STUDY OF APPLICATION OF L.E.D. LIGHTING SYSTEM IN MINES

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology in Mining Engineering

By

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National Institute of Technology Rourkela-769008
2012

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CERTIFICATE

This is to certify that the thesis entitled, "**Study of Application of L.E.D. Lighting System in Mines**" submitted by **Mr. HITESH MISHRA, Roll No. 108MN020** in partial fulfillment of the requirement for the award of Bachelor of Technology Degree in Mining Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any University/Institute for the award of any Degree or Diploma.

Date: May 10, 2012

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An assemblage of this nature could never have been attempted without reference to and inspiration from the works of others whose details are mentioned in reference section. I acknowledge my indebtedness to all of them.

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Date: May 10, 2012

Hitesh Mishra

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CONTENTS

ABSTRACT

The work done on the project contains field observations for lighting in underground and open-cast mines showing general requirements of lighting and sources of lighting. Regulations related to mine lighting are briefly enumerated. Illumination and cost comparison of different lighting sources is done showing advantages of Light emitting diode (LED) system of lighting over conventional system. Iluminance Measuring techniques and instrumentation for conducting illumination survey are briefly enumerated giving brief description of Metravi 1332 luxmeter. Comparison between different features of CFL, LED and Incandescent bulbs of application of LED system of lighting for effective energy conservation, better illumination, lower cost per day, etc..

Illumination levels at different working places in Tirap open cast coal mine, NEC, a subsidiary of Coal India limited are illustrated. And a study is done showing power savings and cost effectiveness if L.E.D. lighting system is used against the conventional lighting system used at Tirap OCP, NEC. Power saving was found to be about 73.487 % and a significant amount of cost saving was also shown. A critical comparison emphasizing the use of L.E.D. cap-lamp over conventional cap-lamp is shown with reference to experimental studies done at GDK-10 incline, SCCL. The LED cap lamp produced an illumination of 38 lux at a distance of 4 m from the source as compared to the 21 lux produced by conventional cap lamp. Thus, it was found that LED lighting system had more advantages over conventional lighting system.

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CHAPTER 1

INTRODUCTION

1.1. BACKGROUND OF THE PROBLEM

Lighting is a major requirement when we deal with working inside a mine whether it is Underground or Opencast mining. In opencast mining efficient lighting system is required while working during dark hours. In underground mining a very efficient lighting system is required when worked underground hours for whole day long. It is also required in terms of cap-lamps used inside a mine. Thus, it is required that whatever lighting system is used should follow the mining rules and regulations and should consume minimum power with maximum light output and minimum maintenance problems. Presently mostly conventional systems of lighting are used inside the mine which extract a lots of power and deal with major maintenance problems. So a replacement to such methods is required for establishing an appropriate lighting system with may overcome all the flaws and improvements required in the current conventional lighting system.

1.2. AIM OF THE STUDY

The objective of this project is to investigate the advantages of L.E.D. lighting system over conventional lighting system in terms of effective energy conservation, better illumination, resistant to shock and vibration etc.. This has been achieved by the following specific objectives.

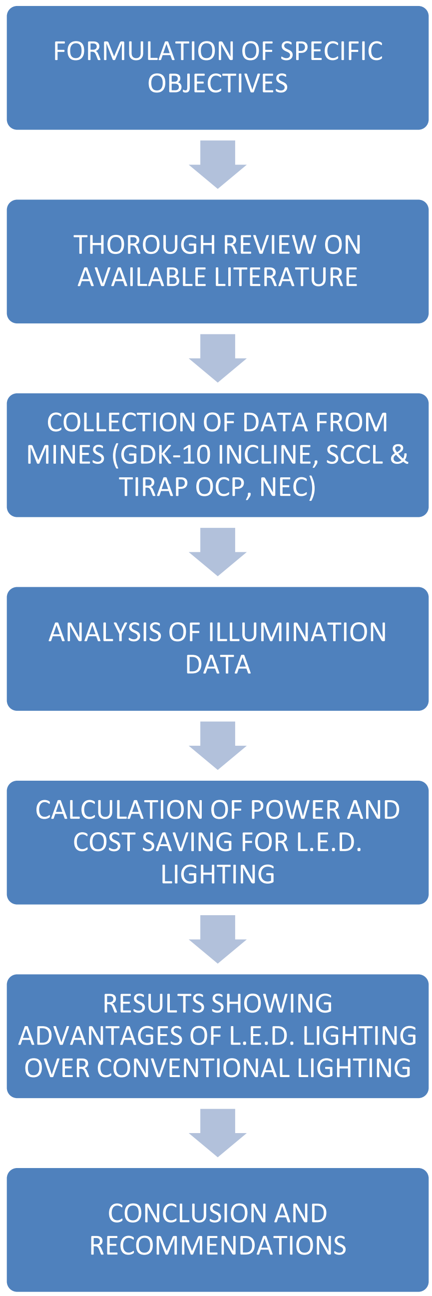
1.2.1. Objectives

The primary objective of this project is to study the effectiveness of L.E.D. lighting system over conventional lighting system with special reference to Mining Industry . It has the following specific objectives:

- Critical review of the available literature to understand the issues involved.
- Collection of data from field or an operating mine.
- Analysis of the data to compare the L.E.D. lighting system with conventional lighting system.
- Prediction of advantages based on the analysis of the data.
- Suggestions for bringing up a better lighting system(L.E.D.).

1.3. METHODOLOGY

The methodology for this project is grouped into several stages as shown below.



CHAPTER 2.

LITERATURE REVIEW

2.1. PHOTOMETRIC TERMINOLOGY:

1) **Luminous flux:** Lumen is the unit of luminous flux. It is the time flow rate of light energy. The unit of luminous flux, the lumen, is commonly used to describe the lighting power of light sources.
2) **Lumen (unit):**The lumen (symbol: **lm**) is the SI unit of luminous flux. It is the measure of the perceived light power. Luminous flux differs from radiant flux, the measure of the total power of light emitted, in that luminous flux is adjusted to reflect the varying sensitivity of the human eye to different wavelengths of light.
3) **Illuminance:** Illuminance is the amount of light falling on a surface. The unit of measurement is lux (lx) and lumen /min2 the SI system (or lumens per square meter = 10.76 foot candles, fc). A light meter is used to measure it. Readings are taken from several angles and positions.
4) **Luminance:** Luminance is the amount of light reflected from a surface. The unit of measurement is candela per square metre (equals 0.29 foot-lamberts). An illuminance meter is used to measure it. Several measurements are made and averaged. Luminance tables are consulted for reference values.
5) **Reflectance:** This is the ratio of reflected luminous flux to incident luminous flux. In other words, the ratio of light energy reflected from a surface to the amount striking it. Objects with higher levels of reflectance will appear brighter than those of lower reflectance under the same lighting conditions.
6) **Contrast:** The relative difference in luminance between two adjacent surfaces. In other words, how bright one surface looks compared to the other or the background against which it is being viewed.
7) **Glare:** There are two types of glare: disability glare and discomfort glare .Disability glare is defined as glare resulting in decreased visual performance and visibility. The cause is stray light which enters the eye and scatters inside. This produces a veiling luminance over the retina, which has the effect of reducing the perceived contrast of the objects being viewed. Discomfort glare causes fatigue and pain caused by high and non-uniform distributions of brightness in the observer’s field of view.
8) **Luminaire:** The complete lighting assembly, less the support assembly. For purposes of

determining total light output from a luminaire, lighting assemblies which include multiple unshielded or partially shielded lamps on a single pole or standard shall be considered as a single unit.

9) **Differences between lumens and lux:** The difference between the unit's lumen and lux is that the lux takes into account the area over which the luminous flux is spread. A flux of 1000 lumens, concentrated into an area of one square metre, lights up that square metre with an illuminance of 1000 lux. The same 1000 lumens, spread out over ten square meters, produce a dimmer illuminance of only 100 lux.

10) **Horizontal Illuminance :** The measure of brightness from a light source, usually measured in foot-candles or lumens, which is taken through a light meter's sensor at a horizontal position on a horizontal surface.

11) **Vertical Illuminance:** The measure of brightness from a light source, usually measured in foot-candles or lumens, which is taken through a light meter's sensor at a vertical position on a vertical surface.

12) **Uniformity Ratio:** It describes the uniformity of light levels across an area. This may be expressed as a ratio of average to minimum or it may be expressed as a ratio of maximum to minimum level of illumination for a given area.

13) **Direct Illumination:** Illumination resulting from light emitted directly from the lamp, off of the reflector or reflector diffuser, or through the refractor or diffuser lens, of a luminaire.

14) **Flood or Spotlight:** Any light fixture or lamp that incorporates a reflector or a refractor with a diffusing glass envelope to concentrate the light output into a directed beam in a particular direction.

15) **Height of Luminaire:** The height of a luminaire shall be the vertical distance from the ground directly below the centerline of the luminaire to the lowest direct-light-emitting part of the luminaire.[11]

2.2. ILLUMINANCE MEASUREMENT

There are many different units for measuring light and it can get very complicated. [9] Here are a few common measurement terms:

1. **Candela(cd)**

   Unit of luminous intensity of a light source in a specific direction. Also called *candle*. Technically, the radiation intensity in a perpendicular direction of a surface of 1/600000 square metre of a black body at the temperature of solidification platinum under a pressure of 101,325 newtons per square metre.

2. **Footcandle(fc or ftc)**

   Unit of light intensity, measured in lumens per square foot. The brightness of one candle at a distance of one foot. Approximately 10.7639 lux.

3. **Lumen (lm)**

   Unit of light flow or luminous flux. The output of artificial lights can be measured in lumens.

4. **Lux (lx)**

   Unit of illumination equal to one lumen per square metre. The metric equivalent of foot-candles (one lux equals 0.0929 footcandles). Also called metre-candle.

2.3. FACTORS AFFECTING VISUAL ENVIRONMENT

Levels of illumination are only one of the factors that determine the quality, and hence safety, of a visual environment. In coal mining, other factors that have been identified as affecting the overall quality of the visual environment are:

- Inherent vision of the mine population
- Low surface reflectance, usually less than 5%, which almost eliminates secondary reflections and indirect lighting;
- Suspended dust and water vapor cause backscattering reducing apparent illuminance.
- Mounting height restrictions and job tasks place the luminaries in the worker's direct line of sight causing glare;
- Mounting positions restrict the size, location and light distribution of the luminaries.

- Luminaries must meet the safety requirements for use in hazardous atmospheres.

(Source: ECSC, 1990)

2.3.1. Glare

Glare is a major problem in the coal mining industry. To decrease this, it is better to have lower powered lights with small distances between them, than to have high powered lights far apart. The following ways to reduce glare in the mining industry: [10]

i) Move Illuminance sources out of the direct field of view;

ii) Shielding of sources from direct view;

iii) Keeping differences in luminance between visible source and background small

iv) Keeping background and source illuminance high.

v) Position work and lighting properly.

vi) A void specular surfaces.

vii) Use light of the correct quality.

2.3.2. Reflectance

It is found that underground work environments differ significantly in surface luminance and reflectance, output of luminaries and types of visual impairment that are present. For a given illuminance, light levels and distribution can be enhanced by improving the reflectance of surfaces. Generally light colored surfaces reflect more light than dark colored surfaces. Some typical percentages of reflectance in coal mines are shown in the Table 2.1. .

Table 2.1. Reflectance of typical surfaces in Coal Mines

SURFACE	REFLECTANCE
Coal	3-15 %
Calcite stone dust	59 %
Dolomite stone dust	9 %
Rust	9 %
Fresh whitewash	65-95 %
Faded whitewash	20-60 %

As it can be seen from the above table, whitewashing a wall can increase its light reflecting ability considerably. Most underground mines make use of whitewash as a cost effective means of improving lighting performance, and the need to whitewash particular locations is required by legislation in some countries.

Similarly, stone dusting as well as being a safety measure for mitigating the effect of explosions, can also improve the reflectivity.

2.3.3. Contrast

In terms of providing a safe and efficient visual working environment, lighting levels do not address the problem fully. Detecting the presence of a potential hazard is probably the most common and also the most critical visual task in terms of ensuring safety (for example, the need for drivers to see pedestrians or other obstructions, the need for pedestrians to see slip, trip, fall hazards, etc.). In such situations, it is frequently the contrast between the visual target and the background that is most important in determining the reliability of hazard detection. However, with more light the eye can see more detail, hence less contrast is required.

2.3.4. Visibility

Determining what areas miners need to see in order to perform their job efficiently and safely are generally referred to as visual attention areas. Poor sightlines are common to a large range of underground mobile machinery. A study in the United States (US Department of Labour, 1980) concluded that approximately 36% of the fatalities involving underground coal mine mobile equipment between 1972 and 1979 were directly or indirectly caused by improperly designed operator compartments.

2.4. INDIAN STANDARDS OF UNDERGROUND LIGHTING

[2]Good visibility is essential for work persons carry on any job in a safe and efficient manner .Regulations 151 of CMR, 1957 and Reg.146 of MMR ,1961 require adequate general lighting to be provided at specified places both on surface and in underground . [6] It also requires that the lighting provided in a mine shall as far as possible be so arranged as to prevent glare or eye strain .In terms of Reg.154(2)b of CMR ,1957 ,the Director General of Mines Safety may, form time to

time by notifications in the official Gazette specify the standard of lighting to be provided in any specified area or place in a mine.

Table 2.2. Minimum standards recommended for underground lighting*(CMR, 1957)*

PLACE	MINIMUM AVERAGE ILLUMINATION LEVEL (lux)
Pit bottom	15-30
Main junctions	12.5
Roadways	4
Haulage engines, control gear and haulage drum	15

The roof and side should be properly white- washed and stone dusted on the floor as required under the statue to achieve the illumination to the standards for providing necessary visibility for safe and efficient work at different places. The standard of lighting in depillaring area should be at less 1.5 lumens/Sq.ft at the floor level .Suitable flood lighting may be arranged by 4 or more 250 W bulbs with reflector (matt surface) in degree I gassy mine .In degree II and III gassy seams a cluster of 15 to 20 cap lamps should be placed on suitable stand in the area in addition to individual lights. Some standards of illumination at certain places [1] is provided in table 2.3.

Table 2.3. Standard of illumination at certain places[1]

SL. No.	Place/ Area	Minimum	
1.	At the bottom of a sinking shaft	10 Lux	Vertical
2.	At the mechanized quarry face	15 Lux	Horizontal
3.	At the coal depot where wagons are	10 Lux 3 Lux	Vertical Horizontal

	loaded		
4.	At fully mechanized longwall face	10 Lux	Vertical

2.5. LIGHTING STANDARDS FOR OPENCAST MINES

The general lighting scheme of an opencast mine generally connected to common power source. The electric power failure may occur at any time when the whole area may be plunged in absolute darkness which may lead to an accident .Individual lights may, therefore, be provided to individual workers in addition to the general lighting scheme in the opencast mines.

The very high benches ,up to 45m high ,made by draglines or other heavy earth moving machinery (HEMM) are very difficult to keep properly illuminated .It may become difficult to pinpoint the places require dressing ,from the working points over the draglines or Shovels .Moving flood lights, akin to the hunters search light on the boom of the draglines or on the bucket of the shovels ,may be mounted and these flood lights may be rotated at will lighting up every nook and corner of the high benches. The Minimum standard recommendations for opencast mines are provided in table 2.4. [1]

Table 2.4. The minimum standards recommended for Opencast mines[1]

Sl. No.	**Place/Area to be illuminated**	**Manner in which it is to be illuminated**	**Minimum standard of illumination(lux)**	**Plane level in which tha illumination is to be provided**
1.	General working area as determined by the manager in	-	0.2	At the level of surface to be

	writing			illuminated
2.	Work place of heavy machinery	So as to cover the depth and height through which machine works	5.0	Horizontal
3.	Area where drilling rig works	So as to illuminate the full height of the rig	10.0	Vertical
4.	Area where bulldozer or other travctor mounted machines work	-	10.0	At the level of crawlers tracks
5.	Places where manual work is done	To be provided at level of the surface on which work is done	5.0 10.0	Horizontal Vertical
6.	Place where loading or unloading or transfer, loading of dumpers, trucks or trains is carried on	-	3.0	Horizontal
7.	Operators cabin of machines or mechanism	To be provided upto a height of 0.8m from floor level	30.0	Horizontal
8.	At hand picking points along conveyor belt	To be provided upto a distance of not less than 1.5m from picker	50.0	On the surface of conveyor belt
9.	Truck hauling	To be provided at the	0.5 to 3.0	Horizontal

	roads	level of the roads		
10.	Rail haulage track in the pit	To be provided at he level of the rail heads	0.5	Horizontal
11.	Roadways and footpaths from bench to bench	-	3.0	Horizontal
12.	Permanent paths for use of person employed	-	1.0	Horizontal

The US regulations are probably the most prescriptive in terms of specifying illumination requirements. Provision 75.1719-1(d) of the Codes of Federal Regulations (Mine Safety & Health Administration, 1988) states that: "The luminous intensity (surface brightness) of surfaces that are in a miner's normal field of vision of areas in working places that are required to be lighted shall not be less than 0.2 cd/m2 [0,6 foot lamberts].

2.6. INTERNATIONAL ILLUMINATION STANDARDS

In order to expand or clarify legislative requirements, the Inspectorate and/or mining companies of some countries have provided guidance or recommended illumination levels of different areas and operations underground. Good visibility is essential for work persons to carry on any safe job in a safe and efficient manner. Defining appropriate illumination levels for underground coal mines is a complex task. Table 2.5 demonstrates the level of variation across countries for each of the specified areas and operations. In considering health and well being, Odendaal (1997) states that the recommended minimum light level for general underground work is 54 lux, higher than many of the values in the Table 2.5.

Table 2.5. Summary of International Illumination Levels (in lux) (ECSC, 1990; MVS, 1992; Piekorz, 1997)

	SHAFTS	LOADING	AROUND MACHINES	HAULAGE	HEADINGS	U/G WORKSHOP
BELGIUM	20-50	20	25	10		
HUNGARY	40-100	40-60	20-50	2-10		20-50
CANADA	21			21	53	
POLAND	30	30	10	2-10	5-15	30
UK(BRITISH COAL)	70	30		2.5		50-150
EUROPEAN COAL AND STEEL COMMUNITY	40-90	15-80		5-15	10-30	
WEST GERMANY	30-40	40	80	15		
CZECHOSLOVAKIA	15	20	20	5		
SOUTH AFRICAN GOLD MINES	20-160	160		20		400

2.7. VOLTAGE LIMITS IN MINES

In a mine the maximum allowable Energy that can be transmitted in 11000 volts and maximum limit for using power in 6600 Volts. Provided that:

i) For hand-held apparatuses, the voltage should be less then 125 volts.

ii) For the use of electricity: -

(a) For underground mines, the lighting system should be properly grounded with a neutral wire and voltage should not exceed 125 volts.

(b) For open cast mining projects, maximum limit of 250 volts is allowed over a condition that the neutral wire shall be properly grounded and between the phases voltage should be less then 250 volts.

iii) Maximum 30 volts power supply can be used for portable hand held apparatus.

iv) For the use of remote controlled and electric interlocking of any apparatus, the circuit voltage should be less then 30 volts.

2.8. MAJOR SAFETY ISSUES IN MINES

The lighting equipments that are to be used inside the mine should primarily follow two criteria-

- **INTRINSICALLY SAFE**: Intrinsically safe means a device is safe to use in hazardous areas that may contain fuel in the atmosphere, such as flammable gasses or vapors, or combustible dust.
  An intrinsically safe device is therefore incapable of releasing sufficient electrical or thermal energy to ignite the fuel and cause fire or explosion.
- **FLAME-PROOF**: It should be resistant to catch fire. That is, under the conditions of any explosion or fire, it should not act as a self fuel and should not assist the fire.

2.9. DESIGN OF LIGHTING SYSTEM FOR MINES

For designing a lighting system in a mine, the illumination differs as the height of the luminaire is changed. The illumination produced by the light source decreases with increase in height. At a height of 12 m, the area covered by the illumination produced has length and width of 15m x 42 m with 12 lux levels as shown in Fig. 2.1.

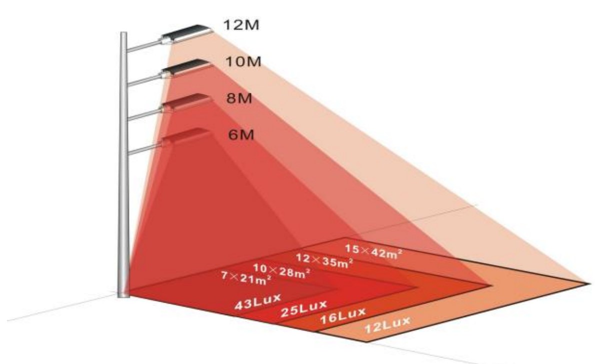


Figure 2.1. Illumination levels at different height [4]

2.9.1. Designing of Lighting System for Under Ground Mining:

The environment of an underground coal mine is a dynamic one that includes dust, confined spaces, low reflective surfaces and low visual contrasts. Lighting is critical to miners since they depend heavily on visual cues to spot fall of ground, pinning and striking and slipping and tripping hazards. Consequently, illumination greatly affects miners' ability to perform their jobs safely. Typically, a miners' caplamp is the primary and most important source of light for underground coal mines. Lighting plays a critical role for miners as they visually inspect the mine roof, ribs, back and floor for slip, trip and fall hazards. Objects associated with these hazards are typically of very low contrast and reflectivity. Secondly, there are age-related factors that require a better quality of light. Diminished night vision is one of the most common problems experienced by older people because there are changes in the eye that include decreased pupil size, cloudier lens and fewer rod photo receptors that are very sensitive to light. Designing of good lighting systems for underground coal mines is not an easy task because of the prevailing unique environment and nature of work encountered. The primary objective of this paper is, therefore, to identify the major problems encountered in this lighting application and to provide guidance in the solution of these problems. If carefully designed and implemented, lighting systems provide mine workers improved visibility and contribute to improved safety, productivity and morale. Properly designed lighting systems can improve visibility and safety during working in underground coal mines. Also it can prove to be a very cost effective investment for the mine operator. [2]

An underground coal mine is the most difficult environment to illuminate. Basically a lighting system designed for underground coal mines should have the following features:

- Intrinsically safe and externally harmless;
- High-levels of brightness and intensity in adverse environment;
- High-efficiency in terms of lumens output per unit of watt
- Low-voltage and current requirements as lightweight battery is recommended;
- Low radiated heat to prevent any electrical hazards
- Resistant to shock, vibration and atmospheric pressure fluctuations;
- No UV rays should be produced;
- Easy to install; and

- The light source should draw constant current instead of constant voltage.

Table 2.6. Illumination and cost comparison of different lighting sources [3]

Lux	Incandescent bulb	DC/ Power Source	Cost of Power/Day (AC)	**Colour rendition**	CFL	DC/, Power Source	Cost of Power/ Day (AC)	**Colour rendition**	LED	DC/, Power Source	Cost of Power/ Day (AC)	**Colour rendition**
455	40	Yes	4.32	Good	10	Yes	1.08	Good	3	Yes	0.324	Excellent
810	60	Yes	6.48	Good	14	Yes	1.512	Good	5	Yes	0.54	Excellent
1200	70	Yes	7.56	Good	17	Yes	1.836	Good	8	Yes	0.864	Excellent
1500	100	Yes with limitations	10.8	Average	25	Yes with limitations	2.7	Good	14	Yes	1.512	Excellent
2650	150	Yes with limitations	16.2	Average	30	Yes with limitations	3.24	Good	20	Yes	2.16	Excellent
3000	180	Not advised	19.44	Fair	45	Yes with limitations	4.86	Good	29	Yes	3.132	Excellent
3600	200	Not advise	21.6	Fair	56	Yes with	6.048	Good	30	Yes	3.24	Excellent

		d				limitations						
4000	250	Not advised	27	Fair	65	Yes with limitations	7.02	Good	40	Yes	4.32	Excellent

Table 2.7. Comparison between different features of CFL, LED and Incandescent bulbs

Features	Incandescent bulb	CFL	LED
Durability (in respect of shock, vibration)	Not very durable. Glass envelop can be broken easily.	Not very durable. Glass envelop can be broken easily.	Very durable. Reflective lens envelop cannot be broken easily.
Heat generation during operation	High	Medium	Negligibly low
Fire hazard	Hazardous	Hazardous	Hazardless
Sensitivity to low and high temperature environment as in underground coal mines	Moderate sensitive	High sensitive. It does not work properly at 15ºF or over 100ºF.	Negligibly low sensitive
Turn-on mechanism	Instantly	Delayed	Instantly
Mercury content	NO	Yes	NO
Carbon dioxide emission (bulb/year)3, kg	68	15.8	6.8
Life span, in Hrs	1000	12000	100000

2.10. **LED LIGHTING SYSTEM AND ITS ADVANTAGES**

LED light has complete and continuous spectrum similar to daylight. [4][5]

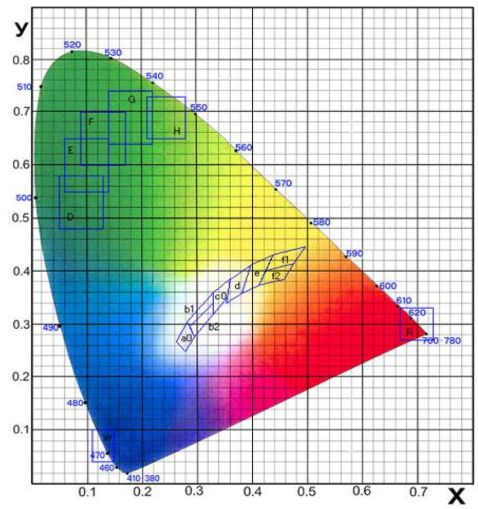


Figure 2.2. Spectrum of LED light

- LED Lighting system is need-of-the- hour product and Green Product due to the following factors
- Major energy savings of about 65~70%
- Solid-state, high shock / vibration resistant. Conforms to the standards.
- Long life LED's are maintenance-free for over 5 years.
- Very low power consumption, better visibility and super intensity due to high efficacy.
- Reduces light pollution.
- Eliminate cold start problems
- Water proof design
- Eliminate mercury and other hazardous chemicals.
- Downward throw of the makes the light pollution reduced.
- LED Luminaries produce high quality white light @ 5500K color temperature which greatly enhances the night time visibility, color rendition & Scotopic (night time) visibility of the human eye.

- Voltage fluctuation losses during “peak” “off-peak” hours are zero.
- Line losses are minimal due to the low power consumption
- Power factor losses are not applicable as there are no inductors.
- Height of the pole can be reduced and thus the cost.
- Cable cost can be reduced drastically with the LED lighting due to the low power when compared to the regular lighting.
- Maximum KVA demand comes down and the initial high investment reduces.
- Overall the major energy saving comes through the carbon credit.
- Maximum KVA demand comes down and the initial high investment reduces.
- High quality SMPS controller
- No electrodes or filaments,
- Completely solid state, high shock / vibration resistant.
- Line losses are minimal due to the low power consumption
- Wide voltage (160-277V) / wattage range (3W - 60W). [7]
- Available color temperatures: 2800K, 3500K, 4100K, 5000K, 6500K
- Excellent Lumen Maintenance over life
- Color Rendition CRI 75 with no shifting over life
- Optimal Power Factor of 1
- Overall the major energy saving comes through the carbon credit

CHAPTER 3.

EXPERIMENTAL TECHNIQUES AND FIELD OBSERVATIONS

3.1. EXPERIMENTAL TECHNIQUE FOR MEASURING ILLUMINANCE

For measuring illuminance for the though study of illuminance in the mines , Metravi Luxmeter 1332 was used. The luxmeter was placed directly in front of the light source for observing the Vertical Illuminance of the source. The Metravi luxmeter takes the reading into two units Lux and Foot-candela. Where 1 Foot-candela = 10.73691 lux.

3.1.1. INSTRUMENTATION FOR MEASURING ILLUMINANCE

For measuring illuminance of different lighting systems and for the purpose of carrying out illuminance survey luxmeter is used. The luxmeter used for carrying out field observations during the working of this project is Metravi 1332 Digital Luxmeter as shown in Fig. 3.1. [8]

Figure 3.1. Digital Luxmeter (*http://www.metravi.com/1332.html*)

The different features of metravi 1332 luxmeter are-

Features

1. CE Approval
2. Two unit options- Lux and Foot-Candela
3. With PEAK /HOLD data function

4. Cosine corrected: f'2 <3%

5. Backlight Display

Specifications

i) Display: 3 1/2 digit liquid display (LCD) with maximum reading of 1999

ii) Over range is displayed

iii) Indication for Low battery:A warning is displayed if the battery voltage drops down below the operating level

iv) Measurement Range: 2.5 times per second, nominal

v) Operating Environment: 0°C to 50°C (32°F to 122°F) at < 70% relative humidity

vi) Accuracy: Stated accuracy at 23°C ± 5°C (73°F ± 9°F) < 70% relative humidity

vii) Battery: Standard 9V battery (NEDA 1604, IEC 6F22 006P)

viii) Battery life: 200 hours typical with carbon zinc battery

ix) Dimensions: 190mm (H) x 65.5mm (W) x 35mm (D)

x) Weight: 210g including battery

xi) Photometric Formulas:

10.764 foot candles = lux (lumens/meter2)0.0929.lux = foot candles (lumens / foot2)

xii) Range: 200lux, 2000lux, 20klux, 200klux, 200fc, 2000fc, 20kfc, 200kfc

xii) Resolution: 0.1lux, 0.1fc

xiii) Spectral Response: Metravi photopic (The Metravi photopic curve is an international standard for the color response of the average human eye)

xiv) Acceptance Angle: f2 < 3% cosine corrected (150°)

xv) Temperature Coefficient: 0.1x (specified accuracy) / °C (<18°C or > 28°C), 0.056x (specified accuracy) / F° (<64.4°F or 82.4° F)

xvi) Peak hold response time: > 50mS pulse light

3.2. ILLUMINATION SURVEY IN TIRAP OCP, NEC

Illumination survey was done at Tirap open cast mine, North Eastern Coalfields to analyze the illumination standards of the mine. Both horizontal and vertical illumination readings were observed by using the luxmeter. The illumination survey was done at different places for the working of Heavy Earth Moving Machinery, Railway Sidings, Hall Roads, etc. The illumination levels were found to be appropriate as per the regulations of DGMS and CMRI, 1957. [3]

Table 3.1. Illumination levels at different working places in Tirap open cast coal mine

SL. NO.	PLACE	MINIMUM STANDARD OF ILLUMINATION(LUX)	ACTUAL OBTAINED VALUE (LUX)
1.	WORKING PLACES OF HEMM	5.0H 10.0V	
a)	1st OB Bench of East Section.	5.0H 10.0V	6.0H 14 TO 15V
b)	2nd OB Bench of East Section.	5.0H 10.0V	8.0H 14 TO 15V
c)	3rd OB Bench of East Section.	5.0H 10.0V	6.0H 16 TO 17V
d)	4th OB Bench of East Section.	5.0H 10.0V	7.0H 14 TO 15V
e)	5th OB Bench of East Section.	5.0H 10.0V	7.0H 14 TO 15V
f)	20'Coal Bench of East Section.	5.0H 10.0V	6.0H 15 TO 16V
g)	60'Top OB Bench of East Section.	5.0H 10.0V	7.0H 14 TO 15V
h)	60' Coal Bench of East Section.	5.0H 10.0V	6.0H 14 TO 15V
i)	1st OB Bench of West Section.	5.0H 10.0V	6.0H 15 TO 16V

j)	2nd OB Bench of West Section.	5.0H 10.0V	6.0H 15 TO 16V
k)	3rd OB Bench of West Section.	5.0H 10.0V	6.0H 14 TO 15V
l)	4th OB Bench of West Section.	5.0H 10.0V	6.0H 15 TO 16V
m)	5th OB Bench of West Section.	5.0H 10.0V	6.0H 14 TO 15V
n)	20'Coal Bench of West Section.	5.0H 10.0V	8.0H 14 TO 15V
o)	60'Top OB Bench of West Section.	5.0H 10.0V	6.0H 14 TO 15V
p)	60' Coal Bench of West Section.	5.0H 10.0V	6.0H 14 TO 15V
2.	Area where Bull Dozer & Other Tractor mounted Machinery working	10.0 Lux at the level Of Crawler Track.	
3.	Railway Siding (where Loading& Unloading & Transfer of Coal is carried out).	3.0 H	13.0H
4.	Roadway & Footpath from Bench to Bench.	3.0 H	-

Thus, the illumination survey was conducted to obtain the illumination data from different points at Tirap, OCP.

3.3. MINE LIGHTING ARRANGEMENTS AT TIRAP OCP, NEC

The data relevant to the luminaries used in Tirap, OCP were also obtained. The data was taken from the asset list of Tirap colliery. The luminaries used were tabulated as follows:

TABLE 3.2. List of different lighting assets at Tirap OCP, NEC

NAME OF THE ASSET	QTY OF LUMANARIES USED IN
Flood Light Complete with high mast (8*2*400 W)	1
150w metal halide integral flood type luminaries with cast aluminum . Housing comp. With 150w ballast	15
250w metal halide integral flood type luminaries with cast aluminum. Housing complete with 250 w ballast,	17
400w metal halide integral flood type luminaries with cast aluminum housing complete with 400w ballast	22

The following data was used to obtain the Power and Cost relationship between Conventional and L.E.D. luminaries.

3.4. CONVENTIONAL CAP-LAMP vs. LED CAP-LAMP SURVEY AT GDK-10 INCLINE, SCCL

A comparative study for illumination produced by L.E.D. cap lamp used at GDK-10 incline, SCCL vs. Conventional cap lamp was done . The study was carried out with the help of Metravi 1332 lux-meter. Vertical illuminance was noted down by direct the light from the source cap lamps directly towards the lux-meter. The distance of the Lux-meter from the source was regularly and uniformly increased.

The specifications of the L.E.D. cap lamps used at GDK-10 Incline , SCCL is as follows:

- MCL-4LM
- EX-I Safety Cap-light
- IEC 62013-1 $T_o > 40^0$ C
- Ex- 1b , Group 1, IP- 65, T6
- IEC 60079-11 [18:5780]
- Battery Rating: 3.7V/ 800 mA/ 4 Ah
- CMRI No. : 2319 A CMRI/ TC/P/H/225.
- DGMS No. : S66021/96/3006/GENL/5079
- FCG Hi-Tech Pvt. Ltd.

The illuminance produced by L.E.D. cap-lamp was then compared with that of a conventional cap-lamp.

Table 3.3. CONVENTIONAL CAPLAMP vs. L.E.D. CAPLAMP (Illumination study)

DISTANCE FROM THE	L.E.D. CAPLAMP	CONVENTIONAL CAPLAMP (lux)
1 m	641	390
2 m	291	186
3 m	64	43
4 m	38	21
5 m	26	12
6 m	14	4
7 m	7	-
8 m	5	-
9 m	3	-

Thus, illumination data was generated with the help of Metravi luxmeter and was tabulated as above. The distance was calculated with the help of measuring tape. Readings were taken at an interval of 1 m.

CHAPTER 4.

ANALYSIS

The data obtained from field observations and experimental studies was analyzed thoroughly. Comparative study was done using appropriate mathematical formulae and hence results were obtained.

At first, the asset list of Tirap OCP was observed, the relevant data was collected and analyzed. The power consumption of the conventional luminaries was observed, and possible replacement were suggested on the basis of the Illumination levels produced by luminaries. The data is tabulated below:

Table 4.1. CONVENTIONAL LIGHTING ASSETS USED AND THEIR PROPOSED REPLACEMENTS

Name of the asset	Total Power Consumption for a Period of 12 hours(Conventional Luminaire)	Initial Cost of Investment for 1 Luminaire (Conventional Luminaire)	Suggested Replacement (L.E.D. Luminaire)	Total Power Consumption (L.E.D. Luminaire)	Initial Cost of Investment for 1 Luminaire (L.E.D. Luminaire)
Flood light complete with high mast (8*2*400 w)	76800 W	-	L.E.D. Flood light (8*2*100W)	1600 W	-
150w metal halide integral flood type luminaries with cast alumi. Housing comp. With 150w ballast	1800 W	Rs. 10000	60 W L.E.D. LAMP	720 W	Rs 13000
250w metal halide integral flood type luminaries with cast alumi. Housing complete with 250 w	3000 W	Rs. 12000	80 W L.E.D. LAMP	960 W	Rs. 15000

ballast,					
400w metal halide integral flood type luminaries with cast aluminium housing complete with 400w ballast	4800 W	Rs 15000	100 W L.E.D. LAMP	1200 W	Rs. 18000

Hence, the lighting replacements are suggested with could be used against conventional luminaries. These L.E.D. replacements that can be used are less power consuming and produce better illumination. The initial cost of investment of these luminaries was also observed.

Then, total power consumed by conventional lighting luminaries was calculated. Relative study of power consumed by L.E.D. luminaries was also calculated. Then the power consumed by both the luminaries was calculated. Thus, power and cost comparison was done when 1 luminaire was used for a period of 1 year. The data is tabulated in table 4.2.:

Table 4.2. POWER AND COST COMPARISON STUDY FOR 1 LUMINAIRE

Name Of the Asset	Power Consumption for a Period of 1 yr (Conventional Luminaire)	Power Consumption for a period of 1 yr (L.E.D. Luminaire)	Commercial Rates for Use of Power in Tirap OCP(Rs/ KWH)	Expenditure for conventional Luminaire / yr (Rs)	Expenditure for L.E.D. Luminaire / yr (Rs)
Flood Light	28689 KW	5840 KW	5.40	154920.6	31536
150w metal halide	657 KW	262.8 KW	5.40	3547.8	1419.12
250w metal halide	1095 KW	350.4 KW	5.40	5913	1892.16
400w metal halide	1752 KW	438 KW	5.40	9460.8	2365.2
Total	32193 KW	6891.2 KW		173842.2	37212.48

Thus it was observed that even for 1 luminaire, there was significant amount of power and cost savings can be done by replacing Conventional luminaries with L.E.D. luminaries. It was calculated by taking into account the Commercial Rates of power supply at Tirap OCP, NEC. The commercial rates were Rs. 5.40 per unit of power consumed.

Then, all luminaries used at Tirap, OCP were considered and power and cost comparison study for the whole lighting system was done. Similar study for the suggested replacement was also done. The data is tabulated in table 4.3.

Table 4.3. Cost and Power comparison for all luminaries at Tirap OCP, NEC

Name Of the Asset	**Qty of lumanaries used in tirap ocp**	**Expenditure for conventional Luminaire / yr (Rs)**	**Expenditure for L.E.D. Luminaire / yr (Rs)**	**Total Power Consumption for a period of 1 yr (Conventional Luminaire)**	**Total Power Consumption for a period of 1 yr (L.E.D. Luminaire)**
Flood light	**1**	154920.6	31536	28689 KW	5840 KW
150w metal halide	**15**	53217	21286.8	9855 KW	3942 KW
250w metal halide	**17**	100521	32166.72	18615 KW	5956 KW
400w metal halide	**22**	208137.6	52034.4	38544 KW	9636 KW
Total	**55**	**516796.2**	**137023.92**	**95703 KW**	**25374 KW**

From the final calculated data, it was observed that quite a significant amount of power can be saved by replacing conventional luminaries with the proposed L.E.D. luminaries.

The total power saving done in the process is calculated to be,

Total Power Saving = 95703-25374 =**70329 KW**

The percentage of power saving was calculated to be.

Percentage Power Saving = (95703-25374)/95703*100 = **73.487 %**

The total money that can be saved by using L.E.D. luminaries against conventional luminaries,

Money Saving= **516796.2- 137023.92** = **379772.28 Rs.**

Thus a significant amount of money can be saved if LED luminaries are used as a replacement of conventional luminaries. Eventually a huge amount of power saving can also be done for the same.

Similarly, the LED cap lamps produce better illumination then the conventional cap lamps and the illumination extends for greater distances. As the distance increase the illumination produced by conventional cap lamps diminishes at a greater rate than LED cap lamps. Moreover, Led Cap-lamps do not use any harmful electrolyte that could produce any noxious gas. They are quite lighter in weight and have longer working hours then conventional cap lamps. The charging time is also less

CHAPTER 5.

CONCLUSION

By thorough analysis of the illumination data and by the mathematical study of the power and cost comparison of the conventional luminaries and there suggested L.E.D. replacements, following conclusions were drawn-

- LED Cap-lamps produce better illumination as compared to conventional Cap-lamps. As it was observed that even at a distance of 4 meters from the source, the illumination produced by LED cap lamp was 38 Lux as compared to 21 Lux produced by conventional cap lamps.
- Led Cap-lamps have several advantageous features over conventional Cap-lamps such as light Weight, more Rated Life, more working hours, less charging time, no harmful electrolyte used.
- With LED light used at Tirap OCP, NEC, about 70329 KW of power (73.487%) and Rs. 379772.28 can be saved per year.

Thus, L.E.D. lighting system is superior over other conventional lighting systems like incandescent, metal halide, fluorescent, etc. Thus it is recommended that L.E.D. lighting system should come as an appropriate replacement of the usual conventional lighting systems.

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