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

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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, 2018

Reporting Period End Date: March 31, 2018

Report Term or Frequency: This report covers the period from October 1, 2017 to March 31, 2018, 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 nine 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.

Project 5: Development of a Marine Engine Continuous Emissions Monitoring System which operates on actual at-sea vessels as well as in the lab.

Project 6: Studies the capability of particular Algae strains to produce Glycerin fuel for use as a low cost low emissions transportation fuel.

Project 7: Development of Medium Speed Engine Testing Laboratories for Efficiency Improvement and Emissions Reduction Technology Evaluation.

Project 8: Sustainability Education and Laboratory Training for Workforce Enhancement

Project 9: Efficiency Improvement of Workboats through Hull Form Optimization Develop a high efficiency, advanced hull form for application to the coastal fishing fleet.

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:

- Completed soot morphology comparisons of combustion emissions from an indirect injection diesel engine using Transmission Electron Microscopy (TEM) for ultra-low sulfur diesel, biodiesel and diesel/biodiesel/glycerol emulsion fuels.
- Produced 20 L of thermal deoxygenation oils for upgrading and blending research.
- Completed hydrotreatment of thermal deoxygenation oils using a Ni/Si-Al catalyst in a trickle bed reactor for fractionation and blending in diesel combustion performance research at Maine Maritime Academy.
- Evaluated the use of Iridium as a selective ring opening catalyst for cetane improvement of thermal deoxygenation oils.
- Contact resistance issues on TEG identified, solutions being investigated
- Implemented continuous flow/monitoring system in a "mock" algae farm style system.
- Studies continuing on for salinity shocking to induce algae to excrete glycerin to be collected from the media as fuel.
- Completion of second stage continuous emissions and performance monitoring system installed in medium speed diesel engine lab. Testing for industry client currently underway.
- Significant progress on construction of experimental Work Boat at The Landing School in Arundel, Maine (70% complete).

Refinement of the test infrastructure to support the various research projects is ongoing.

The following summarizes the tasks for each project which were accomplished over the reporting period:

Project 1: Diesel Glycerin Emulsion Fuel Project

The summarized accomplishments for the reporting period are:

- Completed soot morphology comparisons of combustion emissions from an indirect injection diesel engine using Transmission Electron Microscopy (TEM) for ultra-low sulfur diesel, biodiesel and diesel/biodiesel/glycerol emulsion fuels.
- Completed analysis of soluble organic fraction (SOF) of soot and partial oxidation products using gas chromatography mass spectrometry.

Description of accomplishments:

A Caterpillar C2.2L diesel engine consisting of 4 indirect injection cylinders, rated for 25 kW, was used to compare the combustion and emissions behavior of ultra-low sulfur diesel (ULSD), biodiesel/ULSD at 50:50% (vol:vol) and diesel/biodiesel/glycerol emulsion fuels. The glycerol emulsion fuel content was 0, 10, 20 and 30 wt% and utilized the diesel:biodiesel blend as a base stock. Fuels were evaluated at a fixed engine speed of 1,800 RPM under variable load conditions. Soot was collected for each fuel and engine condition in two ways; First, transmission electron microscopy (TEM) grids were loaded thermophoretically with soot particles within the undiluted exhaust stream for imaging and; Second, soot was collected with 0.45 microns disc filters for soluble organic fraction determination using methanol extraction.

Partial oxidation products in the diesel exhaust was captured using 2,4-dinitrophenylhydrazine absorbent cartridges (Sigma Aldrich) by drawing 5L of exhaust, at 1 lpm

using a vacuum pump. Derivatized products were eluted with 3 mL acetonitrile for analysis by Gas chromatography mass spectroscopy (GC-MS).

Average primary soot particle diameter and cross-sectional area were determined from TEM images using Fiji from 25 individual particles at each fuel and load condition. The primary particles exhibited consistent dimension across the fuel set with an average of 22.13 +/- 5.7 nm. Agglomeration of primary particles, however, appears inhibited in the emulsion fuels with small soot particles trending with increased glycerol content. The smallest soot particles were observed for the 30 wt% glycerol emulsion fuel, as shown in Figure 1, which exhibited soot particles with cross-sectional area nearly half that of ultra-low sulfur diesel fuel at each load condition.

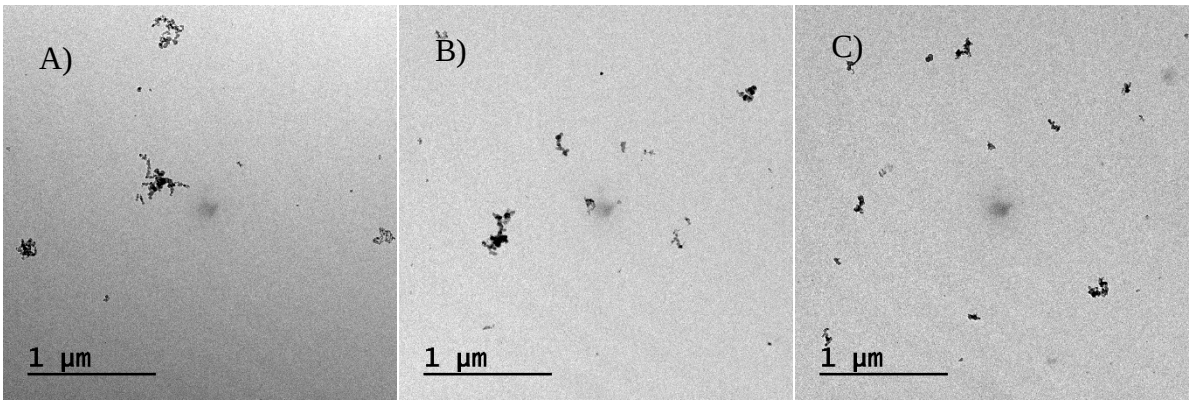


Figure 1: TEM images comparing diesel soot morphology of ultra-low sulfur diesel (A), 50:50% (vol:vol) blend of ultra-low sulfur diesel and biodiesel (B) and 30 wt% emulsion of diesel/biodiesel/glycerol (C) at idle conditions. Emulsion fuels exhibit low agglomeration and result in finer particles.

The authors believe that condensed-phase material coating soot particles inhibits the rate of agglomeration. Thermogravimetric analysis and GC-MS results indicate emulsion fuel soluble fraction accounted for up to 70 wt% of the soot and consistent primarily of unreacted long-chain esters, likely derived from the biodiesel base stock. The implications of these observations are still under considerations and the environmental health ramifications of the soot chemistry remains and open question.

Project 2: Hydrogen Injection Fuel Project

The summarized accomplishments for the reporting period are:

- No work performed during this reporting period. We plan on closing this project shortly.

Description of accomplishments for the Hydrogen Injection Fuel Project:

We anticipate finishing research and closing the project out during next period activities.

Project 3: Forest Biomass Diesel fuel project

The summarized accomplishments for the reporting period are:

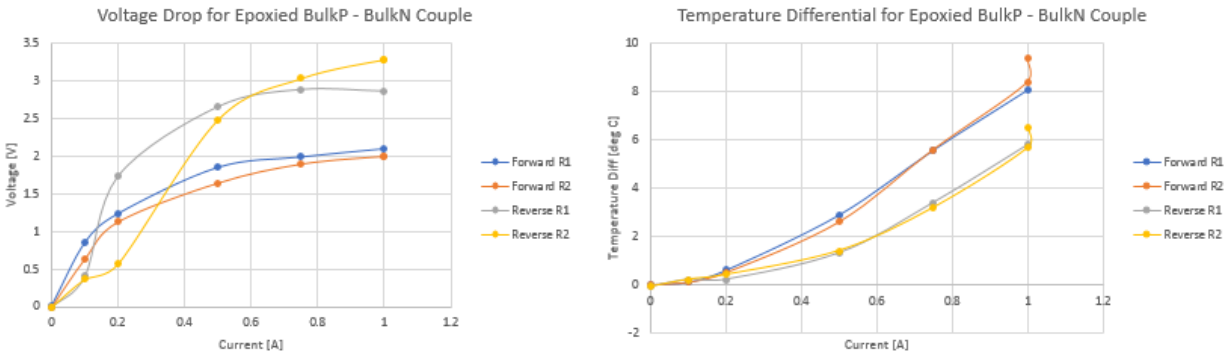
- Produced 20 L of thermal deoxygenation oils for upgrading and blending research.
- Completed hydrotreatment of thermal deoxygenation oils using a Ni/Si-Al catalyst in a trickle bed reactor for fractionation and blending in diesel combustion performance research at Maine Maritime Academy.

- Evaluated the use of Iridium as a selective ring opening catalyst for cetane improvement of thermal deoxygenation oils.
- One M.S. Thesis focused on hydrotreating of Formate Assisted Pyrolysis oils
- One M.S. Thesis focused on upgrading of glycerol to value-added propane diols

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

- Material performance testing underway
- Contact resistance issues observed and solutions being investigated
- Seebeck measurement load bank constructed

Description of accomplishments for the thermoelectrics:
While performing Peltier testing of the couples, it was observed that reversing the polarity of the current flowing through the couple produced a different result for the power versus temperature profile. Upon investigating the interactions of the materials using in the initial TE couple, it was realized that there is a work function mismatch between the semi-conductor and the metal contact. The original construction of the TE couple included the use of silver paste or epoxy, which proved to be an incompatible match to the n-type thermoelectric that was causing additional joule heating when the electrons attempt to cross the boundary between the silver and n-type bismuth telluride. Figure 2 shows the differences in the TE couple temperature profile when conducting a Peltier test with forward and reverse polarity current. At these current settings, 0-1A, the temperature difference is greatly affected by the increase in joule heating, as the cold side temperature rose, albeit at a slower rate than the hot side. To alleviate this issue, a study was conducted to find a material that was a closer match to the work function for both the p and n type bismuth telluride. Nickel and gold were both identified as available materials that were close in work function to allow the transfer of electrons more freely. Figure 3 shows the results of Peltier testing of the TE couple using nickel as a boundary contact pad between the p-type and n-type TE elements. As can be seen, using a 1mm thick nickel strip as a contact pad improved the temperature stability of the couple at the lower current setting. The development of an appropriate method of depositing a Ni layer on the ends of the TE couple is underway.



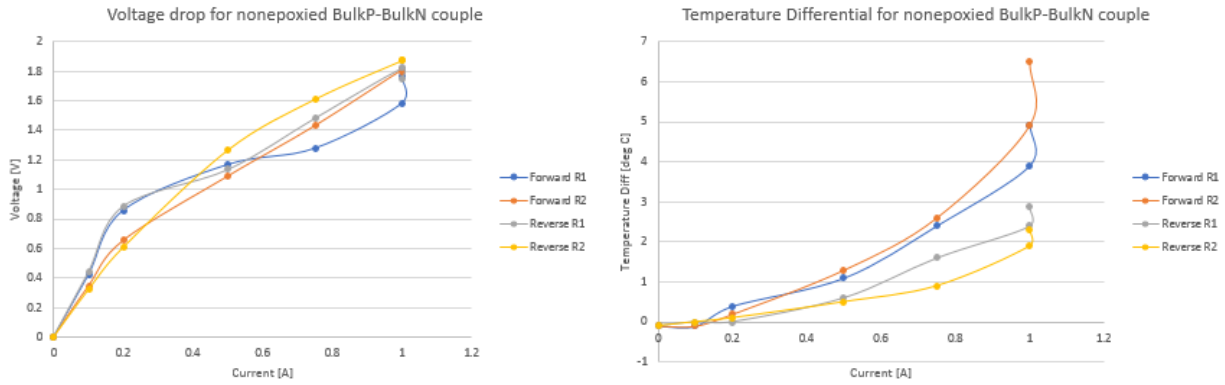


Figure 2: Results of forward and reverse polarity current through TE couple with epoxy and without epoxy

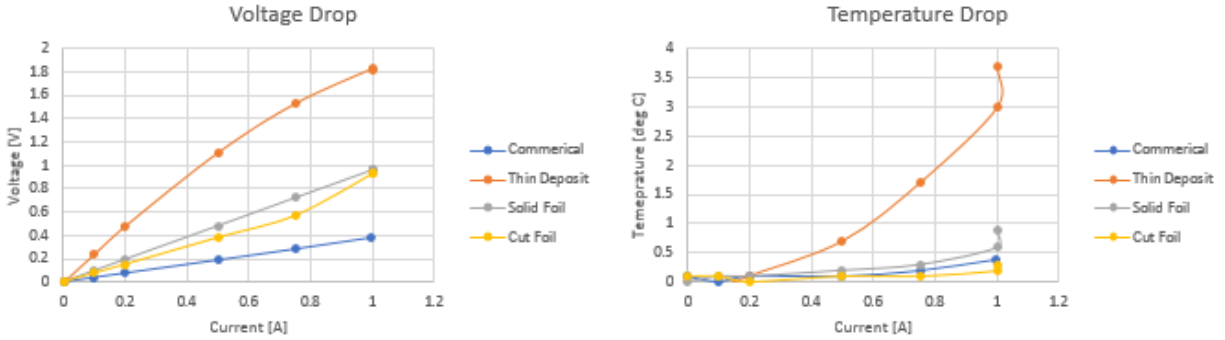


Figure 3: Results of TE couple using nickel contacts in place of silver epoxy

The construction of a customized load bank has been completed. This load bank, used in concert with a heat source and heat sink, will be used to characterize the materials using a selectable load of MOSFET circuitry. This load bank will be able to provide a complete power versus temperature differential curve for the couple. Troubleshooting the load bank capabilities and validation of output curves using commercially available materials is underway.

Project 5: Marine Engine Continuous Emissions Monitoring System

The summarized accomplishments for the reporting period are:

- Completion of second stage continuous emissions and performance monitoring system installed in medium speed diesel engine lab
- Performance and emissions data of fuel additives and lube oil were collected in the medium speed engine lab as part of client testing.

Description of accomplishments:

The continuous emissions and performance monitoring system was expanded during this reporting period. New features include a dedicated engine monitor, remote control of engine loading, and in cylinder pressure monitoring. Figure 4 illustrates the dedicated engine monitoring screen. Fifty engine and subsystem parameters are actively monitored while the most critical parameters are continuously displayed in real time. All parameters were traceably calibrated to ensure data quality. The monitoring screen additionally includes an alarm screen, which displays

an alarm message in the event that a critical parameter is out of operational specification. The alarm screen consists of 15+ operational alarms.

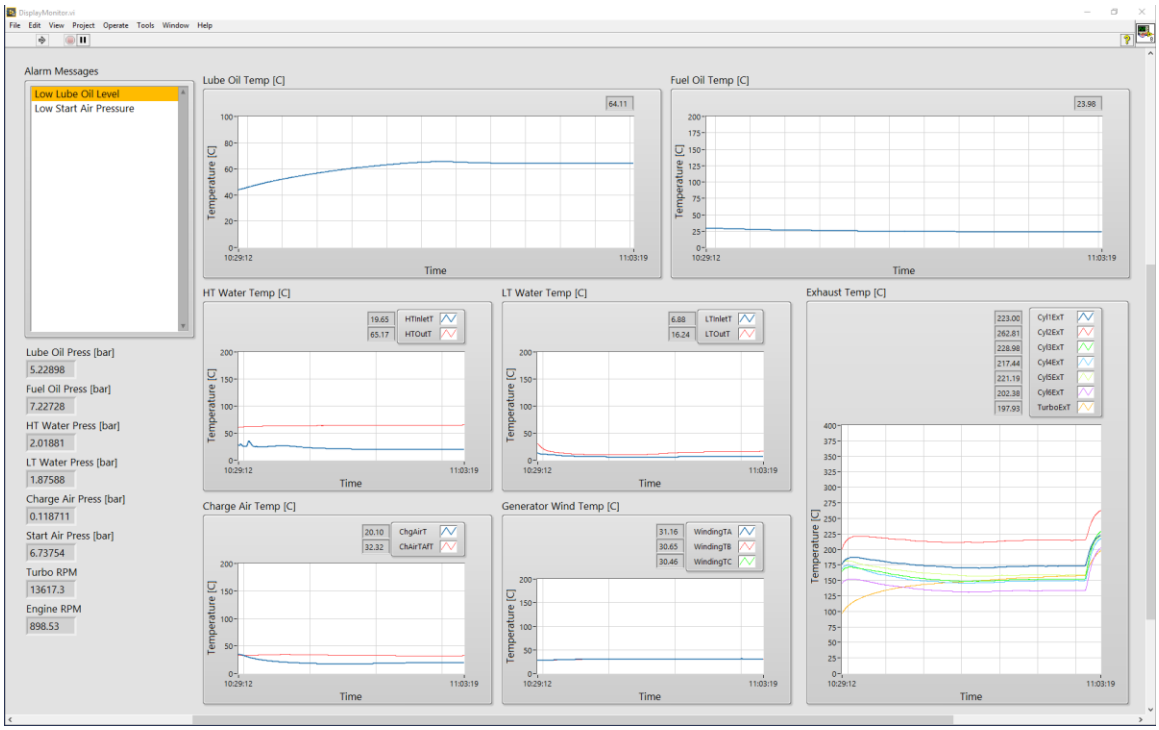


Figure 4: Engine monitor displaying important operational parameters. An alarm screen is also included which displays an alarm message in the event that a critical parameter is out of operational specification.

Figure 5 illustrates the modified power tab of the monitoring and control program. The tab now includes functionality to manually control engine loading or automate a load cycle for precise testing. A variety of load cycles can be programmed and automated depending on testing requirements.

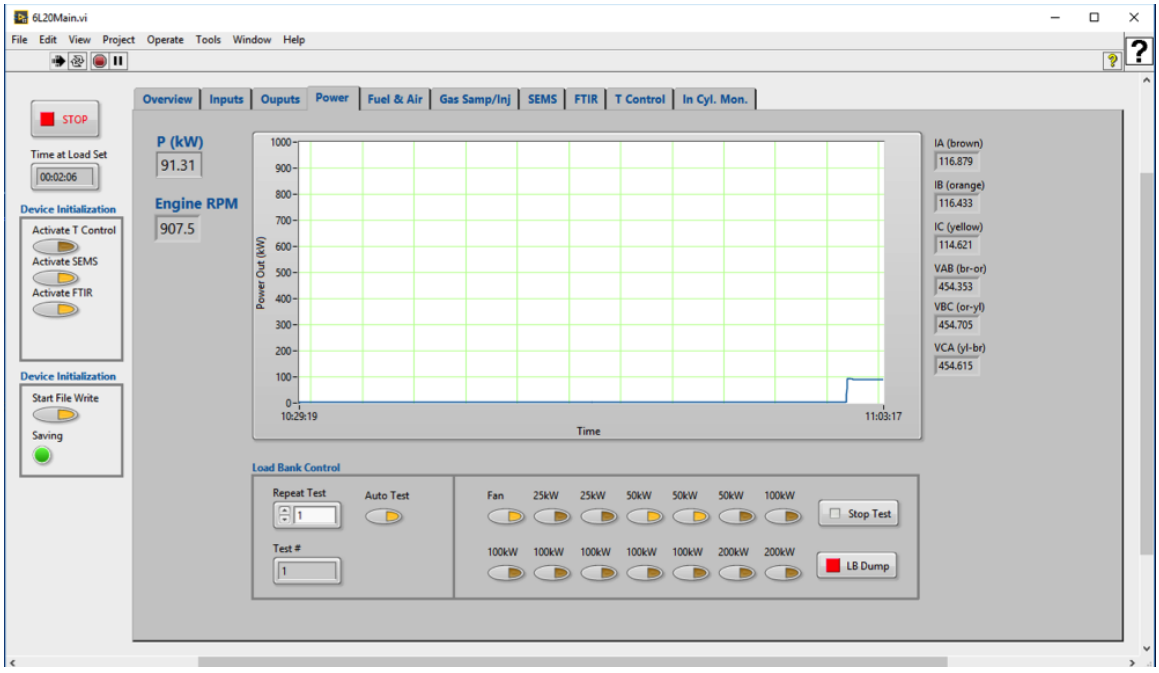


Figure 5: Modified power tab of the monitoring and control program including new functionality for manual or automated remote loading of the engine test cell.

Figure 6 illustrates the in cylinder pressure monitoring system developed for the engine test cell. In cylinder pressure is collected for all six cylinders and displayed as pressure vs. crank angle and as a pressure-volume (PV) diagram. In cylinder pressure data can be collected and saved manually or automatically as part of an automated load cycle test.

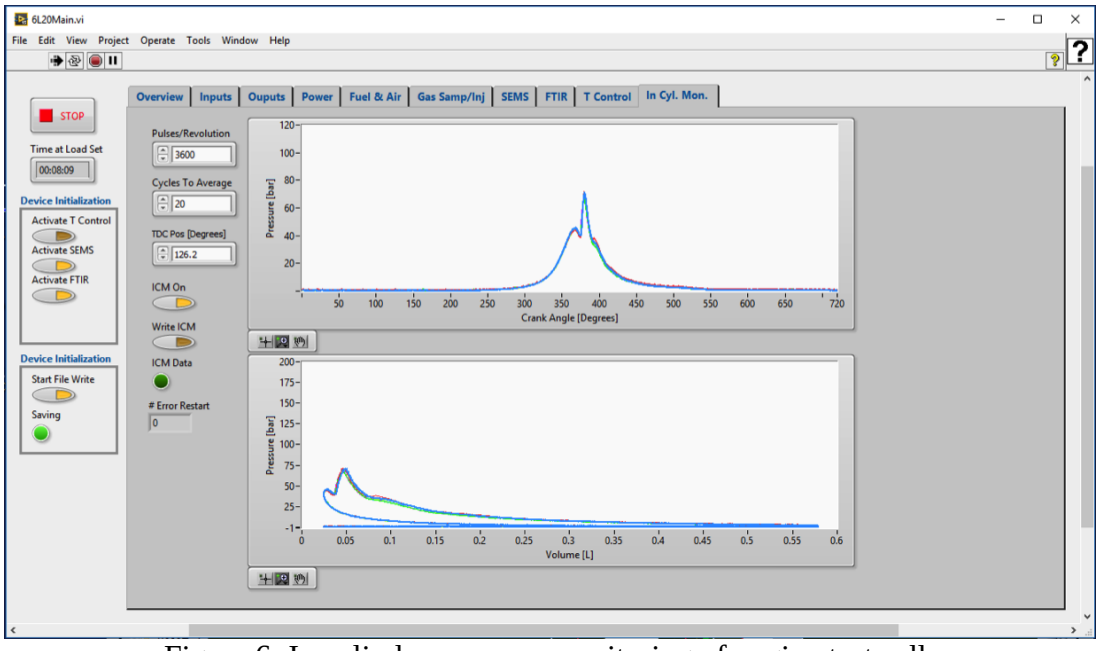


Figure 6: In cylinder pressure monitoring of engine test cell.

The new CEMS system was used to conduct one research project this reporting period. Several fuel additives were evaluated as part of client testing. The new system is also currently being used to conduct testing of client lubricity testing.

Project 6: Algae based glycerin fuel project

Summarized accomplishments:

- Implemented continuous flow/monitoring system in a "mock" algae farm style system.
- Implemented Conductivity and Refractive index for mapping salt and determining Glycerin in media. Validated results in the actual growth media
- Implemented a carbonate doping system and CO2 monitoring system for use in the mock algae farm to study the effects of carbon content n algae growth
- Studies continuing on for salinity shocking to induce algae to excrete glycerin to be collected from the media as fuel.

Description of accomplishments for the Algae Glycerin Fuel project:

Figure 7 shows the mock farm style system with continuous data monitoring and carbonate control system. Shown also in figure 7 is the control schematic for this system. This system allows us to move away from the flask based laboratory experiments to a small scale algae farm production system for development and optimization of the algae glycerin production on a system that could be scaled to a larger agricultural scale.

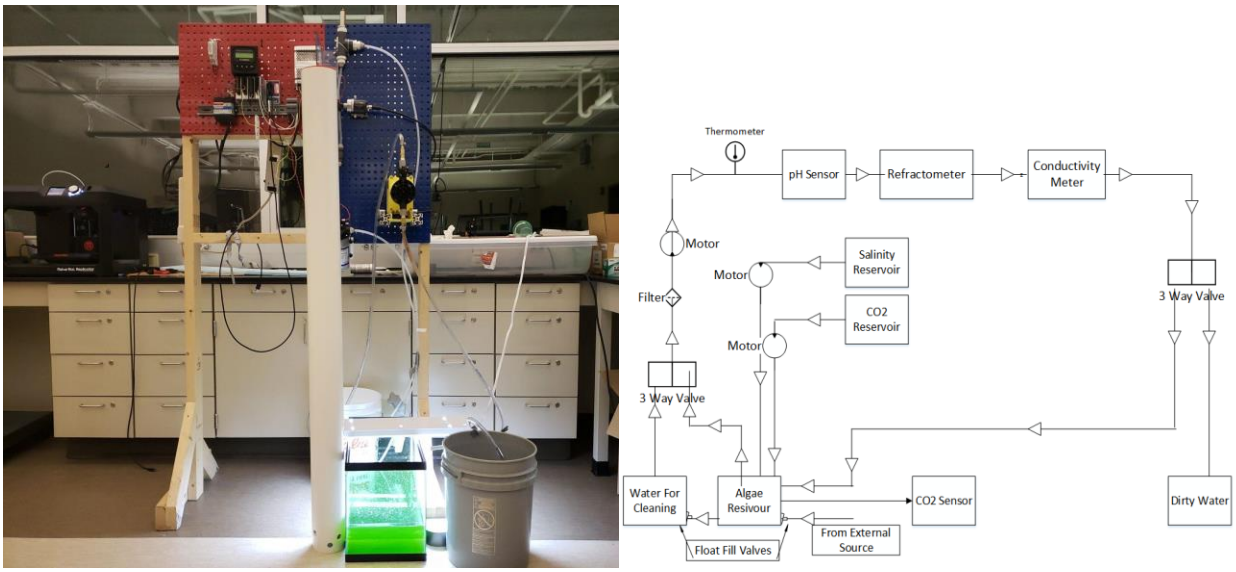


Figure 7: Mock "farm" style Algae system with continuous monitoring system Actual system shown with control schematic.

The system includes PH monitoring for CO2 measurement, conductivity for salinity measurement and Refractive index for Glycerin content estimation and allows studies on CO2 effects, salinity effects and osmotic shocking experiments and control of the glycerin harvest intervals.

Studies also continue on the effects of osmotic shocking at the laboratory scale, the results of which will be used to design the continuous mock farm system control system.

Project 7: Development of Medium Speed Engine Testing

Summarized accomplishments:

- Automation and data acquisition improvements and upgrades completed
- Second client test contract underway
- Engine running condition improvements underway

Description of accomplishments:

The previously planned engine improvements are now complete. Besides the installation of temperature probes and pressure sensors in the water and air systems on the engine, in-cylinder pressure monitoring sensors were installed on the individual cylinder indicator valves and an automated system of engine loading was also developed. Using the manufacturer's installed relay circuitry in the load bank, the engine monitoring system was improved to include an automated timed load change program to maintain a consistent loading profile while performing ISO 8178 engine testing protocols between differing test runs. With the initial round of automation and data acquisition improvements completed, client testing resumed.

METEL has begun its second testing contract for testing the performance of a lubricating oil. In order to meet the requirements of this test, more improvements were required for the laboratory, which includes an upgrade to the in-cylinder pressure monitoring system and the installation of engine intake air conditioning. The original pressure sensors that were installed on the engine required replacement due to potential higher operating temperatures at extended periods of time for this test. METEL is actively working with sensor manufacturers to procure a solution.

To meet the requirements of the current test protocol, improvements are also needed to modify the operating conditions of the engine. One observation made during the trial test of the new instrumentation was that the engine room temperature rise causes an increase in engine intake temperature, regardless of the charge air cooler's effect. The installation of an intake air conditioner is underway. This air conditioner will allow METEL to control the temperature of the intake air to a constant and consistent temperature using water to air heat exchangers while using the LT and HT water systems to provide the required heating and cooling fluid for the heat exchange.

Project 8: Sustainability Education and Laboratory Training for Workforce Enhancement

MMA continues to implement the Environmental minor with the offering of courses EN101 and EN232 Pollution control and Remediation offered this spring, as well as the introductory course EN101 Intro to Environmental Compliance. Development of the course EN401 Air Pollution & Emissions Testing and Control has commenced this semester. This course will be offered in the fall 2018 semester and will feature emissions testing and control using the DOT UTC METEL Medium Speed Diesel lab as the main laboratory for the course. This lab uses the state of the art emissions monitoring and control systems on this world class laboratory asset. Such exposure to real world, power plant emissions system is an incredible improvement to our ability to train our students on the latest and most advanced equipment that they will see in their industries.

The Medium speed diesel lab also continues to be a resource for students in several marine training courses including: EG101 Fundamental of Engineering Operations, EG234 Power Equipment Lab EG 292 and EG392 Diesels I & II and ET 431 Thermal Fluids Laboratory. Students utilize the lab for various labs in the courses including system tracing and identification, Diesel equipment operations, Diesel maintenance and thermal systems labs involving engine performance.

The METEL lab also participated in the Maine Engineering Exposition at the University of Maine Orono in March 2018. The METEL lab offered displays and our students were on hand to present the work of METEL to High School seniors and juniors attending the event as a motivation as to the type of big world problems that they could be involved in solving in they choose Marine engineering as a profession.

The direct activities of both the environmental initiative and the incorporation of the METEL labs in the current curricula of Marine Engineering are direct impacts on the workforce development activities of our training at MMA, which are giving students hands-on experience with state of the art equipment relevant to their profession.

Project 9: Efficiency Improvement of Workboats through Hull Form Optimization

Maine Maritime Academy has developed a high efficiency, advanced hull form for application to coastal fishing and transportation. The design has undergone extensive model testing and exhibits improved performance in the typical cruising speed range of these vessels. Reductions in fuel consumption and emissions are in the range of 15% to 25% depending on loading condition and sea state. The design achieves these reductions through the use of an optimized trimaran hull, allowing for the large required deck space without the large waterline beam and power requirements of current boats.

The summarized accomplishments for the reporting period are:

- Design calculations for half-scale prototype complete (stability, weight, power, structural loading, and scantlings).
- Significant progress on construction at The Landing School in Arundel, Maine (70% complete).
- New design details allow for experimental variation at prototype scale.
- Substitution of full inboard diesel engine in lieu of outboard gasoline engine

Results:

The prototype vessel is in the final stages of construction at The Landing School in Arundel, Maine. The project is currently on budget, with a total grant value of $97,257. Launch is projected to be in August, with sea trials taking place at MMA in the fall semester.

The construction arrangement is shown in Figure 8. Note the upper hull portion, which looks like a flat-bottom skiff, attached to a long, narrow main hull underneath. Side hulls are about 45% of the length of the main hull and bolt on to the upper hull. A photo of the current state of construction is shown in Figures 9 & 10. The upper hull is to the left, with the main hull to the right. The inboard diesel engine can be seen in the main hull. Figure 9 shows the main hull test fit to the upper hull.

Several details have been changed to allow experimental variation of the hull geometry at prototype scale:

- A removable bow section to test forefoot depth and bow bulbs for resistance and maneuvering characteristics
- Removable side hulls to test different stability configurations. Prototype scale stability required new geometry since people do not also scale down.
- The built-in stern wedge was removed to simplify strip-plank construction. A stern wedge/flap will be bolted on to the transom to test different angles.

These features will allow further optimization of the design for both fishing vessels and coastal transportation.

The design was originally proposed with a small outboard engine to reduce cost. After further consideration, propulsion was changed to a full inboard diesel engine. This arrangement will allow the prototype to much more closely match the maneuvering characteristics of the full-scale vessel. A low-cost, four-cylinder diesel of about 38 hp. (a marinized Kubota engine by Nanni) allowed the change with minimal impact on budget. The engine can be seen in Figure 9.

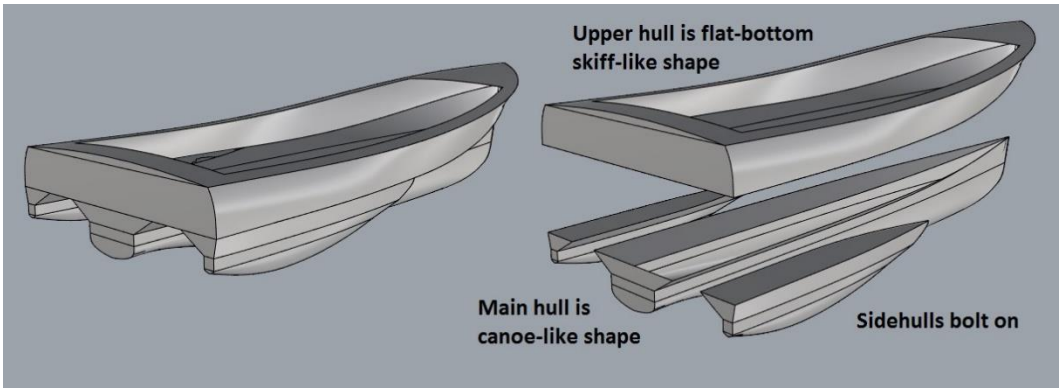


Figure 8: Construction breakdown of demonstrator under construction at The Landing School.

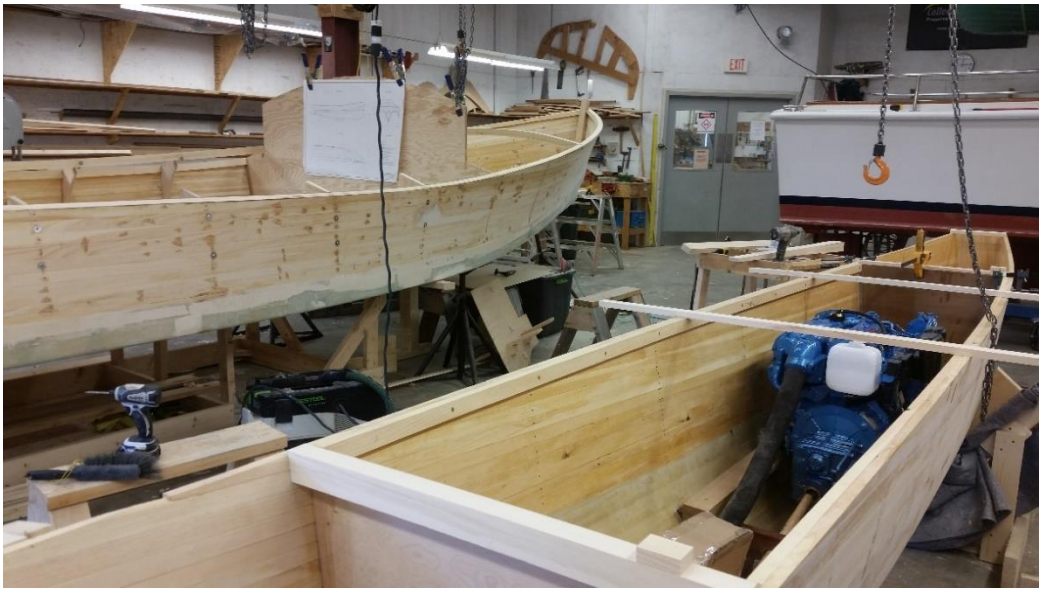


Figure 9: Construction progress showing diesel engine in main hull.

Figure 10: Test fit of upper hull to main hull. Note removable bow section.

Education, Workforce development and STEM accomplishments

STEM Events:
The METEL lab also participated in the Maine Engineering Exposition at the University of Maine Orono in March 2018 as described in Project 8.

Significant Results:
Project 1: Diesel/Glycerin Emulsion fuel project

- Completed soot morphology comparisons of combustion emissions from an indirect injection diesel engine using Transmission Electron Microscopy (TEM) for ultra-low sulfur diesel, biodiesel and diesel/biodiesel/glycerol emulsion fuels.
- Completed analysis of soluble organic fraction (SOF) of soot and partial oxidation products using gas chromatography mass spectrometry.

Project 3: Forest Biomass Diesel fuel project

- Technoeconomic Analysis of Formate Assisted Pyrolysis shows renewable gasoline and diesel could be produced at $4.58 per gallon.
- Techoeconomic Analysis of TDO oil production shows that oil could be produced at less than $3.00 per gallon.
- Iridium-impregnated Ni/Si-Al catalysts show potential to improve cetane values of TDO oils due to enhanced activity to convert dicyclic components to monocyclic alkanes.
- Approximately 12 L of TDO were hydrotreated which will be used to prepare fuel blends for engine tests at MMA

Project 7: Development of Medium Speed Engine Testing

- A large testing program is currently underway for major industrial client
- First industrial test contract successfully completed in October 2017

Key Outcomes:
How have the results been disseminated?
Project 1: Diesel/Glycerin Emulsion fuel project

- Completed soot morphology comparisons of combustion emissions from an indirect injection diesel engine using Transmission Electron Microscopy (TEM) for ultra-low sulfur diesel, biodiesel and diesel/biodiesel/glycerol emulsion fuels.
- Completed analysis of soluble organic fraction (SOF) of soot and partial oxidation products using gas chromatography mass spectrometry.

Project 2: Hydrogen Injection Fuel Project

- Nothing to report for this period

Project 3: Forest Biomass Diesel fuel project

- Technoeconomic Analysis of Formate Assisted Pyrolysis shows renewable gasoline and diesel could be produced at $4.58 per gallon.
- Techoeconomic Analysis of TDO oil production shows that oil could be produced at less than $3.00 per gallon.
- Iridium-impregnated Ni/Si-Al catalysts show potential to improve cetane values of TDO oils due to enhanced activity to convert dicyclic components to monocyclic alkanes.
- Approximately 12 L of TDO were hydrotreated which will be used to prepare fuel blends for engine tests at MMA

Project 4: Thermoelectric Exhaust heat recovery generator project

- Material performance testing underway
- Contact resistance issues observed and solutions being investigated
- Seebeck measurement load bank constructed

Project 5: Continuous Emissions Monitoring System

- Completion of second stage continuous emissions and performance monitoring system installed in medium speed diesel engine lab
- Performance and emissions data of fuel additives and lube oil were collected in the medium speed engine lab as part of client testing.

Project 6: Algae Based Glycerin fuel project

- Awarded National Science Foundation (NSF) MRI grant for triple quad GCMS
- Identified temperature as a major variable controlling cell density

Project 7: Development of Medium Speed Engine Testing

- Automation and data acquisition improvements and upgrades completed
- Second client test contract underway
- Engine running condition improvements underway

Project 8: Sustainability Education and Laboratory Training for Workforce Enhancement

- Nothing to report for this period

Project 9: Efficiency Improvement of Workboats through Hull Form Optimization

- Design calculations for half-scale prototype complete (stability, weight, power, structural loading, and scantlings).
- Significant progress on construction at The Landing School in Arundel, Maine (70% complete).
- New design details allow for experimental variation at prototype scale.
- Substitution of full inboard diesel engine in lieu of outboard gasoline engine

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

- Prepare a manuscript for submission to a refereed journal on the characterization of soot morphology of glycerol/biodiesel/diesel emulsion fuel diesel combustion.
- Closeout the project and complete final report.

Project 2: Hydrogen Injection Fuel Project
- Conclude Hydrogen project and complete final report.

Project 3: Forest Biomass Diesel fuel project
- Submit manuscript for hydrotreating of Formate-Assisted Pyrolysis Oil
- Fractionate hydrotreated TDO oil for blending
- Blend fractionated crude TDO oil for delivery to MMA
- Conduct economic sensitivities to distributed pre-processing of pyrolysis feedstocks for centralized pyrolysis processes

Project 4: Thermoelectric Exhaust heat recovery generator project
- Publish paper pending acquisition of data
- Complete project, graduate PHD student

Project 5: Continuous Emissions Monitoring System
- Complete equipping medium speed engine with in-cylinder monitoring
- Closeout the project and complete final report.

Project 6: Algae Based Glycerin fuel project
- Close out the project and complete final report.

Project 7: Development of Medium Speed Engine Testing
- Continue testing for industry
- Closeout the project and complete final report.

Project 8: Sustainability Education and Laboratory Training for Workforce Enhancement
- Continue STEM outreach activities with existing working groups

Project 9: Efficiency Improvement of Workboats through Hull Form Optimization
- Complete construction of work boat.

Education, Workforce development and STEM:
- Work with The Landing School recently built three 19 foot vessels for Efficiency Improvement of Workboats through Hull Form Optimization

2. PRODUCTS: What has the program produced?

Publications, conference papers, and presentations

Journal publications:

Project 1: Diesel/Glycerin Emulsion fuel project
- Nothing to report

Project 2: Hydrogen Injection Fuel Project
- Nothing to report

Project 3: Forest Biomass Diesel fuel project
- AlMohamadi, H, Gunukula, S., DeSisto, W. J. and Wheeler, M. C., "Formate-assisted pyrolysis of biomass: an economic and modeling analysis," Biofuels, Bioprod. Bioref. 12:45-55 (2018); DOI: 10.1002/bbb.1827 http://onlinelibrary.wiley.com/doi/10.1002/bbb.1827/epdf .
- Gunukula, S., Klein, S.J.W., Pendse, H.P., DeSisto, W.J., and Wheeler, M.C., "Techno-economic analysis of thermal deoxygenation based biorefineries for the coproduction of fuels and chemicals," Applied Energy (2018) https://doi.org/10.1016/j.apenergy.2018.01.065
- Other publications, conference papers and presentations:

- Gunukula, S., DeSisto, W.J. ,Pendse, H. and Wheeler, M.C., Economic and Modeling Analysis of Product and Energy Driven Biorefineries Based on Thermal Deoxygenation Pathway, AIChE Annual Meeting, Minneapolis MN, November 2017.
- Gunukula, S., DeSisto, W.J. ,Pendse, H. and Wheeler, M.C., Assessment of Economic Potential of Furfural Platform. AIChE Annual Meeting, Minneapolis MN, November 2017.

Project 4: Thermoelectric Exhaust heat recovery generator project
- Nothing to report

Project 5: Continuous Emissions Monitoring System
- Nothing to report

Project 6: Algae Based Glycerin fuel project
- Nothing to report

Project 7: Development of Medium Speed Engine Testing
- Nothing to report

Project 8: Sustainability Education and Laboratory Training for Workforce Enhancment
- Nothing to report

Project 9: Efficiency Improvement of Workboats through Hull Form Optimization
- Nothing to report

Books or other non-periodical, one-time publications:

Chi Truong, Pressureized Fast Pyrolysis of Calcium Formate-Pretreated Biomass, University of Maine Master's Thesis, 2016

Other publications, conference papers and presentations:

Oral Presentations:
- None 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 Nothing to Report

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. Paul Wlodkowski
Program/Project Role	STEM Coordinator/Faculty
# Hours worked during reporting period	0.5 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	1200 hrs (Full time since March 7, 2014)
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	Brendyn Sarnacki
Program/Project Role	Research Engineer (Full time)
# Hours worked during reporting period	1200 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	Travis Wallace
Program/Project Role	Research Engineer (Full time)
# Hours worked during reporting period	1200 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. Scott Eaton
Program/Project Role	METEL Seniod Personnel, all projects
# Hours worked during reporting period	540
Contribution to Program/Project	Mechanisms of TDO, Emulsion Fuels
Funding support	DOT UTC 1 month (DOT)
Collaborated with individual in foreign country	No

Name	Dr. Clay Wheeler
Program/Project Role	UMaine Co-P.I.
# Hours worked during reporting period	20
Contribution to Program/Project	Lead P.I. for UMaine effort; Leading the TDO/FAsP project at UMaine
Funding support	0 month (DOT), 1.55 month (UMaine)
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. William DeSisto
Program/Project Role	UMaine Senior Personnel
# Hours worked during reporting period	20
Contribution to Program/Project	Co- P.I. for UMaine effort; Co-supervising graduate student research.
Funding support	1.06 month (DOT) 1.67 month (UMaine)
Collaborated with individual in foreign country	No

Name	Mubarak Khleewee
Program/Project Role	M.S. Student
# Hours worked during reporting period	520
Contribution to Program/Project	HDO of FAsP oil
Funding support	0 month (DOT) 0 month (UMaine)
Collaborated with individual in foreign country	No

Name	Abdulazeez Khleewee
Program/Project Role	M.S. Student
# Hours worked during reporting period	520
Contribution to Program/Project	HDO of phenol
Funding support	0.53 month (DOT) 0 months (UMaine)
Collaborated with individual in foreign country	No

Name	Raliat Alabi
Program/Project Role	M.S. Student
# Hours worked during reporting period	433
Contribution to Program/Project	High Pressure Pyrolysis
Funding support	2.59 month (DOT) 0 month (UMaine)
Collaborated with individual in foreign country	No

Name	Karl Olson
Program/Project Role	M.S. Student
# Hours worked during reporting period	260
Contribution to Program/Project	Alternative uses for glycerol
Funding support	1.56 month (DOT) 0 month (UMaine)
Collaborated with individual in foreign country	No

What other organizations have been involved as partners?
None for this reporting period. Note: Test contract clients have requested anonymity due to the propriety nature of their products.

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;
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