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:** X Quarter 1 (January 1 – March 31) ☐ 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	$108,097	45%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$17,526	$17,526	5%

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 one or both of 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.

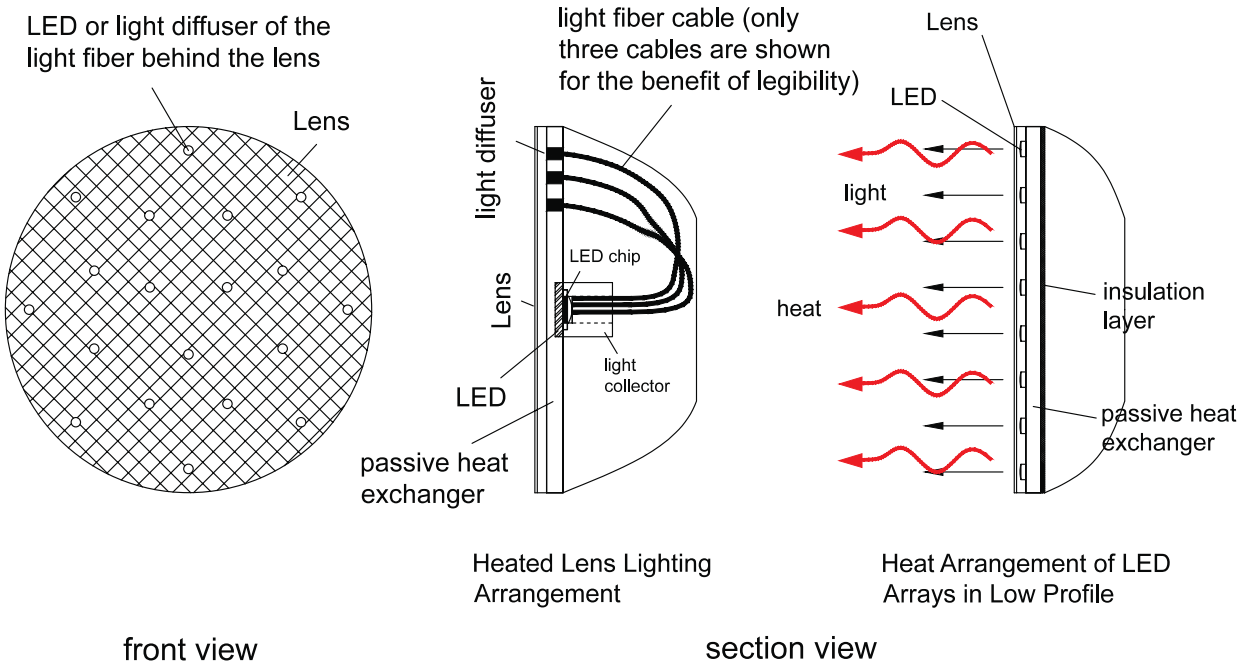


Figure 1 The concept of the self de-icing LED signal light, which adopts new architecture of "Heated Lens Lighting Arrangement" or "Heat Arrangement of LED Arrays in Low Profile"

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 focuses on laboratory development and tests. Work in Stage 2 focuses 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 involves 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 first quarter (January 1, 2018 – March 31, 2018) in 2018 of the project period, we have the following accomplishments.

In the past quarter, the research team has been closely working with the plastic molding company — Eco Molding — to custom make the new housing of the fully working prototype signals of Type 1. We have finalized the design of the new housing with up-to-date inputs from other assembly parts, such as Fresnal lens, and mounting glass panels, and screws, etc.. Eco Molding has completed tooling for the fully working prototype signals, as shown in Figure 1, and is currently making samples of the new plastic housing for validation of the designed geometries for further adjustments before the actual production.

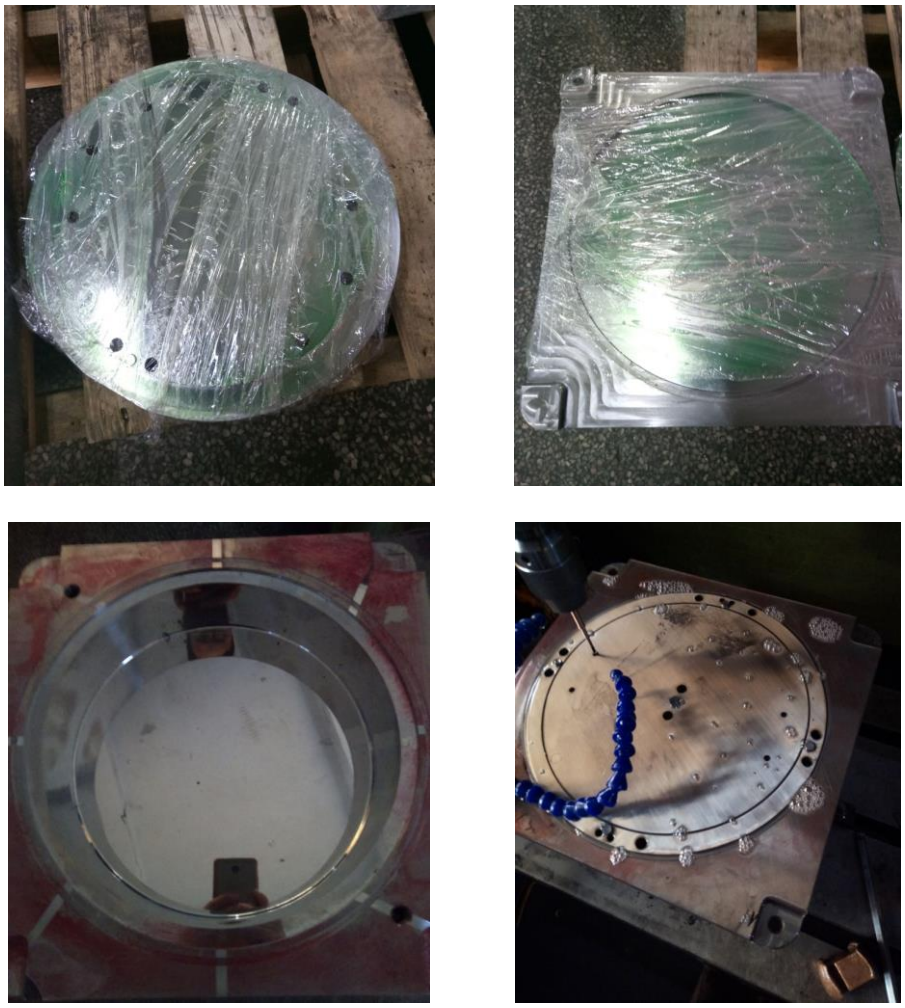


Figure 1 The complete tooling of the finalized design of the new housing of the fully working prototype signals of Type 1, modelled in the factory of Eco Molding. Two metal tools are modelled and ready for making three plastic parts, including the whole-piece of new housing that accommodate 96 small Fresnel lenses for light collimation of individual LEDs, a cover for the new light engine, and a new back cover for the housing which will be used to mount the new custom-made LED drivers.

For the major housing of Part1, which is the whole-piece of signal lens and housing, we will use UV Stabilized Polycarbonate materials. The materials are required to be transparent with visible light transmittance at least 88%, and strong enough to hold wild temperature in a range of -40°C (-40°F) to +74°C (+165°F)

without any problems like cracks, shape changing, or turning yellow due to long time exposure to air, moisture, heat, and UV light. Other two parts of the housing, Parts 2 and 3, which are plastic covers, will also use opaque UV Stabilized Polycarbonate materials, no need to be transparent. The materials should also hold the wild temperature in a range of -40°C (-40°F) to +74°C (+165°F) without any problems like cracks, shape changing, or turning yellow due to long time exposure to air, moisture, heat, and UV light. The warranty should be at least 5 years (by code), ideally 10-15 years.

Secondly, our Fresnel lens provider has shipped their latest lenses (model # HX-F0150115) to us, which have diameter 15 mm, focal length 11.5 mm, and thickness 2.0 mm, as shown in Figure 2. We measured the dimensions of 100 samples to double check, the thickness is average 1.98 mm with standard deviation of +/- 0.19 mm. The diameter is average 14.91 mm with standard deviation of +/- 0.09 mm, which are good to use. Additionally, we custom-made another important part — a glass disc with mounting holes (diameter 260 mm, thickness 3mm), as shown in Figure 2 — to hold those 96 lenses inside the plastic housing and secure their positions for the best lighting performance.

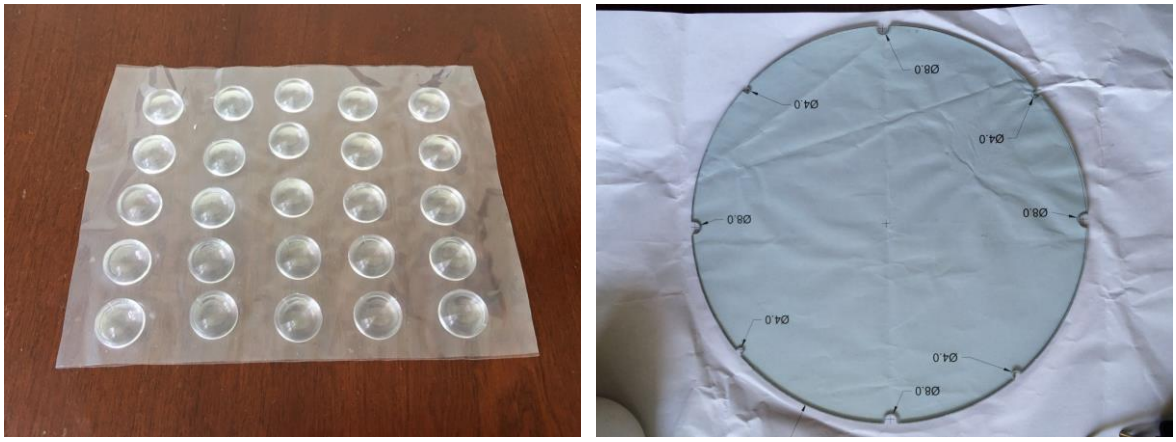
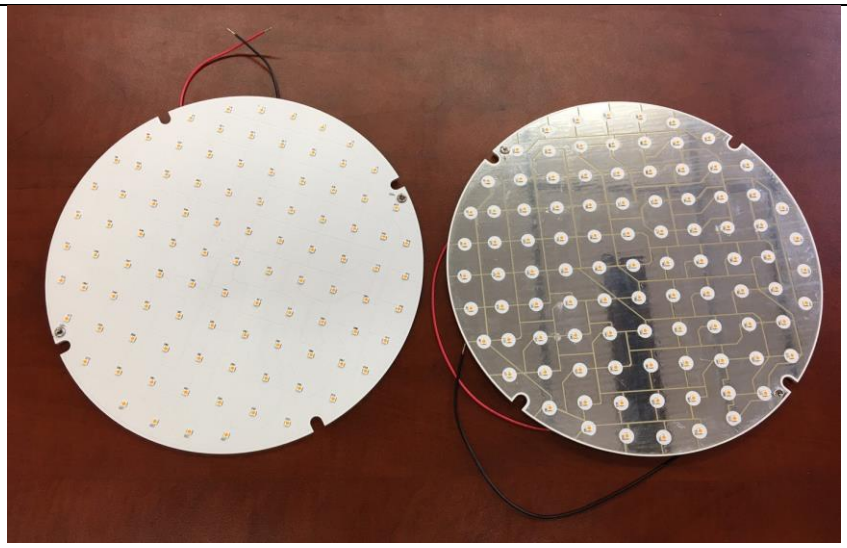
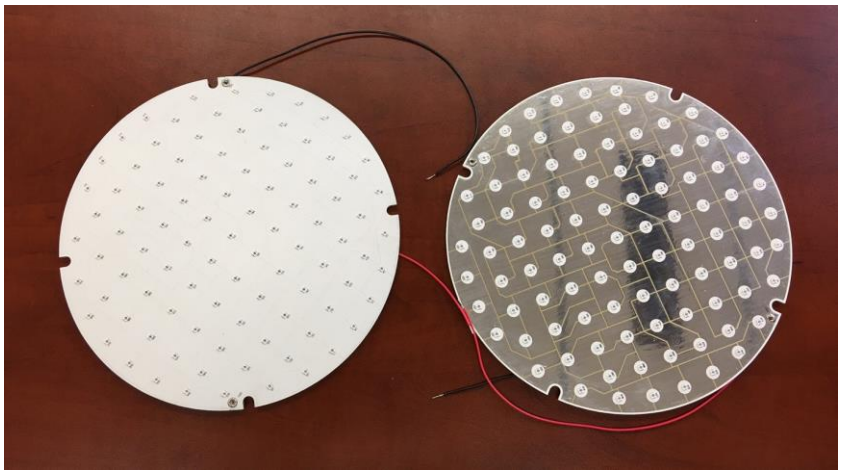


Figure 2 The latest Fresnel lens model # HX-F0150115 (diameter 15 mm, focal length 11.5 mm, and thickness 2.0 mm) and their supporting glass disc (diameter 260 mm, thickness 3mm) custom made in a factory.

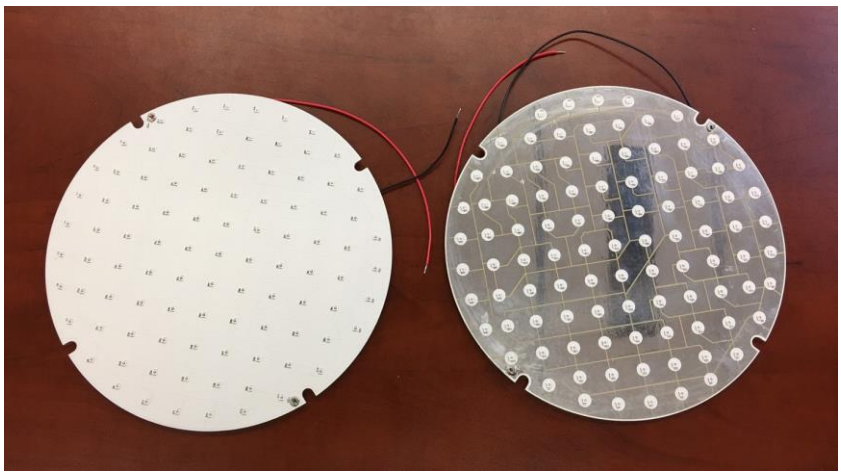
Thirdly, our industrial partner (Sunlite LED company) has shipped us the latest LED engines in red, yellow, and green colors (Figure 3) and custom-made LED drivers (Figure 4). The LED engines are finalized to fit the new housing with all updated mounting accessories. The provided LED engines come with two surface materials, one with regular white painting, the other one with TIN coating. Both will be tested in the to be assembled fully working prototypes to find the best performance. The LED drivers will take input power of 110 – 480 VAC. The output specifications include driver for red signal (output 1.1 A, 25.0V, 27.5 W), driver for yellow signal (0.7 A, 38.0 V, 26.6 W), driver for green signal (0.7 A, 38.0 V, 26.6 W).



Yellow color



Red color



Green color

Figure 3 The latest LED light engines custom made by Sunlite LED company in red, yellow, and green colors, coming with two different surface materials: regular white painting and TIN coating, both will be tested in the to-be-assembled fully working LED signal lights.

Figure 4 The custom-made LED drivers used to power the LED light engines in red, yellow, and green colors, which will be tested in the to-be-assembled fully working LED signal lights. The specifications include driver for red signal (output 1.1 A, 25.0V, 27.5 W), driver for yellow signal (0.7 A, 38.0 V, 26.6 W), driver for green signal (0.7 A, 38.0 V, 26.6 W).

All parts are ready and waiting for the new plastic housing. Once the new housings are available, we will start to assemble the final fully working signal signals for field tests.

Anticipated work next quarter:

Starting from April 01, 2018 till June 30, 2018, we are planning to conduct the following tasks.

1. The molding company – Eco Molding – will complete calibrations of the tooling and start making the actual products of the LED signal housing for custom making the fully working prototypes.

2. LED light engines and all electronics will be custom made / ordered and ready for assembly of fully working prototypes in house.

3. Complete testing 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" in the laboratory and in the closed-course setting. We will complete R&D work in Stages 1 and 2.

4. Final fully-working prototypes for field tests will be custom-made and all other field test equipment and devices will be purchased and ready for field tests.

5. Start talking with different states to figure out the field test sites and all other requirements in preparation for field tests. Field trips will be tentatively scheduled.

Significant Results:

As of March 31, 2018, 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).

- Developed 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.

- Found and selected a qualified plastic molding company to custom make the three parts of the plastic housing of 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". The new housing will be used for the new LED signal lights.

- The non-provisional patent application for the invention of Type 2 self de-icing signal light was officially approved by the USPTO and issued on Dec 26, 2017, patent No. US 9,851,086 B2.

- Started custom-making and modeling of the signal housing. Three samples were delivered for examinations and laboratory tests for necessary calibrations and further improvements.

- Started custom-making the LED drivers with desired specifications based on our test results. Seven ;ED drivers were delivered for sample testing.

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

- A project addendum is proposed to conduct two additional field tests, one in Wisconsin and another one in a test site among Maryland, Pennsylvania, and New Jersey. A budget of $80,000 for the addendum is proposed to be spent starting on 5/18/2018 until the end of the project

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.