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) ☐Quarter 2 (April 1 – June 30) X 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	$75,837	40%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$34,162	$34,162	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.

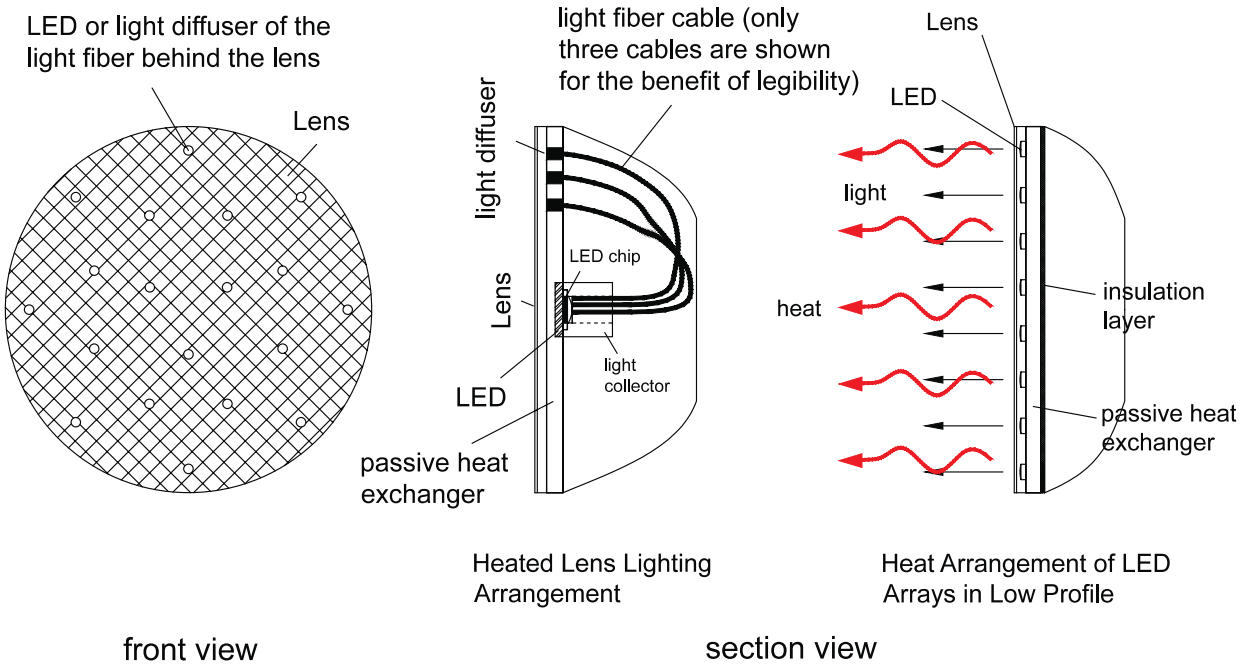


Figure 1 The concept of the self de-icing LED signal light, which adopts new architecture of "Heated Lens Lighting Arrangement" or "Heat Arrangement of LED Arrays in Low Profile"

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 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 third quarter (July 1, 2017 – September 30, 2017) in 2017 of the project period, we have the following accomplishments.

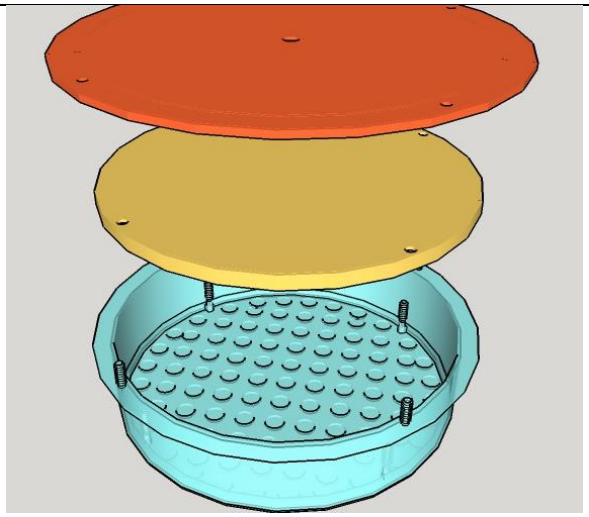
In the past quarter, the research team has been working closely with the industry to custom make the fully working prototype signals of Type 1 in multiple factories. Through communication with different vendors for quotes and techniques on custom making the prototypes, the design of the fully working prototype signals has been improved and finalized, including new housing (Figure 1), new light engine using 96 medium-power LEDs and their appropriate layout on the heat exchanger, new signal lens integrated with 96 small Fresnel lenses (diameter 15 mm, focal length 6 mm, thickness 1.9 mm) for light collimation of individual LEDs, and new custom-made LED drivers with the desired specifications.

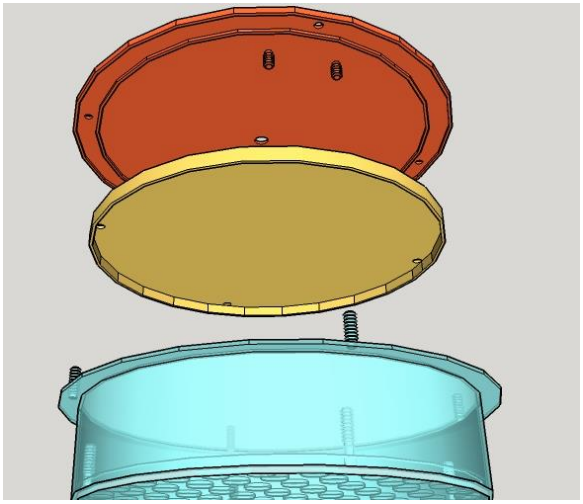
As shown in Figure 1, the new signal light housing approximately in diameter 305 mm and depth 70 mm will include three parts for modeling individually.

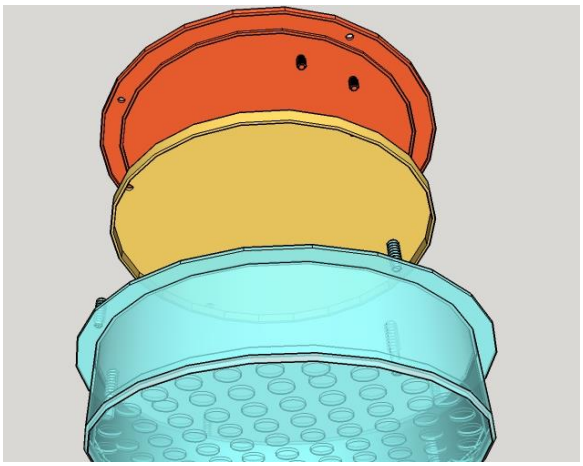
1) Part1, which is the whole-piece of signal lens and housing, as shown in the lower big transparent bow-shape part, will use UV Stabilized Polycarbonate materials. The materials are required to be transparent with visible light transmittance at least 86%, ideally 90%, and strong enough to hold wild 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. The warranty should be at least 5 years (by code), ideally 10-15 years.

2) Parts 2 and 3, which are the above two plastic covers, will also use UV Stabilized Polycarbonate materials. The PC materials could be opaque, 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.

As shown in Figure 1, all parts have been modelled on computer in detail and are custom making in factories using UV Stabilized Polycarbonate materials. It takes a long time for undergoing a process of finding right plastic modeling companies with capacity of the job with high quality work, comparison of quotes, custom modeling, and actual product production. Once all custom-made components and parts are available, they will be assembled to make the final fully working signal signals for field tests.







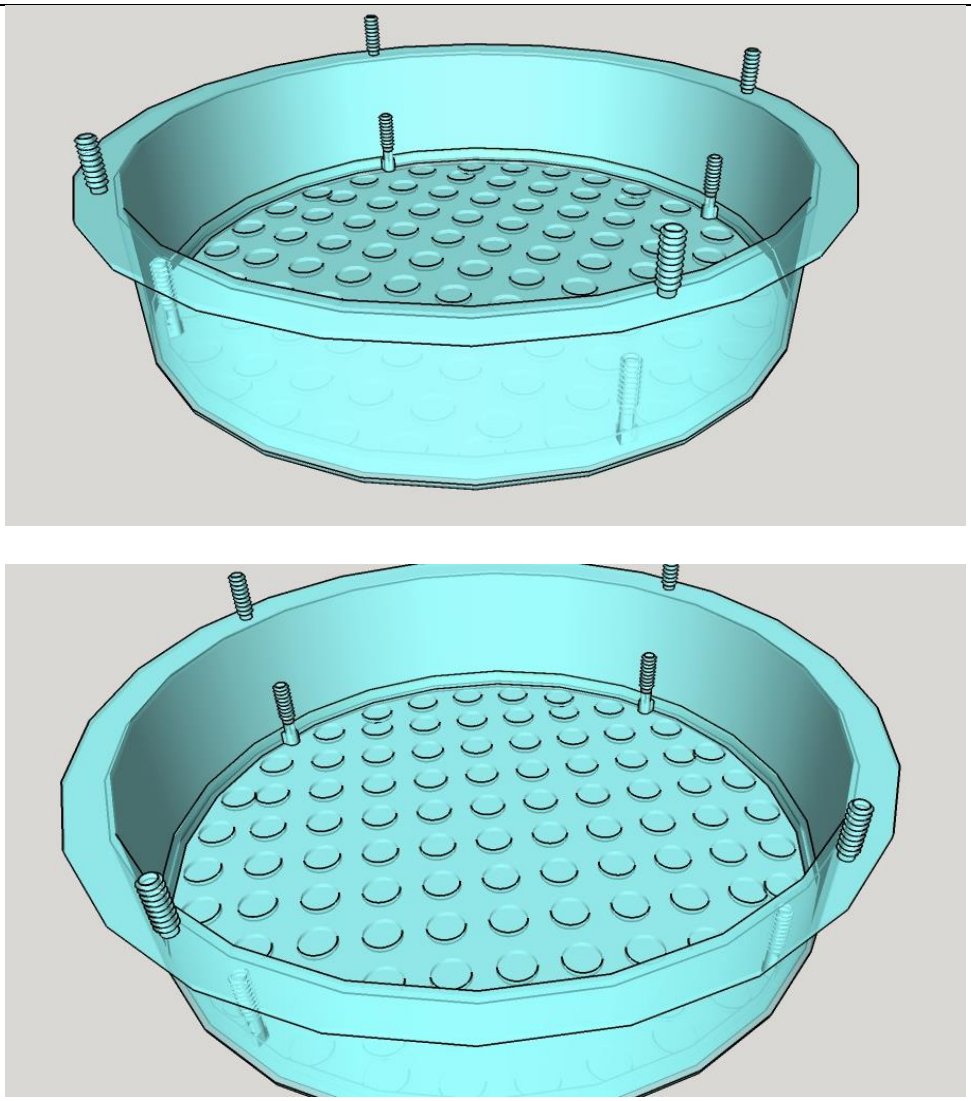


Figure 1 The housing of full working prototype signals of Type 1, which are modelled on computer in detail and are now custom making in factories using UV Stabilized Polycarbonate materials. Three parts shown in Figure 1 include the whole-piece of new housing that accommodate 96 small Fresnel lenses (diameter 15 mm, focal length 6 mm, thickness 1.9 mm) 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 lower major housing, the materials are required to be transparent with visible light transmittance at least 86%, ideally 90%, 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. For the upper two covers, the PC materials could be opaque. The warranty should be at least 5 years, ideally 10-15 years.

Anticipated work next quarter:

Starting from Oct. 01, 2017 till Dec. 31, 2017, we are planning to conduct the following tasks.

1. Complete molding the three parts shown in Figure 1 in a vendor and start to make actual products of the LED signal housing after calibrations.

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 September 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).

- 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.

- 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.