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A New, Durable and Efficient Optical Lens Design for Driver Cabs' of the DMUs

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Abstract. Driver Cabs' Marker and Tail lights have significant importance in railway transportation. There are several requirements mentioned in the international standards for estimation and operation clauses. In this study a new Polycarbonate lens design for MT15400 series Diesel Multiple Units (DMU) of Turkish Wagon Industry instead of existing Glass lenses is realized. Tests and measurements held to prove the advantages of the new design: better visibility, light intensity and light distribution.

Keywords: Lens optic, Lens design, Railway lighting, Visibility

1. Introduction

In this study, the effect of changing glass based optical lenses with Polycarbonate based optical lenses on lighting characteristics of Marker lights on MT15400 series Diesel Multiple Units (DMUs), which has been manufactured by TÜVASAŞ "Turkish Wagon Industry Inc." and owned by TCCD Transportation Inc., is explained.

Manufacturing of MT15400 series DMU started in 2010 and twenty four (24) units had been manufactured in the first order. Quantity of MT15400 series DMUs is going to be fifty four (54) until the end of 2017. There is a driver cab on the each end of the MT15400 series DMUs to control the unit. Figure-1 shows the front view of MT-15400 series DMUs.

Fig. 1: Signal (Marker) and Tail Light on the Driver Cab

As seen on the Figure 1; There are four signal (marker) lights standing two on each side and two tail lights standing one on each side of driver cab of MT15400 series DMUs, totally there are eight signal (marker) lights and four tail lights on each DMUs.

While Marker lighting equipment has LED light sources and transparent glass optical lens, it emits white colour. Tail light equipment has also LED light source and transparent Red coloured glass optical lens, and it emits red colour as the related standards ordered. Both types of lighting equipments have same mechanical dimensions. Principal mechanical dimensions of so called lighting equipments are given in Figure 2.

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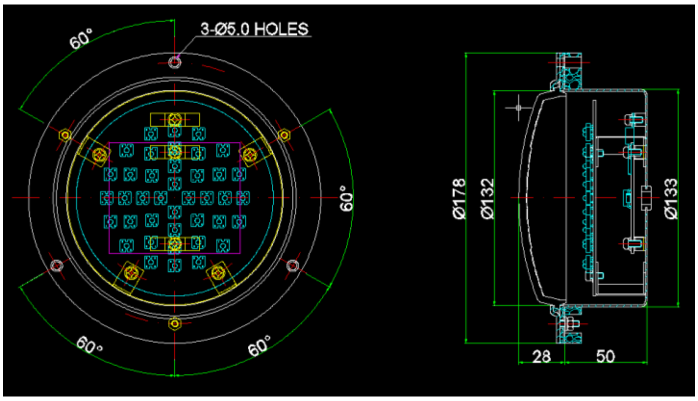

Fig. 2: Mechanical dimensions of lighting equipment

2. International Regulations and Requirements for the New Lens Design

Marker lights emit white light on the front cab in the course of travelling on the driving direction, while tail lights are emitting red light on the rear cab which is not active. These lighting equipments are used to make train visible from other living things such as other trains, people, animals etc.

In the current study, glass lensed LED marker and tail lights are used and these equipments are produced in South Korea. Having glass lens and supplying these from South Korea create some difficulties during maintenance and repair phases. Supplying the product from South Korea causes difficulties in low-volume orders, such as increasing delivery time and product price, even in some cases; it is not possible to procure the product. Having glass lens causes frequent fractures during the active use because of hitting of small particles and pressure. This condition requires lighting equipment changes frequently.

Because of mentioned reasons above; Polycarbonate optical lens design has been held and manufacturing for marker light has been planned. In this process, mechanical constraints of assembling of lights to vehicle body, and mechanical dimensions of glass optical lenses remained the same. Same design process has been started for tail lights. After the design believed to be adequate, manufacturing of Polycarbonate lens as a prototype has been realized.

During this study, Glass and Polycarbonate lighting equipment have also been tested according to TSI (technical specification for interoperability [1] and also according to EN 15153-1[2]. TSI requests some design constrains for lights which are used on rolling stock [1]:

The colour green shall not be used for external light or illumination; this requirement is made to prevent any confusion with fixed signals. This requirement is not applicable to lights that are included in push buttons for the command of passenger doors (not continuously lit) with intensity of lower than 100 cd/m^2 [2]. The colour of marker lamps shall be in accordance with the values specified at Table 1 [2].

Table I: The Chromaticity Coordinates of the Intersection Points of the Colour Specification for Marker Lamps

Colour of marker lamp	CIE (1931) chromaticity coordinates of the intersection points						
White	Point	I*	J	J'	K'	K	L*
	x	0,310	0,440	0,500	0,500	0,440	0,310
	y	0,348	0,432	0,440	0,382	0,382	0,283

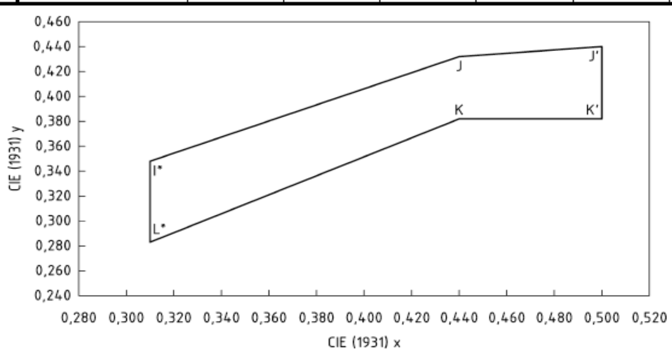

Fig. 3: Chromaticity diagram to illustrate the colour specifications for marker lamps according to Table 1

The spectral radiation distribution of light from the marker lamps shall be in accordance with the values specified in Figure 3 [2]. Also this amount of distribution has to carry a significant amount of luminous intensity for visibility on the rail road (Table 2).

Table II: Luminous Intensities for Marker Lamps

Marker lamp function	Full lower marker lamp	Full upper marker lamp	Dimmed lower marker lamp	Dimmed upper marker lamp
Luminous intensity (cd) along the optical axis	300 to 700	150 to 350	100 to 300	50 to 150
Luminous intensity (cd) at 10 ° on both sides of the optical axis in the horizontal plane	No requirement	30 to 350	No requirement	10 to 150
Luminous intensity (cd) at 45 ° on both sides of the optical axis in the horizontal plane	15 to 40	No requirement	3 to 40	No requirement

3. New Optical Design and Test Results

New Polycarbonate optical lenses designed for marker lamps has to meet the standards given above in Chapter 2. Since the existing glass based optical lenses meet the standards successfully, they are scanned through a 3-D Scanner. After getting the lens model successfully, a new mold is prepared for it. For a better light transition a transparent material is chosen. Plastic injection methodology is used for the lens production. The new lens produced for the marker lamp can be seen in Figure 4.

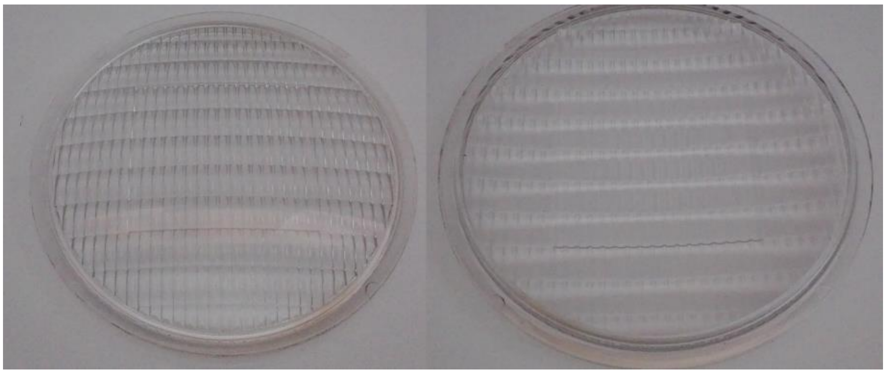

Fig. 4: The New Marker Lamp Lens (Both Sides)

A test process realized in an internationally accredited lighting Laboratory based in Ankara city (Arlight A.S. Lighting Laboratory) to prove that the designed new Polycarbonate lenses met the minimum requirements given in the standards. First of all chromaticity level of the new lens is researched. As seen in Figure 5, the new lens meets the required diagram levels given in Figure 1 (between 0.29 and 0.32-y axis, between 0.28-0.30, x axis).

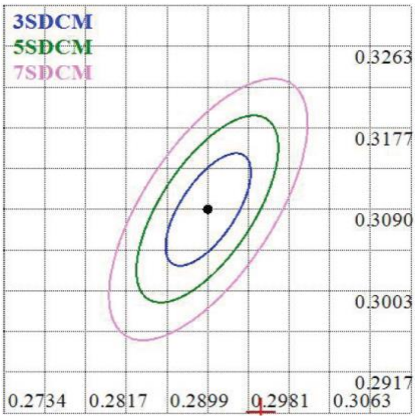

Fig. 5: Chromaticity Levels of the New Marker Lamp Lens

Looking at the Spectroradiometric parameters for both of the designs, light colour and Colour Rendering Index (CRI) are the factors that can be evaluated. Light spectrums of the both designs are quite similar. Talking about the new design, it is seen that «white» colour is pretty dominant on other colours. Because the marker lamp required to illuminate white light a wavelength of 489 nm is absolutely satisfying. Existing design - the glass lens gives out a 485 nm of white light, but it is not as dominant as the new lens. White colour purity comparison is better on the new design as 0.1638 to 0.0544. CRIs of the existing and new Polycarbonate lenses are measured as 65.3 and 90.8 respectively. This result also indicates that the transparency and light transition without reflection and light wave losses is a great advantage of the new Polycarbonate design.

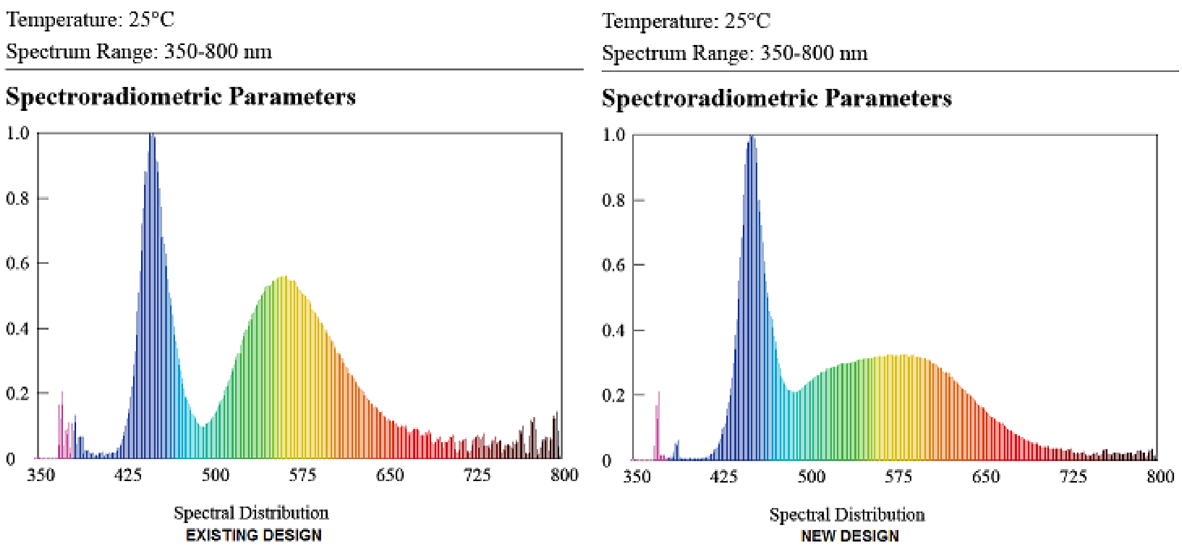

Fig. 6: Spectroradiometric Parameters for Existing and New Design

Figure 7 indicates the light intensity curve for the marker lamp with the new polycarbonate lens. Results obtained from the curve shows that the maximum light intensity value on the optical axis is about 171 cd and 173 cd on 10 degree per direction, meeting the standards given in Table 3 for full upper marker lamps.

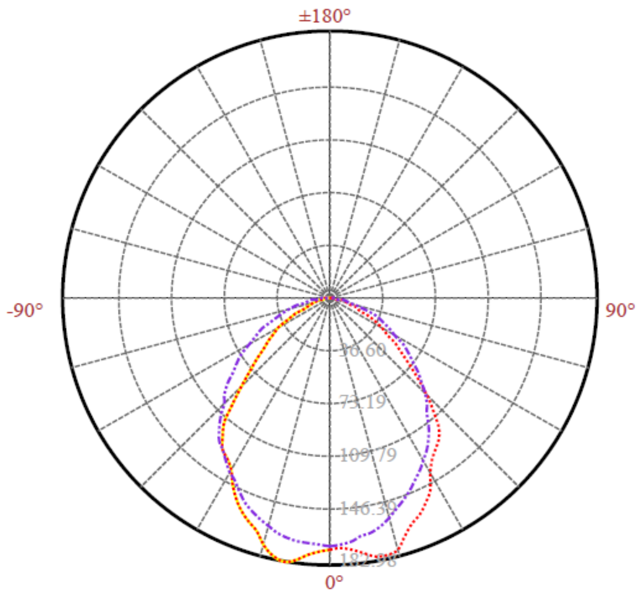

Fig. 7: Light Intensity Curve of the Marker Lamp with the New Lens

Visibility from distance is another significant issue in railway lighting design. Visibility should be taken into account exceptionally in the station mediums. In different publications of CIE - International Illumination Committee - 0.8 lux is given as the minimum limit to take measures against any dangers in 4 meters of distance [3]. Looking at the visibility and illumination level gathered by the marker lamp equipped with the new polycarbonate design, 10,76 lux comes as an adequate value to see the train and take measures in a train station (Figure 8).

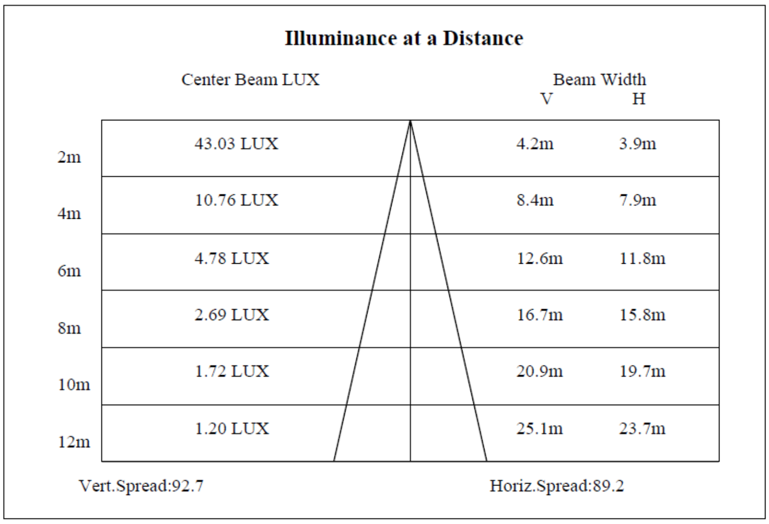

Fig. 8: Illuminance at a Distance with the New Lens (Visibility)

4. Conclusion

Most important subject of Railway lighting is the visibility for the passengers and the drivers. Passengers should be aware of estimating trains and the drivers should see every sign along the railroad. Existing glass lenses used in LED lamped luminaires, fracture easily due to high speed, pressure and unexpected particles. Using durable polycarbonate material which has better optic features compared to conventional glass lens creates a great advantage on visibility for both sides. Meeting all requirements given in the standards and having a longer economic lifespan Polycarbonate lenses will be used not only for DMUs but also for the new series of trains and driver cabs of TUVASAS.

5. Acknowledgments

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6. References

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