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Problems Encountered in the Types of Lighting Systems Generally Used in Surface Mining Projects A Case Study.

N.Lakshmipathy[1], Ch.S.N.Murthy[2], and M. Aruna [3]
[1]*Asst. Professor, Dept. of Electrical & Electronics Engg., Dr.TTIT, Oorgaum, K.G.F – 563120,*
[2] *Professor, Dept. of Mining Engg., NITK, Surathkal, Mangalore – 575025,*
[3]*Professor, Dept. of Mining Engg., NITK, Surathkal, Mangalore – 575025*

ABSTRACT
Mining is one of the major occupations in India, employing a large workforce that is likely to grow. Mining is a hazardous occupation, with workers exposed to adverse conditions; apart from the need for hard physical labor, there is exposure to stress and environmental pollutants like dust, noise, heat, vibration, poor illumination, radiation, etc. Visibility is restricted when operating load haul dump, Heavy Earth Moving Machinery (HEMM) vehicles resulting in a number of serious accidents one of the leading causes of these accidents is the inability of the equipment operator to see clearly people, objects or hazards around the machine. Results indicate blind spots are caused primarily by posts, the back of the operator's cab, and by lights and light brackets. Impaired visibility on some machines was caused by the wheel well covers, bucket lip extension, fire extinguisher, over-sized buckets, light posts, radiator back, booms, hoses on the booms, engine and the air intake cylinders. To ensure safe movement of men and machinery and for efficient working conditions, good artificial illumination needs to be provided during night hours. In mines a good lighting installation is one, which promotes good conditions of seeing. The important aspect of lighting design is to provide sufficient illuminance on visual tasks. The illuminance level, distribution of light (i.e. uniformity) and glare are the three important design parameters, which influence the visibility during night times. Power LEDs used in lighting have many advantages comparing to the widely used high pressure sodium vapor lamps or metal halide lamps. But power LEDs need switched mode electronic drives which cause high disturbances both in harmonics and in transients. Results of this study have been used to conduct "visibility" awareness campaigns to evaluate design modifications to Opencast (surface) mine with the goal to improve visibility. This paper highlights Types of Lighting Systems Generally Used in Surface Mining Projects.

Key Words: *light, luminaire, Illuminance, luminance, tilt angle. efficacy*

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I. INTRODUCTION

It recaps the summary of importance covered under illumination engineering for lighting, behavior of eye, principles of artificial lighting, measurements, calculations and applications. Good lighting aims so that our eyes clearly and pleasantly perceive things. Invariably artificial lighting schemes use some form of physical phenomena. All lighting sources today employ electrical energy. Electrical energy sources may be D.C (Direct current) or A.C (Alternating current) single phase or three phases. Usual sources of electrical energy are hydro and thermal etc.

A) Radiation

Light is the radiant energy that provides visual sensation. Human eye can sense over the 380nm (violet) to 700nm (red) wavelength. Maximal relative energy content of sunlight around 550 nm coincident with maximal luminosity of human eye. Artificial light sources employed may be broadly categorized as Incandescent Lamps and gas discharge lamps. These are based on the following four physical processes:

- Incandescence
- Luminescence
- Fluorescence
- Phosphorescence

However, we learn as we go along that good efficient lighting is obtained by combining luminescence and fluorescence. Having learnt about necessity of artificial illumination and radiation characteristics, it is time to look at how the eye responds.

B) Eyes & Vision

A Human eye resembles a camera in structure and function. Important parts of a human eye are Iris/pupil, lens and retina. The vision is either photopic (dealing with fine image details and color discrimination, due to cone cells) or scotopic (functions in dim light and no image details, due to rod cells). The human eye is achromatic in nature. Dispersive power of human eye is little greater than water. Eye is subject to purkinjee effect essentially dealing with shift of luminosity and ability of eye to adjust. Best sensitivity of cone cells is around 550nm (i.e. yellowish green hue) and that for rod cells is around 507nm (i.e. bluish green). Good lighting scheme should aim at prevention of defective vision, optimization of resources and improving conditions of visibility. Visibility depends on the (Observer Issues) size/details of object, level/quality of illumination, contrast/color and available time. It also depends on efficacy of individual, one's eye defects, optical/physical fatigue and distraction. The causes of fatigue could be rotating source, focusing on the source of glare, reading

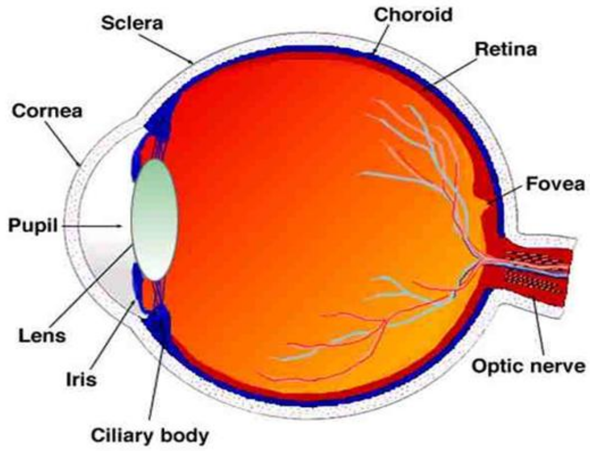

Fig:1 sectional view of human eye.

double impression. Usually after a day's work pupil is dilated a nights rest offsets fatigue due to a day's work. Visibility reduces due to eye defects and fatigues. Eye defects are caused due to aging, use or abuse. Hence, good illumination looks for producing clear and quick images. Illumination affects physiology as well as psychology, hence quality lighting is important. Factors governing illumination quality are glare, diffusion, direction/focus, composition and distribution. Minimum lighting required for good visibility is 100 ft-cd or more. For good visibility, brightness of surrounding should be greater than 0.01 ft-L & also should be less than that of the test object[(20)]. Apart from illumination, visibility is talked in terms of visual acuity, visual efficacy, visual speed and visual health.

C) Principle of lighting

Comfortable vision is highly subjective parameter, which may be difficult to ascertain. It is influenced by various factors, both physical and personal. An effective lighting installation is one, which has been designed and installed so as to provide sufficient illumination on a visual task. So while designing illumination system one must remember that it is not the machines that need light, but the men who are to operate the machines, and others who must work and move in their vicinity.

D) Light and vision

Light plays a major role in life as all activities of human beings ultimately depend upon the vision process. Light is the means of visual perception of the task and surrounding environment[(20)]. Where there is no natural light, artificial light is to be provided for better seeing. Lighting designers are responsible for optimizing the visual environment taking in to consideration of various parameters including energy, cost, visual performance, comfort and appearance.

E) Light and its physical properties

Light is a form of radiant energy within a certain range of wavelengths, capable of stimulating the eye[(3)]. It travels though space from its point of origin in all directions as a cyclical wave pattern. When the body is red hot, the wavelength of the radiated energy will be sufficiently large and the energy available is in form of heat. When the temperature increases, the body changes from red hot to white hot state, the wavelength of

energy radiated becomes smaller and smaller and enters into the visible range. Ever since Newton, it is known that different wavelengths correspond to
different colours[4], the "spectral colours". Visible light has wavelength extending from 380 nm for violet light to 760 nm or shorter than 380 nm stimulate very little or no response in the eye.

F) Perception of light

It is essential to have clear notion about a few common
terminologies in the field of illumination. 'Illuminance' is the level of light falling on the surface to be viewed and is expressed in the unit of lux (lm/m^2). 'Luminance' is the level of light emitted from the surface of light source or surface to be viewed and expressed in unit of cd/m^2. It is the luminance level reflected from the surface that helps in the vision process[5]. The eye does not respond equally to all the wavelengths in the visible range. The CIE (Commission Internationale de'Eclairage) has defined an 'average eye' corresponding to the 'spectral luminous efficiency curve' as shown in fig-1 Maximum visibility is for about 550 nm, corresponding to yellow light. 'Brightness' is a subjective evaluation of luminance. It depends both on the luminance level of the surface as well as the luminance level of the surrounding. In dark surrounding low luminance surface also may appear to be dazzling bright[5].

G) Transmission, reflection and absorption of light

When light encounters an object, it is partly transmitted, partly reflected and remaining is absorbed by the object. These three ratios transmittance, reflectance and absorptance can be used to quantify in what proportion light energy striking on a given material is distributed. Transmitted of light through a medium is affected by various properties of that medium. Light can be controlled by using a material with certain transmission capabilities to cause scattering. This is known as diffusion. The dichroic reflector, an example of this type of medium, is used in headlights of some heavy vehicles to reflect a beam of visible light forward but transmit infrared wavelength backwards[9].Diffusion is extremely important in the design of lighting systems for visual diffusion is to make the light source appear of larger and hence less bright to cause any dazzling light. Reflected light is that part of the incident light which does not penetrate through object; rather it bounces of the surface. It is this reflected light that helps in the process. Luminance of the surface is dependent on the amount of light striking the surface and the amount of light being reflected back to the eye as referred to Fig-2. For diffusing surfaces, $L=p*E/\pi$

Where,

L=luminance of surface in cd/m^2

E= illuminance falling on surface in lm/m^2

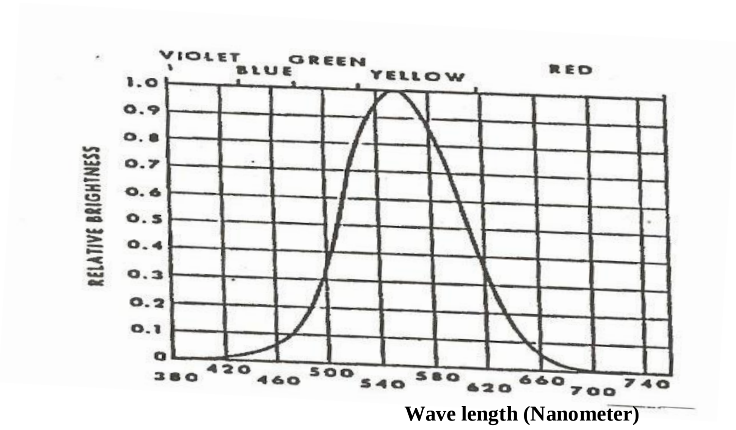

Fig-2. Brightness sensitivity of eye as a function of light wavelength (lewis, 1986.) viewing an object[20]
ρ=reflectance of surface, and π= .142[The constant Pi (in steradian) is needed because of the way in which SI (SystemInternational) units are defined] objects distribute reflected light depending upon texture of the

surface[5]. The ratio of reflected light and incident light is called reflectance. The reflectance is expressed as number less than 1, or reflection factor expressed as percentage [6]. In illumination design it is very important to evaluate the proportion of light the environment reflects as well its distribution. There are various type of reflection namely, specular reflection, diffuse reflection[7]. Spread reflection and combination of the above of which diffuse reflection is always desirable for general illumination[8]. In general, color is a result of absorption of light.

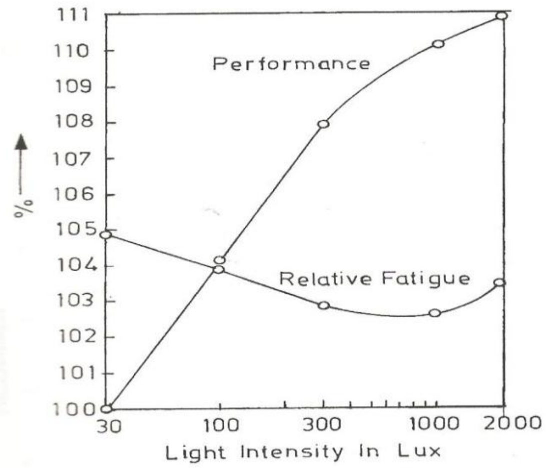

Fig: 3. Virtual Performance versus Light Intensity in Lux

H) Visual acuity

The ability of the eye to see fine details is termed s visual acuity [1, 8]. It is define as a measure of the ability of the eye to distinguish minute details of any task[10]. Visual acuity primarily depends upon the size of the object, its contrast with the background, luminance of the surface and time available to see the task. Size is the most generally recognized and accepted factor in seeing. By bringing the object closer to eye, the visual angle is increased, making the object clearer. When lighting is poor the time required to 'see accurately and act quickly' increases and one cannot react to a danger instantaneously. Visual acuity increases with the contrast. Generally a high illumination results in higher acuity and it reaches maximum at about 1600 cd/m^2 luminance level[11]. Since lightening engineer has little or no control over size and time, ability to see details is dependent on task contrast and background luminance. Visual acuity is better with a monochromatic light source then with a full spectrum or broken spectrum source. Several researches[11] have shown that in order to maintain a given degree of visual acuity in all age groups, the illumination on the task for the older groups must be progressively higher than that for younger groups as shown in fig-4.

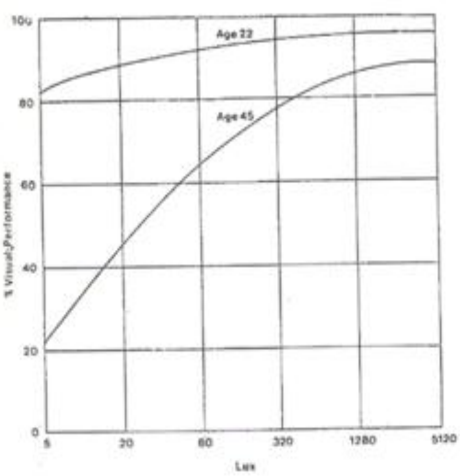

Fig. 4 Iluminance loss with age of a person (Trotter, 1982)

II. REQUIREMENTS OF GOOD LIGHTING

A) General requirements

Since miners are to work hard in contaminated and dusty atmosphere at elevated temperature, exposed to high frequency noise and vibration, dense cloud of fog in case fog hilly deposits an adequate lighting without any irritating glare problems would provide some respite. Improper artificial lighting at dark hours and in fog/smog has been responsible for many accidents(12). It need not be emphasized(6,13) has indicated that for any task to perform safety and efficiently, good illumination should be provided so that one can see the task and its surroundings very clearly. The number of error falls to a minimum with good lighting(6,11).

Proper selection of light source for particular type of work is very important. By simply providing bigger and brighter lights than the required ones do not necessarily produce better mine illumination(14), rather, in all probability, it is likely to affect the performance of workers. Figure-2 shows the effect of light intensity on the performance and fatigue. Lighting system should always be designed for older eyes(15,,18). Figure shows illuminance loss with age of a person. A good mine illumination system is expected to meet the following three concept (19).

(i)Worker acceptance: the mineworker must realize benefits from the cost of illuminated working area.

(ii) Operator acceptance: the mine operator must realize benefits from the cost of illumination system.

(iii) Compliance: The illumination system should comply with the guidelines specified by the regulatory bodies.

B) Technical requirements

An effective lighting installation is one, which has been designed and installed so that individual may work with safety and efficiency, and with reasonable comfort(10). This is influenced by three main lighting design parameters: illuminance level on the surface, uniformity of light distribution and glare from sources. The most important aspect of lighting design is to provide sufficient illuminance on a visual task. For example when a road is referred to as being 'evenly lit', this means that, when viewed from a haul truck, the road surface appears to be 'evenly bright(20), i.e. the luminance of the road surface should be as uniform as possible without dark patches(21).

Luminous intensity of light source takes care of illuminance on visual tasks, where as uniform distribution pattern depends on the technological aspects like luminaire layout, aiming angle and positioning of the light sources(1). Lighting system should not render irritating glare reflectors etc, glare play significant role in designing of illumination system, in order to reduce glare in field of vision. To some extent tip-frosted bulb avoid glare from the source(11,23) as this design conceals the filament of the bulb from direct vision. However, glare is not a major problem in surface mine lighting as the lamps are, in general, mounted at considerable height. Moreover, bulb material is selected to provide diffuse transmission causing scattering of lights. These two aspects reduce the burden on the designer as only illuminance level and uniformity ratio are to be taken into consideration for general lighting in surface mines.

C) Important places to be illuminated

Some of the activities/areas that require sufficient illumination in the surface mine are:

- Material to be loaded and filling level in the bucket or bowl.
- Illumination of haulroads.
- Spotting dumpers for loading and unloading at dumpyards, stackyards etc.
- Viewing the edge of the dump ad along walkways.
- Inside the cabins of machinery and along walkways.
- Below the shovels, under the carriage to identify any leakages and for handling of trailing cables ring relocation manoeuvres.
- Over the deck of shovels and draglines for routine maintenance and inspection.

III. SOURCES OF LIGHTING

The principle characteristics of light sources are:

1) Luminous flux – Time rate of flow light expressed in lumens (lm).
2) Luminous efficacy-Ratio of the luminous flux emitted by a lamp to the power consumed by it expressed in lumens per watt (lm/w).
3) Lamp mortality – Usually expressed as the number of operating hours elapsed before a certain percentage of the lamps fail.
4) Lumen depreciation- percentage of the original luminous flux after a certain number of operating hours given by lumen depreciation factor.

5) Color appearance- The lower the color temperature, the more reddish the source, the higher the color temperature, the more bluish the source.
6) Warm- up time.
7) Re- ignition time.
8) Whether or not ballast and/or ignition is needed.

A broad classification of electric lamps (conventional):

A) Incandescent lamps Tungsten filament lamp is most common type used in interior lighting of buildings in surface mine projects. It produces light with a continuous spectrum. These lamps have a limited life and efficacy(22). Lamp efficacy varies directly with filament temperature. Due to its high operating temperature, the tungsten filament evaporates leading to blackening of the lamp and finally to failure of the lamp. A newer upgrade to the family is tungsten halogen incandescent lamp. In this lamp, a halogen is added to the fill gas thereby preventing blackening of the lamp and this principle makes it necessary to adopt a smaller bulb and to increase the pressure of the inert gas, but the temperature can be higher than with normal incandescent lamps resulting in lights, traffic signals projectors and spotlights. Due to their low efficacy and rather limited life, they are not recommended for load lighting purpose.

B)Fluorescent lamps

The earlier fluorescent lamps (FTL) were of the ‘preheat’ type, which required the use of a starter. With this type lamp, the cathodes are preheated to emit electrons to aid in the striking of the arc at lower voltage. ‘Instant start’ lamps were developed next, primarily as an attempt to overcome the slow starting of preheat lamps. This simplifies auxiliary circuit requirements, but the required ballasts are large and expensive (23). The tubular fluorescent lamp consist of a tabular bulb having an electrode sealed into each end and containing mercury vapour at low pressure with a small amount of inert gas to aid starting. The inner surface of the tube is coated with fluorescent powders. When electric current is passed through the gas mixture, predominantly ultraviolet (UV) radiation is produced. The fluorescent powders absorb the UV (ultraviolet) radiation and radiate in the visible range. By varying the composition of the fluorescent powders, lamp types with different color appearance and color rendering properties can be made. Fluorescent lamps are commonly available in the range of about 100 lm to 10,000 lm
corresponding to 4W to 110 W. for the given lamp length of a is the tube.

C) High pressure mercury vapour (HPMV) lamps

It consists of two operating electrodes with an electron- emission coating, a gas. Starting electrode, some liquid mercury, argon gas. The arc tube is where the light is produced. Collisions between electrons and mercury atoms in the arc ionize the mercury atoms to produce the characteristics spectral lines of mercury. This occurs when the outer electrons of mercury atoms return to their normal state and release radiant energy in the transition. Some energy is in the UV region and is absorbed by the glass envelope. If fluorescent powder are coated on the inside of the envelop, the UV radiation can be converted to visible light. If this is done the lamp is usually called ‘color improved’.

D) Metal Halide (MH) lamp

Fig-5 shows the Metal Halide (MH) lamps are similar in construction to the HPMV lamps, the major difference being that the discharge tube of the former contains one or more metals in addition to mercury. A typical combination of halides used is that comprising of the iodides of sodium, indium and thallium. These halides give an increase in intensity in three spectral bands: blue, green and yellow-red. The radiation emitted lies in region of the spectrum to which the eyes are highly sensitive. The result is a lamp with reasonable color rendering and an efficacy of over 80 lm/w for a 400W lamp. Its main application lies in the floodlighting for large areas. The life of the metal halide lamps is shorter than that of corresponding wattage of other discharge lamps. So these lamps do not offer an economical solution for road lighting. Most metal halide lamps are commonly available in the approximate range of 20,000 to 2,00,000 lm corresponding to 250 to 2000W.

E) Low pressure sodium (LPS) lamps

Fig-6 shows the The lamp consists of a borate coated sodium resistant U- shaped tube contained inside a cylindrical glass envelope. A small quantity of sodium is operated inside a U-shaped tube at a temperature around 235 ^{0}c. A mixture of insert gasses like neon, argon, xenon and helium is present to aid in starting. A high vacuum is applied inside the outer glass envelope to prevent convection heat losses from the arc. When first started, the lamp appears red due to neon discharge, but this gradually gives way to the characteristic yellow as the sodium is vaporized the lamp may require 15 minutes to reach full brightness and 1 to 2 minutes to restart after a power failure. Low-pressure sodium lamps are available in approximate range 2000 to 3500 lm corresponding to 18 to 180 W. Low pressure sodium vapour lamp have not become popular for mine lighting.

Fig 5: 150W metal halide

Fig 6: Low pressure Sodium vapor lamp

F) High pressure sodium vapour (HPSV) lamps

The Fig-7shows the arc tube in high pressure sodium vapour (HPSV) lamp is smaller in diameter then the arc tube of a mercury vapour lamp and is made of a translucent high-transmissivity, polycrystalline-alumina

Fig 7: High Pressure Sodium vapor lamp.

ceramic.Contents of the arc tube include two operating electrodes, mercury -sodium amalgam and xenon gas. As the narrow diameter arc tube maintains a high operating temperature, starting electrode is not required for warming up. HPSV lamp has about twice the efficacy of the HPMV lamp. Sodium gives a higher proportion of radiation at wavelengths in the visible range for which the eye has its maximum sensitivity than does mercury, hence the higher efficacy of sodium lamp. The lamp was made possible by the invention of a translucent ceramic arc tube and a process for sealing electrodes in the tube to with stand high temperatures and corrosive effects of heated sodium vapours. In case of HPSV lamps, a special ballast circuit is utilized to provide a short duration, high voltage spike across the main electrodes, which readily ionizes the xenon gas. The xenon gas vaporizes the amalgam that enters the arc stream. Lumen output increases until a steady state operating condition is reached in about 3 minutes .HPSV lamps are available in the range 3000 to 130000 lm corresponding to 50 to 1000 W.

G) LED Source:

Some special diodes that emit light when connected in a circuit. They are frequently used as "pilot" lights in electronic appliances to indicate whether the circuit is closed or not. The two wires extending below the LED epoxy enclosure, or the "bulb" indicate how the LED should be connected into a circuit. The negative side of an LED lead is indicated in two ways: 1) by the flat side of the bulb, and 2) by the shorter of the two wires extending from the LED. The negative lead should be connected to the negative terminal of a battery. LED's operate at relative low voltages between about 1 and 4 volts, and draw currents between about 10 and 40 mill amperes. Voltages and currents substantially above these values can melt a LED chip.

The most important part of a light emitting diode (LED) is the semi-conductor chip located in the center of the bulb as shown in Fig-7. The chip has two regions separated by a junction. The p region is dominated by positive electric charges, and the n region is dominated by negative electric charges. The junction acts as a barrier to the flow of electrons between the p and the n regions. Only when sufficient voltage is applied to the semi-conductor

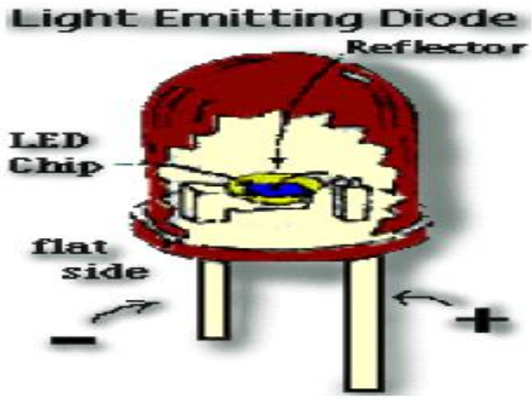

Fig 9: LED source.

chip, can the current flow, and the electrons cross he junction into the p region. In the absence of a large enough electric potential difference (voltage) across the LED leads, the *junction* presents an electric potential barrier to the flow of electrons. The electric energy is proportional to the voltage needed to cause electrons to flow across the p-n junction.

IV. PROBLEMS IN SURFACE MINE LIGHTING

A) System of surface mining lighting

The general lighting scheme of an opencast mine is usually connected to a common power source. So, to avoid complete darkness in case of power failure, every Heavy Earth Moving Machinery (HEMM) is provided with self mountain lighting system. The modern heavy-duty face machinery dictate increasing in the bench height, forcing individual face lighting system. Individual lights may also be provided at active zones in addition to the general lighting scheme. The luminaries may be mounted on:

- machines used in the mines.
- movable telescopic as well as tiltable trolley mounted lighting mast.
- low height (1.5- 2.0 m) tripods for spot face lighting .
- towers erected on planned locations outside the blasting zone.

Generally lamps mounted on tripods are used near the loading machines at the face. The cable wheel may be placed at one end, so that the cable can be stretched along the length of the face. Telescopic lighting mast (also called mobile lighting towers) either self-powered or towable type is used at the place, where more number of activities is carried out simultaneously. In some critical areas such as dumpyards, stackyards etc.

where the dumping activities and vehicle movement are being carried out, it is advisable to go for movable lighting system connected to the main lighting scheme. In many of the mines it is found that the separate portable type generator set is provided for the dumpyard illumination.

The haul roads are illuminated with single side arrangement of poles, which can be suitable and erected on a pre-planned safe distance. In most of the Indian mines the height of the poles vary from 7 to 12 m , with the angle of the light arm usually 35 degree to 70 degree, vertically upward with horizontal. The HPSV and FTL are very commonly used for surface mine lighting. In some mines HPMV lamps are specially used for roadway lighting. In semi-mechanized mines, where FTL are used, halogen lamps (HAL) are employed for illuminating the road junctions.

B) Adverse working condition

Because of adverse conditions in the mines light should come from the right direction, in right quantity and of right colour, ideally without a glare. But due to typical working nature in the mines it is very difficult to fulfill these requirements, and also the orientation of the light at work site is a challenging task. Due to this reason machine operator and other workers in a mine need to be able to orient themselves in a difficult visual environment. The haul roads always keep on changing to tune with the mining activity. Other critical area such as dumpyards, stackyards etc also change their phase with time, and it is difficult to illuminate such areas. For example, at dumpyards lighting should be provided at the drivers' side, which is always not possible, due to changing configuration of dumpyards. The movement of HEMM generates dusts, which causes significant reduction in light emission from the sources. Its was estimated that the dust and dirt collected on a lamp or luminaire cover can reduce the light output by as much as 20%. In some mines fog is a major problem, due to which the loss in working hours is even up to 120-240 hrs/yr. The major effect of fog is to reduce the contrast of colour and brightness of surrounding environment. Contrast is usually low in a mine, since most of the light is absorbed by surrounding rock. In hilly deposits, in monsoon, due to rough weather condition breakages of light fixtures especially fluorescent tube lights are very common. Due to continuous movement of task and undulating terrain it is difficult to maintain the uniform light level in the work site.

C) Surface wetness and poor reflectance

Lighting in mines presents special problems due to dark surrounding and low reflectance of mine surfaces. The reflectance depends on the nature of ore/overburden. Due to continuous sprinkling of water for dust suppression, the surface reflectivity further reduces, resulting in poor visibility. In case of dry surfaces, the reflected light is mainly a function of the materials colour and the surface texture. In a dry mine, most surfaces exhibit diffuse specular reflectance. But a very dusty or powdery surface would exhibit completely diffuse reflectance. Light falling on a rough surface will scatter or diffuse in all the directions. When a surface is perfectly diffusing, the light reflected is constant in all directions, regardless of the angle at which the surface is viewed. Reflectivity for such surface is therefore a constant for all the angles. In wet condition i.e. when the surface is moistened, the thin layer of water changes the scattered light. The light entering in to the water and substance interface scatters deep in to the material, than when the material is dry. Due to this the final light, which leaves the surface, is dimmer than the light scattered by the surrounding dry surfaces. The texture depth of a surface has an important bearing on the specularity when it is wet. With increase in texture depth, the light naturally strikes many more faces and certain fraction of light is absorbed, and hence the intensity of light further reduces.

D) Illuminance and luminance level

Illuminance is one of the factors, which influences visibility. Illuminance is governed by lighting standards specified by various regulatory bodies. These standards are for the purposes of guidance only, because depending on other factors, better visibility may be achieved with lower illumination, or even the standards mentioned may give inadequate lighting. In fact illumination affects visibility in an indirect manner. The amount of light reflected from the object to be seen, i.e. its brightness level is of direct importance. An increase in lumen output probably means an increased surface brightness. The brightness of the surface is mainly depending upon the incident illumination falling on the surface and also on its reflection factor. In mines because of poor surrounding reflectance the actual required light level is very high, compared to the recommended standards. As far as possible, the lighting level should be specified in terms of luminance levels.

E) Uniformity

Good lighting is not only the matter of more light but is also a matter of proper distribution of light. For example, well-lit road surfaces have to appear evenly illuminated, with no apparent dark patches and a minimum of glare. It is possible only when the distribution of light is more or less uniform throughout the length of haul road. Uniformity ratio of illuminance on a given plane is a measure if the variation of illuminance over it. There are two ways of expressing uniformity ratio, (i) ratio of the minimum to maximum illuminance or (ii) ratio of the minimum to average illuminance. The later is known as overall uniformity ratio and denoted as Uo. It is recommended that uniformity should not be less than 0.3 for the perception to remain acceptable. Bell introduced the concept of diversity ratio which is reciprocal of uniformity ratio. He suggested the ratio of maximum to minimum resonance as 5:1 for any lighting installation. The renowned British lighting engineer, W.R. Stevens, mentioned that a diversity ratio of 1.5 to 1 in illumination should generally be accepted as permissible minimum level .The Australian standard (AS) 1680-1 requires that the ratio of the minimum to average illuminance on an obstructed workplace should not be less than 0.8.

F) Glare

Glare is caused as a result of any excessively bright source of light in the field of view that results in the loss of visibility, discomfort, annoyance, interference with vision, or eye fatigue. Trotter and Louis justified that glare is not only due to bright light; it also depends upon other factors, both physical and technical. Glare may be of two types, namely disability glare and discomfort glare. Disability glare is caused by the action of stray light, which enters the eye and scatters within. It causes a 'veiling luminance' over the retina, which in turn as the effect of reducing the perceived contrast of the objects being viewed. Discomfort glare is a sensation of annoyance or in extreme cases causes pain by high or non uniform distribution of brightness in the field of view. It does not affect all individuals to the same extent. Disability glare directly interferes with visibility and ultimately with visual performance. Disability glare is very important in mining.

Glare problems in the mine may include those resulting from:

- improper focusing of face lights
- focusing of headlights of down coming vehicles
- extreme glare from the machine canopies
- flashing of lights during swinging action of loading machinery
- glare from lights on the sides of machines

Unlike underground mines, glare is not a major problem in surface mines. A study of glare reduction for light fixtures used in mining was initiated by Donald trotter in his work granted by national sciences and engineering research council. Mine lighting glare can probably be best limited by fixture and their placement. Glare from the source can be controlled by using frosted bulbs are with certain diffusion material, which makes the light source to scatter larger and hence less bright. Small brightly-lit areas reduced the workers effective vision, thus increasing the danger from glare. To avoid or reduce glare, illuminance should be fairly of even intensity throughout the visual field.

G) Tilt angle

Fig- 8 shows the Inclining or tilting the luminaires up from the horizontal is done to increase light coverage across the road compared to the mounting height, tilting the luminaires will facilitate improving light level at the far side of the road. But high tilting will diffuse the light and reduce its distribution along the longitudinal direction of width at a given mounting height. But this measure is not very effective. If the effective road width is large the road. It is recommended that the angle of tilt, with respect to the normal height of mounting, be limited to an absolute maximum of 10 degree, a top limit of 5 degree being preferable. In general the angle varies from 10 degree to 15 degree. High tilting especially at bends in the road, also increases the chances of glare being produced and makes it difficult to provide good visual guidance as shown in the fig-4.

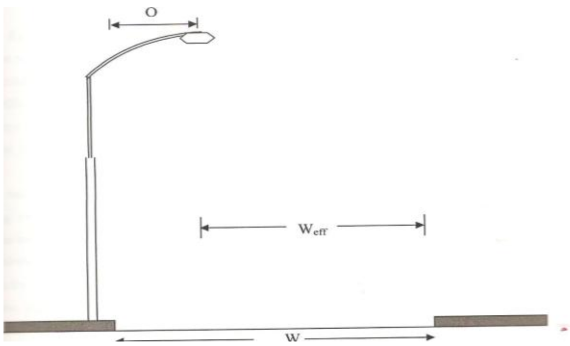

Fig- 8. Effective Road (W_{eff}) Equal to actual width (W) minus luminaire Overhang

V. CONCLUSIONS

One would expect that better lighting would reduce accidents, increase production and reduce health hazards. Due to continuous sprinkling of water for dust suppression, the surface reflectivity further reduces; resulting in poor visibility. The movement of HEMM generates dusts, which causes significant reduction in light emission from the sources. It was estimated that the dust and dirt collected on a lamp or luminaire cover can reduce the light output by as much as 20%. In some mines fog is a major problem, due to which the loss in working hours is even up to 120-240 hrs/yr. The major effect of fog is to reduce the contrast of colour and brightness of surrounding environment. Furthermore, for the incandescent lamp, the floor temperature directly under the lamp is high (32.2 to 42.7˚ C) compared to the comfort temperature generally recommended (from 24 to 30˚ C).The temperature distribution pattern is not circular for the halogen lamp. This is due to the "tube shape" of the halogen lamp.

The design of lighting systems to meet all the demands of colliery operations requires a holistic approach and greater consideration. As the vision process is dependent on the reflected light, it is hoped that in near further, mine lighting design would also give due weightage to surface reflectance. In that case this paper would act as a leading study towards Problems Encountered in the design of different lighting systems in open cast/surface mine lighting.

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AUTHORS:

1. Mr.N.Lakshmipathy

Mr. N.Lakshmipathy has been teaching profession for the last 15 years. A graduate in B.E (E&E) , he completed M.E (Powerelectronics) from University Vesvesvaraya College Engineering, Bangalore . He is assistant professor, Department of Electrical Engineering at the Dr.T.Thimmaiah institute of Technology, KGF Karnataka, .

2 . Dr.Ch.S.N.Murthy :

Dr.Ch.S.N.Murthy has been in the teaching profession for the last 26 years. A graduate in 1980 from K.S.M osmania university hyderbad and has 5½ years in underground coal mines. Under his guidance 2 Ph.D has been awarded and 2 Ph.D scholar submitted thesis and waiting for results., 8 Ph.D students are presently working. He has published 110 technical research paper in international / national/ journal/conferences/ symposium. Actively involved in organizing various programmes in the department for the benefit people in industries.

3. Dr. Aruna Mangalpady

Dr. Aruna Mangalpady did his graduate programme in Mining Engineering from Karnataka Regional Engineering College, Surathkal, Mangalore University in the year 1993 and completed Ph.D. degree from Indian School of Mines University, Dhanbad in the year 2008. Worked for 5 years in large mechanized iron ore mines in various capacities. Joined NITK, Surathkal in the year 1998 and at present he is Associate Professor in the Department of Mining Engineering. He is involved in various R&D and industrial consultancy projects. He is recipient of "Young Scientist Award" from the Department of Science & Technology, Govt. of India.