TRANSPORATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (University or Contractor):__Kansas DOT_____

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Project Number **TPF-5(351)**		**Transportation Pooled Fund Program - Report Period:** ☐Quarter 1 (January 1 – March 31) X Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)
Project Title: Self De-Icing LED Signals		
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Lead Agency Project ID: **RE-0721-01**	**Other Project ID (i.e., contract #):**	**Project Start Date:** August 15, 2016
Original Project End Date: **August 2019**	**Current Project End Date:** **August 2019**	**Number of Extensions:** 0

Project schedule status:

X On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Total Percentage of Work Completed
$240,000	$41,675	35%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$14,843	$14,843	10%

Project Description:

This pooled fund project will develop and demonstrate new self de-icing LED signals for highway signalized intersections and railroad signaling applications to solve a well-known problem of the existing LED signal light whose lens is too cool to melt snow and de-ice in wintery conditions. The self de-icing LED signals will adopt two novel architectures (Figure 1), including (a) "Heated Lens Lighting Arrangement" that uses a single high-power LED and (b) "Heat Arrangement of LED Arrays in Low Profile" that deploys multiple LEDs. The heat generated by the LED(s) is harvested by the passive heat exchanger and stored to heat the lens for melting snow and de-icing in wintery conditions.

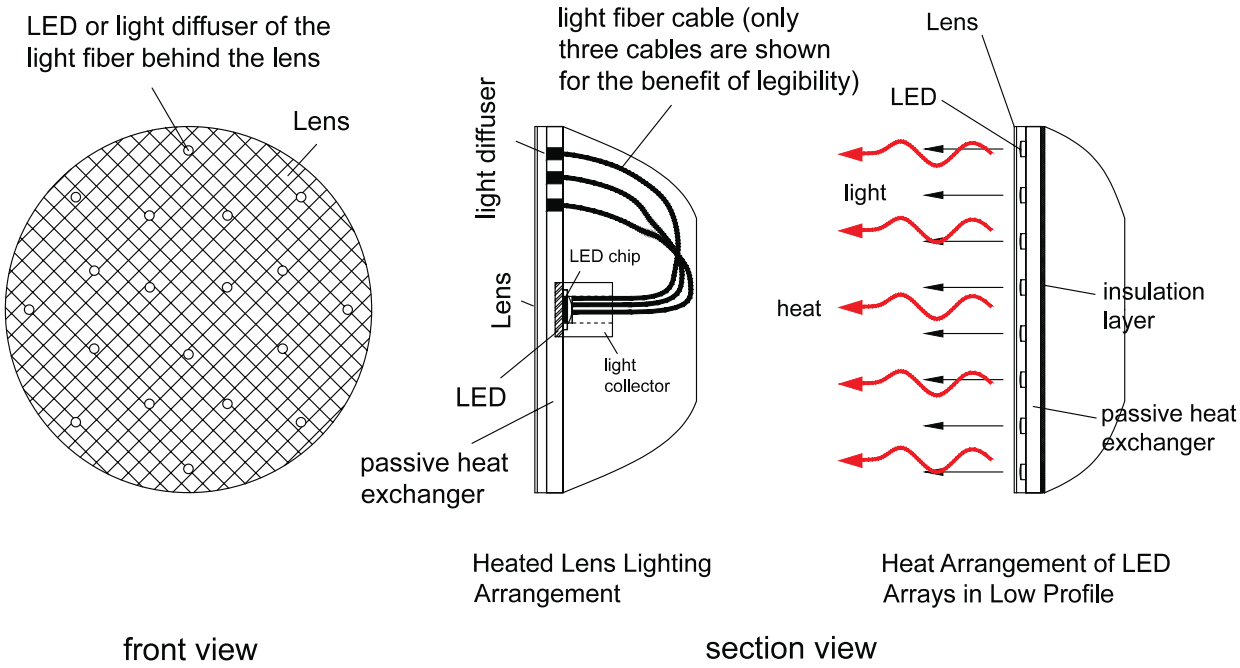


Figure 1 The concept of the self de-icing LED signal light, which adopts new architecture of "Heated Lens Lighting Arrangement" or "Heat Arrangement of LED Arrays in Low Profile"

Fully working prototypes of the self-de-icing LED signals are under development and tests in the laboratory. They will be tested in closed-course settings and then in field on highway intersection and railroad wayside or at-grade crossing signal lights. Each participating agency is required to provide support of three years of funding ($20,000/year, totaling $60,000) and will be guaranteed a field test site in each state for testing the custom-made prototypes catering to their specific needs of the new type of signals. The research team will work with each participating agency to identify the desired test site on highway intersections or rail track sections and the desired technical specifications of the prototypes.

The investigative approach for the proposed project is divided into the three stages. Work in Stage 1 is underway that focuses on laboratory development and tests. Work in Stage 2 will focus on testing the three prototypes in a closed-course setting, for example, mounted on the roof of the University of Kansas engineering complex and powered by the signal controller cabinet. Work in the third and final stage will involve field testing of the developed prototypes on identified highway signalized intersections and rail track sections. On-site demonstration of the prototype signals will also be held for project partners and state DOTs to initiate the implementation process. A final report will provide all relevant data and results along with plans for implementation of the self-de-icing LED signals in affected states.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

During the second quarter (April 1, 2017 – June 30, 2017) in 2017 of the project period, we have the following accomplishments.

In the past quarter, the research team has been working closely with the industrial partner (Sunlite Science & Technology, Inc.) to custom make three fully working prototype signals of Type 1 in the factory. The research team has first tested three light engines with regular paint coating (Figure 2), and then improved and tested three new light engines with Tin coating (Figure 3) to improve the heating performance (to make faster heat transfer). Both light engines used 96 medium-power LEDs (0.25 Watt each).

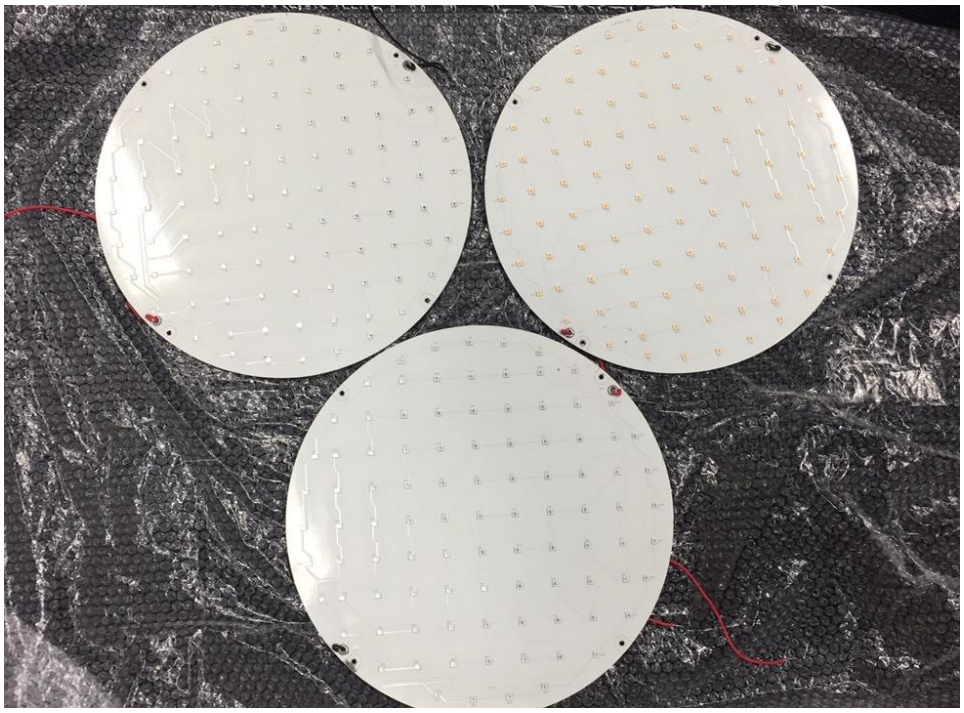


Figure 2 The prototype signals of Type 1 with regular white paint coating.

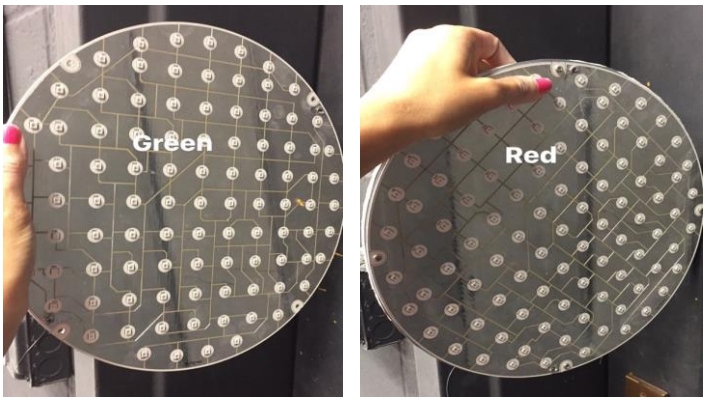


Figure 3 The improved signals of Type 1with TIN coating.

Based on the test results, the specifications for the to be custom-made LED drivers will be as follows:
Red signal: 1.0-1.2 A, 24.8-25.0 V, 24.8-30.0 W
Yellow signal: 0.7-0.8 A, 36.2-36.6 V, 25.3-29.3 W
Green signal: 0.7-0.8 A, 37.3-37.4 V, 26.1-29.9 W

The nominal wattage of signals would be around 25.5 W, but could be overpowered up to 30 W if necessary. The LED drivers are currently being custom-made in a factory with the aid of our industrial partner (Sunlite Science & Technology, Inc.).

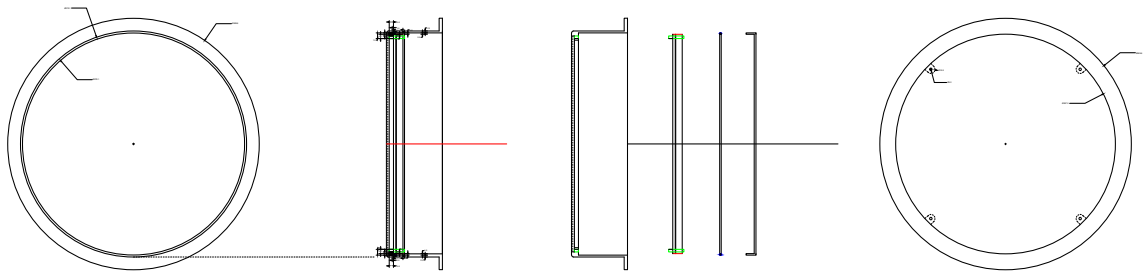
Additionally, in the past quarter, the research team contacted 12 companies making Fresnel lenses, and eventually worked with a company called HongXuan Optoelectronic which makes Fresnel lens meeting our needs. We tested two types of out-of-shelf lenses, including Lens #1 HX-F024012 with diameter 24 mm and focal length 12 mm (Figure 4), and Lens #2 HX-F015006 with diameter 15 mm and focal length 6 mm (Figure 5). Based on the extensive laboratory results, we decided to use Lens #2 with diameter 15 mm and focal length 6 mm.

Figure 4 Lens #1 HX-F024012 with diameter 24 mm and focal length 12 mm.

Figure 5 Lens #2 HX-F015006 with diameter 15 mm and focal length 6 mm.

Figure 6 shows the detail of the updated lens design of the self de-icing LED signal of Type 1. In this design, the signal lens adopts a whole piece design with smooth and flat outside surface and integrated with 96 Fresnel lenses (Lens #2 HX-F015006 with diameter 15 mm and focal length 6 mm) recessed mounted inside the inner surface of the signal lens over each LED to focus the light serving as a collimator lens. This design allows a small gap of 4-6 mm between the LEDs and the lens for enhanced thermal performance.

Figure 7 illustrates the details of the signal lens design at the corner for dust-proof sealing design. A rubber UV light proof O ring (the blue dot as a section view) is added in the gap of the backpack plastic cover and the front LED light engine, serving as dust-proof sealing and an insulation layer on the top. The design is also used as a control for remaining 8 mm thickness of the insulation materials Thermal Wrap™ 8-mm Aerogel Blanket for best insulation purpose, so it won't be squeezed over time.



front view of the signal lens

back view of the signal lens

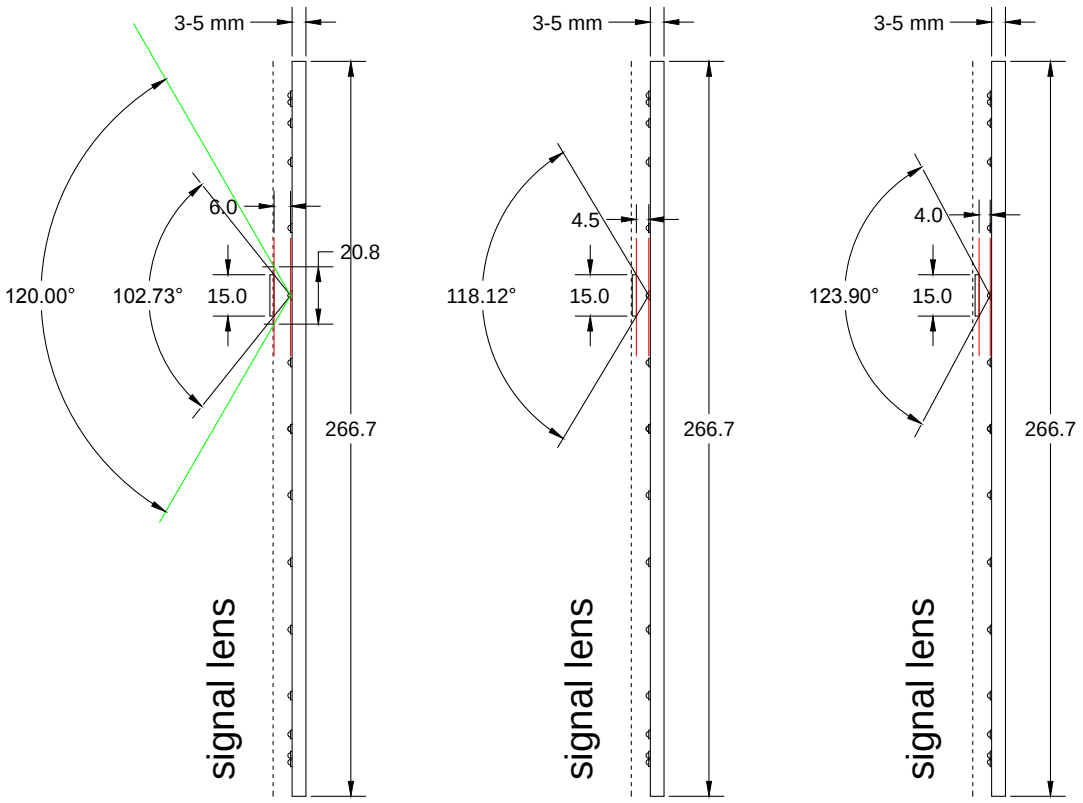


Figure 6 The updated lens design of the self de-icing LED signal of Type 1.

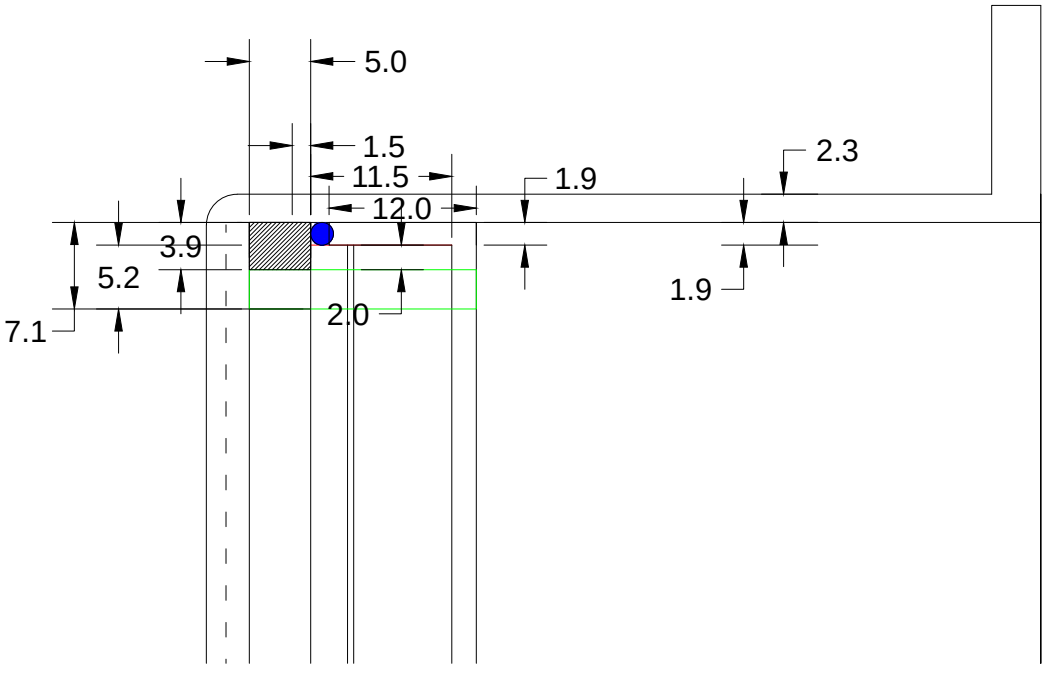


Figure 7 The detail of the signal lens design at the corner for dust-proof sealing design.

As a result, we have updated our design on the fully-working prototypes, including the new light engines with TIN coating, new housing (a single piece to be custom made, as shown in Figure 6) with recessed mounted LED Fresnel lenses (diameter 15 mm and focal length 6 mm), and LED driver. With the aid the industrial partner, the final version of fully working prototypes are being custom made in the factory, which takes time to complete.

Anticipated work next quarter:

Starting from July 01, 2017 till September 30, 2017, we are planning to conduct the following tasks.

1. Develop and custom make the new whole-piece signal housing, new Fresnel lenses, LED drivers, and other accessories for the Type 1 self de-icing LED signal lights, with the aid of the industrial partner.

2. Custom make three fully working prototypes of Type 1 signals that deploy 96 mediate-power LEDs via the architecture of "Heat Arrangement of LED Arrays in Low Profile", then continue to test them in the laboratory, and complete the laboratory tests in Stage 1.

3. Start to test the fully working prototypes in closed-settings in Stage 2.

Significant Results:

As of June 30, 2017, we have achieved the following significant results.

- This project was launched in Aug 2016 with six participating states (Kansas, California, Michigan, New Jersey, Wisconsin, and Pennsylvania) and an initial budget of $240,000. Maryland is expected to officially join the study by the end of this year with additional contribution of three years funding.

- An expert panel meeting was held in early March. Discussions were held on desired specifications of the prototype signals and possible field test sites as well as the field evaluation of the prototypes.

- Necessary equipment, components and insulation materials are being procured to develop and build the fully working prototypes of the finalized design and test for their thermal and lighting performance. We will continue to order LED drivers, electricity monitors, waterproof security video cameras, other mounting accessories and materials, etc., for monitoring the performance of the prototypes in the field tests in the upcoming winter season.

- Appropriate color LED modules, which are not available in the market, were designed in-house and custom-made with the aid of the industrial partner.

- Three preliminary prototype signals (Red, Yellow, and Green) of Type 1 have been developed in house, each deploying 26 custom-made color LEDs mounted in an array via "Heat Arrangement of LED Arrays in Low Profile". They are under laboratory testing for improvements.

- Tested the lighting and thermal performance of the preliminary prototypes of the Type 1 signal lights (Figure 1). Based on the test results, new design with a lot of changes and improvements has been finalized for final products.

- Finalized the design of Type 1 self de-icing LED signals using 96 custom-made mediate-power color LEDs mounted in an array via "Heat Arrangement of LED Arrays in Low Profile". Designed in house and custom-made our own color LED modules (for each color R, G, Y) for making the fully working prototype signals of the first type with the aid of our industrial partner.

- Worked with the factories to optimize the mounting method of the custom-made LED modules on the 3-5 mm thick aluminum MPCB back plate serving as the passive heat exchangers of aluminum alloy for assembly.

- Custom-made three prototypes of the LED signals of Type 1 using 96 custom-made mediate-power color LEDs mounted in an array via "Heat Arrangement of LED Arrays in Low Profile", with regular paint coating (Figure 2), and finished laboratory testing for improvements and optimizations to finalize the design.

- Improved and custom-made three new signal light engines using 96 medium-power LEDs (0.25 Watt each) mounted in an array via "Heat Arrangement of LED Arrays in Low Profile" but with Tin coating (Figure 3) and tested them to improve the heating performance (to make faster heat transfer).

- Finalized the design of the signal lens that adopts a whole piece design with smooth and flat outside surface and integrated with 96 additional custom-made Fresnel lenses sitting inside the signal lens over each LED on the inside surface to focus the light serving as a collimator lens. Based on the testing results, the signal light engines with TIN coating may have superior thermal performance, however, further testing in the laboratory and field is necessary to validate the final choice.

- Identified and started custom-making the Fresnel Lens from HongXuan Optoelectronic company with diameter 15 mm and focal length 6 mm (model # HX-F015006, Figure 5).

- Started custom-making and modeling of the signal housing, which takes time to complete.

- Started custom-making the LED drivers with desired specifications based on our test results.

- Seven states have officially participated in this project, including Kansas, California, Michigan, New Jersey, Wisconsin, Pennsylvania and Maryland to provide support.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.