Reflector Design Using *LightTools*

LightTools can be used to design and analyze the performance of a wide variety of illumination systems. Recently, *LightTools* was put to the test to redesign a segmented-reflector stop lamp at Yorka North America. Using *LightTools* to precisely analyze the luminous intensity and illuminance distributions in the original design, we were able to correct the design problems, meet SAE standards, and build a prototype that agreed very well with the simulations. This paper describes how the redesign was accomplished.

Analyzing the Original Design

The first step was to simulate the original system to reproduce the problems seen in the initial prototype. The original geometry of the segmented-reflector stop lamp was imported into *LightTools* (see Figure 1) using the IGES import capability. Then, a 3157 bulb was added to each section. A near-field model of the 3157 bulb is shown in Figure 2. In addition, reflective surface properties and two receivers were added to complete the simulation setup. One receiver was a far-field receiver that measured the luminous intensity output, and the other was a surface receiver that measured the illuminance distribution hitting the outer tail lens.

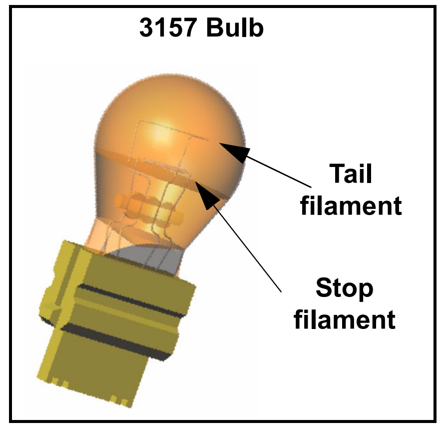

Figure 2: Near-field model of the 3157 bulb. This bulb has two filaments, and only one is lit at a time. The major, stop filament is brightest [33 Mean Spherical Candle Power (MSCP)], while the minor, tail filament produces only 3 MSCP.

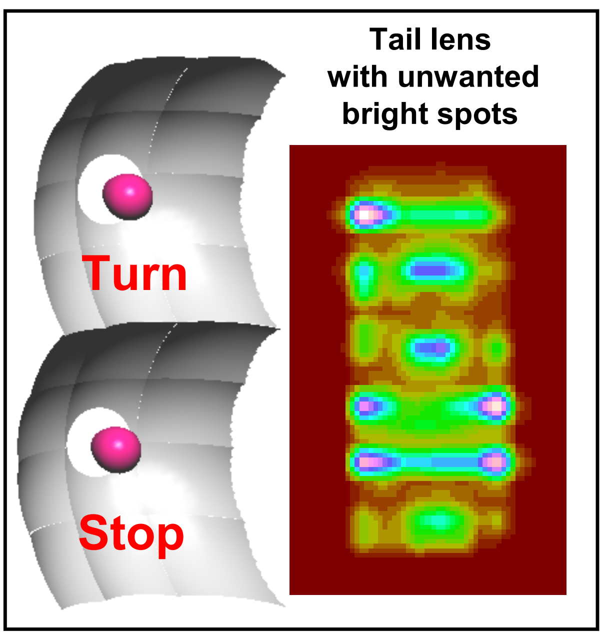

Figure 1: Original system, modeled in *LightTools:* a two-compartment stop lamp using segmented reflectors. The illuminance on the outer tail lens, which had an undesirable streaked appearance, failed to comply with SAE J585 and J586 requirements.

Simulation analysis of the original design identified two major problems.

- **Unpleasant lit appearance:** Hot spots and streaks were seen on the clear outer tail lens. The simulation of the illuminance in Figure 1 shows how the filament was focused on the outer tail lens by individual segments.

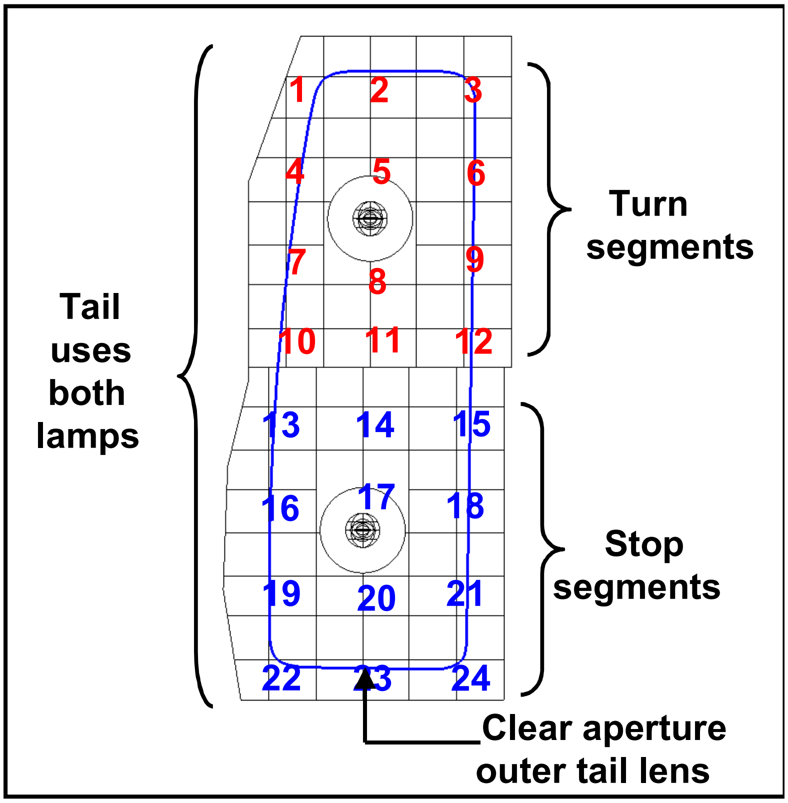

Figure 3: System geometry. The turn and stop functions are lit from a single bulb (major filament), while the tail function is lit using two bulbs (minor filaments). The boundary of the clear aperture of the outer tail lens shows that some segments are blocked.

- **Too much light:** The performance of the lamp failed to meet SAE J585 tail lamp specifications because there was too much light in the tail function. When the stop and turn sections were both lit, the tail output had a peak luminous intensity of greater than 45 candela, which greatly exceeded the SAE maximum of 25 candela.

Redesigning the Segmented Reflector

The segmentation of the original reflector was used in the redesign. The segment boundaries for the turn segments 1-12 and stop segments 13-24 were maintained, as shown in Figure 3, while the shape of each segment was redesigned to fix the major problems.

The first goal of the segment redesign was to eliminate the hot spots on the outer tail lens. Figure 4 shows how the original elliptical reflector segments were focusing light from the filament directly onto the tail lens. Changing the reflector design to use a diverging approach instead of converging approach removed the hot spots on the tail lens, as shown in Figure 5. The new reflector segments were designed using a *LightTools* macro that tailored the surface shape to aim light from the center of the filament along user-specified directions. The LT Macro language, which is similar to the Basic Programming language, is a powerful tool that can be used to automate the design and analysis of complex systems.

The beam pattern from each reflector was developed to match the beam shape specified by SAE (i.e., approximately ± 20 degree horizontal, ± 10 degree vertical). The choice of source center (major or minor filament) was a free parameter. By

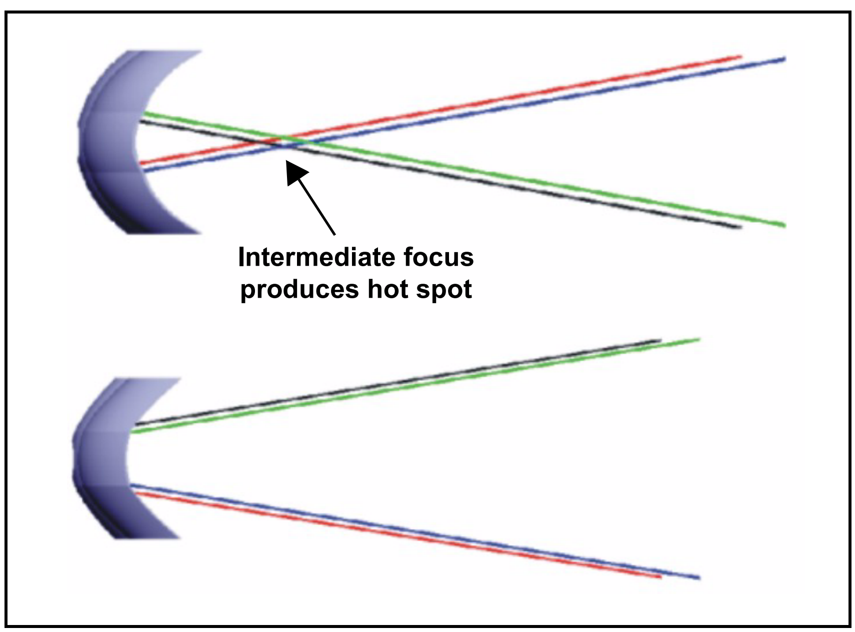

Figure 4: Converging and diverging design forms. The use of elliptical segments (top image) focused the filament image onto the outer tail lens, causing streaks. Using a diverging approach (bottom image) removed problems with streaking.

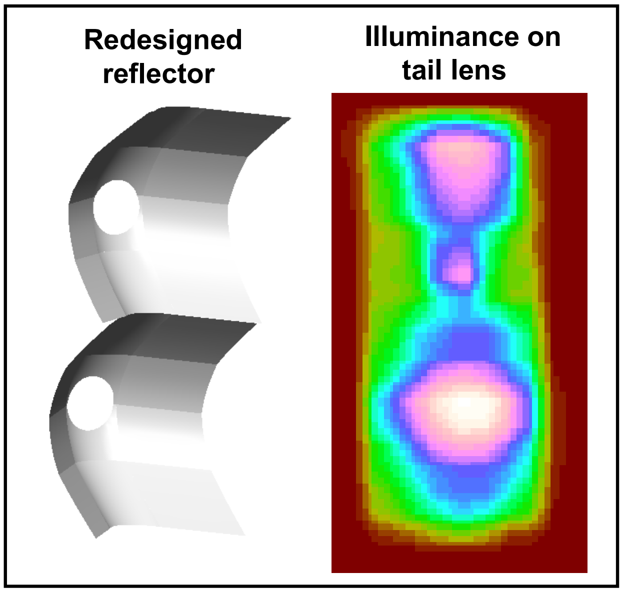

Figure 5: Redesigned reflector geometry. The redesign used diverging reflector segments (left). The illuminance on the outer tail lens (right) shows the hot spots/streaks have been removed. The beam is now spread more uniformly over a much larger area.

designing the segments using the major filament center as the source center, the angular spread of the tail function was increased, relative to the stop and turn functions, as shown in Figure 6. This allowed the relative peak intensity of the tail function to be lower, while maintaining a high peak intensity of the stop and turn.

The redesign simulations showed that the original tail function peak of more than 45 candela was lowered to 18 candela, which is well under the SAE J585 maximum of 25 candela. Because the stop and turn peak intensities were maintained, the SAE ratio requirement between the stop and tail of 5:1 was satisfied. This was accomplished even though the tail function used two bulbs, while the stop function used only one.

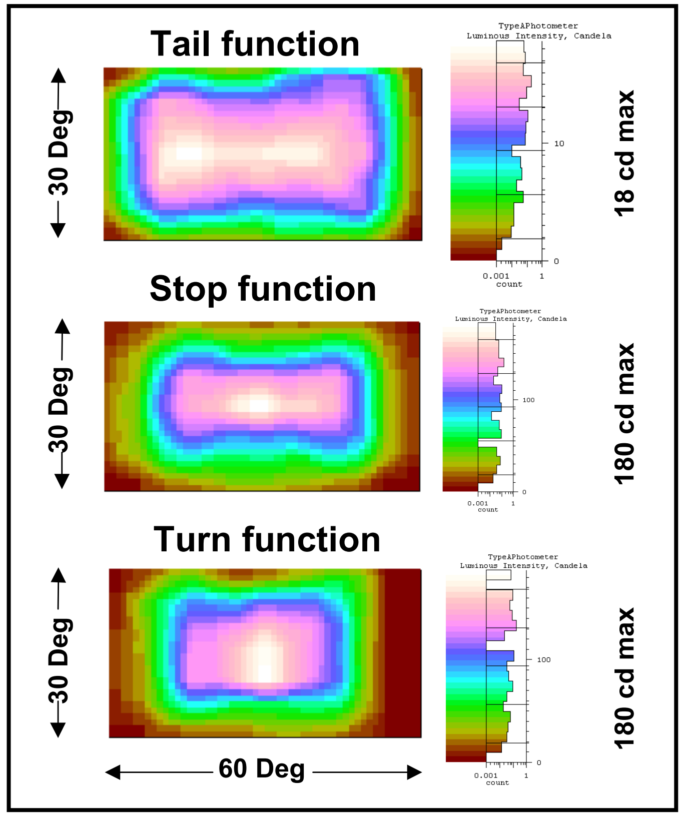

Figure 6: Simulated luminous intensity of redesign. A far-field receiver was oriented to handle Type A Photometry for stop, turn, and tail functions. The output beam patterns of the stop, turn, and tail functions all match the ± 20 degree horizontal, ± 10 degree vertical beam shape desired by SAE. The tail function spread was increased relative to the stop and turn to improve performance.

Table 1: Redesigned Tail Results (Simulated vs. Actual) Requirements SAE J585

Test-Point	Simulated Cd	Actual Cd	Requirement	Pass/Fail
10U-5L	13.6	10.2	0.7	
5U-20L	14.3	12.7	0.5	
5D-20L	13.9	11.9	0.5	
10D-5L	9.8	9.7	0.7	
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ZONE 1	51.7	44.5	2.4	PASSED
5U-10L	15.5	14.3	1.4	
H-10L	16.6	16.8	1.4	
5D-10L	13.1	13.2	1.4	
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ZONE 2	45.3	44.3	4.2	PASSED
5U-V	15.5	16.0	3.1	
H-5L	16.9	17.3	3.5	
H-V	16.4	18.3	3.5	
H-5R	17.1	18.4	3.5	
5D-V	12.0	14.1	3.1	
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ZONE 3	77.9	84.1	16.8	PASSED
5U-10R	15.8	15.5	1.4	
H-10R	17.3	18.8	1.4	
5D-10R	14.2	15.4	1.4	
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ZONE 4	47.4	49.7	4.2	PASSED
10U-5R	13.1	12.0	0.7	
5U-20R	16.8	15.5	0.5	
5D-20R	15.9	15.4	0.5	
10D-5R	13.1	9.9	0.7	
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ZONE 5	58.8	52.8	2.4	PASSED

Comparing the Simulated and Actual Performance

The simulated performance of the tail lamp matched very well with prototype measurements. Table 1 lists the performance at various testpoints of the tail function, and all points agree to within 5-10%. The turn function listed in Table 2 also gives excellent agreement. The testpoint evaluation was performed using Type A Photometry analysis macros that can analyze performance against most SAE standards.

This example demonstrates how *LightTools*' illumination capabilities can contribute to the design and analysis of automotive exterior lighting systems. The far-field and surface receivers collected light rays and successfully predicted the luminous intensity output of the tail, turn, and stop functions, while the illuminance on the outer tail lens showed that undesirable hot spots and streaks had been spread out and would not be a problem.

Optical Research Associates wishes to thank Dave Crossman, Yorka North America, for supplying the measured results.

Table 2: Redesigned Turn Results (Simulated vs. Actual) Requirements SAE J588

Test-Point	Simulated Cd	Actual Cd	Requirement	Pass/Fail
10U-5L	90.7	101.8	16.0	
5U-20L	31.4	27.5	10.0	
5D-20L	32.6	31.0	10.0	
10D-5L	48.9	54.6	16.0	
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ZONE 1	203.7	214.9	50.0	PASSED
5U-10L	101.9	106.1	30.0	
H-10L	99.6	104.2	40.0	
5D-10L	103.4	98.5	30.0	
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ZONE 2	304.9	308.8	100.0	PASSED
5U-V	121.3	127.7	70.0	
H-5L	129.4	112.5	80.0	
H-V	150.0	144.3	80.0	
H-5R	131.8	140.1	80.0	
5D-V	154.6	140.5	70.0	
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ZONE 3	687.1	665.1	380.0	PASSED
5U-10R	107.5	131.2	30.0	
H-10R	119.0	135.1	40.0	
5D-10R	120.7	131.4	30.0	
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ZONE 4	347.2	397.7	100.0	PASSED
10U-5R	77.5	100.9	16.0	
5U-20R	54.9	67.5	10.0	
5D-20R	61.0	73.6	10.0	
10D-5R	77.5	66.2	16.0	
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ZONE 5	270.9	308.2	50.0	PASSED

OPTICAL
RESEARCH
ASSOCIATES

3280 East Foothill Boulevard, Pasadena, California 91107
Phone: (626) 795-9101, FAX: (626) 795-0184
E-mail: service@opticalres.com, Web Site: http://www.opticalres.com