# Program Progress Performance Report for University Transportation Centers
# Marine Engine Testing and Emissions Laboratory (METEL)
# Led by Maine Maritime Academy

- **Federal Agency and Organization Element to Which Report is Submitted:**
U.S. Department of Transportation Research and Innovative Technology Administration

- **Federal Grant or Other Identifying Number Assigned by Agency:** DTRT13-G-UTC43

- **Project Title:** Tier 1 Marine Engine Testing and Emissions Laboratory

- **Program Director: Dr.** Richard Kimball, richard.kimball@mma.edu, 207-326-2375

- **Submission Date:** April 30, 2014

- **DUNS and EIN Numbers:** 071746630 and 01-60000724

- **Recipient Organization:** Maine Maritime Academy, Pleasant Street, Castine Maine 04420

- **Recipient Identifying Number or Account Number:** Not Applicable

- **Project/Grant Period:** October 1, 2013 – September 30, 2017

- **Reporting Period End Date:** March 31, 2014

- **Report Term or Frequency:** This report covers the period from October 1, 2013 to March 31, 2014, per the Grant Deliverables and Requirements for UTCs instructions

- **Signature of Submitting Official:** 

## 1. ACCOMPLISHMENTS

*What are the major goals of the program?*

The Marine Engine Testing and Emissions Laboratory (METEL) focuses on research and development of practical and commercializable emissions reductions technologies and engine efficiency enhancement technologies for marine and related power plants (US DOT strategic goal focus area of environmental sustainability).

METEL also provides maritime transportation workforce development and educational opportunities for undergraduates, graduate student as well as middle and high school students (Through its STEM activities).

METEL has four projects as the focus of the UTC funded activities which are:

Project 1: Field Testing of Diesel/Glycerin Emulsion fuels as a low cost, low emissions, drop-in fuel for marine diesels. This fuel is being developed and commercialized by the startup SeaChange Group LLC

Project 2: At Sea testing of a hydrogen injection system on MMA Work Vessel for emissions reduction. This system is being developed by Global Marine Consulting

Project 3: Development and engine testing of Forest Biomass fuel derivatives being developed at UMaine's Chemical Engineering Department and Forest Bioproducts Research Institute.

Project 4: Development and testing of an exhaust heat recovery thermoelectric generator (TEG) for marine engine efficiency improvement using current advances in thermoelectric materials.

All of the projects work with commercial partners and have the potential to be practical solutions which can be implemented into the maritime industry in a timely, cost effective manner. Testing at METEL is a vital step toward proving out these technologies for practical use in the real working environment for which they would be subjected.

*What was accomplished under these goals?*

**Major Activities and Specific Objectives**

***General METEL accomplishments:***

- Three research engineers hired
- Website online: www.mainemaritime/metel

A primary activity for METEL over its first six months of operation focused on the hiring of staff for the center and the project work as well as contracting the sub-awardees and subcontractors for the various project efforts as called out in the METEL budget and work plan. The following summarizes the tasks which were accomplished over the reporting period:

***Project 1: Diesel/Glycerine Emulsion fuel project***

The summarized accomplishments for the reporting period are:

- Subaward and collaboration agreement with Seachange Group LLC completed
- Orders for Blending Sonolator and blending skid system placed, construction underway
- Preliminary Eco-Hybrid Fuel tests on 4 Cyl. Generator completed

The *Quickwater* has been selected by METEL as a platform to perform at sea testing on a variety of alternatives to traditional diesel fuels [Figure 1]. *Quickwater,* a Maine Maritime Academy vessel, is a decommissioned 41ft Coast Guard utility vessel with twin 360 hp Cummins diesel engines [Figure 2].

Figure 1: Quickwater at Maine Maritime Academy

Figure 2: Twin Cummins diesels onboard Quickwater.

*Quickwater* will be outfitted with secondary fuel tanks and fuel systems to accommodate alternative fuels in addition to traditional diesel fuel. In addition, the vessel will be fitted with all necessary instrumentation to accurately measure and record the emissions and efficiency of the engines.

The engine requirements and current fuel system on board *Quickwater* have been examined to establish design parameters for a secondary system and fuel tanks. The fuel system design is sufficiently complete to solicit quotes for needed equipment. Necessary hose and valve sizes have been determined and the fuel system schematic has been drawn [Figure 3].

To facilitate switching fuels 3-Way fuel switching valves with electric actuators have been sourced and quoted. Bid requests for the hoses and fittings have been submitted.

The first alternative fuel we will test in the *Quickwater* is a glycerin-diesel emulsion produced by SeaChange Group. METEL has placed a 100 gallon order for testing, with delivery expected this quarter.

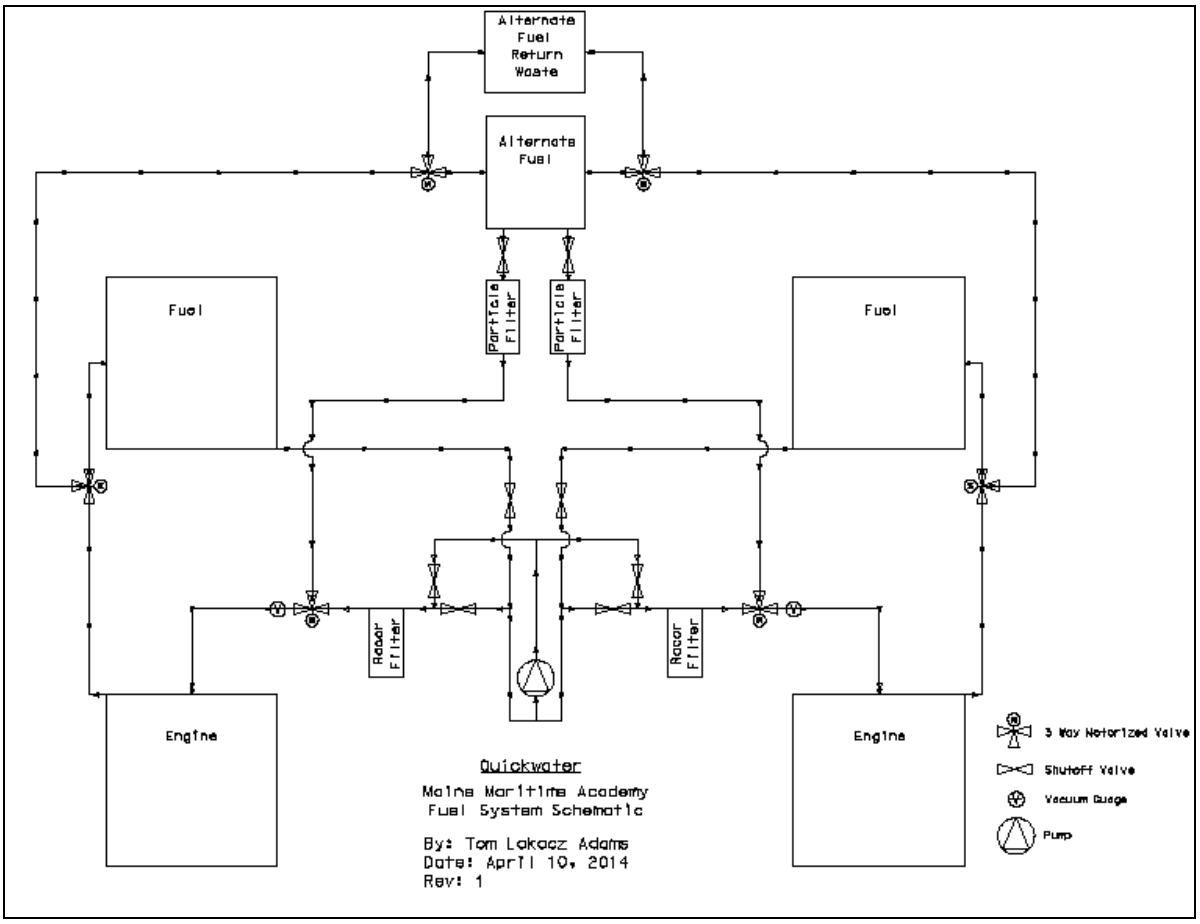


Figure 3: Fuel System schematic onboard Quickwater.

***Project 2: Hydrogen Injection Fuel Project***

The contract to Global Marine Solutions for the Hydrogen Injection System is underway and acquisition and preliminary testing of this system is on schedule for the next reporting period.

***Project 3: Forest Biomass Diesel fuel project***

The summarized accomplishments this project include:

- Subaward to UMaine issued
- Single Cylinder Diesel engine test stand built and tested

**Single Cylinder Diesel Engine Tests Stand:** Figure 4 shows the single cylinder diesel test stand created under the DOT UTC effort. The newly created diesel engine test stand allows testing for viability of biodiesel blends across a wide array of control factors. Using a Hatz 1B30 diesel engine as the foundation for the test stand, auxiliary systems have been designed and implemented to accurately and precisely measure the fuel consumed by the engine through a 24-bit fuel weight measurement system, control the fuel admitted to the cylinder remotely by

position through a rotary motor, and load the engine through a water brake dynamometer. These systems allow the measurement of RPM, torque, and fuel consumption to validate performance characteristics of the test stand under various loading conditions.

Figure 4: METEL Single Cylinder Diesel Engine Test Stand

The system incorporated three major instrumentation sub systems as described above. The first of these systems was the computer controlled dynamometer braking systems shown in Figure 5. This system allows automated control of the engine load during testing.

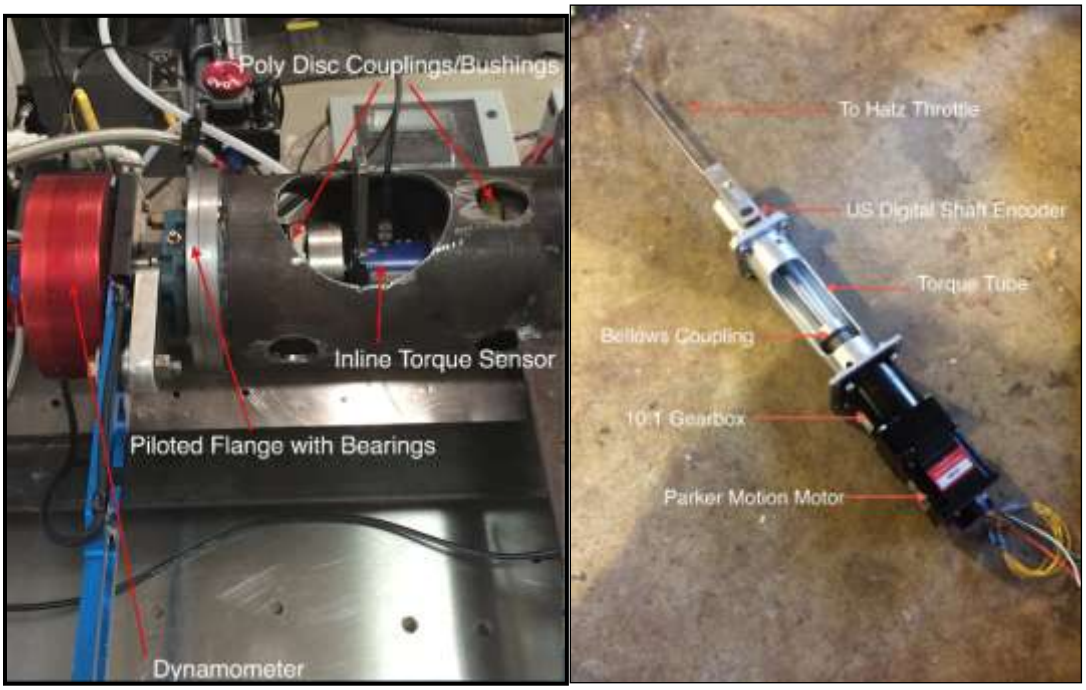


Figure 5: Water Brake Dynamometer system and throttle control system

The second subsystem was the throttle actuation control system (also shown in figure 5). This system used a stepper motor/gearbox control system allowing precise control of throttle

position. The final subsystem constructed was the fuel flow measurement system shown in figure 6. This system used a fuel tank hanging from an analog load cell, hooked to a high precision 24-bit National Instruments strain gauge conditioner allowing precise measurement of fuel flow rate.

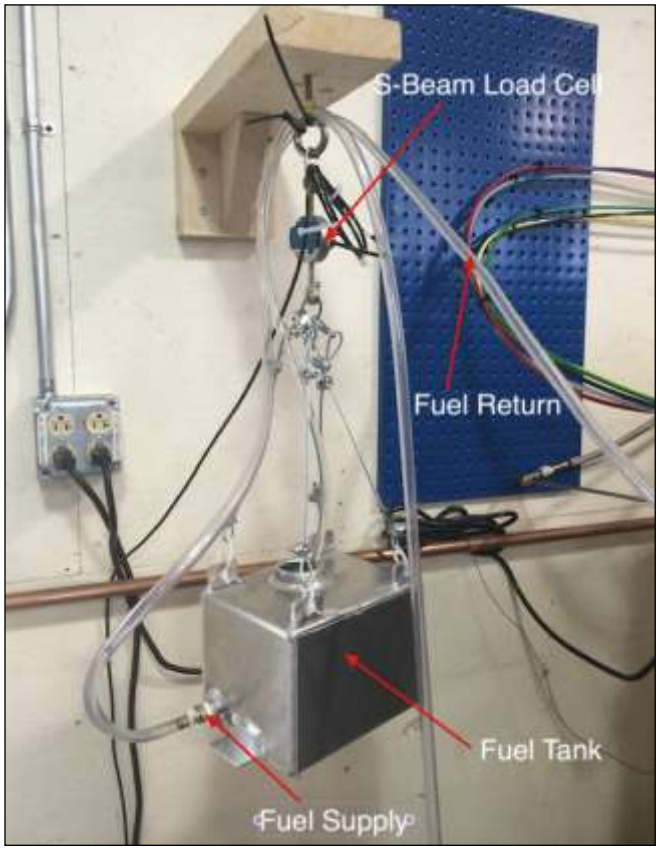

Figure 6: Fuel flow measurement system.

The system was run and load dynamometer curves were collected to validate the instrument system measurements and control.

This work was done by a Marine Systems Engineering senior capstone project team. See publications list below.

**Project 4: Thermoelectric Exhaust heat recovery generator (TEG) project**

Summarized accomplishments:

- Thermoelectric device characterization system built and tested
- Thermoelectric Exhaust heat recovery test apparatus built.

Description of accomplishments for the TEG project:

Figure 7 shows the thermoelectric device characterization system built and tested at METEL. The system consists two thermo-coupled copper blocks between which the thermoelectric device is sandwiched. By heating the lower block with a hot plate an cooling the upper block

with water or ice, the temperature differential to drive the device is established. The thermoelectric module the puts out power which is varied via a computer controlled resistor bank consisting of MosFETS running in linear mode, controlled by a NI Compaq daq system.

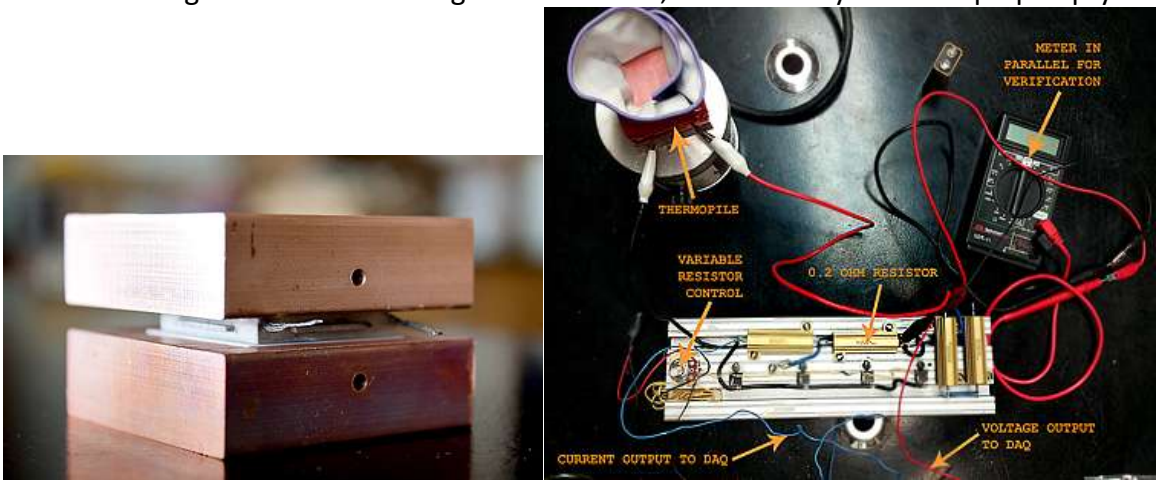


Figure 7: Thermoelectric Characterization measurement system

Figure 8 shows the output performance measured by the thermo electric device characterization system using a Hi-z thermoelectric module. The results of the power output and voltage output measured by the device are plotted next to the manufacturers data showing good agreement and validating the instrument.

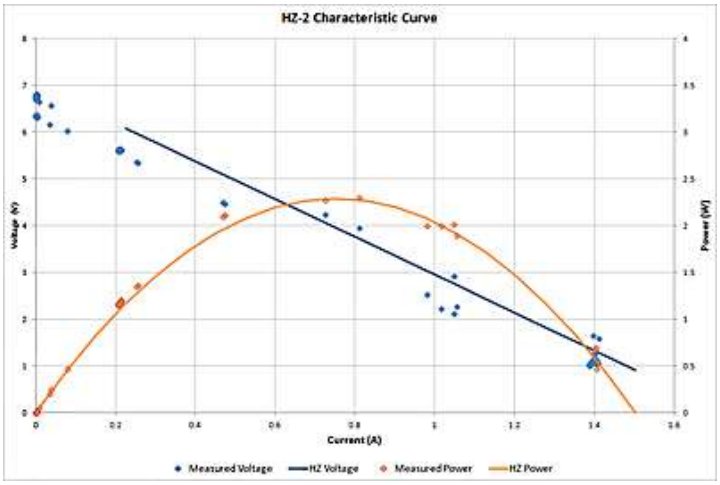


Figure 8: Validation of thermoelectric characterization device vs manufacturers data.

Figure 9 shows the TEG research apparatus consisting of an adjustable slot width exhaust flow channel mounted in a box (top side). On the bottom of the apparatus the test thermoelectric devices are mounted and sandwiched between the lower exhaust channel wall and a water cooled plate system, thereby simulating a basic seawater cooled TEG exhaust heat recovery device. The system includes thermocouples in the exhaust as well as on either side o the thermoelectric devices. In addition, pressure taps are located on either end of the slot to

measure exhaust side pressure drop. The system is design to study and control TEG heat transfer and exhaust pressure drop by varying the slot width of the channel. The tradeoff between high heat transfer (low slot width) and low exhaust pressure drop (large slot width) is considered a critical tradeoff in the design of TEG systems. This apparatus is designed to provide fundamental data used for validating computer models of the system used for the design of these systems.

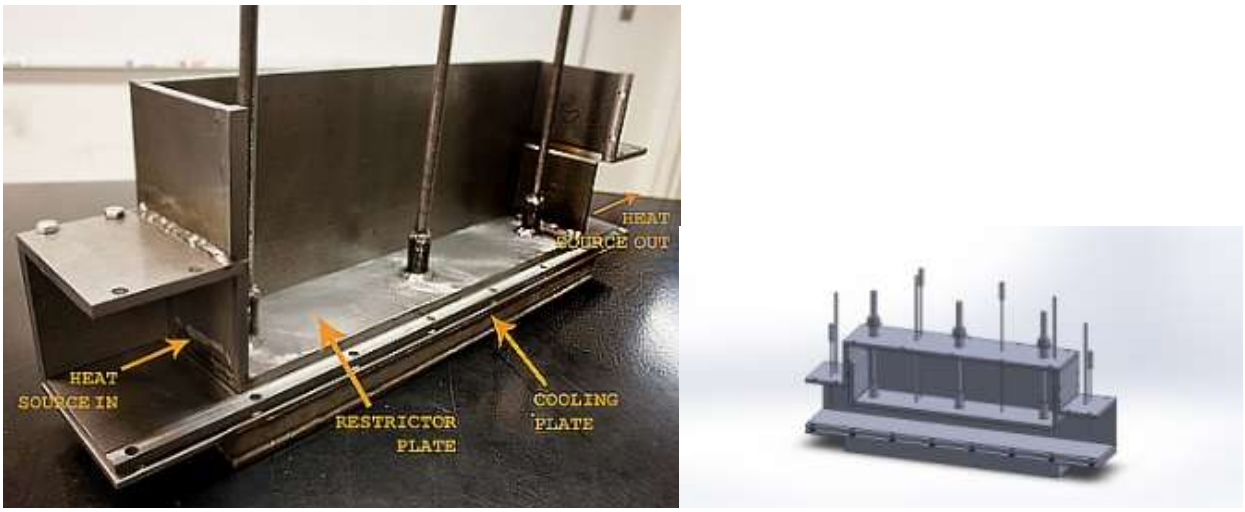

Figure 9: TEG Research Apparatus

This work was completed by a Marine Systems Engineering senior capstone project team. See publications list below.

**Education, Workforce development and STEM accomplishments**
The accomplishments in this area are summarized as:

- (2) STEM events funded/attended
- Glycerine from Algae STEM effort initiated

**STEM Events:** METEL is committed to exposing students of all ages and particularly high school students to our research through participation in numerous events and outreach activities. Under the leadership of Professor Paul Wlodkowski, the STEM coordinator at MMA, METEL has participated in two major events in cooperation with MMA's engineering department. METEL has provided displays and hands-on activities at these events, along with lab personnel to explain our research and answer general questions about the science and engineering behind our projects.

The first such activity was the Engineering Expo held in Bangor on March 22, 2014 as part of Maine Engineer's Week. The event attracted between 2000 and 2500 members of the general public with a large number of middle school and high school students attending. METEL

contributed a strong presence to the MMA booths, with a number of lab personnel engaged with the public at the booth and both hands-on and active displays of METEL projects to augment the MMA display. Hundreds of students stopped by the booth to interact with both the displays and METEL engineers.

The second activity was The Maine State Math Meet held in Bangor, Maine on April 8, 2014. Over 900 of the state's top mathletes get together to compete for state titles, with the winning teams going on to the regional competition. METEL set up a booth with information and static displays and had engineers on hand to talk to students during breaks and at lunch, as well provide information and outreach to parents and teacher in attendance.

**Algae Based Glycerine Fuel STEM Project**

Preliminary work on the development of an algae based glycerin fuel project was begun as an extension of the Diesel/Glycerin fuel project to develop a middle school science STEM project for use by teachers. The project uses a special algae which can produces and excrete significant quantities of glycerin. METEL has acquired cultures of this algae and is developing a system to study the growth of this algae in a "Farm" situation in order to produce glycerin biofuel. The STEM project is developing a low cost, easy to use Algae farm kit, which students can use to study an optimize the production of this biofuel, processing into fuel and then burn it in a simple engine. Figure 10 shows our bioreactor for culturing the algae and the resulting culture.

Figure 10: Algae Biofuel reactor and Algae culture

The project, though simple, touches on many important STEM areas and contemporary issues. The system promotes careful laboratory study techniques, requires the use of dimensional analysis to scale up the number to a real farm size, connects biological science with

engineering, acts as a conduit to studying global warming using data and analysis as well as studying global energy security. The projects intent is to motivate students that by being good scientists and engineers they can solve major real world issues and make a difference to the planet.

**Significant Results:** None to report at this time

**Key Outcomes:** None to report at this time

*How have the results been disseminated?*

Thus far two engineering capstone papers has been completed and presented at MMA. In addition, two STEM outreach activities were conducted which consisted of
1)A Booth funded by the project at the Maine State Engineers Week (A STEM symposium for middle and high school students showcasing the states engineering colleges and labs)
2) A both funded at the Maine State Math Meet finals; A high school event consisting of top math students from all high schools around the state of Maine.

*What do you plan to do during the next reporting period to accomplish the goals?*

Over the next reporting period we plan the following goals and accomplishments for the projects:

Project 1: Diesel/Glycerin Emulsion fuel project
- Blending Sonolator and blending skid system placed, completed and operational
- Production of pilot quantities of fuel using the aforementioned fuel production skid
- Setup of Vessel R/V Quickwater for Fuel and emissions tests and sea trials using the fuel

Project 2: Hydrogen Injection Fuel Project
- Acquisition of GMC system
- Setup of GMC system on R/V Quickwater
- Sea Trials of GMC system on R/V Quickwater

Project 3: Forest Biomass Diesel fuel project
- Production samples of TDO and FAsPyrolosis fuel
- Preliminary tests of fuel on the Single Cylinder Diesel engine test stand

Project 4: Thermoelectric Exhaust heat recovery generator project
- Testing of the Experimental TEG test system on single cylinder diesel using Hi-Z thermoelectric modules

Education, Workforce development and STEM:

- Development of Algae STEM project for use by middle school science teachers
- Development of Lab for the Environmental Compliance course at MMA

**2. PRODUCTS:** What has the program produced?

*Publications, conference papers, and presentations*

P. Levesque, T. Doane; *Thermodynamic analysis for Optimized Waste Heat Power Generation in Marine Applications*; 2014 MSE Capstone Presentation, Maine Maritime Academy Apr. 24, 2014

B.Scully, D.Blasius, Z.Lawrence; *Single Cylinder Diesel Engine Research Test Stand*; 2014 MSE Capstone Presentation, Maine Maritime Academy Apr. 24, 2014

*Journal publications:* Nothing to Report

*Books or other non-periodical, one-time publications:* Nothing to Report

*Other publications, conference papers and presentations:* Nothing to Report

*Website(s) or other Internet site(s)*
The METEL website can be found at: www.mainemaritime/metel
This is the main website for the DOT UTC Center, describing the center's mission as well as the projects, key personnel and serves as a repository for the research reports generated by the project.

*Technologies or techniques* Nothing to Report

*Inventions, patent applications, and/or licenses* Nothing to Report

*Other products*
*Instrumentation:*
- Single Cylinder Diesel Engine Test Stand
  Used for fuel testing and characterization of marine diesel fuels
- Thermoelectric material test apparatus
  Characterizes the basic performance of thermoelectric materials
- Thermoelectric Exhaust Heat Recovery research test apparatus.
  Specialized apparatus to provide basic data for designing TEG Systems

**3. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS**: Who has been involved?
*What individuals have worked on the program?*
The tables below summarize the information for the individuals who have worked on the program:

| | |
|---|---|
| Name | Dr. Richard Kimball |
| Program/Project Role | P.I. /Technical Director |
| Work Effort during reporting period | 3 months |
| Contribution to Program/Project | METEL Technical Director |
| Funding support | DOT UTC |
| Collaborated with individual in foreign country | No |
| Country of Foreign Collaborator | NA |
| Travelled to Foreign Country | No |
| If travelled to foreign country(ies) duration of stay | NA |

| | |
|---|---|
| Name | Dr. Darrell Donahue |
| Program/Project Role | Co-P.I. Administrative Director |
| # Hours worked during reporting period | 1 month |
| Contribution to Program/Project | METEL Administrative Director<br>Contracts and sponsored programs activities |
| Funding support | MMA internal |
| Collaborated with individual in foreign country | No |
| Country of Foreign Collaborator | N/A |
| Travelled to Foreign Country | No |
| If travelled to foreign country(ies) duration of stay | N/A |

| | |
|---|---|
| Name | Dr. George Harakas |
| Program/Project Role | Researcher/ Faculty |
| # Hours worked during reporting period | 0.5 months |
| Contribution to Program/Project | Webmaster, Diesel/Glycerin fuel Project |
| Funding support | DOT UTC |
| Collaborated with individual in foreign country | No |
| Country of Foreign Collaborator | N/A |
| Travelled to Foreign Country | No |
| If travelled to foreign country(ies) duration of stay | N/A |

| | |
|---|---|
| Name | Dr. Clay Wheeler |
| Program/Project Role | UMaine Co-P.I. |
| # Hours worked during reporting period | 0.5 month |
| Contribution to Program/Project | Lead P.I. for UMaine effort; Leading the TDO/FAsP project at UMaine |
| Funding support | None to date |
| Collaborated with individual in foreign country | No |
| Country of Foreign Collaborator | N/A |
| Travelled to Foreign Country | No |
| If travelled to foreign country(ies) duration of stay | N/A |

| | |
|---|---|
| Name | Dr. Paul Wlodkowski |
| Program/Project Role | STEM Coordinator/Faculty |
| # Hours worked during reporting period | 0.25 Months |
| Contribution to Program/Project | Leading STEM efforts for program |
| Funding support | MMA Internal |
| Collaborated with individual in foreign country | No |
| Country of Foreign Collaborator | N/A |
| Travelled to Foreign Country | No |
| If travelled to foreign country(ies) duration of stay | N/A |

| | |
|---|---|
| Name | Thomas Lokocz |
| Program/Project Role | Research Engineer |
| # Hours worked during reporting period | 120 hrs (Full time since March 7) |
| Contribution to Program/Project | METEL Research Engineer (full time) for all projects |
| Funding support | DOT UTC |
| Collaborated with individual in foreign country | No |
| Country of Foreign Collaborator | N/A |
| Travelled to Foreign Country | No |
| If travelled to foreign country(ies) duration of stay | N/A |

| | |
|---|---|
| Name | Richard Smith |
| Program/Project Role | Research Engineer (Part time) |
| # Hours worked during reporting period | 60 hours |
| Contribution to Program/Project | METEL Research Engineer for all projects |
| Funding support | DOT UTC |
| Collaborated with individual in foreign country | No |
| Country of Foreign Collaborator | N/A |
| Travelled to Foreign Country | No |
| If travelled to foreign country(ies) duration of stay | N/A |

| | |
|---|---|
| Name | Dr. Joshua Henry |
| Program/Project Role | Research Engineer (Part Time) |
| # Hours worked during reporting period | 30 hours |
| Contribution to Program/Project | METEL Research Engineer; TEG project and STEM Algae project |
| Funding support | DOT UTC |
| Collaborated with individual in foreign country | No |
| Country of Foreign Collaborator | N/A |
| Travelled to Foreign Country | No |
| If travelled to foreign country(ies) duration of stay | N/A |

| | |
|---|---|
| Name | Patricia Dunford |
| Program/Project Role | Undergraduate researcher |
| # Hours worked during reporting period | 40 hrs |
| Contribution to Program/Project | STEM Algae project |
| Funding support | DOT UTC |
| Collaborated with individual in foreign country | No |
| Country of Foreign Collaborator | N/A |
| Travelled to Foreign Country | No |
| If travelled to foreign country(ies) duration of stay | N/A |

| | |
|---|---|
| Name | Brenden Scully |
| Program/Project Role | Undergraduate Researcher |
| # Hours worked during reporting period | 40 hrs |
| Contribution to Program/Project | Senior Capstone project: Construction of diesel Engine Test stand |
| Funding support | DOT UTC |
| Collaborated with individual in foreign country | No |
| Country of Foreign Collaborator | N/A |
| Travelled to Foreign Country | No |
| If travelled to foreign country(ies) duration of stay | N/A |

*What other organizations have been involved as partners?*

Organization: SeaChange Group LLC (SCG) , Brunswick Maine
Contribution to Project: SCG is providing the Diesel/Glycerin Emulsion fuels for testing in MMA's test engines and marine vessels. They are constructing and operating the fuel blending skid and collaborating with MMA on the engine and vessel testing.

*What other collaborators or contacts been involved?*
Nothing to Report

**4. IMPACT:**

*What is the impact on the development of the principal discipline(s) of the program?*
Nothing to Report

*What is the impact on other disciplines?*
Nothing to Report

*What is the impact on the development of transportation workforce development?*
Nothing to Report

*What is the impact on physical, institutional, and information resources at the university or other partner institutions?*

**Physical resources such as facilities, laboratories, or instruments;**

Development of the Single Cylinder diesel engine stand is a new physical resource which will impact both research capabilities as well as engineering training in the thermodynamics lab sequences as well as the environmental compliance course at MMA.

*What is the impact on technology transfer?*
Nothing to Report

*What is the impact on society beyond science and technology?*

Nothing to Report

**5. CHANGES/PROBLEMS**

Nothing to Report

**6. SPECIAL REPORTING REQUIREMENTS**

Nothing to report