements including stabilization
    e. Ambient temperature
    f. Details of photometric method used and conditions under which test is conducted
    g. Correction factors applied
    h. Photometric measurement conditions
    i. Measured safety and performance parameters
    j. Statement of uncertainties (if required)
    k. Deviation from standard operating procedures, if any

The report shall incorporate other parameters as deemed necessary by mutual agreement of TPIA and EESL. The report should be submitted to EESL within a considerable time frame as mutually agreed upon.

6. Assist EESL in analyzing the test reports and provide clarifications of any queries related to the tests.
7. Performing re-tests, in case any discrepancies are observed in the performance of any specific test or a report

The results of these tests will be submitted to EESL, which will take decision of accepting and rejecting the product based on the compliance requirements as discussed earlier.

# 7. Appendix

## 7.1. Quality Control Flowchart