Technical Elements of Snow Venue Event Lighting

Overview –

From the Olympics to the X-Games to World Cup competitions, events are increasingly being hosted at night. As this trend accelerates, ski area operators, event managers, and competition officials are faced with the challenge of properly lighting competition venues with more than just safety in mind. The lighting needs to be financially practical while fulfilling all requirements, including current video specifications. To be sure, competition lighting has not been appropriately addressed by the ski industry for many decades. This is evidenced by the Fédération Internationale de Ski (FIS) rule language that only provides superficial guidelines which do not have sufficient detail for objective implementation. With this in mind, technical elements of snow venue event lighting can be put into useful perspective.

FIS Guidelines –

The following excerpt covers FIS guidelines for "Competitions under Artificial Light:"

655 Competitions under Artificial Light

655.1 Competitions under artificial lights are permitted.

655.2 Lighting must meet the following specifications:

655.2.1 The light level anywhere on the course must not be less than 80 lux, measured parallel to the surface. The lighting should be as uniform as possible.

655.2.2 Floodlights must be placed so that the light does not alter the topography of the course. The light must enable the competitor to discern the terrain and must not alter the depth perception or definition.

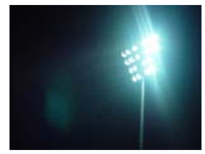
655.2.3 The lights should not cast the competitor's shadow into the racing line and should not blind the competitor by glare.

655.3 The TD together with the Jury must check in advance that the lighting conforms to the rules.

655.4 The TD must submit a supplementary report on the quality of the lighting.

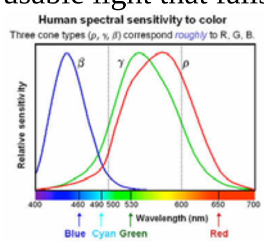
The first requirement in §655.2.1 refers to lighting intensity of no less than 80 lux (7.43 foot candles) anywhere on the course. The light should be measured parallel to the surface; however, no parameter is given for the distance from the snow surface which is critical for any actual measurement. Equally important, there are no specifications for particular light characteristics that include color temperature and the associated color rendition index (CRI), spectrum balance, glare, diffusion, distribution, and bleed (light pollution). This raises more questions than answers because 80 lux represents a seemingly arbitrary level and is actually inappropriate for the reflectivity of a white snow surface using metal halide, high pressure sodium, or even new LEDs.

The 80 lux FIS standard was derived purely from the television lighting requirements for old cathode ray video tubes (vidicon tubes) that required high intensity reflective light for activation. These tubes were extremely bulky and generated considerable heat. They were incorporated into very large casings to accommodate power supplies, fans, and other tubular electronic components. Old television cameras used a series of rotating fixed lenses to change the focal length. Even under intense lighting, videography was difficult at night because cameras were subject to distortion from ambient background light.



Ironically, today's cameras use a hypersensitive charged couple device (CCD) that can resolve better under balanced light than the high intensity light commonly used at snow sports events. Problems associated with conventional snow venue lighting include lens refraction glare and over-lighting washout. Since lighting is mounted in fixed positions along the slope, there is no way to avoid conflicting angles when filming an event. This is why video production managers usually prefer daylight filming. However, daylight has its challenges because the sun's angle changes rapidly throughout a winter day and other lighting interference can come from intermittent cloud cover. More importantly, snow conditions are far less controllable under sunlight as the snow surface is affected by heating and cooling. Light can flatten from one competitor to the next simply with a cloud that changes visual perception and the appearance of the snow surface.

The 80 lux guideline was written for a conventional light meter measuring photopic lighting from any source. These measurements include ultraviolet and near-ultraviolet light as well as infrared that cannot be seen by the human eye. The result is that a typical measurement of 80 lux for a hot metal halide fixture may contain only 60% to 70% of usable light that falls into the effective range of human vision. The ratio of various



wavelengths within the spectrum determines how well the eye can detect color, contrast, and even depth perception. Visually effective lumens (VELs) as a criteria for snow venue lighting is critically important because unbalanced high intensity lighting can seriously distort the visual perception of the snow surface and interfere with the eye's focusing mechanism. Technical reasons for this include pupil dilation, lighting angle relative to the field of vision, and slope angle. In a research paper addressing the reaction of the human eye in the dark by H. S. Gradle, M.D; Walter Ackerman, B.S. published by *JAMA* back in 1932, the following conclusions were reported:

> The reaction time of the normal pupil was established by **cinematographic means**. Briefly, it was found that when light is flashed on a normal eye that is accommodated for the dark, there occurs a latent period of 0.1875 second before the pupil begins to contract. Then there follows a rapid primary contraction for 0.4365 second at

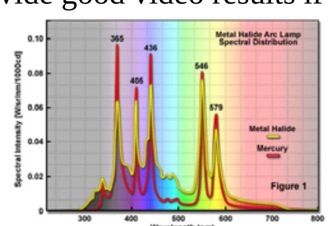
the rate of 5.48 mm. per second. This is succeeded by a secondary contraction of 0.3125 second at the slower rate of 1.34 mm. per second.

Emphasis is added to “cinematographic means” because virtually all lighting standards for filming were derived from early studies. For example, the typical movie camera films at 24 frames per second (fps). This is the slowest rate that can provide reasonably smooth visual frame transition while saving the most amount of physical film. Today, physical film is not a consideration and has no bearing upon video. Still, video standards tend to fall within the same film guidelines to save on memory requirements. Unless there is a slow motion function, the frame rate is between 23.97fps and 30fps. The conscious visual frame rate of the human eye is somewhere between 60fps and 100fps. Subliminal detection can be as fast as $1/1{,}000^{th}$ of a second. Race car drivers and fighter pilots have been tested using a strobe light to arrive at these results.

Ski and snowboard athletes fall within the same visually elite categories. For example, a freestyle mogul skier must judge distance, contour, horizontal angle, speed, and vertical depth, simultaneously. A slalom skier must visually compute distance, snow contour, horizontal angle of attack, vertical depth, speed, pole color, snow markings… all while achieving maximum speed and maintaining stability. New Olympic events like freestyle aerial jumping inject incredibly complex visual challenges that require different lighting considerations for the approach, the ramp, air hang time, and the landing. In addition to the competitor, lighting must provide the maximum visual experience for judges while meeting technical specifications for new video recording equipment.

Unfortunately, very little attention has been paid to technical aspects of night time event lighting as evidenced by the entire FIS §655 inclusive. When the television standard was originally conceived, there wasn’t any freestyle skiing or snowboarding. The half-pipe did not exist. Speeds were slower and even artificial snow-making and grooming lacked today’s sophistication. The primary importance is athlete safety and performance. Lighting must provide maximum visual acuity for the least capital and operating cost. Thus, light quality should be combined with energy efficiency to accomplish the ultimate goal.

Today’s video camera technology can resolve images in less than 1 lux. Color rendering can be clear at 5 lux or less than half a foot candle. The more important elements of television lighting are color temperature, spectral balance, consistency, and stability. Having uneven lighting that spot measures at 80 lux will not provide good video results if the intensity is uneven or there is spectral bias that distorts the image color. A spectrum balanced for video at an intensity of only 10 lux can produce better results than a conventional metal halide lamp that provides 80 lux. As the chart illustrates, conventional metal halide and mercury arc lamps produce spectral concentrations in the ultraviolet range at 365nm, 405nm, and 436nm. More than 30% of the spectral balance is outside the eye’s most sensitive visual range. As it happens, video cameras are designed to accentuate the range within the visually effective range. There is a significant spectral void from 450nm to



535nm which is right in the middle of human visual acuity and the preferred range of modern video equipment.

Mercury vapor lamps are no longer sold due to environmental restrictions. Metal halide remains the most popular type of outdoor floodlight despite spectral deficiencies. The ideal spectrum for human visual acuity and video emphasizes the midrange from 450nm to 650nm. An evenly distributed spectrum within these intensities is optimum for both the human eye and video. The Snow-Bright™ spectrum is specifically tuned using proprietary LumenTec® technology to maximize visual acuity while providing enhanced video performance. Lighting sources are compared using the S/P ratio which stands for scotopic/photopic. A metal halide light source has an approximate S/P ratio of 1.49 which is likely to be used to measure 80 lux under the FIS guideline. Even new LED lamps activate light meter measurements from portions of the spectrum that do not maximize visual acuity. Some high intensity LEDs boast very high lumens-per-watt (lpw or "efficacy") of more than 120, but only generate 80% within the most sensitive regions for human vision. Thus, the 80 lux measurement is not accurate for snow venues because the spectrum is not balanced for a snow surface that is white and reflective.

Moreover, 80 lux does not address the color sensitivity of modern CCD camera technology. Typically, metal halide color temperatures are 4,500K to 5,000K with a color rendition index of .70. Most high intensity LEDs are the same; from 4,100K to 5,500K. Snow-Bright™ fixtures have a color temperature exceeding 6,500K and are UV truncated. The color rendition index is .95. Comparatively, Snow-Bright™ lighting will be 2.77 times more effective than conventional snow venue lighting for vision and video.

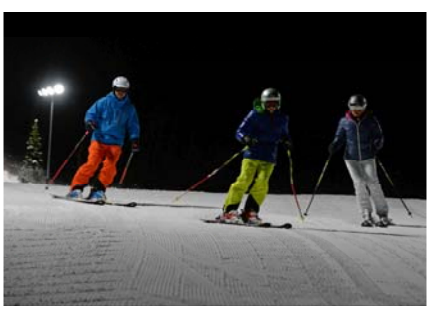
A Snow-Bright™ 300-watt fixture can replace a 1,000-watt metal halide light and provide better visual performance. A measurement of less than 25 lux (2.32fc) under Snow-Bright™ lighting will yield better visual results and video production than the FIS 80 lux guideline. In particular, using a balanced spectral output produces a more accurate white balance since white is literally a combination of all colors. When too much ultraviolet is present, there will be overemphasis of blue hues. There is more energy in the shorter spectrum which can overwhelm CCD cameras. This has been a problem for sports casting soccer, American football, and baseball that are played on green fields. The void from 500nm to 550nm can make fields look washed out. The solution is to push the camera in the missing spectrum to correct the color.

FIS §655.2.2 covers lighting placement to avoid altering the slope topography while allowing the competitor to clearly discern terrain and maintain accurate depth perception. Again, guidelines are extremely vague. As it turns out, overly intense artificial lighting is more likely to alter depth perception by flattening contours. Depth perception is a function of combining visual vectors. This is the stereoscopic effect produced by having different perspectives from two eyes. Opposing lighting can alter this perspective by presenting irregular lighting fields of different intensities. This is why properly diffused light with the correct dispersion pattern is so important for snow venues. Diffused light allows the eye to perceive the different reflection angle off of the white snow surface.

FIS §655.2.3 specifies that lighting should not cast a shadow into the competitor's field of vision. At the same time there should not be glare that impairs perception. Conventional lighting has been deficient in meeting these criteria. For example, many ski areas use high pressure sodium (HPS) lights because they were considered energy efficient. HPS is known for their distinct orange color which is monochromatic and has a very low color rendition index (CRI) below .40. In reality, HPS is very poor lighting for all aspects of snow venue illumination. It is virtually impossible to distinguish colors, the light flattens the snow surface, and high intensity causes excessive glare. HPS fixtures have hard focus geometry as shown by the picture of Mt. Peter in Warwick, NY before retrofitting to Snow-Bright™ magnetic induction lighting (MIL). The picture shows the sharp "V" pattern of the HPS fixture compared with the Snow-Bright™ foreground that has uniform light with clear rendering of the snow surface. HPS is not suitable for videography.

Shadowing is a function of lighting placement. Obviously, a competitor will cast a shadow from a single light source unless there is an opposing light that fills in for the obstructed light. This presents a perplexing problem because conventional lighting cannot be pointed uphill. If high intensity lighting is pointed uphill it can blind a competitor coming down into the light. Thus, even when using opposing lights facing downhill, the competitor will cast a shadow *forward* from left to right moving down the course. The only ideal solution is to project light onto the competition course from below without the glare that can impair vision. Snow-Bright™ nano-particle technology immediately disperses light from the large format bulb. Competitors can actually look directly into a Snow-Bright™ fixture without the blinding effect.

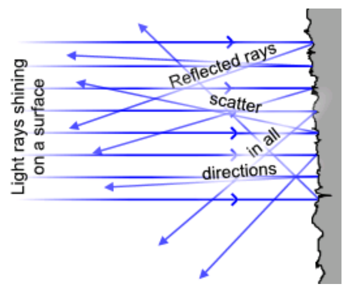
Objectively, throwing light behind the field of view provides optimum visual perspective. The forward view must be uniformly illuminated to avoid excessive pupil adjustment coming down the slope. The picture shows a very narrow shadow field cast from skier's right to left *behind the uphill ski*. This is achieved by up-lighting from in front of skier's right. Notice the uniformity of the lighting field ahead of, and behind each skier. Consider the benefits of this in a multi-competitor field like ski-cross and border-cross.



Maintaining the topographical visual perception of any slope requires several considerations that include slope dimensions and grade, lighting height off the slope, lighting angle to the snow surface, and lighting angle to the competitor's field of vision. Surprisingly, the vast majority of lighting plans provided by conventional outdoor lighting manufactures and consultant/design firms only address lighting levels at the snow surface. Typically, large lighting arrays that may have 1,000-watt to 1,500-watt metal halide high intensity lamps are placed high above the slopes like field or stadium lighting. Alternatively, slopes are lined with 20-foot to 40-foot poles with one or more fixtures that point at a steep angle to the snow to avoid night-blinding skiers. Again, the only consideration appears to be foot candles rather than visual experience. These approaches significantly alter topographical visual perception. Conventional high intensity lighting and new LEDs create hard beams of light that can be harmful to the eye and cause hot spots and voids.

Ideally, fixtures should emit a diffused field with relatively equal distribution to eliminate hot spots and voids while maximizing distribution between lighting towers or poles. Here's how the science should work. Recall there is a latent period of 0.1875 seconds before the pupil begins to contract followed by a rapid primary contraction for 0.4365 second at the rate of 5.48 mm. per second. This is succeeded by a secondary contraction of 0.3125 second at the slower rate of 1.34 mm. per second. A skier traveling at 25mph is covering 36.66 feet per second (fps). To maintain reasonable consistency, the lighting transition from pole to pole would need to be .1875 + .4365 + 2.3125 = 2.9365 seconds X 36.66 fps giving us 107.65 feet from transition to transition. What about a competitive skier traveling at 70mph which is 102.667fps? The transition time computes to a wider field of vision. Understand that the pupil reaction time was measured from darkness to light whereas a skier will be traveling from one light level to another. The actual time for visual adjustment *will be less*.

The solution to this "time versus distance" problem is to take advantage of two light properties; 1) diffusion and 2) refraction. Snow-Bright™ fixtures use a nano-particle reflector that uniformly diffuses light rather that creating a sharp beam. This results in a "lighting field" that can be adjusted using unique Vari-Beam® technology. The proprietary Snow-Bright™ spectrum is scientifically tuned to laterally refract through the snow surface, providing exceptional clarity. As refracted light exits from the snow surface, all contours and characteristics are clearly visible without shadowing that might normally be generated by terrain topology. The foreground of the Mt. Peter picture shows how evenly and clearly Snow-Bright™ illuminates the slope surface. Since light is traveling laterally through the snow, the distance between poles can be fixed for skiers traveling from a standstill to 85mph-plus. There is no adverse affect from pupil dilation and contraction.



New LED lighting has been gaining attention among ski area managers. Two serious LED drawbacks literally disqualify them from snow events. First and foremost, many LEDs flicker which causes "strobe effect." The flicker usually corresponds to the 60Hz cycle of AC current in North America or 50Hz in Europe and other countries. Although the flicker rate may be above conscious visualization, the physics still apply. Perception mechanics are not precise from individual to individual, but a 60 cycle strobe will generally remove .7333 feet per second from a static object at a viewer's acuity of 60 frames per second. If the object is a skier traveling at 45mph, the conversion is 66 feet per second causing a loss of 1 foot. This is extremely dangerous for judging depth perception and slope contour.

High frequency flicker is associated with significant health hazards including strobe epilepsy, migraine headaches, nausea, impaired visual acuity, poor concentration, sleep disorders, mood swings, eye strain, and a lack of eye/hand coordination. The problem is serious enough for the IEEE Standards Working Group, IEEE PAR1789, to take up "Recommending practices for modulating current in High Brightness LEDs for mitigating health risks to viewers." This process has been put in place to advise the lighting industry, ANSI/NEMA, IEC, EnergyStar and other standards groups about the emerging concern over flicker in LED lighting. Unfortunately, none of this is divulged in LED sales literature. Although the information is widely available on the internet, ski area managers do not often have the time or resources to conduct extensive lighting research.

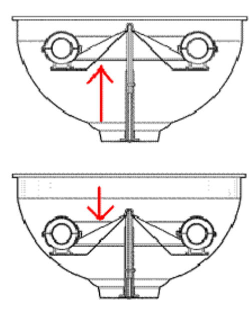
Flicker presents serious challenges for television production because a 60 cycle strobe can interfere with the video frame rate. Flicker can cause strobe lines in the video as well as 60 cycle voids. It is difficult to correlate the video frame rate to avoid interference. The good news is that the random filming frequently avoids direct correlation with LED strobe rates. The bad news is the excessive risks because coordinating filming with LED flicker rates is hit or miss. To be sure, LED manufacturers are trying to address high frequency flicker, but costs for raising the frequency can make high intensity LED flood lighting prohibitively expensive while converting drivers from AC to DC current reduces efficiency and is also costly.

LED lighting was used at the 2014 Sochi Olympics. The games were marked by performance failures by snowboarder Shawn White and others. The consensus was that snow quality was to blame for poor showings. However, an examination of the event suggests that competitors were unable to judge timing, distance, and orientation. This would be due to strobe effect and poor spectral balance. The same inconsistencies did not occur during the daylight competitions even with the same snow conditions.

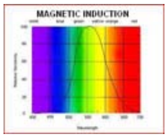
The Snow-Bright™ Solution -

Snow-Bright™ technology reduces electrical operating overheads by more than 85% over conventional lighting like metal halide and high pressure sodium. Equally important, conventional lighting can require up to twenty times operating power to ignite (light up) and needs time to warm up or cool down. This means a typical 1,000-watt metal halide can draw 20,000 watts when it is turned on, substantially increasing electrical demand charges. This makes Snow-Bright™ the most efficient lighting for snow venues.

Only Snow-Bright™ has Vari-Beam® focusing technology that adjusts the illumination field to precisely regulate the amount of light that falls within the intended location. The entire bulb and central reflector assembly can be moved forward or backward within the reflector to change focal length. For most applications, the medium setting is sufficient. For critical applications, the fine adjustment can make a difference.



The balanced Snow-Bright™ spectrum is concentrated within the visually effective range



of the human eye allowing less light to produce more visual acuity. The light is particularly effective for video production including slow motion and stop action. Competitors can face lights without adversity while

cameras can film into a Snow-Bright™ fixture without lens refraction or overwhelming CCD circuitry to produce camera glare.

Since Snow-Bright™ lighting refracts through the snow surface, the field of view will be uniform. This means competitors will not need to make visual adjustments during events and can concentrate upon maximizing physical performance. Camera crews will not need to make significant lighting compensation adjustments from field angle to field angle. The high color rendition index maintains exceptional color resolution and white balance. As a competitor moves down the course, the lighting uniformity remains constant. Even with a

dip in the slope as seen in the picture, the light will continue to follow down the fall line.

For extremely steep terrain or jumps and aerial ramps, the Snow-Bright™ race hill fixture can be laterally tilted to follow the slope angle. This increases lighting performance while reducing the propensity for light pollution. The long format bulb enhances lateral light distribution for maximum efficiency.

Most applications can use the Snow-Bright™ 300-watt round flood which generates an evenly dispersed light with an adjustable focal length. A single 300-watt Snow-Bright™ fixture can replace a 1,200-watt high pressure sodium or a 1,000-watt metal halide, reducing overall operational electricity by more than 85% including ballast overheads. Again, the wide area light source reduces glare and permits uphill lighting without interfering with the descending competitor's vision.

Summary –

Snow venue event lighting requires a multi-faceted approach that addresses the safety and performance of competitors while providing adequate illumination for video and still-shot photography. Snow-Bright™ technology has been proven on competition courses including bump runs and terrain parks at Steamboat Springs, Mt. Peter, Snow King, Powder Mountain, and more.

Snow-Bright™ eliminates flicker, glare, flattening, contour distortion, and color impairment while saving energy, and reducing maintenance. Snow-Bright™ is rated for a 100,000 hour lifecycle that translates into 11 hours X 365 days per year. For most ski areas, the fixtures should last *more than a century*.

To discuss your lighting needs and develop a plan call Philip Gotthelf at
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