Video Camera Image Quality in Physical Electronic Security Systems
In the second decade of the 21st century, annual revenue for the global physical electronic security market is estimated to be approximately $20.57 billion (USD), with video surveillance products and systems constituting a $10 billion market share. Whether used to identify and defeat potential acts of terrorism, in local law enforcement and fire protection activities, or in commercial and industrial security programs, video surveillance technology has become a common communications medium and an essential tool for public safety officials and security professionals.

The growing and diverse use of video technology has resulted in increased attention to the quality of video imagery. Poor quality video can blur or mask important details that slow or prevent appropriate and timely response, or lead to inaccurate interpretations of data or events. Since video surveillance systems are only as effective as their individual components, poor quality video can diminish the benefits expected from a significant financial investment.

There are a number of standards already available that can be used to assess the capabilities of products used in physical electronic surveillance systems, including standards for alarm intrusion systems, sensors, smoke alarms and fire panels, and control systems. These standards facilitate the objective evaluation of security system components and enable procurement specialists to select those products most appropriate for their specific security application.

To objectively evaluate video camera models for use in specific physical electronic security applications, UL has released UL 2802, the Standard for Performance Testing of Camera Image Quality. Unlike many UL Standards that focus exclusively on the hazard-related safety of a product, UL 2802 incorporates performance criteria based on a camera’s critical operational parameters. Video camera products evaluated to the requirements of the Standard are awarded performance scores that can be considered in the procurement selection process, facilitating objective comparisons between camera models.

This white paper provides a summary of the objectives and requirements of UL 2802 for evaluating digital images from video cameras used in a variety of applications. The paper begins with a discussion of issues related to video camera image quality. The paper then provides a detailed review of the specific performance tests found in the Standard, as well as other considerations for achieving compliance.
Video Image Quality Issues and Concerns

Video surveillance products and systems collectively include video cameras, transmission infrastructure, video storage equipment, and command and control software to manage the video surveillance system and imaging functions. The advent of Internet protocol (IP)-based video in the physical electronic security market has supported significant improvements in the quality and effectiveness of surveillance activity and security systems in general. Video-based security systems can provide effective, widespread surveillance more efficiently than methods that depend on deploying personnel, and at a fraction of the cost. Video security systems also produce documentary information that can be used for training or research purposes and, in some cases, as evidence in criminal investigations or other significant events.

However, with video surveillance equipment constituting half of all expenditures in the global security marketplace, video quality is a key factor in procurement decisions made by law enforcement departments and safety and security professionals. Poor quality video can impede an effective initial response by safety or security officials, potentially resulting in loss of life or property. Poor quality video can also hamper efforts to reconstruct a security or safety incident in order to determine an actual cause or causes, or can compromise the video’s usefulness as evidence in criminal proceedings.

Efforts to procure video cameras that produce images of suitable quality for the intended safety and security application can be confusing and technically challenging due to the multitude of video cameras offered in the marketplace, and the significant variety of available camera features and options. Procurement is further complicated by the absence of image quality standards with metrics that would enable objective, quantitative comparisons between seemingly similar video cameras. This can result in the selection of a camera that either exceeds the quality requirements of the intended application or fails to meet them altogether. In either case, procurement resources are not efficiently utilized and the value of a significant financial investment is compromised.

UL 2802 Camera Performance Criteria and Testing

UL 2802 provides specific criteria for objectively assessing the image quality of individual video camera models. The Standard details a method for assessing image quality using a series of performance-based tests conducted on production camera samples. Since no single number or criterion can provide a reasonably accurate and objective evaluation of a given camera, lens, software, image processor, camera lens housing, electronic components, or any combination of the like critical elements, UL 2802 uses several different quantifiable metrics to assess a video camera’s performance. These metrics, along with consistent, documented test methods, eliminate any potential variations in the evaluation of a camera.

The following sections detail the specific imaging quality metrics used to assess the image quality performance of a given video camera construction.

**Image Resolution**

Image resolution is one of the most important attributes for the quality of an image captured by a video camera. A recorded digital image is comprised of discrete points or cells (i.e., pixels) stored in the relative dimensions of the actual image. Image resolution is a measure of how closely the digital image captured by a camera matches the actual image, which depends on how many pixels can be stored in a fixed dimension. An accurate resolution measurement requires an evaluation of a camera’s lens and sensors, as well as its imaging software, and is often presented as line pairs per picture height or LP/PH. The metric is a measure of how many distinguishable alternating colors can be represented in an image.

Modulation transfer function (MTF) is a technique used to quantify image resolution in more complex images. MTF corresponds to the spatial frequency of LP/PH, that is, the ability to represent the “real” object by taking the light intensity and plotting it along imaginary lines traversing the representation of the object.

Other mechanisms for measuring distortion are detailed in ISO 12233, Photography -- Electronic still-picture cameras -- Resolution measurements, and in the standard mobile imaging architecture (SMIA) forum specification. UL 2802 uses the same spatial frequency response method for resolution.
measurement as those found in ISO 12233 and SMIA, except that UL 2802 uses a circular edge for consistency (a circular edge reduces test variability caused by the camera and test target tilting).

**TV Distortion**

A camera lens captures the light from a three-dimensional object and then translates it into a two-dimensional image. TV distortion quantifies how much the two-dimensional image captured by the video camera deviates geometrically from the actual object. Lens quality can often influence TV distortion, and distortion can be more prevalent when lens are designed primarily to capture wider angles.

**Relative Illumination**

Relative illumination measures the ability of a camera lens to effectively capture relative light intensity across the entire dimension of an object, with the center of the light source generally appearing in the brightest light. Relative Illumination will be affected by the lens aperture itself, mechanical "vignetting" or by the camera's pixel size.

**Dynamic Range**

A video camera’s dynamic range represents the ratio of the minimum and maximum light intensities captured by the camera. The dynamic range scores the differences between the lowest light and the brightest light where a camera can detect changes in light intensity. A video camera intended for surveillance in outdoor settings would typically require a wider dynamic range to capture events under both daylight and nighttime lighting conditions, while a camera with a narrower dynamic range may be sufficient for use in an office setting or predictable lighting environments. UL 2802 uses high power lamps to evaluate this metric.
Maximum Frame Rate

The maximum frame rate is the fastest rate at which a video camera can continuously capture, record and store an image. Many manufacturers promote the maximum frame rate for their cameras, and buyers typically have some knowledge of the significance of this performance metric. Although a video camera with a higher maximum frame rate is usually preferred (as in cases where a video camera is used to record possible criminal activity or fast-moving objects), it also requires increased processing power, additional storage capacity and greater network bandwidth to transmit the resulting video, as well as software capable of processing and displaying it. Therefore, as a performance metric, the ideal maximum frame rate is dependent on a video camera’s intended application and the number of images required to support its intended use.

Grey Level

An object that is visually captured by a video camera is replicated as a two-dimensional image using the RGB (red, green, blue) color model at each pixel or cell. A camera’s image processing software controls these representations to render an image as accurately as possible, regardless of the lighting conditions. The grey level indicates the color increments that can be represented by the camera for different color intensities or variants of color (ranging from no representation of color to full representation of the actual color), and this metric quantifies how well a camera can differentiate subject areas under different illumination levels, or with different reflectance or luminance levels.

UL 2802 uses 12 lamps at different radiance levels that allow the grey level test to be uniformly diffused, thereby producing more consistent test results. This is a different approach than that used in ISO 14524, Photography -- Electronic still-picture cameras -- Methods for measuring opto-electronic conversion functions (OECFs), and in the SMIA specification.

Sensitivity

A video camera’s sensitivity score represents the amount of light required by a camera to digitally create an image as realistically as possible. The lower the sensitivity score, the more light that is required to accurately represent an image. A camera’s sensitivity score is a helpful metric that can assist in determining the optimal camera location and the best case lighting condition.

Bad Pixel

Manufacturing defects and failures in the quality assurance process can result in a camera with bad pixels, making a bad pixel count an important factor in video quality. Bad pixels are usually defined as those whose output differ from the average of all pixels by more than 20%, and can include pixels that never change color, or those that are completely different than adjacent pixels or that change intensity over an extended period of use. The pixel size of the camera also is relevant, because the ratio of bad pixels to total pixels can offset the total bad pixel count.

Figure 3 A: Original
Figure 3 B: Bad Pixel
Veiling Glare

Veiling glare can be caused by stray light scattering into a camera’s optical system, reflections within the lens and its container, or as a result of leakage current to adjacent pixels attributable to pixel saturation. The purpose of veiling glare test is to quantify the impact of stray light in a digital video camera optical system. A better quality image is produced by an optical system with negligible stray light impact, while a poor quality image results from an optical system that experiences degradation in contrast and color fidelity.

ISO 9358, Optics and optical instruments – Veiling glare of image forming systems – Definitions and methods of measurement, and the SMIA specification both measure veiling glare differently from UL 2802. UL 2802 uses diffused lamps and ambient light in a dark room, effectively quantifying the veiling glare characteristics of the optical system.

Other UL 2802 Considerations

Unlike other UL Standards that focus on addressing safety concerns, UL 2802 provides guidance for both safety and performance characteristics of cameras. Video cameras evaluated according to the performance criteria of UL 2802 must also comply with the safety requirements found in one or more of other applicable product Standards. These Standards include:

- UL 60950-1, the Standard for Safety of Information Technology Equipment, Safety – Part 1: General Requirements
- UL 60065, the Standard for Safety of Audio, Video, and Similar Electronic Apparatus – Safety Requirements
- UL 62368-1, the Standard for Safety of Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements
- UL 2044, the Standard for Safety of Commercial Closed Circuit Television Equipment

Video cameras used in outdoor settings must also comply with the safety requirements found in UL 62368-1 60950-22, the Standard for Safety of Information Technology Equipment – Safety – Part 22: Equipment to be installed Outdoors.
Conclusion

Video image quality is an increasingly important consideration in selecting video camera technology for public and private safety and security systems. However, assessing image quality is complicated by the range of available video camera options, and the difficulty in objectively assessing the quality required for individual applications. UL 2802 details an approach for assessing camera image quality, and provides video camera manufacturers and users with a performance score that facilitates equipment comparisons. Video cameras tested and certified to UL 2802 ease the process of identifying video technology that meets the requirements of specific applications, enabling more effective comparisons of price and performance.

For further information about UL 2802 performance testing and certification of video cameras, contact Louis Chavez, primary designated engineer, at Louis.Chavez@ul.com.