Canon

WHITE PAPER

CINEMA EOS LENSES

PERSONALITY OF THE CANON CINEMA EOS LENS: *COLOR REPRODUCTION*

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The Personality of the Canon Cinema Lens – Session #3

Personality of the Cine Zoom Lens in Relation to Operation as a Variable Prime

Canon's Cinema lens project aspired to develop a new generation of cine zoom lenses that could, for those who wanted, be credibly deployed in place of a set of fixed focal length prime lenses. Clearly, no one zoom lens could achieve this. But, a survey of the contemporary sets of prime lenses available from the world's great optical manufacturers show broad diversity in the ranges of focal lengths they collectively cover. There are sets that range from 14/16mm to 65/75 mm and others that range from 32/35mm to 95/150mm, and there are other variants. These individual sets generally have maximum relative apertures that are equal – critical to the DP changing lenses on a given scene.

Canon currently offers four cine zoom lenses that between them span some 14.5mm to 300mm. The behavior of their respective Maximum Relative Apertures over their focal lengths is shown in Figure 1.

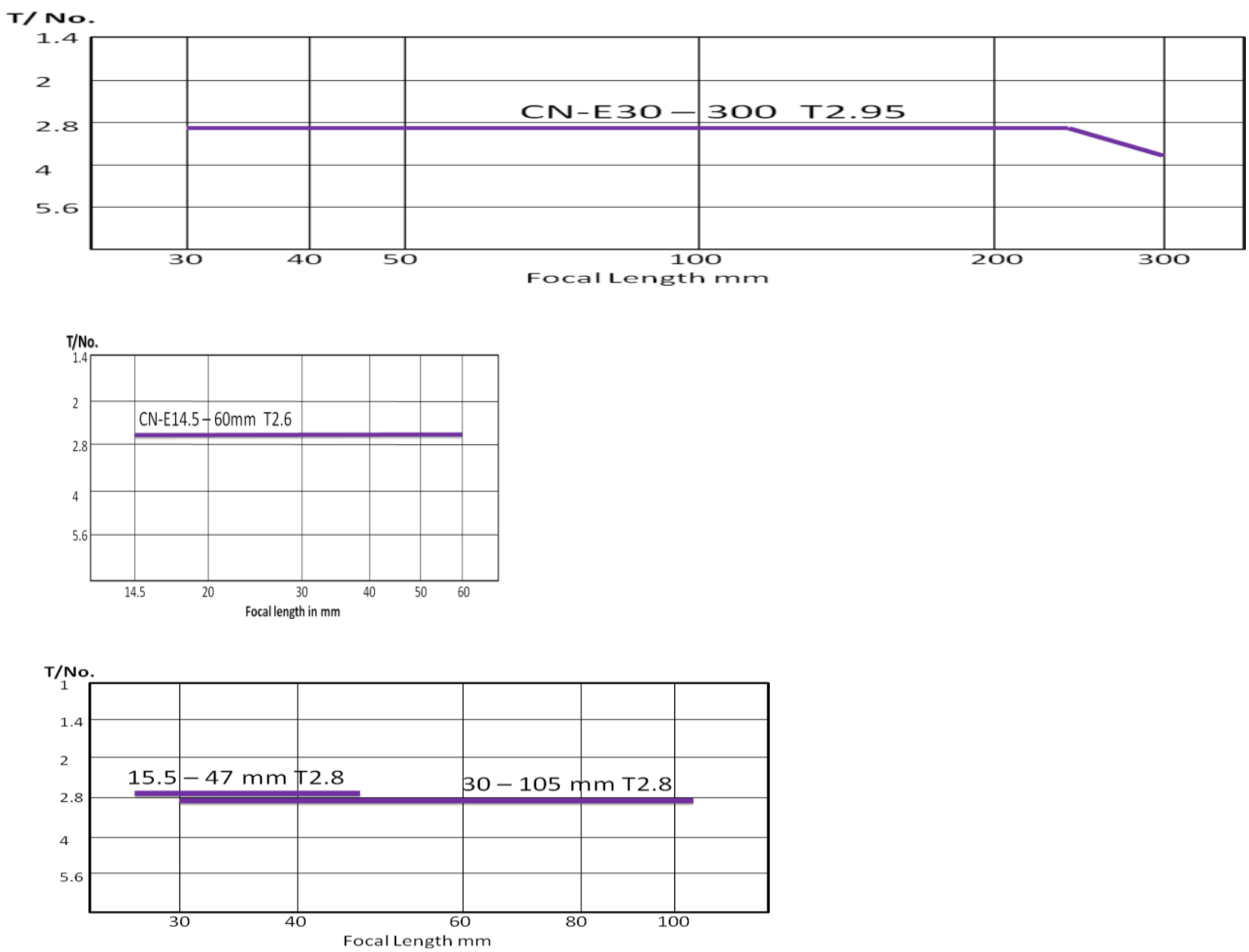

Figure 1 *Showing the behavior of the Maximum Relative Aperture of the four Canon Cinema Zoom lenses*

Three of the zoom lenses hold perfectly constant Maximum Relative Aperture over their respective zoom ranges. The long zoom CN-E30 – 300mm lens holds it constant over an 8:1 zoom range (from 30 through 240mm). The ramping that does take place after 240mm is the result of a pragmatic design compromise having a goal of being the smallest and lightest of all 10:1 Super 35mm cine zoom lenses presently in the marketplace – but with more than 4K performance. The ramping is clearly indicated on the lens focal range scale by a change in color as shown in Figure 2.

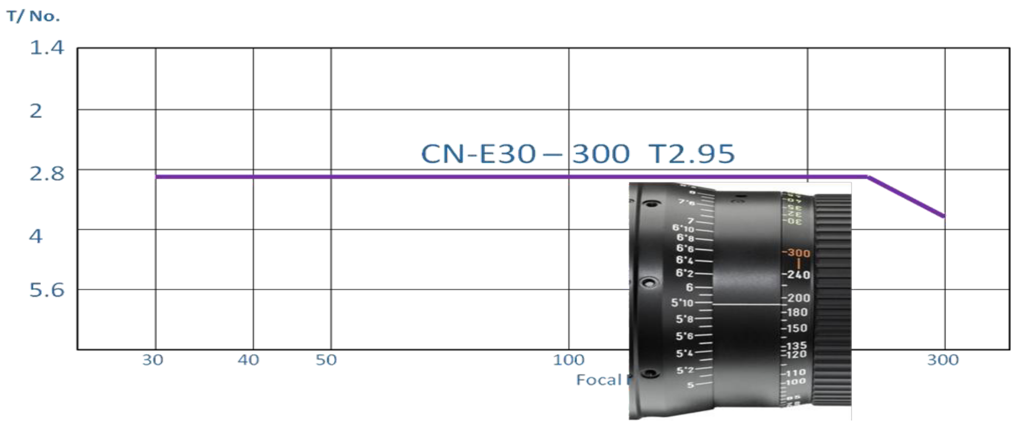

Figure 2 *Showing the modest ramping characteristic of the CN E30 –300mm cine zoom lens*

Personality of the Canon Cine Zoom Lens in terms of Color Reproduction

Perhaps one of the most discussed aspects of a cine lens "personality" is its color reproduction. The color reproduction of a lens is determined by its spectral transmission characteristic. This is actually a quite complex discussion – primarily because the lens characteristic cannot be separated from that of the camera to which it is coupled. Most of the long-established Super 35mm cine lenses were developed for motion picture film cameras where their respective designs had to be cognizant of prominent film stocks. The still relatively new digital cinematography era has introduced some quite new consideration with respect to color reproduction.

While managing the huge amount of variables associated with the overall optical design, the cine lens designer is simultaneously preoccupied with shaping the overall spectral response of the multi-element lens system. A number of considerations factor into this design. Our discussion here will attempt to simplify what is a highly sophisticated design project – with only the basic principles being outlined.

The shape of the lens spectral curve (especially at the blue and red end of the visual spectrum) works in concert with the spectral characteristic of the image sensor, the RGB spectral separation of the color filter array (CFA), the spectral shape of IR optical filter, and finally, the linear matricing strategy employed by the camera manufacturer to implement the final digital camera system colorimetry – as outlined in Figure 3.

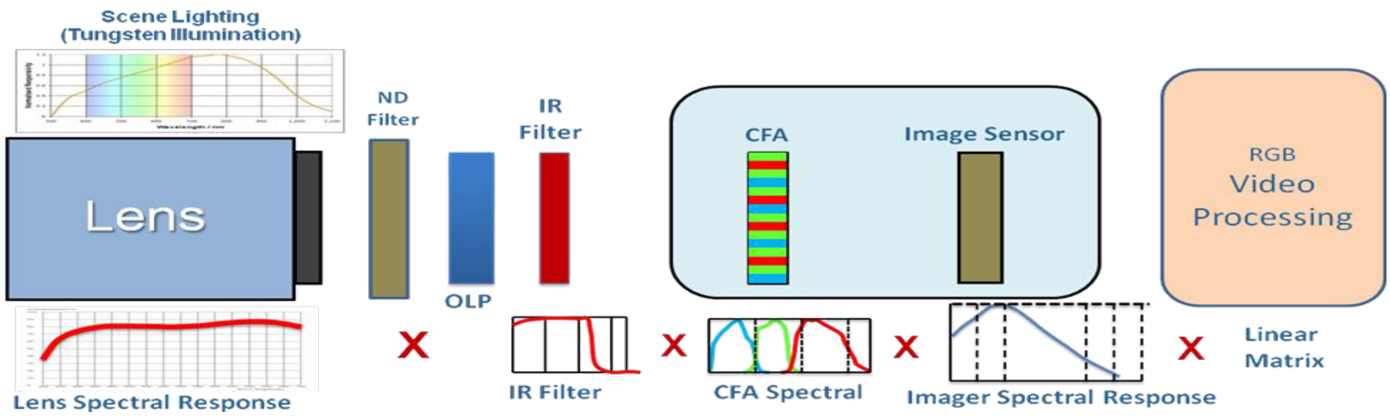

Figure 3 *Showing the separate determinants of the color reproduction characteristic of a Cine Lens-Camera system*

In our development of the Cinema EOS system, Canon had the significant technical advantage of designing all of the components of the cinema lens-camera system. All of these separate elements could be accurately simulated within a powerful computer aided design process – as simplistically outlined in Figure 4. This afforded a unique ability to seek optimization of a number of key imaging parameters. Central to this task was the optimization of the color reproduction of the lens-camera system – ultimately leading to the specific design of the lens spectral response.

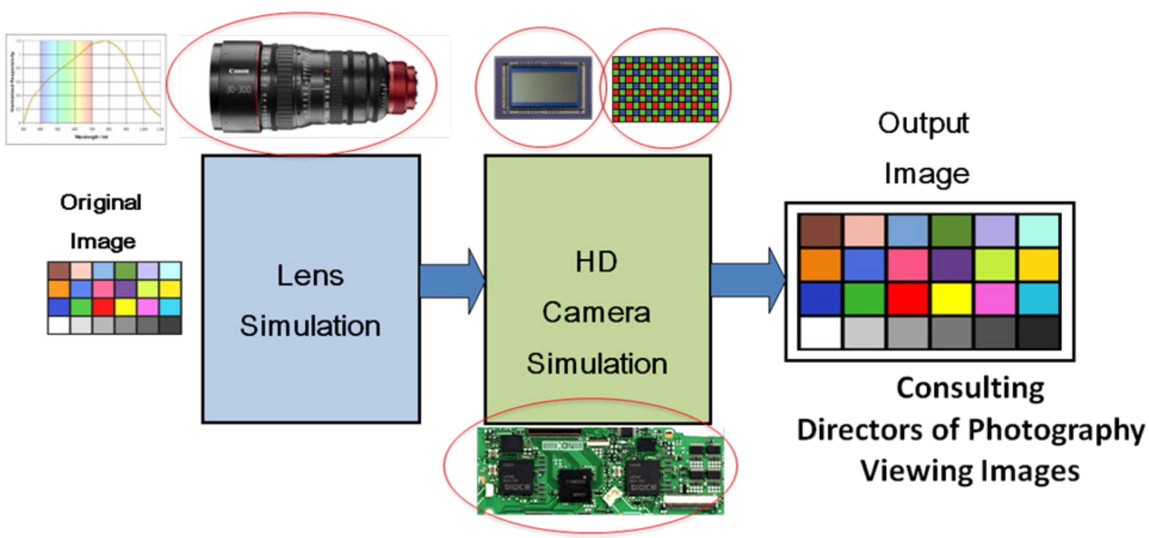

Figure 4 *Showing the principle of the computer simulation system used to design the spectral responses of a cinema lens that was optimized for the Canon Super 35mm 4K CMOS image sensor*

The Color Contribution Index (CCI)

The spectral transmittance design of this new generation cine lens family employed the principles of the Color Contribution Index (CCI). This is a methodology developed in the era of motion picture film cinematography which indicates the amount of color variation within a specific film imaging system, caused by different lens transmittance characteristics. This is a topic too complex to fully examine in this paper. Those interested can learn more from references [1], [2], and [3]. However, the principles entailed are as follows:

Three numbers in the form a/b/c express the index; these numbers being relative values expressed as logarithms of lens transmittance at three chosen RGB primary wavelengths. Color balance is assessed by comparing the three values to an ISO specified reference lens value (this reference having been pre-established by averaging a very large number of lenses from multiple optical manufacturers). In Figure 5 the portrayal of the CCI is shown to be a trilinear chart that can plot the three numbers referred to. The sextant shaped outline is the boundary that encompassed the dozens of cine lenses studied by the CCI committee some years ago.

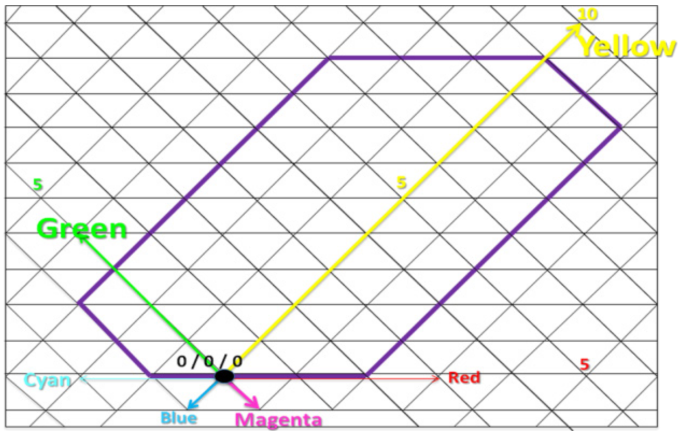

Figure 5 *Showing the trilinear chart that maps the three numbers that define a given lens when working with a specific motion picture film stock*

Benchmarking a Cine Lens Design for a Digital Camera

Computer simulation was employed to study the spectral characteristics of three long-established Super35mm cine lenses in combination with the digital camera color reproduction characteristics of the Canon Cinema EOS cameras outlined in figure 3. The lenses chosen had been designed in the era when motion picture film dominated high-end production – but all are still in use today on Super 35mm digital cine cameras. Studying how each of these lenses convoluted with the Canon CMOS image sensor and allied Canon CFA helped establish overall color reproduction benchmarks that guided the subsequent exploration of the new Canon cinema lens spectral response. Video processing – in the form of the digital linear matricing system – was also optimized. The judgment of color balance was made by Canon color scientists in concert with invited directors of photography studying the simulated imagery.

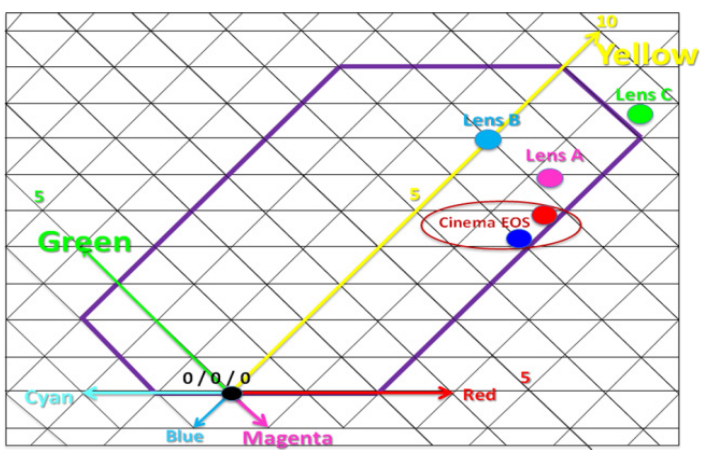

Figure 6 *Showing the final placement of the Canon Cinema EOS lenses on the CCI trilinear chart*

Finalizing the Color Reproduction Personality of the Cinema EOS lenses

A final step in the shaping of the Canon cinema lens spectral response took account of an important human visual phenomenon. In bright daylight our human Photopic vision affects the perceived contrast of different colors. For a specific red and blue object – with identical surface reflectance under normal illumination—the red object will appear bright while the blue will exhibit lower relative brightness. On the other hand, in very low illumination environs, the human Scotopic vision dominates. Now the blue object will appear brighter and the red more dull. This subjective alteration is most apparent at the transition between primary use of the Photopic (cone-based) and Scotopic (rod-based) systems – the region of the human visual response known as the Mesopic. This phenomenon is termed the Purkinje effect [3]. Taking this effect into account was deemed important because directors and DPs frequently choose to shoot in outdoor twilight illumination, or indoor in low-lit illumination (possibly candle-lit) for special "mood" scenes.

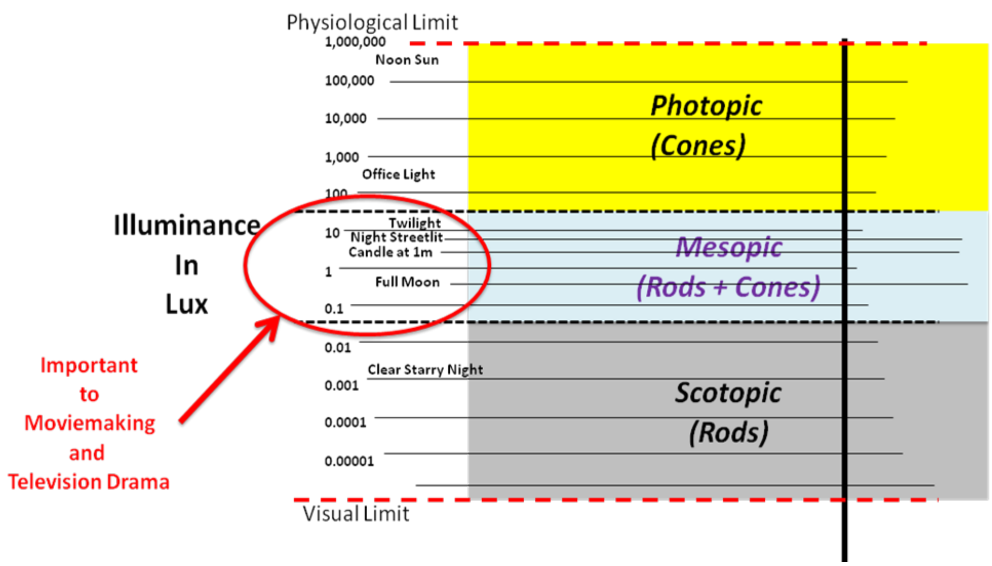

Figure 7 *The Mesopic region of human visual sensitivity is important to image making in outdoor twilight or low indoor illumination*

The Canon Cinema lenses incorporated a final adjustment to their spectral characteristics to compensate for how this affect Purkinje effect manifests itself on color reproduction of the Cinema EOS lens-camera combination. This entailed a gentle boost of the spectral response toward the red wavelength end of the curve.

Summary

The new generation of Canon cinema lenses paid high attention to optimization of color reproduction of the lens plus camera system – deeming this a critical aspect of the cine lens "personality". Particular attention was assigned to how the lens-camera system reproduces skin tones of various ethnicities, while also ensuring an overall neutral color balance (neither warm nor cool) when the Cinema EOS camera (C500, C300, and C100) video controls are in their normal detent settings.

It might well be asked if a lens optimized in color reproduction for a specific digital cine camera means less than optimization when that same lens is mounted to other digital cine cameras. The only response to this is that we live in a cinematography world today where all cine lenses (from disparate manufacturers) differ in their color spectral responses with little data published. After all, it was this reality that spawned the significant effort to develop the CCI system. The same reality applies to the many contemporary digital cine cameras – where no manufacturer publishes data on the spectral responses of their respective image sensors. Where this is a concern, the directors and DPs typically test favored lenses on the digital cine camera of choice, and happily, it is rare that significant disappointment emerges. Generally, minor on-set camera adjustment is sufficient to achieve the basic "look" desired.

Canon's rigorous approach to the color reproduction of our Cinema system stemmed from a significant capability in color management science within our R&D group – one that has been especially preoccupied with the optimization of skin tone reproduction. It made technical sense to harness this capability given that the Cinema EOS lens and camera were being designed in concert. This was rendered even more important given the long term strategy to expand the Canon cinema system's color gamut – a project that will soon come to fruition with the recently announced firmware update [5] for the Cinema EOS cameras. The experiences of the past eighteen months have shown that the Canon cine lenses perform remarkably well on all of the prominent digital cine camera presently active in the global marketplace.

References:

[1] Japanese Standards Association: "Determination of ISO Colour Contribution Index [ISO/CCI] of Camera Lenses", *JIS B 7097 (1986)*

[2] ISO 6728: 1983 *"Determination of ISO Color Contribution Index (ISO/CCI)",* International Standards Organization, 1983

[3] EBU Technical Report 3249-E, Sep 1995, *"Measurement and Analysis of the Performance of Film and Television Camera Lenses",* Section 2.7: Spectral Response

[4] Heinweg Lang, *"Colour and Its Reproduction, Part1: Colorimetry", Pages 33 – 36,* Muster-Schmidt Verlag, Gottingen, Zurich, *August 2001*

[5] Canon Press Release MELVILLE, N.Y., September 4, 2013
"*Canon Cinema EOS Cameras and XF300-Series Camcorders Receive Enhanced Upgrades Through New Firmware"*
New Capabilities Include ACESproxy Output, Full RAW 120fps 4096 x 1080 Resolution and DCI-P3+ Color Gamut Support for the EOS C500 Camera, and 80,000 ISO Shooting for All Three Cinema EOS Camera Models