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:
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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

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

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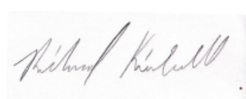
Recipient Organization: Maine Maritime Academy, Pleasant Street, Castine Maine 04420

Recipient Identifying Number or Account Number: Not Applicable

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

Reporting Period End Date: September 30, 2015

Report Term or Frequency: This report covers the period from April 1, 2015 to September 30, 2015, 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 six 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
>
> Project 6: Studies the capability of particular Algae strains to produce Glycerin fuel for use as a low cost low emissions transportation fuel.

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.

- Installation of the Hydrogen Injection system to Lab Dyno was completed and both emissions and efficiency data was obtained.
- Produced more than 4 L of TDO oil using 50 L reactor to investigate effects of sulfur and furfural on oil yield and quality.
- Produced 2 L of TDO oil using new 2-stage production method for TDO oil that improved yields in the 50 L reactor to be similar to 300 mL scale reactions.
- Graduated one M.S. student and two Ph.D. students.

- Fabricated and tested a bench-scale (100 g/hr) high pressure (150 psig) pyrolysis system to replace the previous atmospheric pressure system.

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 performance and emissions comparison of glycerol/water/diesel emulsion fuel and certified diesel conducted on Quickwater and CAT C2.2 diesel generator

Results:
A glycerol/water/diesel emulsion fuel was tested and benchmarked in comparison to diesel fuel over standard engine load cycles both in the laboratory and at sea. Fuel performance and emissions were continuously monitored during testing. Real time data included emissions of NOx, CO, unburned hydrocarbons, and particulate matter along with performance characteristics including fuel consumption and engine power output.
Fuel performance during sea trials was similar to that of diesel, exhibiting comparable engine efficiency over all load settings. However, maximum rated engine power was not achievable with the emulsion test fuel. EPA regulated energy normalized mass emissions of NOx + THC shown in Figure 1 were comparable between the two fuels at equal load settings during sea trials. Figure 2 illustrates that energy normalized mass emissions of CO were also comparable and minimal, indicating complete combustion. On the contrary, energy weighted soot particulate number presented in Figure 1 was found significantly elevated when operating the Quickwater on the emulsion test fuel.

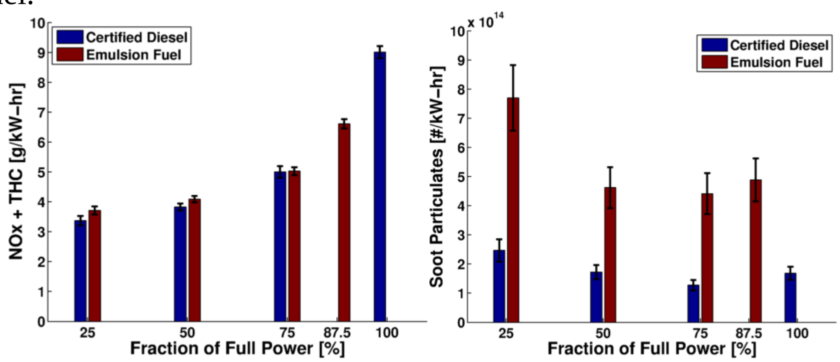


Figure 1 Averaged energy weighted emissions of Left: Combined NOx + THC and Right: Soot particulate number over engine load percentage from sea trial tests on board Quickwater.

Fuel performance and emissions from laboratory testing on the CAT C2.2 marine diesel generator deviated significantly from sea trial test results. Energy normalized mass emissions of NOx + THC shown in Figure 3 were slightly reduced. However, the reduction in NOx + THC arose from a reduction in NOx emissions while significantly elevating emissions of unburned hydrocarbons. Energy weighted mass emissions of CO shown in Figure 4 were also elevated indicating an issue of incomplete combustion of the emulsion test fuel.

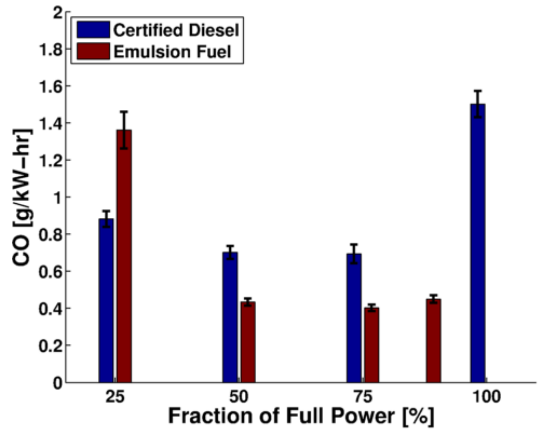


Figure 2:Averaged energy weighted Emissions of CO from sea trial on board vessel R/V Quickwater

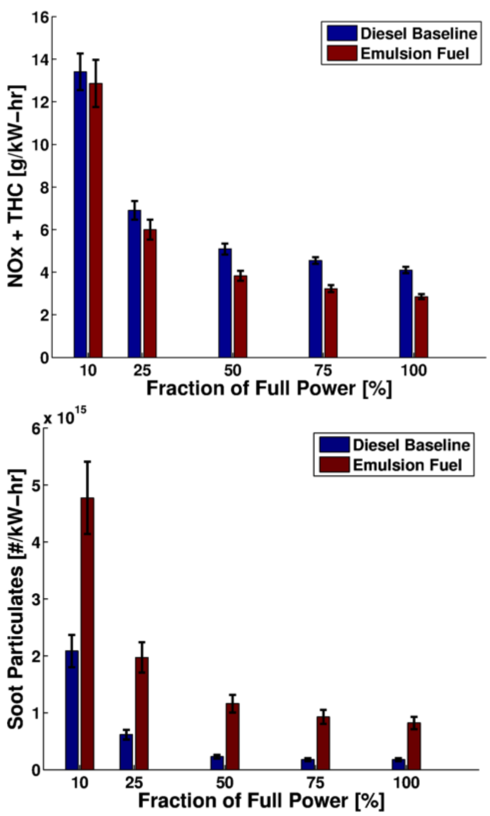


Figure 3 Averaged energy weighted emissions of Left: Combined NOx + THC and Right: Soot particulate number over engine load percentage from laboratory CAT C2.2 diesel generator.

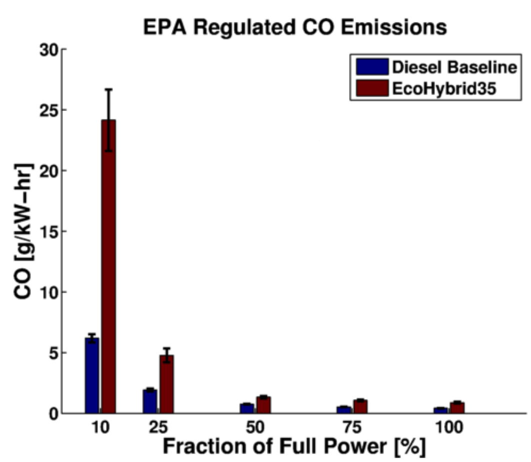


Figure 4: Average energy weighted emissions of CO from Laboratory CAT C2.2 Diesel generator testing

A several percent reduction in engine efficiency was also observed over all load settings. In contrast to gaseous emissions, energy normalized number emissions of soot particulates were again found significantly elevated for the emulsion test fuel in comparison to diesel during CAT generator testing.The pervasive elevated soot number emissions from all glycerol diesel emulsion fuel testing prompted data collection of soot samples on TEM grids for additional detail in terms of soot size and correlation with trends from gaseous emissions. The soot images from diesel fuel shown in Figure 5 look similar to typical results found in literature. In contrast, the emulsion fuel results shown in Figure 6 are notably unique. Two soot size modes (primary spherules and aggregates) are especially noticeable at 100% load for the emulsion fuel. Additionally at idle, a diffuse opaque substance coating the soot particles is observable. Judging by the incomplete combustion at low loads identified by high CO and THC, the substance is likely some unknown composition of heavy condensed organics. It is worth noting that the substance did not appear to evaporate under the electron beam during TEM imaging. It is also interesting that the soot particles appear to act as a nucleation site for the diffuse material. In response, the morphology of the soot is significantly affected likely due to liquid surface tension.

TEM images reveal that while soot number concentration is higher for the emulsion fuel, the soot particles also appear smaller in general. Contributing factors for this likely include a change in fuel atomization due to higher fuel viscosity in the emulsion fuel along with reduced soot formation and surface growth from fuel born oxygen resulting in a less rich diffusion flame. The same trend is expected from the Quickwater data likely without the issue of incomplete combustion. Development and testing of the glycerol/water/diesel emulsion fuel remains a priority.

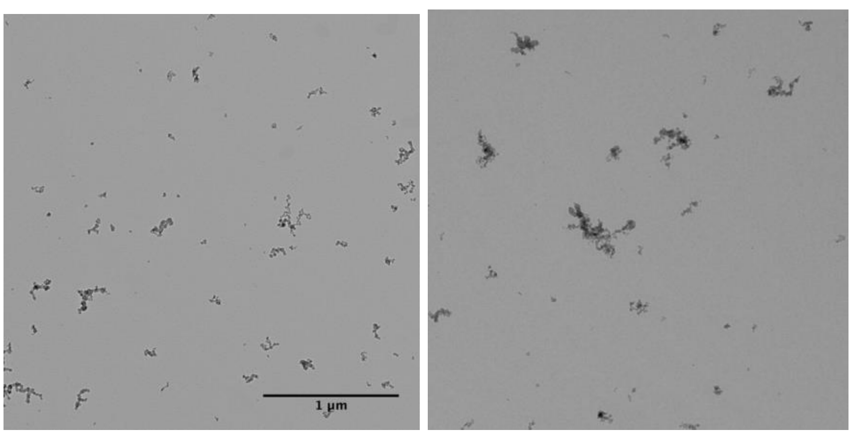


Figure 5 TEM soot samples collected from the CAT C2.2 diesel generator burning diesel fuel at idle (left) and 100% (right) engine load.

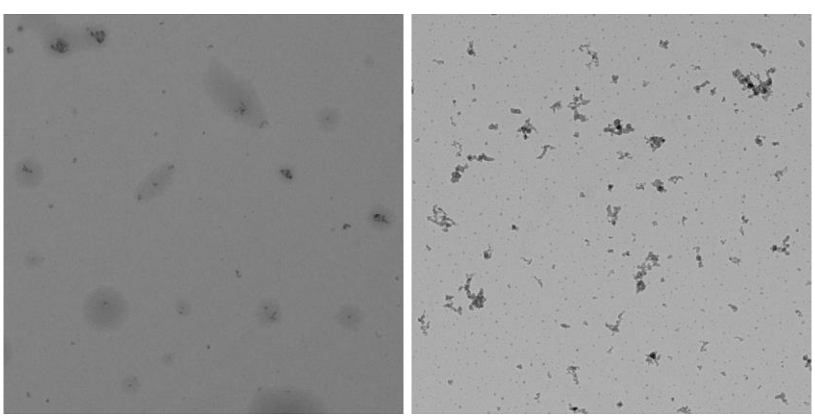


Figure 6 TEM soot samples collected from the CAT C2.2 diesel generator burning glycerol diesel emulsion fuel at idle (left) and 100% (right) engine load

Project 2: Hydrogen Injection Fuel Project

The summarized accomplishments for the reporting period are:

- The installation of the Hydrogen Injection System supplied by Global Marine Solutions (GMS) in the Quickwater's air intake systems was completed and both emissions and efficiency data was obtained.
- Installation of the Hydrogen Injection system to Lab Dyno was completed and both emissions and efficiency data was obtained.

Description of accomplishments for the Hydrogen Injection Fuel Project:

Approximately 6 LPM of HHO (Hydrogen and Oxygen) was supplied to the port engine of the Quickwater, a 14.8L Cummins VT-903. The results did not show any discernable changes in either efficiency or emissions when compared to the base line diesel alone.

Lab testing following the guidelines outlined in CFR title 40 part 1065 was performed by supplying our Lab Dyno (a turbocharger of the Caterpillar C2.2 genset) with 6 LPM of HHO. Results show that the HHO has the overall effect of reducing efficiency and increasing emissions. The electrical power required to produce the HHO is included in the efficiency. Figure 7 shows the efficiency and CO emissions. Figure 8 shows the NOx and Total Hydrocarbons emissions. Soot emissions remained essentially unchanged as shown by Figure 9.

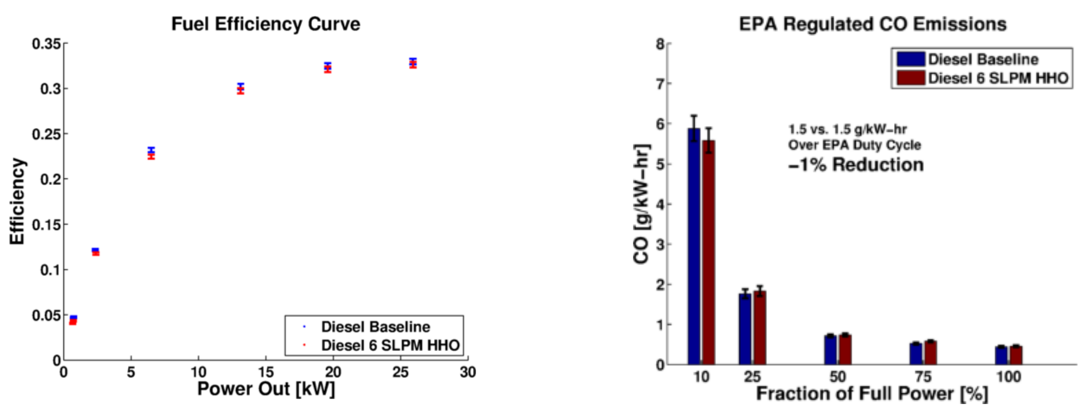


Figure 7 Left: Fuel efficiency vs power including electrical power required for HHO production. Right: CO Emissions vs power.

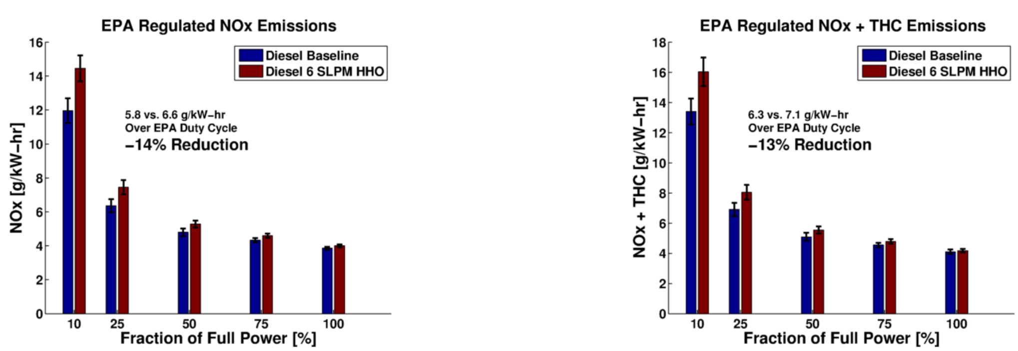


Figure 8 Left: NOx Right: Combined NOx + THC

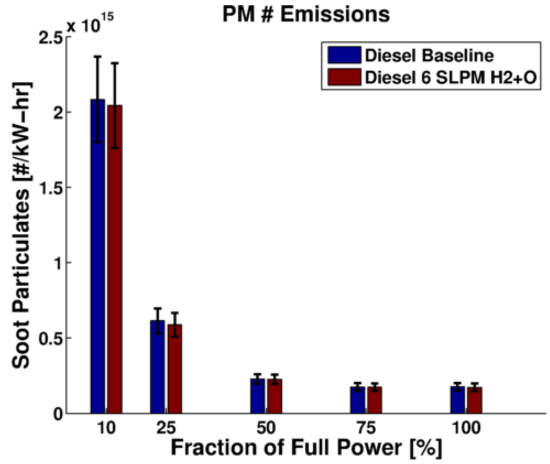


Figure 9 Soot Particulate Emissions vs Fraction of Full Power

Project 3: Forest Biomass Diesel fuel project

UMaine 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). Below is a summary of accomplishments for each processing route .
The summarized accomplishments for the reporting period are:

- Produced more than 4 L of TDO oil using 50 L reactor to investigate effects of sulfur and furfural on oil yield and quality.
- Produced 2 L of TDO oil using new 2-stage production method for TDO oil that improved yields in the 50 L reactor to be similar to 300 mL scale reactions.
- Graduated one M.S. student and two Ph.D. students.
- Created a plan, to be implemented during next reporting period, for producing blends of TDO oils for engine testing.
- Fabricated and tested a bench-scale (100 g/hr) high pressure (150 psig) pyrolysis system to replace the previous atmospheric pressure system.

Results:

- The yield of organic liquids at large scales was improved (approaching 80% of theoretical yield) by pretreating TDO feedstocks at 250°C and size-reducing the resulting intermediates prior to pyrolysis. New understanding of the reactions involved in Thermal DeOxygenation shows that there are two distinct reaction regimes. The low temperature regime evolves water and forms a pumice-like material with reduced oxygen content. The decomposition reactions between 250°C and 500°C produce organic liquids. Because the pretreatment temperature is relatively mild, existing industrial equipment, such as porcupine processers, would be reasonable for the first-stage processing. Then, it will be worthwhile to identify the most effective pyrolysis method for second-stage processing, for instance fast versus slow pyrolysis.
- Major chemical pathways were identified for the formate assisted pyrolysis of pretreated lignin, cellulose and hemicellulose. These pathways provide insight into yield losses during pyrolysis. Future experiments using the new high-pressure pyrolysis system will

explore the effects of fluidization gas composition and pressure on the overall yield and product quality of FASP oil.

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

The summarized accomplishments for the reporting period are:

- Ball milling of raw thermoelectric material pellets commenced
- Initial grinding study completed to determine highest yield process
- Particle characterization work started on TE material in solvent suspension with LUMiSizer 610

Results:

A major obstacle to the incorporation of new thermoelectric materials into devices for power generation is producing these materials at the thicknesses required. From METEL's modeling results, shown in Figure 10, the peak power output from a p-type Bismuth Antimony Telluride material occurs in the 10^{-5}-10^{-3} m (10^{2}-10^{3} μm) range. In collaboration with the Laboratory for Surface Science and Technology at the University of Maine at Orono, METEL has initiated a project to produce and characterize 10^{2}-10^{3} μm thick films from nanoparticle TE materials using a bench top chemical technique called layer-by-layer (LBL) growth.

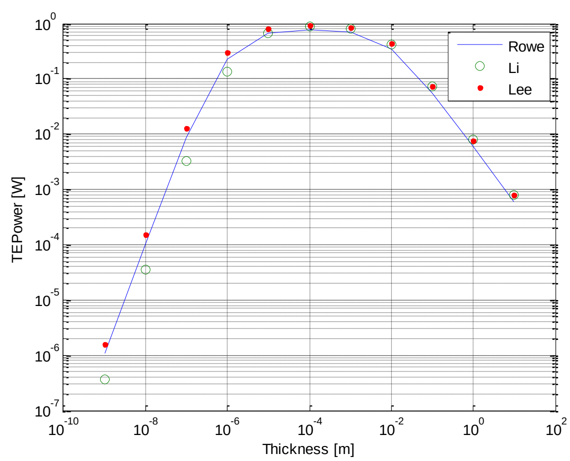


Figure 10 Predicted thermoelectric power generated from Bi0.5Sb1.5Te3 as thickness is decreased

To begin pure, millimeter-sized pellets of $Bi_{0.5}Sb_{1.5}Te_3$ were purchased from Sigma Aldrich and milled using a ball and capsule amalgamator, which simulates a ball and mill process well. A series of grinding runs were completed to determine which ball bearing size, if any, could be used to achieve a reasonable yield of submicron particles. The powder created by the milling process was passed through a 90 micron sieve to strain out larger particles. The percent mass of material that passes through the sieve compared to the mass of material before sieving is shown in Figure 11. The 5/32" ball bearing showed the highest % yield and was tested further with varying numbers of ball bearings.

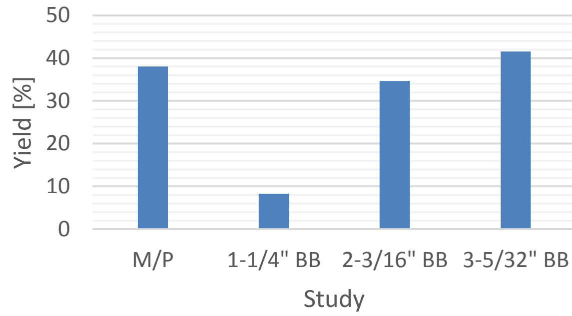


Figure 11 Grinding study performed on Bi0.5Sb1.5Te3 using varying size ball bearings

The resulting powders were then analyzed for particle size using SEM (Figure 12). The average particle size was difficult to determine due to agglomeration of particles, but it is clear that many of the particles are much larger (>10 µm in diameter) than needed. To get an idea about the size distribution of the smaller particles, a few milliliters of deionized water was added to each of the powders. The smaller particles are actually solvated, which allowed them to be analyzed by METEL's recently procured LUMiSizer 610. The average size of the particles is apparently 2-3x greater than what is needed, but experiments continue.

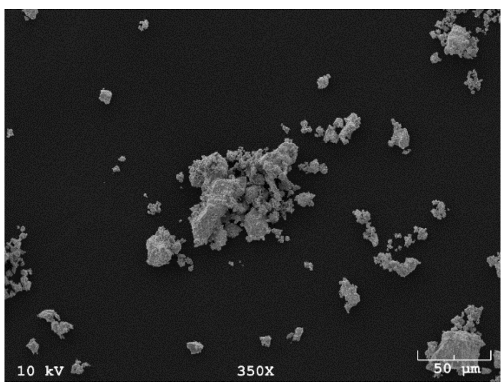


Figure 12 Examples of thermoelectric raw materials at 350x magnification in SEM

The samples were suspended in deionized water, in order to break the static electricity bonds holding the particles together. The samples were allowed to settle, so that the smaller particles were left in suspension in the water. METEL's LUMiSizer 610 was used to determine the amount of particles and the size distribution of the grains there were held in suspension. An example result of one of these studies are shown below in Figure 13, which shows the particle size distribution using two 3/16" ball bearings. As is shown in the figure, only particles up to 3 microns were held in suspension in the deionized water, as the volume weighed particle distribution ends at approximately 3 microns. Further work is needed to determine the mass yield of the material held in suspension in the deionized water.

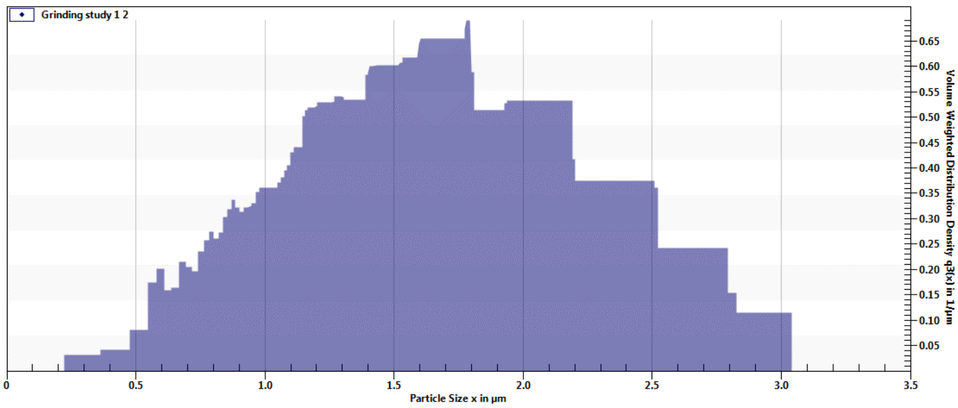


Figure 13 Particle suspension results for 3/16" ball bearing grinding study

Project 5: Marine Engine Continuous Emissions Monitoring System

The summarized accomplishments for the reporting period are:

- Detailed performance and emissions comparison of glycerol/water/diesel emulsion fuel and certified diesel conducted on Quickwater and CAT C2.2 diesel generator
- FTIR sent to MKS for repairs
- CPC sent to BMI for upgrades and modifications to remove device optical flooding issue due to large waves during sea trials.
- Scanning Electrical Mobility Spectrometer (SEMS) ordered as add on to BMI CPC for measuring soot particle size distribution in real time
- In cylinder monitoring system installed on CAT C2.2 diesel generator with real time LabVIEW data acquisition module completed

Results:

<u>In-Cylinder Real-Time Monitoring</u>

An Optrand AutoPSI pressure transducer and US Digital 3600 pulse per revolution encoder were sourced to build and test an in-cylinder real-time monitoring system as an additional combustion diagnostic tool. The equipment was installed on the lab based CAT C2.2 diesel generator. Calibration of the encoder to the cylinder top dead center was completed. A LabVIEW data acquisition module was completed for the in cylinder monitoring system as an add-on to the primary continuous emissions monitoring software. The in-cylinder data is saved as a separate file and time synced to the primary CEMS data file for complementary analysis. The LabVIEW module is shown in Figure 14. With the calibrated top dead center position provided, the module averages data over a specified number of cycles, saves the raw pressure vs. crank angle data and displays real-time crank angle vs. pressure and pressure volume diagrams.

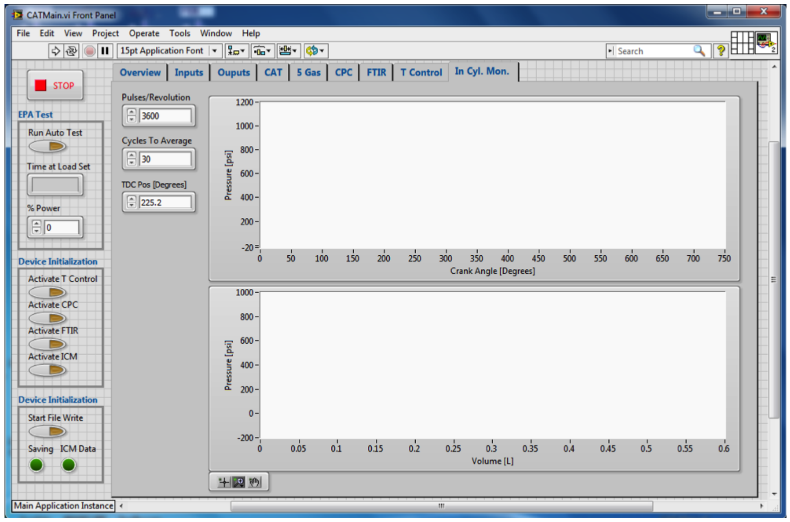


Figure 14 In-Cylinder Monitoring CEMS LabVIEW module.

Figure 15 shows in-cylinder pressure as a function of crank angle and a pressure volume diagram for the CAT C2.2 generator at 100% load. The uncertainty in the pressure data is 30 psi. The results will be further tested and verified for accuracy moving forward. In-cylinder heat release rates and fuel burn rates can be calculated from the pressure vs. crank angle data. Data processing for these combustion diagnostics will be undertaken in the next reporting period.

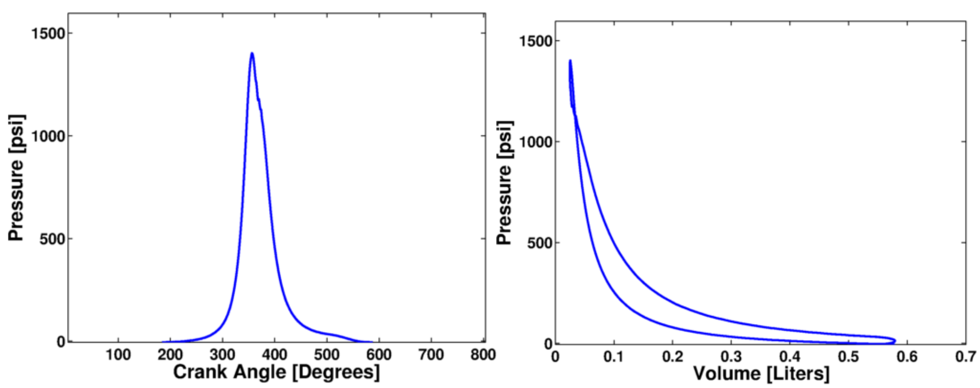


Figure 15 Left: In-cylinder pressure vs. crank angle. Right: Pressure volume diagram.

Project 6: Algae based glycerin fuel project

The summarized accomplishments for the reporting period are:

- Bioreactor with automated measurement tools completed
- Survey of effect of media macro and micro nutrient concentrations on glycerol production of microalgae species Dunaliella tertiolecta nearly complete
- Submitting collaborative biofuels grant with National Center for Marine Algae (East Boothbay Harbor, ME) and nanofiltration startup Cerahelix (Orono, ME).

Results:

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]

What differentiates our approach from other groups working on algae biofuels is our focus on small molecules, like glycerol, that are expelled from the algae into the extracellular media. The goal of the project is to develop instrumentation for quantifying, characterizing and extracting small molecules without killing the microalgae culture. An initial step forward in instrumentation has been the development of small-scale bioreactor programmed to automatically measure the temperature, conductivity and refractive index of the culture. Graphs of these variables, taken every twenty minutes for the first ten days of a culture of *Dunaliella tertiolecta*, are shown in Figure 16. Refractometry is a common method determining solute concentrations since refractive index (n) changes with solute concentration (C). The refractive index, however, also changes with salinity and temperature (T), as does the degree of change $\left(\frac{dn}{dC}\right)$. We are monitoring salinity, temperature and refractive index and in an effort to develop an algorithm for glycerol concentration. In the meantime we have developed a Nuclear Magnetic Resonance (NMR)-based procedure for glycerol quantification that is both more sensitive (~10 micromolar/0.01 mg/ml), more reliable and requires less sample than conventional spectrophotometric assays. Figure 17a. shows NMR spectra of microalgae media taken over the course of the lifecycle of *Dunaliella tertiolecta.* We have confirmed that extracellular glycerol concentration increases with the age of the culture, but not at the concentrations reported in the literature. We suspect this is attributable to the assay used to quantify glycerol concentration. Figure 17b. shows that glycerol is clearly not the only hydrocarbon in solution and polyunsaturated aldehydes and carboxylic acids along with other molecules have been documented and a nonspecific assay could mistake these species for glycerol. Work on identifying and quantifying these species as well as optimizing culture conditions to promote extracellular carbon production continues.

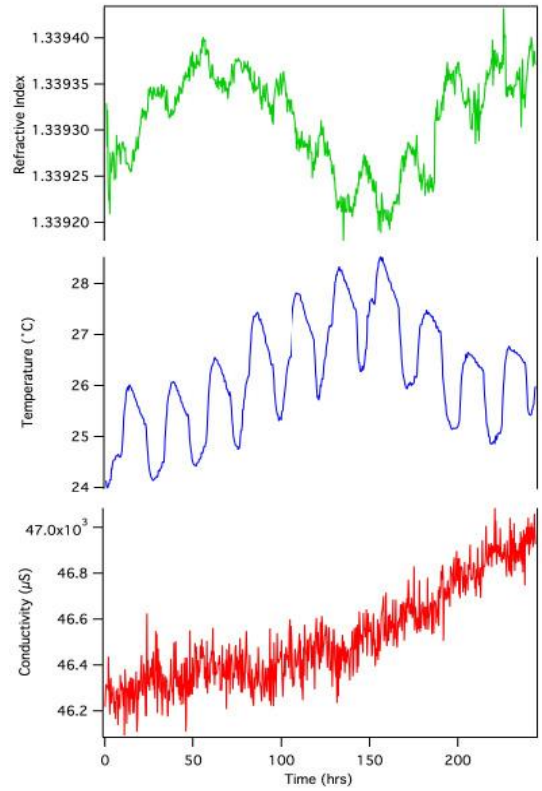


Figure 16 Data from instrumented METEL microalgae bioreactor. The periodic changes in temperature correspond to the 14/10 hr daily lighting schedule for the culture.

METEL continues to work with Bigelow Laboratory for Ocean Science’s National Center for

Marine Algae (NCMA) to develop a microalgae biofuels research project in Maine and is submitting a grant with NCMA and startup company Cerahelix (Orono, ME).

Education, Workforce development and STEM accomplishments

STEM Events:

None to report at this time

Significant Results:

- Demonstrated high-fidelity emissions measurements aboard a vessel at sea.
- Characterized performance and emission of Diesel/Glycerin emulsion fuels in a vessel at sea.

Key Outcomes:

<u>How have the results been disseminated?</u>
One refereed journal publication, three theses, and 6 presentations at national conferences and other universities.

<u>What do you plan to do during the next reporting period to accomplish the goals?</u>

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

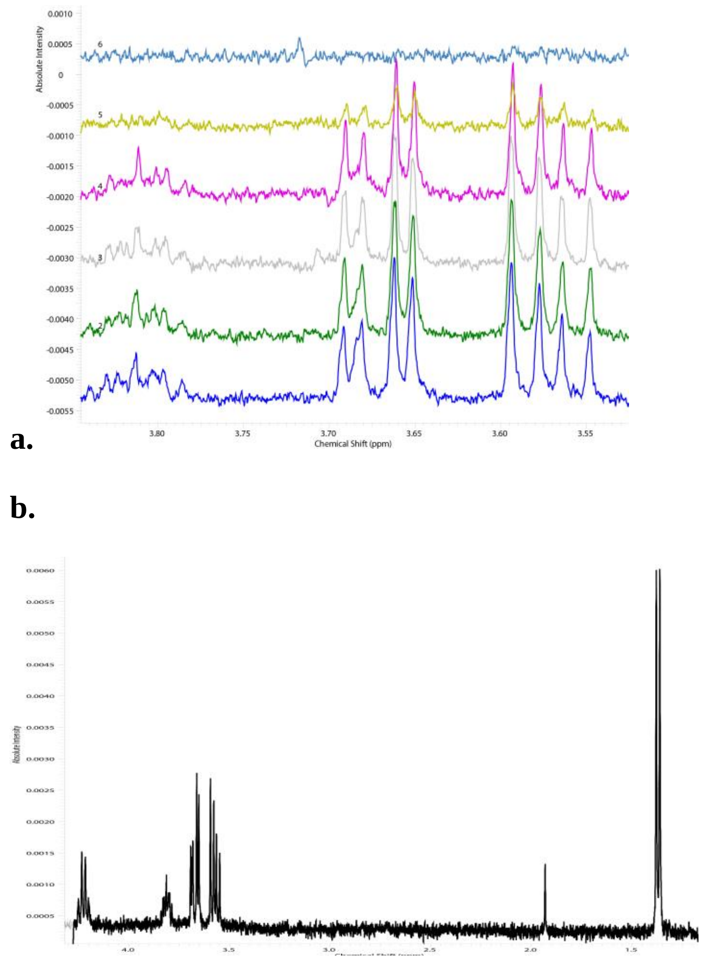


Figure 17 H-NMR spectra of the extracellular media of Dunaliella tertiolecta. A. Glycerol peaks appeared after 2 weeks. Integrated peak intensities increased consistently over the next month. b. Other peaks from unidentified hydrocarbons appeared at about the same

Project 1: Diesel/Glycerin Emulsion fuel project
- Production of pilot quantities of fuel using the fuel production skid
- Examine fuel atomization, effects of temperature and viscosity
- Examine fuel stability

Project 2: Hydrogen Injection Fuel Project
- Vary concentration of Hydrogen and monitor effects in Lab Dyno
- Look at data from in-cylinder pressure monitoring in Lab Dyno
- Conclude Hydrogen project

Project 3: Forest Biomass Diesel fuel project
- Produce approximately 20L of TDO oil, and prepare blends for engine tests.
- Continue experiments to explore the effects of process conditions on FASP yields.
- Present student research results at the International Bioenergy & Bioproducts Conference in Atlanta Georgia.

- Recruit a graduate student to study continuous processing of TDO salts.
- Recruit a graduate student to conduct technoeconomics on TDO and FASP processes.
- Recruit a graduate student to study in-situ catalytic hydropyrolysis.

Project 4: Thermoelectric Exhaust heat recovery generator project

- Create and characterize elements

Project 5: Continuous Emissions Monitoring System

- Complete CPC upgrade and test
- Accept delivery of SMPS and test system
- Continue development of post processing code for in cylinder pressure monitoring of Lab Dyno

Project 6: Algae Based Glycerin fuel project

- Develop small scale reactor
- Work on continuous monitoring system for glycerin production.

Education, Workforce development and STEM:

- Development of an Environmental course sequence and minor for implementation at MMA
- Began implementation of Transportation related engineering lab upgrades and curriculum development.
- Sponsored 3 Internships and 2 undergraduate research assistants to work on METEL projects

2. PRODUCTS: What has the program produced?

Publications, conference papers, and presentations

Journal publications:

- Scott J. Eaton , Sedat H. Beis , Sampath A. Karunarathne , Hemant P. Pendse , and M. Clayton Wheeler; "Hydroprocessing of Biorenewable Thermal Deoxygenation Oils," Energy Fuels, 2015, 29 (5), pp 3224–3232 http://pubs.acs.org/doi/abs/10.1021/acs.energyfuels.5b00396

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

- Scott Eaton, Ph.D. Thesis, Chemical Engineering, University of Maine, August 2015: “Thermal Deoxygenation of Levulinated and Formate Salts for the Production of Transportation Fuels.”
- Paige Case, Ph.D. Thesis, Chemical Engineeering, University of Maine, May 2015: “Fundamentals of Pyrolysis of Pretreated Biomass.”
- Hamad AlMohamadi, M.S. Thesis, Chemical Engineering, University of Maine, December 2014: “Techno-Economic Analysis of Formate Assisted Pyrolysis.”

Other publications, conference papers and presentations:

- B. Sarnacki, R. Kimball, T. Wallace, T. Lokocz, G. Harakas. (2015). Real Time Emissions Monitoring of Diesel Engines Aboard Marine Vessels.250th National Meeting of the American Chemical Society.
- S.J. Eaton, P.A. Case, W.J. DeSisto, and M.C. Wheeler, Poster: “Decomposition Pathways during Pyrolysis of Hydrolyzate Salts,” tcs2014: Symposium on Thermal and

Catalytic Sciences for Biofuels and Biobased Products, Denver, CO, September 2-4, 2014. *(not included in last year's PPPR)*

- P.A. Case, M.C. Wheeler, and W.J. DeSisto, Second Place Student Poster Competition: "Proposed Mechanisms for Pyrolysis of Calcium Pretreated Pine," tcs2014: Symposium on Thermal and Catalytic Sciences for Biofuels and Biobased Products, Denver, CO, September 2-4, 2014. *(not included in last year's PPPR)*
- Scott Eaton and M. Clayton Wheeler, Contributed Presentation: "Levulinate and Formate Salt Reactions during Thermal Deoxygenation (TDO)," 14AIChE Annual Meeting, Atlanta, GA, November 19, 2014.
- Hamad AlMohamadi, William J. DeSisto and Clayton Wheeler, Contributed Presentation: "Techno-Economics of Formate Assisted Pyrolysis," 14AIChE Annual Meeting, Atlanta, GA, November 18, 2014.
- Clayton Wheeler, Invited Presentation: "UMaine Forest Bioproducts Research Institute: Transportation Biofuels," University of New Mexico Department of Chemical and Nuclear Engineering, May 1, 2015.

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

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

	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

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

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

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

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

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

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

Name	Jessica Menges
Program/Project Role	Undergraduate researcher
# Hours worked during reporting period	400 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

Name	Scott Eaton
Program/Project Role	Graduate Student
# Hours worked during reporting period	6 month
Contribution to Program/Project	TDO fundamentals
Funding support	DOT
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	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	0 month (DOT) 1.67 month (UMaine)
Collaborated with individual in foreign country	No

Name	Nathan Hill
Program/Project Role	UMaine Research Technician
# Hours worked during reporting period	912
Contribution to Program/Project	Equipment design and fabrication. Production of TDO oil.
Funding support	5.26 month (DOT) 0 month (UMaine)
Collaborated with individual in foreign country	No

Name	Elisha Cram
Program/Project Role	Research Engineer
# Hours worked during reporting period	44
Contribution to Program/Project	Assist with processing of TDO oil
Funding support	0.25 month (DOT) 0 month (UMaine)

Collaborated with individual in foreign country	No

Name	Scott Eaton
Program/Project Role	Ph.D. Student
# Hours worked during reporting period	1040
Contribution to Program/Project	Mechanisms of TDO
Funding support	12 month (DOT) 0 month (UMaine)
Collaborated with individual in foreign country	No

Name	Paige Case
Program/Project Role	Ph.D. Student
# Hours worked during reporting period	57
Contribution to Program/Project	Mechanisms of Formate Assisted Pyrolysis
Funding support	0.66 month (DOT) 9 months on UMaine Fellowship
Collaborated with individual in foreign country	No

Name	Chi Truong
Program/Project Role	M.S. Student
# Hours worked during reporting period	961
Contribution to Program/Project	High Pressure Pyrolysis
Funding support	11 month (DOT) 0 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.

Organization: Global Marine Consulting (GMC)
Contribution to Project: GMC is providing the Hydrogen Injection test equipment and have delivered most of the system. Preliminary test have been run on a lab diesel engine.

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?

- METEL Lab capable of performing EPA certified Diesel engine emissions tests for our industry (one outside contracted industry test performed in this performance period)

What is the impact on other disciplines?

- METEL Diesel engine testing capabilities can support other commercial diesel disciplines including Rail, commercial roadway engines and stationary powerplants used in the pipeline industry.

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;

- Fabricated a 150 g/hr high pressure pyrolysis process.
- Finalized development of Laboratory High speed Diesel test stand for EPA testing
- Vessel board emissions measurement system implemented and demonstrated on board MMA Vessel R/V Quickwater
- Purchased SMPS, Lumisizer and Bomb Calorimeter (Fuel Chemistry lab development)

What is the impact on technology transfer? Nothing to Report

What is the impact on society beyond science and technology?

- METEL Diesel engine test capabilities developed w/ DOT funds ad diesel emissions testing and evalutation capabilities useful for the transportation industries emissions reductions goals

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.*