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

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

Project Title: Tier 1 Marine Engine Testing and Emissions Laboratory

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Recipient Identifying Number or Account Number: Not Applicable

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Reporting Period End Date: September 30, 2016

Report Term or Frequency: This report covers the period from April 1, 2016 to October 30, 2016, 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:

- Performance and emissions testing of emulsion fuels with respect to fuel aging and emulsion stability on CAT C2.2 marine diesel generator performed.
- Completed performance and emissions evaluation of several biodiesel (RME)/diesel/glycerol emulsion fuels demonstrating reduced NOx and PM emissions. – Results published by the International Association of Maritime Universities (IAMU). .
- Conducted hydrotreatment experiments to determine the product reactions and yields of formate pretreated pine pyrolysis oils.
- Presented METEL work on alternative fuels to the Transportation Research Board – Committee of Marine Transportation Systems
- Awarded grant to initiate thermoelectric materials and device research in collaboration with University of Maine Laboratory for Surface Science Technology
- Produced and characterized nanostructured bismuth telluride pellet for Thermoelectric heat recovery systems
- Finalized setup and installation of marinerized particulate measurement suite including BMI SEMS systems
- Correlated SEMS derived mobility diameter with soot aggregate mass by comparison to TEM data.
- Awarded National Science Foundation (NSF) MRI grant ($371,000) for triple quad GCMS instrumentation
- Medium Speed Engine Laboratory space renovations continued including installation of engine and related systems as well as permitting
- Presented to the State of Maine's middle school teachers about research and development
- $400,000 investment made by MMA in its undergraduate training labs
- Perused workforce development opportunities with The Landing School to prototype half-scale high efficiency lobster boat.
- Market survey speed range conducted for high efficiency lobster boat
- Computational hydrodynamic analysis of propeller efficiency and further experimental analysis of maneuvering and sea keeping for high efficiency workboat

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:

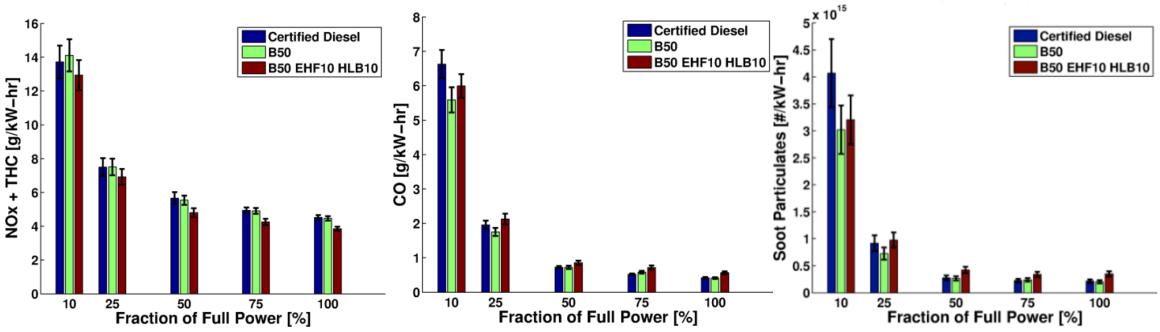
- Detailed survey of biodiesel emulsion fuel blend stability with respect to surfactant.
- Performance and emissions testing of emulsion fuels with respect to biodiesel, glycerol, and water concentration on CAT C2.2 marine diesel generator.

Biodiesel Emulsion Fuel Survey

Laboratory Testing Results

An experimental emulsion fuel blend of 8% glycerol, 2% water, 90% B50 biodiesel (50% biodiesel, 50% diesel) by weight was explored and tested on the CAT C2.2 laboratory test cell.

Figure 6 illustrates the gaseous and particulate emissions measured for diesel, B50 biodiesel, and the glycerol/water/B50 biodiesel emulsion fuel. A modest reduction in energy weighted NOx + THC emissions is observed in Figure 1a for the biodiesel emulsion fuel with the diesel and B50 biodiesel exhibiting equal NOx + THC emissions. Energy normalized CO emissions shown in Figure 1b were unchanged for diesel and B50 biodiesel within uncertainty bounds. CO emissions for the B50 biodiesel emulsion fuel were slightly reduced at 10% load and slightly elevated at higher loads. Figure 1c depicts energy weighted particulate number emissions. Particulate counts are shown reduced on average for the B50 biodiesel in comparison to diesel with near parity observed between the diesel and B50 biodiesel emulsion fuel within uncertainty bounds.



a) b) c)

Figure 1: Emissions from certified diesel and glycerol/water/B50 biodiesel emulsion fuel testing on a CAT C2.2 marine diesel generator over an ISO 8178 duty cycle. Energy weighted mass emissions of a) NOx +THC and b) CO, and energy weighted number emissions of c) soot particulates averaged over each load setting.

Additional B50 biodiesel blends were explored on the CAT C2.2 test engine for their performance and emissions with a focus on distinct changes in soot composition and morphology formed by the fuels. The fuel blends explored were composed of 8% glycerol/2% water, 16% glycerol/4% water, and 24% glycerol/6% water with a balance of B50 biodiesel. Gaseous and particulate emissions were collected with the MKS 2030 FTIR and BMI SEMS. Tests were conducted over a standard ISO 8178 test cycle. Additional gravimetric and thermophoretically deposited soot samples were collected at engine idle, 50% engine load, and 100% engine load for future analysis. A reduction in energy weighted NOx emissions is observed in Figure 2a with increasing glycerol/water composition for the biodiesel emulsion fuels. In contrast, emissions of NOx + THC shown in Fig. 2b) increase at low loads and decrease at higher loads with increasing glycerol/water composition. Energy normalized CO emissions shown in Figure 2c increase with increasing glycerol/water composition. Figure 2d depicts energy weighted particulate mass emissions. Particulate mass is shown reduced with increasing glycerol/water composition although the trend is within uncertainty bounds. The detailed chemical and physical mechanisms driving changes in gaseous and particulate emissions are currently unknown. It is postulated that changes in chemical pathways along with changes in fuel atomization likely play a role and

deserve further study. Detailed analysis of changes in collected soot composition is planned for the next reporting period.

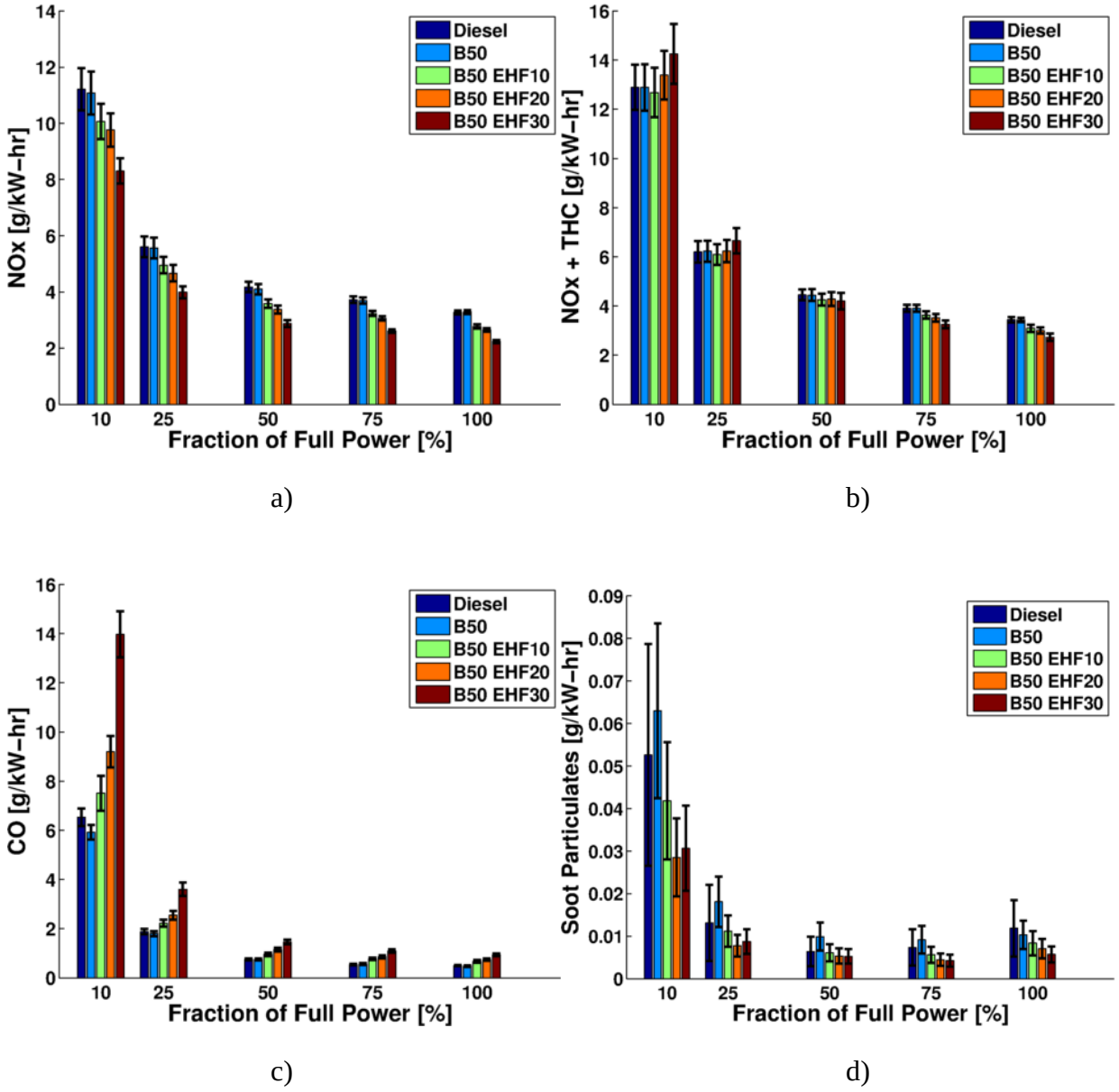


Figure 2: Emissions from certified diesel and glycerol/water/B50 biodiesel emulsion fuel testing on a CAT C2.2 marine diesel generator over an ISO 8178 duty cycle. Energy weighted mass emissions of a) NOx b) NOx +THC c) CO, and d) soot particulates averaged over each load.

Project 2: Hydrogen Injection Fuel Project

The summarized accomplishments for the reporting period are:

- No work performed during this reporting period
- Focus on the medium speed engine lab has temporarily taken time away from this project. We plan on returning to it over the next several months.

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
Lead by UMaine – this project is exploring multiple forest biomass processing routes for the commercial production of liquid transportation fuels. These materials are projected to displace fossil fuel consumption and reduce greenhouse gas emissions within the transportation industries. Two candidate processing routes explored through this center project are formate assisted pyrolysis (FAsP) and thermal deoxygenation (TDO). A summary of accomplishments for each processing route is provided below.

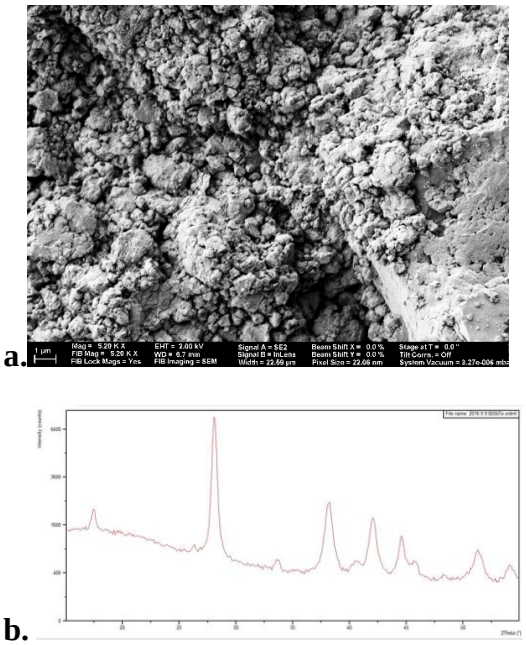
The summarized accomplishments for the reporting period are:

- Conducted experiments to determine the yields and products of hydrtreatment/ hydrodeoxygenation of pyrolysis oils using a continuous packed bed reactor.
- Conducted experiments to compare performance of the high pressure pyrolysis system using pine sawdust and wheat straw as feedstock.

Results:
MS Student Chi Truong successfully defended her thesis on comparing the yields and chemical composition of pine and wheat straw in a pressurized reactor.

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

- Awarded grant to initiate thermoelectric materials and device research in collaboration with UMaine's Laboratory for Surface Science Technology
- Purchased ball mill capable of producing nanoparticle powders
- Produced and characterized nanostructured bismuth telluride pellet



a.

b.

Figure 3: a. SEM image (520x) and **b.** XRD scan of TE disk surface.

Description of accomplishments for the thermoelectrics:
METEL and UMaine researchers were awarded $98,776 from the universities' Research Reinvestment Program to support a grant entitled "Layer-by-layer Fabrication of Thermoelectric Films Using Polymerized Bismuth-Telluride Nanoparticles to Yield High-Efficiency Thermoelectric Generators for Marine Applications." The objective of the project is to develop the methodology for fabricating low-cost, highly efficient TE films using a simple layer-by-layer (LbL) deposition method that aims to yield nanoporous TE films consisting of bismuth telluride (BiTe)

nanoparticles with high electrical/low thermal conductivity.

Initial BiTe films have been produced by grinding bulk, p-type, bismuth antimony telluride from Sigma Aldrich (99.99% trace metal basis). The resulting powders were then pressed in to 13 mm diameter disks using 24,000 psi for 3 minutes. The disks were subsequently annealed in air at 300, 450 and 500˚C for 15 minutes and analyzed for morphology using Scanning Electron Microscopy (SEM) and X-ray diffraction (XRD) (Figure 3). The room temperature electrical conductivity, measured by four-point probe, of the resulting pellets is shown in Figure 4. No electrical conductivity was observed for the pellet annealed at 500˚C. The highest conductivity observed, $7.58 \times 10^3\ S/m$, is 100x lower than the bulk material, but only 2-3x lower than comparably structured, TE materials.

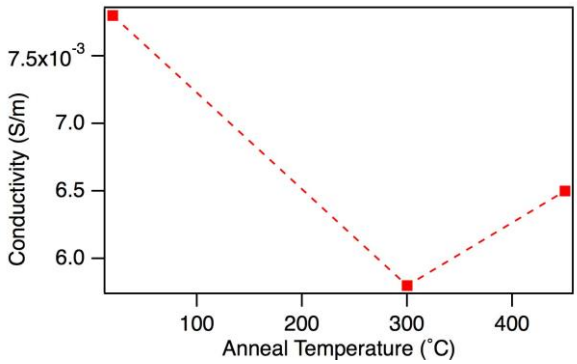


Figure 4: Electrical conductivity of TE pellets plotted versus anneal temperature.

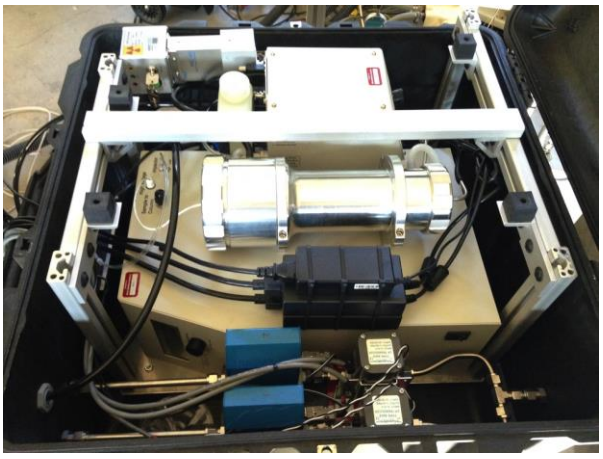
Project 5: Marine Engine Continuous Emissions Monitoring System

The summarized accomplishments for the reporting period are:

- Finalized setup and installation of marinerized particulate measurement suite including BMI SEMS system
- Correlated SEMS derived mobility diameter with soot aggregate mass by comparison to TEM data.
- Performance and emissions data of several B50 biodiesel (RME)/diesel/glycerol emulsion fuels were collected with the CEMS system as part of a publishing effort focused on biofuel emulsion emissions.

BMI SEMS

The BMI 2100 Scanning Electrical Mobility Spectrometer (SEMS) was marinerized, characterized, and used extensively during this reporting period. Figure 5a shows the finalized installation of the SEMS with existing soot sampling equipment.



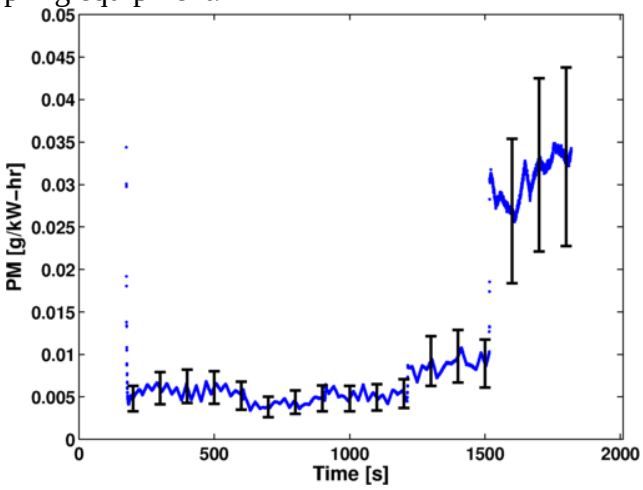


Figure 5: a. Finalized soot particulate measurement suite including BMI SEMS system and sampling equipment. **b.** Derived energy weighted soot mass emissions measured for an ISO 8178 load cycle on a CAT C2.2 marine diesel generator

Upon completion of installation, the SEMS was fully characterized with the CAT C2.2 test engine burning certified diesel fuel. SEMS measured soot particle size distributions were compared to soot samples collected under identical engine conditions and analyzed via transmission electron microscope. An expression was determined via least squares regression relating particle size distribution measured with the SEMS to particle mass distribution determined via electron microscope. The correlation allows for real time measurement of soot mass emissions during engine testing. Figure 5b illustrates energy weighted soot mass emissions measured with the SEMS during an ISO 8178 emissions test using the CAT C2.2 marine diesel generator operating on diesel fuel.

The CEMS system was extensively utilized during this reporting period to measure the performance and emissions of several B50 biodiesel (RME)/diesel/glycerol emulsion fuels. The results of the tests are under investigation with publications planned for submission.

Project 6: Algae based glycerin fuel project

Summarized accomplishments:

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

Description of accomplishments for algae based glycerin fuel project:

The objective of this project is determining whether glycerol and other small molecules, produced by microalgae, can be an energy-positive (i.e. produce more energy than they consume) and economically competitive transportation fuel. Both points rely heavily on minimizing the energy required to grow the algae and extract and purify fuel molecules.[i] Chow *et. al.* have investigated extracellular glycerol production in *Dunaliella tertiolecta* (UT Austin strain: LB-999) and reported concentrations as high 6 mg/ml using a modified ATCC–1174 DA containing 2M NaCl.[ii]

Our efforts to reproduce these results using the identical strain (National Center for Marine Algae: CCMP364) have not been successful. Various salinities (0.5-2.0M), phosphate and nitrate concentrations($[PO_4^{3-}] = 0.4 - 2 \times 10^{-4}M, [NO_3^-] = 0.9 - 5 \times 10^{-3}M$) and light intensities have been investigated, but the highest glycerol concentrations remain <1 ppm. A follow up publication from the same research lab suggests that the large differences in observed glycerol concentrations are not likely attributable to micronutrient

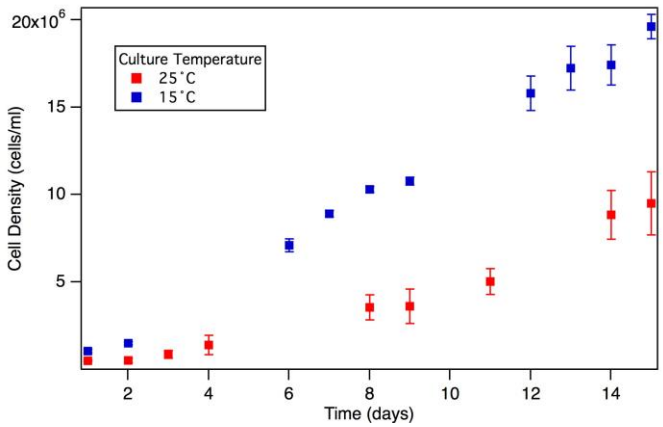


Figure 6: Cell density for *Dunaliella tertiolecta* cultures (identical chemical environments) measured at two different temperatures.

$(e.g. Mn^{2+}, Cu^{2+}, Zn^{2+}, etc.)$ concentrations.[iii]

Algal cell concentrations, however, have been shown to have a large effect on glycerol concentration. Our cultures have had issues maintaining high cell counts beyond 2-3 weeks. To this point little has been done to control dissolved CO_2 concentration, pH and temperature, which are all potential culprits. Cell counts from recent temperature controlled experiments are shown in Figure 6.

Project 7: Development of Medium Speed Engine Testing

Summarized accomplishments:

- Laboratory space renovations continue
- Final laboratory layout is defined
- Engine is mounted on the base plate in the laboratory space
- Work is ongoing to complete system piping to the engine
- U.S. Environmental Protection Agency permitting complete
- Maine Department of Environmental Protection water discharge permitting complete
- Maine Department of Environmental Protection gaseous and particulate emissions permitting underway

Construction on the medium speed engine lab in Andrews Hall at Maine Maritime Academy is occurring at a rapid rate. The building has been renovated to allow for the weight of the engine and the base plate by replacing the original concrete floor with a 10 inch concrete floor that is internally supported. Conduit has been installed to allow for access for salt water cooling suction and discharge lines to be run between the water cooling skid inside the laboratory to the Castine Harbor.

Engine room ventilation is achieved with two circulation fans located in the main engine space and in the water-cooling room which maintains fresh air room supply. The U.S. Environmental Protection Agency has verified that air emissions from our installation meets the standards for an engine test cell. The State of Maine Department of Environmental Protection has also been notified. In addition, we have successfully obtained the State of Maine DEP permit for salt water discharge of cooling water, and is in the process of completing State permitting for the gaseous and particulate emissions from the engine exhaust. These permits are a major barrier to operations which we have successfully completed demonstrating the uniqueness of the testing facility.

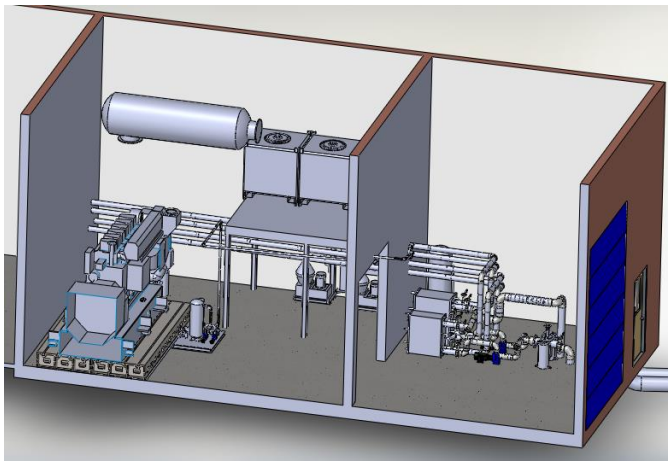


Figure 7: Medium Speed Engine Lab Layout Representation

The engine space layout can be seen in Figure 7 which shows a computer rendering of the test cell. A mezzanine serves as the base for the fuel tank gallery which facilitates the use of marine diesel fuel, heavy fuel oil, and alternative test fuels. These tanks are piped to an industrial-equivalent processing fuel skid which purifies the heavy fuel and maintains thermal parameters for testing. Fuel handling operations have been generously supported through our industrial partner, Emerson Electric Company. The lubricating and fuel oil purifiers are placed under the mezzanine and is piped to the engine's oil sump and an oil storage tank as shown in Figure 8.

Figure 8: Oil and fuel purifiers, from left to right

The starting air skid is also located in the front room of the lab, beside the water cooling skid. The engine is a Wärtzilä 6L20 engine which is a ubiquidous engine in the marine and power industries capable of producing up to 1,200 kW. The engine can handle light distillates and heavy fuels up to 700 cSt. The engine The engine is seen in Figure 9. In addition, the engine can be readily modified to operate in natural gas dual-fuel operations and can be outfitted will all manner of exhaust aftertreatment device to facilitate industry research and fit-for-application testing of emerging technologies. The engine's cooling is provided by a closed loop freshwater heat exchanger which is in turn cooled by sea water piped in from (and returned to) Castine Harbor as seen in Figure 10.

The exhaust ducting will be completed once the remaining exhaust pieces are delivered to connect the engine to the silencer, and the silencer to the existing building ducting. All engine systems are expected to be completed in December with initial engine shakedown testing to be completed in 2017.

Figure 9 METEL's Wärtsilä 6L20 as installed in the Andrews Hall laboratory space

Figure 10: Seawater cooling and air start systems

Project 8: Sustainability Education and Laboratory Training for Workforce Enhancement
Summarized accomplishments:

- Presented to the State of Maine's middle school teachers about research and development
- $400,000 investment made by MMA in its undergraduate training labs

Recognizing that Science, Technology, Engineering, and Mathematics (STEM) is a vital element of our ongoing work with the Department of Transportation (DOT), the Marine Engine Testing and Evaluation Laboratory (METEL) dedicated time this summer towards educating the State of Maine's middle school teachers about its research and development work. The activity culminated in a day-long session on August 3, 2016, organized by the Maine Mathematics and Science Alliance (MMSA) on the Husson University campus in Bangor where MMA Professor of Engineering, Dr. Paul Wlodkowski, presented a talk entitled, "The Grand Challenges for Engineering: A Maine Perspective."

By acquainting our middle school teachers with the fourteen Grand Challenges – put forth by the National Academy of Engineering in Washington, DC in 2008, Dr. Wlodkowski underscored how engineering is critical to solving the world's greatest problems.

With this information, the teachers will be able to help guide their students in understanding what engineers do and why, more than ever, we need the K-12 student population to consider this noble profession. While the Grand Challenges are truly lofty world goals, the middle school teacher audience was truly surprised to learn what Maine institutions and organizations are doing now. By identifying these local resources, their schools can build on this knowledge with classroom projects, guest speakers, or field trips.

Of particular importance is the fact that the fourth Grand Challenge – Managing the Nitrogen Cycle – has direct relevancy to the ongoing work of METEL on the DOT contract. Dr. Wlodkowski took the opportunity to discuss in detail the nature of the projects at MMA. Moreover, he invited the participation of this audience of teachers to involve their middle schools directly with the specific project initiatives at METEL. The talk was enthusiastically received, and MMA expects future involvement from them with assistance from the MMSA.

Commensurate with the aforementioned STEM activity was a recent $400,000 investment made by MMA in its undergraduate training labs. Particularly noteworthy have been the acquisition of state-of-the-art testing equipment in the fluid power, materials science and electronics laboratories.

MMA's Engineering Department also recently developed an Environmental Science Minor comprised of six new courses. This minor combines thermodynamics and other key STEM classes that utilize the new labs as key training tools for workforce development in mitigating and remediating transportation related environmental concerns.

Project 9: Efficiency Improvement of Workboats through Hull Form Optimization

Maine Maritime Academy has developed a high efficiency, advanced hull form for application to the coastal fishing fleet. 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:

- Pursuit of workforce development opportunities with The Landing School, a small vessel construction school in Arundel, Maine. The goal is to produce a prototype of about half-scale (19 to 22 ft. in length).
- Detailed structural calculations needed to prepare construction drawings
- Final stability calculations resulting in new sidehull geometry
- A market survey resulting in more favorable design speed range
- Computational hydrodynamic analysis of propeller efficiency
- Further experimental analysis of maneuvering and seakeeping

Results:

To further reduce risk on a radical new hull design, MMA has been pursuing the construction of a half-scale prototype with The Landing School. The collaboration has led to the investigation of not only the lifetime emission reduction of the vessel, but to reducing the carbon footprint of the hull itself. The Landing School recently built three 19 foot vessels with near-zero carbon footprint for hull construction. In addition, this opportunity provides significant opportunity for workforce development, as the hull will require new construction techniques and structural arrangements. The structural calculations for the construction drawings associated with the half-scale prototype are underway and will be complete by the end of calendar year 2016.

Several technical investigations continue for the project. Engineering calculations for refinement in the areas of stability, maneuvering, seakeeping, and propeller design took place during the performance period. The results will contribute directly to the half-scale prototype.

Finally, a market survey was completed under a separate funding source (a Maine Technology Institute grant). Cruise speed survey results fit within the optimal performance range of the current design (Figures 11a and b). Initial design requirements called for a cruise speed of 16 to 20 knots, but the survey suggests that the 10 to 16 knots is sufficient for most fishermen. Note that Figure 11b compares the trimaran to a moderately beamy traditional vessel considered to have good efficiency for current designs. Performance vs. very wide boats following the recent design trend will be more favorable. A drawing of the trimaran is shown in Figure 12.

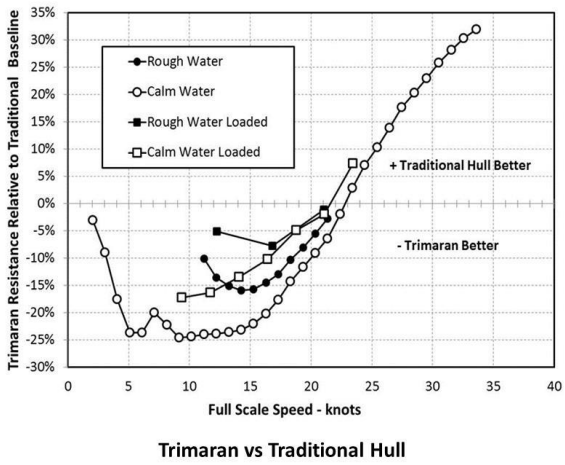


Figure 11a: Design performance of trimaran compared to a traditional vessel

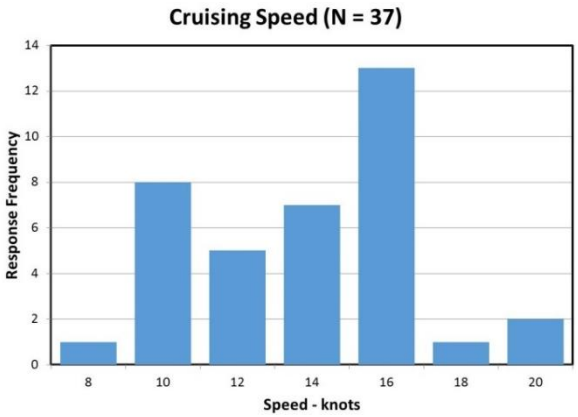


Figure 11b Fishermen response to survey for desired cruise speed

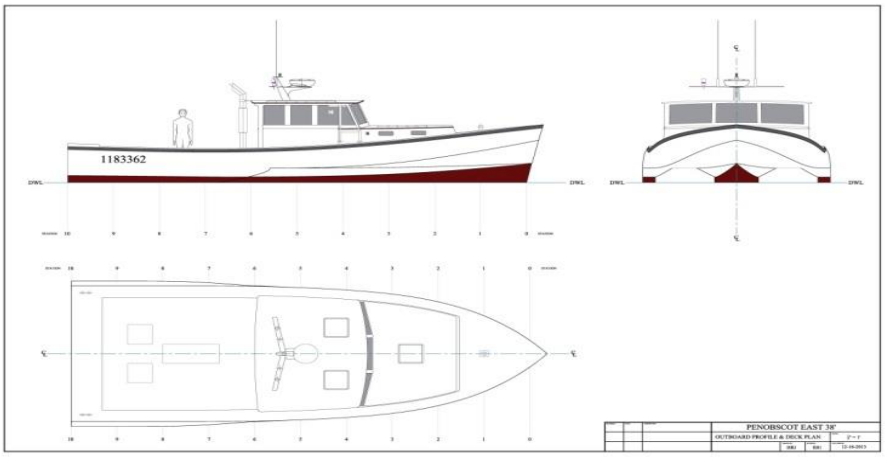


Figure 12: Drawings of 38 ft. low-emissions coastal fishing vessel.

Education, Workforce development and STEM accomplishments

STEM Events:
At an event organized by the Maine Mathematics and Science Alliance (MMSA), Dr Wlodkowski presented to State of Maine's middle school teachers about METEL's research and development.

Significant Results:
None to report at this time

Key Outcomes:

How have the results been disseminated?

Project 1: Diesel/Glycerin Emulsion fuel project

- Results submitted for conference paper and presentation

Project 2: Hydrogen Injection Fuel Project

- Nothing to report for this period

Project 3: Forest Biomass Diesel fuel project

- One article was published in a refereed journal
- One oral presentation at a national engineering meeting
- One oral presentation to the TRB
- One poster presented at a national meeting
- One article was submitted to a refereed journal

Project 4: Thermoelectric Exhaust heat recovery generator project

- One paper published in a refereed journal

Project 5: Continuous Emissions Monitoring System

- Nothing to report for this period

Project 6: Algae Based Glycerin fuel project

- Nothing to report for this period

Project 7: Development of Medium Speed Engine Testing

- Nothing to report for this period

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

- Poster presentation at conference (Green Boats and Ports for Blue Waters III - April 2016, Narragansett RI)
- Invited speaker, Bangor Rotary Club - April 2016, Bangor ME
- Seminar presentation at The Landing School - September 2016, Arundel ME

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

- Submit article to refereed journal on results of latest emulsion fuel testing focused on changes in soot composition and chemistry

Project 2: Hydrogen Injection Fuel Project

- Vary concentration of Hydrogen and monitor effects in Lab Dyno (on direct injection engine)
- Look at data from in-cylinder pressure monitoring in Lab Dyno(on direct injection engine)
- Conclude Hydrogen project

Project 3: Forest Biomass Diesel fuel project

- blend first set of TDO/diesel blends for engine testing at Maine Maritime Academy
- Hydro-treat 10L of TDO oil for fractionation and blending
- Recruit a graduate student to work on either TDO or pyrolysis of biomass feedstock

Project 4: Thermoelectric Exhaust heat recovery generator project

- Future experiments will focus on producing materials with smaller, more uniform nanoparticles and on controlling annealing conditions to prevent oxidation and maximize electrical conductivity.

Project 5: Continuous Emissions Monitoring System
- Equip medium speed engine with in-cylinder monitoring
- Integrate continuous emissions monitoring system into medium speed engine data acquisition and control system

Project 6: Algae Based Glycerin fuel project
- Utilize GCMS to measure the extracellular concentrations of glycerol and other dissolved organic compounds.

Project 7: Development of Medium Speed Engine Testing
- Complete installation of engine and support systems

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 resistance, seakeeping, and maneuvering tests on final sidehull geometry.
- Complete structural analysis.
- Complete design for half-scale demonstrator and begin construction.

Education, Workforce development and STEM:
- $400,000 investment made by MMA in its undergraduate training labs
- 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
- Two journal articles are currently in preparation

Project 2: Hydrogen Injection Fuel Project
- Nothing to report

Project 3: Forest Biomass Diesel fuel project
- DeSisto, W.J. and M.C. Wheeler "A funnel plot to assess energy yield and oil quality for pyrolysis-based processes" *Biomass and Bioenergy* (2016) 93, 254-258
- One publication under review

Project 4: Thermoelectric Exhaust heat recovery generator project
- Wallace, T.T., Jin, Z.-H. & Su, J. "Efficiency of a Sandwiched Thermoelectric Material with a Graded Interlayer and Temperature-Dependent Properties" *Journal of Electronic Materials* (2016) 45(4) 2142-2149

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

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:

- Wheeler, M.C., S.J. Eaton and W.J. DeSisto. Transportation Fuels via a Two-Stage Thermal Deoxygenation Process. 252nd Amercian Chemical Society National Meeting and Exposition, Philadelphia, PA, August 21, 2016
- Kimball, R.W. Marine Engine Testing and Emissions Laboratory (METEL) – Evaluation of Fuel-Side Diesel Emission Reduction Technologies as Low-Cost, Low-Maintenance Solutions for Commercial Diesel Engines. US DOT OSTR Transportation Innovation Series, Washington, DC, May 18, 2016
- Eaton, S.J. Alternative Fuels: Opportunities for Meeting Low Sulfur Targets. 4th Biennial TRB-CMTS Research and Development Conference, Washington, DC, June, 21 2016.
- Presentation abstract submitted and accepted for International Association of maritime Universities 2016 Meeting – Vietnam, October 2016.

Poster Presentations:

- Wheeler, M.C., S.J. Eaton, W.J. DeSisto. Transportation Fuels via a Two-Stage Thermal Deoxygenation Process. 252nd Amercian Chemical Society National Meeting and Exposition, Philadelphia, PS, August 23, 2016.

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	Prof. Laurie Flood
Program/Project Role	Researcher/ Faculty
# Hours worked during reporting period	0.2 months
Contribution to Program/Project	STEM and Environmental Curriculum Development
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. 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	Richard Smith
Program/Project Role	Research Engineer (Part time)
# Hours worked during reporting period	480 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	450 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	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	248
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	267
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

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;
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

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[i] L. Brennan, P. Owende, "Biofuels from microalgae—A review of technologies for production, processing, and extractions of biofuels and co-products." *Renew. Sust. Ener. Rev*. vol. 14. pp. 557–577. *2010*.

[ii] Chow, Y.S.; Goh, S.J.M.; Su, Z.; Ng, D.H.P.; Lim, C.Y.; Lim, N.; Lin, H.; Lee, Y.K. "Continual production of glycerol from carbon dioxide by Dunaliella Tertiolecta." *Biotechnology and Bioengineering*. Vol. 112 pp. 2163-2171. *2015*.

[iii] Chow, Y.S.;Wang, Y.T.; Wang, D.; Ng, D.H.P.; Lee, Y.K. "The Role of Micronutrients and Strategies for Optimized Continual Growth Production From Carbon Dioxide by Dunaliella Tertiolecta." *Bioresource Technology*. Vol. 136 pp. 550-555. *2013*.