

**Texas Commission on Environmental Quality
New Technology Research & Development (NTRD) Program
Monthly Project Status Report**

Contract Number: 582-11-13472-2019

Grantee: Transportation Power, Inc. (TransPower)

Report for the Monthly period: 10/06/12 – 11/09/12 **Date Submitted:** 11/11/12

Section I. Accomplishments

Provide a bulleted list of project accomplishments as well as a description of their importance to the project.

- Integration of Tractor #2 was completed. This is important to the project because it closes out Task 2, which took several months longer to complete than expected, for reasons discussed below and in our Task 2 report, submitted concurrently with this monthly report. This also allows us to focus project resources on Tasks 3 and 4, which involve durability testing followed by in-service testing of both tractors. Figure 1 is a photo of Tractor #2 shortly after integration was completed, with driver-side battery modules visible in the foreground and the under-cab components – interior battery modules, inverter-charger unit (ICU), and central control module (CCM) visible near the top center of the photo.



Figure 1: Tractor #2 showing installation of driver-side and interior battery modules, ICU, and CCM.

- Two months of intermittent validation and durability testing of Tractor #1 was completed. This testing was extended over a longer period than anticipated because of the needs that emerged to improve key vehicle components such as the axles and transmissions, discussed in more detail below. This additional drive testing delayed completion of Task 3, Vehicle durability testing, and delivery of Tractor #1 to H-E-B in San Antonio, Texas, to commence Task 4, In-Service Testing, by about two

months.

- Numerous upgrades were made to Tractor #1 and Tractor #2 as a result of experience gained during two months of intermittent testing and refinement of Tractor #1. Among the key changes made to both tractors, the front axle on Tractor #2 was replaced with a heavier duty axle following determination that the weight placed on the front end of the tractors exceeded the weight limitations of the original front axles. Figure 2 shows the original axle removed from Tractor #2 (left foreground) and the heavier axle purchased for Tractor #1 (background). Another key achievement is that we completed development and bench testing of the communications hardware and software to enable automated shifting of the three-speed transmissions in both tractors. While shifting from first to second gear had previously been demonstrated on a dynamometer, it was discovered after initial drive testing of Tractor #1 that shifting to third gear couldn't be achieved quickly and reliably enough for seamless shifting to higher speed tractor operation. Steps taken to resolve this issue are discussed below. In addition to these achievements, we made numerous smaller improvements in the design of the drive system installed into Tractor #2, based on experience gained in building and testing Tractor #1. These included rewiring of the CCM and general improvements in vehicle wiring that are expected to improve tractor reliability and maintainability.



Figure 22: Axle removed from Tractor #2 (left) and heavier duty axle prior to installation into Tractor #1 (background).

- Final preparations for independent durability testing of Tractor #1 by Southern California Edison were underway. This testing was pushed back two months to allow the drive system improvements deemed necessary after TransPower's own initial testing of Tractor #1.
- Comments were received from the TCEQ on a draft progress report documenting Task 2 activities, and a final version of the Task 2 report was prepared that responds to these comments.

Indicate which part of the Grant Activities as defined in the grant agreement, the above accomplishments are related to:

- The first accomplishment relates to Task 2.2.3.3., “*The PERFORMING PARTY will integrate the complete electric drive system into the second demonstration tractor;*” and Task 2.2.3.4, “*In accordance with the ITP, the PERFORMING PARTY will perform component level testing as installation proceeds.*”
- The second accomplishment relates to Task 2.3.1, “*The PERFORMING PARTY will conduct at least 3 weeks of drive testing of Tractor 1 in simulated and/or actual service.*”
- The third accomplishment relates to Task 2.2.3.1, “*The PERFORMING PARTY will update the electric drive system required components for the second tractor, if necessary, to reflect any changes in components or parts deemed necessary during initial road testing of Tractor 1 in Task 2.3.1,*” and Task 2.3.1.2, “*The PERFORMING PARTY will optimize the drive system to maximize energy efficiency while meeting performance requirements and maintaining driver comfort.*”
- The fourth accomplishment relates to Task 2.2.5. Deliverables: “*The PERFORMING PARTY shall submit a report to the TCEQ upon completion of this task. This report will include but is not limited to pictures of the integrated tractors, an updated materials and components list, and updated integration drawings and installation procedures.*”

Section II: Problems/Solutions

Problem(s) Identified: Report anticipated or unanticipated problem(s) encountered and its effect on the progress of the project

- a) As discussed in last month's report, TransPower engineers discovered a software bug in the control box for the automated shifter that is causing unintended behavior. When instructed by the vehicle control software, the automated shifter is supposed to shift into neutral and await the next gear request. It was discovered that the shifter was actually shifting into a lower gear prior to shifting into neutral. This was behavior that the component manufacturer was unaware of. Traditional applications for this technology utilize a clutch for shifting, rendering them immune to this issue. TransPower's automated manual transmission, however, is clutch-less. This issue also only affects the shift between second and third gears, which is why TransPower's subsystem level testing on a dynamometer did not catch it.
- b) Also as discussed in last month's report, initial drive testing revealed that excessive weight is being placed on the front axle of Tractor #1 and the vehicle's front tires. This is caused by the fact that space constraints required us to install several heavy components toward the front of the tractor, including six battery modules, the ICU, the CCM, and most of the electrically-driven accessories.
- c) Due to the additional time required to complete integration of the two tractors, and the additional time devoted to durability testing of Tractor #1, TransPower has expended 95% of the TCEQ funds allocated to this project, which exceeds the amount of funding TransPower expected to require for completion of these tasks.

Proposed Solution(s): Report any possible solution(s) to the problem(s) that were considered/encountered

- a) Since this is an issue with the software running in the automated shifter control box, the two proposed solutions were to ask the component manufacturer to identify and fix the software bug, or alternatively to build a proprietary control system. As reported in last month's report, the first solution was strongly preferred, but subsequent work with the manufacturer revealed that this approach would not work. As a result, TransPower was forced to rewrite much of the control software for the transmission and to adopt new controller area network (CAN) based communications to enable use of this software.
- b) The potential solutions to the weight problem were to redesign the installation to move components further back in the tractor, reduce the size or number of batteries on the tractor, or strengthen the front end of the tractor to handle the higher weight. As reported in last month's report, the last of these solutions was selected as it was viewed as the least costly and will have the least impact on vehicle performance.
- c) TransPower will inquire with the TCEQ regarding the availability of additional funding to support the in-service testing phase of the project. If additional funding is not available, TransPower will increase its cost sharing as necessary to complete all in-service testing tasks as proposed.

Action(s) Conducted and Results: Describe the action(s) taken to resolve the problem(s) and its effect

- a) Extensive software development was required to solve the transmission shifting problem. Adding to the complexity of the problem, the serial communications link used by the shift mechanism manufacturer was found to be inadequate once the new software was developed. This

unanticipated problem required us to adopt a new CAN-based communication protocol and to make several upgrades to the control system to accommodate this change. The effect of this additional software and control systems development was to delay delivery of Tractor #1 to Southern California Edison for the last phase of durability testing by about a month, from mid-October 2012 to mid-November 2012. This issue has also increased project costs by tens of thousands of dollars.

- b) Two heavier duty axles were purchased from Cargotec. One was installed into Tractor #2. The other will be installed into Tractor #1 once it completes durability testing, prior to its delivery to H-E-B. After further discussions with Cargotec, it was determined that the front tires will not need to be replaced, which at one point was another solution that was contemplated. The effect of this change was an increase of approximately \$10,000 in project costs.
- c) As discussed above, TransPower will inquire with the TCEQ as to whether there are any unspent New Technology Research and Development (NTRD) program funds that can be allocated to this project to help offset some of the cost increases that have been experienced, but is prepared to increase its cost sharing to meet these expenses if such additional funding cannot be obtained.

Section III. Goals and Issues for Succeeding Period:

Provide a brief description of the goal(s) you hope to realize in the coming period and identify any notable challenges that can be foreseen

Goals for the next reporting period (ending December 10, 2012) include the following.

- Complete durability testing of Tractor #1, including one week of independent testing with Southern California Edison.
- Deliver Tractor #1 to H-E-B's facility in San Antonio, Texas. Along with the tractor delivery, TransPower will provide training to H-E-B vehicle operators and maintenance personnel, and will closely monitor the tractor's first few weeks of operation with on-site engineering support.
- Complete or nearly complete durability testing of Tractor #2. Our target date for completion of this task is December 14, 2012.
- Compile preliminary data on the performance of both tractors, including initial estimates of how many hours of tractor operation can be supported on a single battery charge and energy efficiency.
- Begin preparations for delivery of Tractor #2 to H-E-B before the end of 2012.

The most notable challenge that can be foreseen in completing these objectives is to achieve sufficiently reliable operation of both tractors to complete durability testing and deliver them to H-E-B before year-end. The large number of improvements made to the drive system during integration and initial testing of Tractor #1 should improve long-term tractor performance, but in the near term, these changes may complicate the task of completely "de-bugging" the drive system. While the delays in placing the tractors into service are a cause for concern, TransPower continues to believe that the long-term benefits of taking the time to perfect all these new features and capabilities justify these temporary setbacks.

Date: 11/12/12

Authorized Project Representative's Signature

NOTE: *Please attach any additional information that you feel should be a part of your report or that may be required to meet the deliverable requirements for tasks completed during this reporting period.*