SASKATCHEWAN
ENERGY MANAGEMENT
TASK FORCES

TECHNOLOGY INFORMATION SHEET

LIGHTING BASICS

Topics covered by this information sheet:

1. **Light as Service**
2. **What is Light - How is it Defined**
3. **Light Quality - How Much and What Type of Light**
4. **Sources of Light**
5. **Measures of Lighting Effectiveness**
6. **Lighting Design**
7. **Secondary Effects of Lighting**
8. **Lighting Controls**

1. Light as a Service

Lighting provides the following services:

- work in a productive manner
- safety of movement
- protection of eyesight
- aesthetics of buildings and other surfaces
- security
- enhancement of products

It is the services that are needed not the light itself. The type of light - brightness, colour, location, etc., will determine how well the light provides these services.

2. What is Light and How is Light Defined

2.1 What is light

- Light is a stream of high frequency photos made up of different colours of different wavelengths
- Natural or “white” light is a full spectrum provided by the sun’s light.
- The human eye has evolved to use this type of light.
- Artificial lighting therefore should replicate this type of light

2.2 How light is measured

- The intensity or brightness of a light source in a given direction is measured in candelas
- The total flow of light being emitted by the source in measured in lumens
- The amount of this light falling on a given surface (i.e. useful light) is measured in lux (number of lumens / sq.metre) or ft-candles (lumens / sq.ft). The higher the lux the brighter and clearer the lit area
- Use analogy of a water spray - pressure (candelas), flow (lumens), wetness of area (lux)
- Colour of light is determined by the source of light - the wavelengths that make it up.

- Colour Temperature = the temperature of a glowing reference source that produces the same colour of light and depends on the type and design of the light source
- Colour rendering is what an object looks like under the light. e.g. red looks brown under a yellow light. Colour Rendering Index (CRI) = an index of how well the lamp matches natural lighting colour (CRI = 100) and depends on the type and design of lamp

3. Light Quality - How Much and What Type of Light

See also - Energy Efficient Lighting Technology Information Sheet - Light Quality

- Light quality refers to the usefulness and aesthetics of light from a user's perspective.
- Of all topics related to lighting, light quality is the most controversial, since quality, like beauty, is in the eye of the beholder.
- It is difficult to specify a general light quality standard; each application must be independently analyzed.
- Several factors affect how light quality is perceived: (1) light colour, (2) light level, (3) glare, (4) light sources and fixtures, (5) light consistency, and (6) occupant expectancy.
- Eye adapts to light levels
- Higher the lux the clearer and brighter the lit object (but above 500 lux, eye pupil starts to close to compensate)
- The closer the spectrum to white natural light the lower the lux needed. - 3500 - 5000 K best

3.1. Light Colour

Light colour from a lamp is represented by two different measurable quantities: (a) colour rendering index (CRI) and (b) colour temperature.

- CRI is a measure of the difference in colour of objects illuminated by a lamp as compared to the colour of objects illuminated by a reference lamp of the same colour temperature.
- CRI in a space is a function of not only the lamp, but also the fixture reflector and lens. Thus, these factors must also be taken into account to achieve the desired light colour.
- CRI is measured on an index from 0 to 100; sunlight and incandescent light both equal 100.
- Generally, the higher the CRI value the more realistic objects appear.
- Colour temperature is a measure of the colour distribution a light source emits.
- Colour temperature is the temperature in Kelvin at which a perfect radiator would emit the same light spectrum.
- The higher the colour temperature the bluer the light.
- Typical incandescents have a colour temperature of 2800K, halogens 3000K, cool white fluorescents 4100K, and daylight-simulating fluorescents 5000K.
- High colour temperatures at low light levels will often make a room appear

cool and dim while low colour temperatures at high light levels can make a room appear overly colourful.

- Sources around 3500K look good over a wide range of illuminance (light levels).

Note: There are two accepted designations for Colour Temperature. Lamps are usually designated with an RE number. For example, RE70 includes all rare-earth lamps that have a CRI value between 70 and 79. Similarly, RE80 is for lamps between 80 and 89. A combined CRI and colour temperature rating is sometimes included by adding the first two numbers of the Kelvin temperature to the first digit in the CRI. For example, a lamp with a CRI between 70 and 79 and with a colour temperature of 4100 K would be designated as RE741.

3. 2. Light levels

- Light level (illuminance) refers to the magnitude of light per unit area in a room, represented by lux (lumens/m^2) or foot-candles (lumens/ft^2).
- Light level is a measure of the light output (lumens) from a light source in a room relative to the size of the room.
- Light level can be measured at a particular point or over an area.
- The human eye is sensitive to both absolute light levels and light level differences.
- It is usually advantageous for both energy savings and productivity to use task lighting where higher light levels are required, allowing general areas to be kept at a lower light level.
- Minimum light levels for different tasks and areas are specified by Occupational Health and Safety.
- Light levels guidelines have therefore been set for each task.
- Generally lower than before as understanding grew.
- Task change - e.g. drafting -> computers - need lower levels and different design.

3.3 Glare

- Glare is a common problem with computer screens and other reflective surfaces.
- Glare can be often eliminated by using less intensive lights and improving the layout of lights and/or workstations so that computer screens do not “see” direct lighting.
- Glare causes eyestrain and decreases productivity.

3.4 Light Sources and Fixtures

- Light sources and fixtures have specific characteristics that should be matched to the application.
- Halogen, HID, and some incandescent lamps produce a very bright light within a small space which requires the light to be diffused before being received directly by the human eye.
- Fluorescent lamps and most incandescents produce a less intense light over a much larger area that can be looked at directly by the eye.

- Fixtures are used to direct the light being produced by lamps to the area where it is required.
- Fixtures can include reflectors, diffusers, and lenses, each of which absorbs, diffuses, and directly reflects light.
- As light is reflected or diffused from a fixture, its colour may be changed according to the characteristics of the fixture.
- Fixtures and lamps must be chosen together to ensure that the desired light quality is achieved in a space.

3.5 Light Consistency

- Light consistency refers to the difference in light level at different points in a space.
- Often people desire brighter light in specific areas, by simply lowering background light levels these areas appear more brightly lit while energy is saved.
- It is important to also maintain light consistency so that the change in light from one area to another is not abrupt.
- Uniformity of light within a specific task area is critical. Unfortunately, some people are more sensitive to light differences than other.
- Controlling light consistency to maximize light effectiveness and efficiency is best accomplished using a combination of direct and indirect lighting.

3.6 Occupant Expectancy

- Occupant expectancy, like light consistency, is a relative measure that changes from person to person.
- Past experience often dictates what occupants expect in lighting.
- People that are accustomed to incandescent lighting may look for, or expect, small bright sources of light in a room.
- When confronted with fluorescent lighting at the same, or even higher, light levels these people may feel that the light in the room is too dim.

4. Sources of Light

4.1 Types of light source

- Types of sources - Candles, electric filament, burning gas, kerosene lamp, the sun
- Each has different spectrum and lumen output
- Each has different ways of producing light from another form of energy - wax (gms), electricity (watts), gas (cu.m), nuclear fusion, etc..
- Efficiency or efficacy of a light source is the amount of light per unit of energy used. - lumens/watt, lumens/cu.m - chart of different efficacies

4.2 Basic Types of Lamps and Fixtures

- Incandescent - tungsten filament - inert gas or halogen - AC or DC - no ballast.

Fixtures - globe, reflector, miniature, auto, decorator

- Fluorescent - electrode excites gas and causes phosphors to glow - AC only - needs ballast. Fixtures - straight of U

tube troffer, compact (CFL) tube and reflector
- High Intensity Discharge (HID) - AC only - needs ballast. Fixtures - globe, reflector, troffer
- Light Emitting Diodes (LED) - no ballast
  fixtures - bunched, grid

4.3 Getting Light Where it is Needed

- Light from a light source needs to be directed towards the task using some form of fixture or "luminaire"
- Components - troffer, reflector, lens
- Window design - stress the importance of window location, glazings, treatments in providing light
- Important to match lamps with fixtures - show impact of mismatch through example

5. Measures of Lighting Effectiveness

5.1 Energy basics
- Power - measured in watts or BTUs / hr or MJ / hr or cu.metres per min. - the rate at which energy is used - examples the rate energy is used by a furnace, light bulb, TV when they are operating.
- Energy - measured in BTUs or MJ or watt hrs or cu.metres - the amount of energy used over a given period.
- A 100,000 Btu / hr furnace will produce 1 million BTUs in ten hours and use x cu.metres of gas.
- A 60 watt light bulb will use 6000 watthrs (6 kWh) in 100 hrs.

Each of the following provide a measure of lighting effectiveness and efficiency.

5.2 Lamps
- Lamp efficacy = light output / electricity input rating (lumens / watt) and depends on lamp type and design
- Lamp efficiency = efficacy / 643. (643 lumens are equivalent to 1 watt - a perfect lamp has an efficacy of 643 lumens / watt)
- Lumen Depreciation = degree that light output decreases over life of lamp and depends on lamp type and design. T5s have almost no depreciation.
- Colour Temperature = the temperature of a glowing reference source that produces the same colour of light and depends on the type and design of the light source
- Colour Rendering Index (CRI) = an index of how well the lamp matches natural lighting colour (CRI = 100) and depends on the type and design of lamp
- Lamp Life = number of operating (on) hrs that a lamp lasts and depends on lamp type and design

Light Quality and Efficiency - Some lamps such as low pressure sodium lamps have very high efficacies but low colour quality (CRI < 25), whereas, metal halide and T8 fluorescents have both high efficacies (although lower than low pressure sodium) and high colour quality (CRI > 80).

5.3 Ballasts

- Ballast Factor is a measure of the ability of a ballast to produce the rated light output of the lamp. It can be greater than or less than one. It equals the ratio of light output of lamps with ballast / the rated lamp light output (lumens) and depends on type of lamp and ballast
- Power Factor = ratio (or percent) of delivered power over actual line volts x line amps. A low power factor increases demand charges, requires utility to provide higher capacity supply. Can also overload users transformers, switch gear etc.. It depends on ballast design and can be minimized using capacitors in ballast
- Harmonic Distortion = degree of distortion (percent) on third harmonic. Should be less than 20% to keep interference to a minimum (<10%) better.

5.4 Fixtures

- Fixture efficiency = light output of fixture / power draw of fixture (lamps and ballasts). It is not a measure of the fixtures ability to light a task and depends on fixture design, lamps and ballast factor (efficiency).
- Coefficient of Utilization (CU) = ratio of useful light for task on the work plane / light output of lamp(s). It is a measure of the fixture's ability to distribute the required light to the work plane. It depends on fixture design, lamp and ballast efficiency, room reflectance characteristics, room dimensions and relative positions of fixture and work plane (cavity ratio). Supplied by fixture manufacturer.
- Light Loss Factor is a cumulative measure of the loss of light over time due to lamp lumen depreciation and fixture dirt and dust accumulation. A value of 25% is conservative. In a well maintained fixture and lamps such as T8s it is more like 10%

Energy used by fixture for lighting = number of hrs of operation x power draw by fixture (watts). Hrs of operation = number of hrs (per day, week, etc.) that light is required for a task and depends on task and control and daylighting strategy

6. Lighting Design

6.1 Basics of Design

The design of a lighting system has a big impact on its efficiency. In a poorly designed system, much of the light produced by the system will not be used and users will compensate by increasing the power and output of the lamps and fixtures.

- knowing the task(s) to be lit
- maximizing the role of daylighting
- choosing the optimum spacing and location of fixtures
- choosing the right quantity, quality and colour of the lamps and fixtures
- using effective lighting controls to minimize the lamp operating time

6.2 Number of Fixtures

Number of fixtures = (light level x room area) / (lamp lumens x lamps / fixture x CU x loss factor)

6.3 Fixture Spacing

- Space to mounting height ratio = S / MH (a value recommended by manufacturer to ensure even lighting) - normally between 0.9 and 1.2
- Spacing Criterion = maximum diagonal spacing / MH

7. Secondary Effects of Lighting

All light energy is converted into heat either in lamp, fixture or on surfaces lit. All of this heat contributes to the cooling load of the building in summer and supplies some of the heating requirements in winter.

Cooling load breakdown - 40% heat from lighting and equipment and people, 40% cooling new warm ventilation air, 20% heat gain through windows.

Heating contributions - 10 % from lighting and equipment and people, 90% from main heating system

Reducing lighting electricity through efficiency and other measures therefore:

- in an air conditioned building, reduces the electricity or other energy used for cooling and reduces the size of this equipment - examples and rules of thumb
- in a non-electrically heated building, replaces electrical heating with a cheaper energy source - examples and rules of thumb

8. Lighting Controls

8.1 Reason for controls

Artificial light should be used not only where it is needed but also only when it is needed.

Lighting controls should be used to:

- make maximum use of daylighting
- reduce light levels when the task changes
- turn off lighting when light is not needed
- compensate for lamp lumen depreciation

8.2 Types of controls:

- Manual area, room and task switches - on \ off or dimming in response to task, occupancy, or daylight
- Occupancy sensors - on \ off in response to activity
- Timers and computer controls - predetermined on / off or dimming
- Photosensors - on / off or dimming in response to daylighting and lumen depreciation (lamp age or dirt)