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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DUNS and EIN Numbers: 071746630 and 01-60000724

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

Recipient Identifying Number or Account Number: Not Applicable

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

Reporting Period End Date: March 31, 2016

Report Term or Frequency: This report covers the period from October 1, 2015 to March 31, 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 seven 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 was being developed by Global Marine Consulting This project is near completion

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.

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

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. For this quarter, METEL has engaged in efforts with Exxon in relation to the development of the Medium Speed, Heavy Fuel Test Lab project. This lab is becoming a flagship laboratory under METEL with unique capabilities in the Nation to address emission of large diesel engines

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.
- Sea trial performance testing of diesel/biodiesel/glycerin emulsion fuel blends on board Quickwater performed.
- Produced 20 L of TDO oil using new 2-stage production method with improved yields
- Distilled 6 L of TDO oil into 25ºC fractions for blending with certified diesel
- Conducted experiments to compare performance of the high pressure pyrolysis system to previously published results for pine and calcium formate pretreated pine feedstocks
- Trained two new graduate students to perform pyrolysis and hydrotreating experiments
- Modeling of functionally graded material completed
- TEG Heat Exchanger characterization commenced
- TEG Back Pressure effect on performance and engine emissions started
- Performance and emissions comparison of B20 biodiesel (RME)/diesel/glycerol emulsion fuels, B20, and diesel conducted on Quickwater and CAT C2.2 diesel generator
- Upgraded Condensation Particle Counter (CPC) and new Scanning Electrical Mobility Spectrometer (SEMS) received from BMI
- In cylinder monitoring post processing program completed
- Space secured for medium speed engine lab development
- Preliminary system designs completed for medium speed engine lab
- Medium speed engine and main equipment ordered
- NMR quantification of small molecules in microalgae extracellular media
- Development of headspace CO_2 sensor for algae monitoring

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:

- Performance and emissions testing of emulsion fuels with respect to fuel aging and emulsion stability on CAT C2.2 marine diesel generator.
- Sea trial performance testing of diesel/biodiesel/glycerin emulsion fuel blends on board Quickwater.

Results:

Laboratory testing

Small samples of B20 biodiesel/diesel/glycerol emulsion fuels were produced with varying glycerol and surfactant concentrations and rapidly analyzed in the LUMiSizer as a preliminary emulsion stability survey. B20 blends containing 5 and 10 wt% glycerol/water solutions with a constant surfactant concentration were chosen to test fuel stability on emissions and engine performance with the CAT C2.2 marine diesel generator over a three-month period. The fuels

were blended and tested immediately in comparison to certified diesel fuel and standard B20 fuel. The fuels were additionally allowed to age for one and two months and tested in comparison to B20 fuel. ISO 8178 standard engine load cycles were used throughout testing. Fuel heating values were measured with the Parr 6200 bomb calorimeter.

Emulsion fuel engine performance and emissions data was compared to B20 basestock and traditional ULSD fuel. The Data revealed increased fuel consumption for biodiesel containing fuels compared to certified diesel due consistent with their lower energy density. Engine efficiency, however, was equivalent across all fuels. Aging of the emulsion fuels exhibited no loss of engine performance or increase in engine out emissions indicating acceptable emulsion stability for practical fuel usage. Figures 1-3 show energy weighted emissions of NOx + THC (left) and CO (right) for fuel pair comparisons of certified diesel - B20, B20 - B20 5% glycerol, and B20 - B20 10% glycerol collected promptly after fuel blending. All fuels exhibited equivalent gaseous emissions within error bounds over the course of the study.

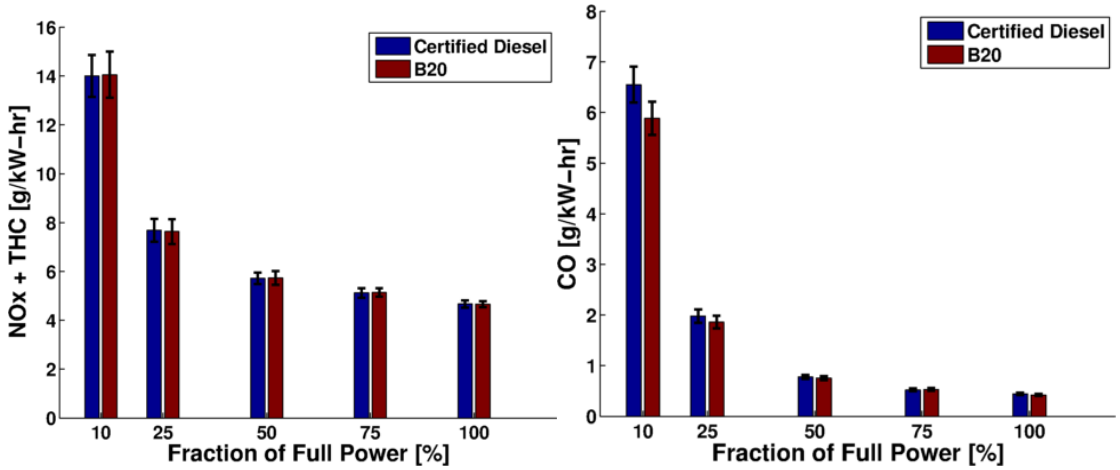


Figure 1: Emissions comparison of B20 and certified diesel fuels promptly after blending. Averaged energy weighted emissions of Left: Combined NOx + THC and Right: CO over engine load percentage from laboratory CAT C2.2 diesel generator testing.

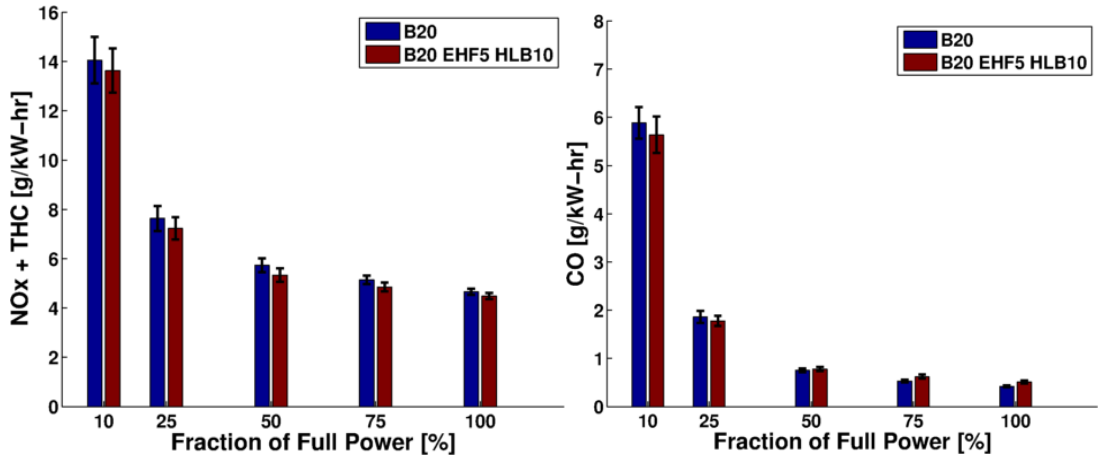


Figure 2: Emissions comparison of B20 and B20/5% glycerol emulsion fuel promptly after blending. Averaged energy weighted emissions of Left: Combined NOx + THC and Right: CO over engine load percentage from laboratory CAT C2.2 diesel generator testing.

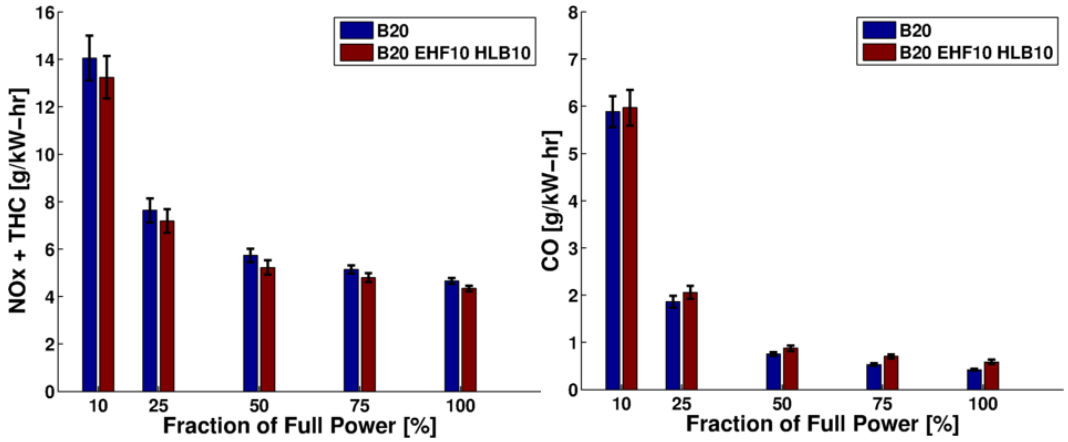


Figure 3: Emissions comparison of B20 and B20/10% glycerol emulsion fuel promptly after blending. Averaged energy weighted emissions of Left: Combined NOx + THC and Right: CO over engine load percentage from laboratory CAT C2.2 diesel generator testing.

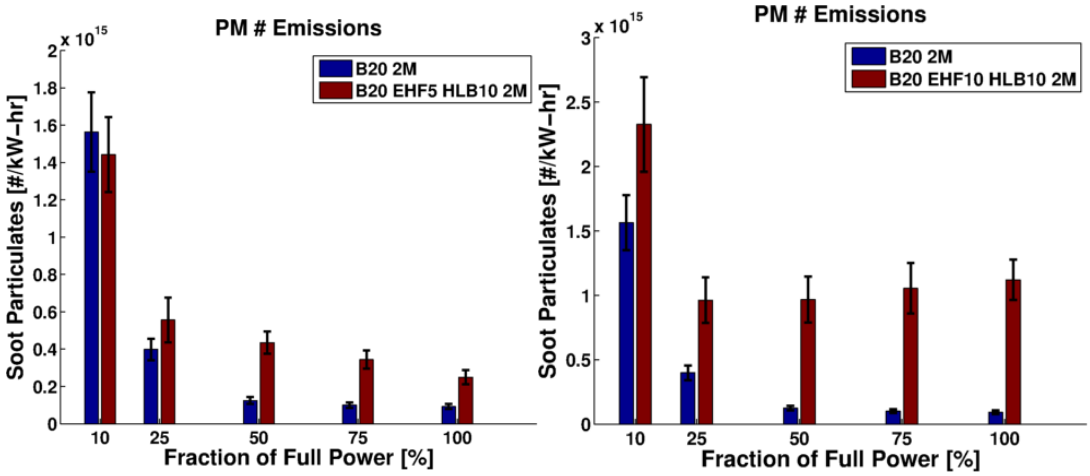


Figure 4: Average energy weighted soot number emissions comparison of Left: B20/5% glycerol and Right: B20/10% glycerol emulsion fuels two months after blending from laboratory CAT C2.2 diesel generator testing.

In contrast to gaseous emissions, energy normalized number emissions of soot particulates were found significantly elevated for the emulsion test fuels in comparison to B20 biodiesel during CAT generator testing. The dependence of soot number emissions on fuel glycerol concentration also appears nonlinear and deserves additional study. The soot particle number increase using glycerin is indicating small particulate size and our new SEMS system will be engaged next quarter to understand the soot size distribution and other aspects of the PM emissions

Quickwater Testing Results

Figures 5 and 6 illustrate measured fuel consumption and engine efficiency for runability testing of B20 biodiesel (RME)/diesel/5% glycerol emulsion fuel in comparison to nonroad diesel fuel on board Quickwater. Fuel performance was found qualitatively acceptable by the vessel captain and quantitatively identical to nonroad diesel within error bounds.

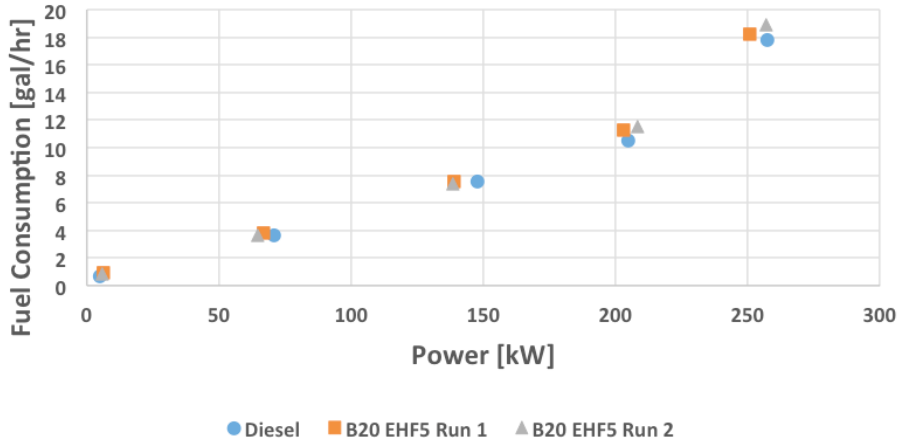


Figure 5: Fuel consumption as a function of measured engine power output for nonroad diesel and B20 biodiesel (RME)/diesel/5% glycerol emulsion fuels.

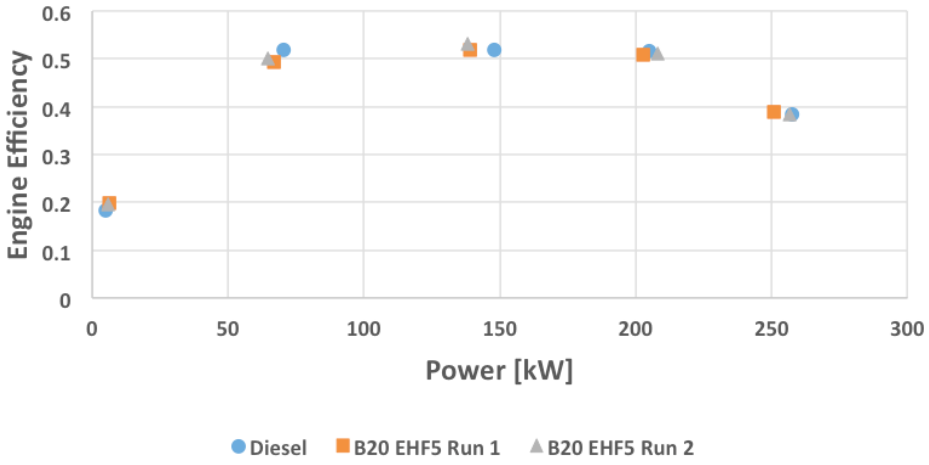


Figure 6: Engine efficiency as a function of measured engine power output for nonroad diesel and B20 biodiesel (RME)/diesel/5% glycerol emulsion fuels.

Project 2: Hydrogen Injection Fuel Project

The summarized accomplishments for the reporting period are:

- No work performed during this reporting period
- Based on results of testing during the last reporting period we would like to perform additional testing on a direct injection engine
- Direct injection engine donation was solicited and obtained. Currently awaiting delivery of the engine sometime in the next 6-8 weeks

Description of accomplishments for the Hydrogen Injection Fuel Project:
No accomplishments to report during this period. We anticipate finishing research and closing the project out during this period.

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). A summary of accomplishments for each processing route is provided below.

The summarized accomplishments for the reporting period are:

- Produced 20 L of TDO oil using new 2-stage production method with improved yields
- Distilled 6 L of TDO oil into 25ºC fractions for blending with certified diesel
- Conducted experiments to compare performance of the high pressure pyrolysis system to previously published results for pine and calcium formate pretreated pine feedstocks
- Trained two new graduate students to perform pyrolysis and hydrotreating experiments

Results:
An understanding of the effect of pre-heating the fluidizing gas on the yield and composition of bio-oil allowed us to reconcile differences between the performances of the pyrolysis system.
Preliminary results indicate that increased pressure may enhance formate-assisted pyrolysis. A commercial NiMo catalyst was tested for upgrading a model compound and was deemed ineffective for upgrading TDO oil via hydrodeoxygenation

Project 4: Thermoelectric Exhaust heat recovery generator (TEG) project
The summarized accomplishments for the reporting period are:

- Modeling of functionally graded material completed
- TEG Heat Exchanger characterization commenced
- TEG Back Pressure effect on performance and engine emissions started

Results:

A paper was published in the Journal of Electronic Materials entitled "Efficiency of a Sandwiched Thermoelectric Material with a Graded Interlayer and Temperature-Dependent Properties" outlining the results of Fortran modeling of functionally graded (FGM) thermoelectric materials. The modeling was conducted using sigmoidal functions and volume fraction blending of compatible materials, such as bismuth and lead telluride, to allow for blending transitions to reduce the contact resistance between two dissimilar materials. Figure 7 shows some of the results from the paper with a 0.5mm and 1mm graded interlayer between various thicknesses of bismuth telluride of a 5mm total element thickness. Both of the figures show that an increase in material efficiency over either homogeneous material can be achieved using the graded interlayer FGM material.

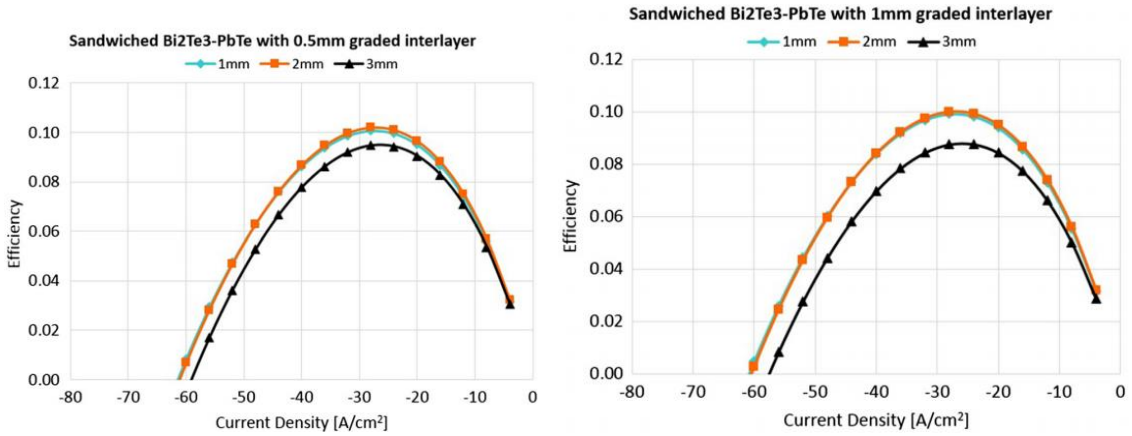
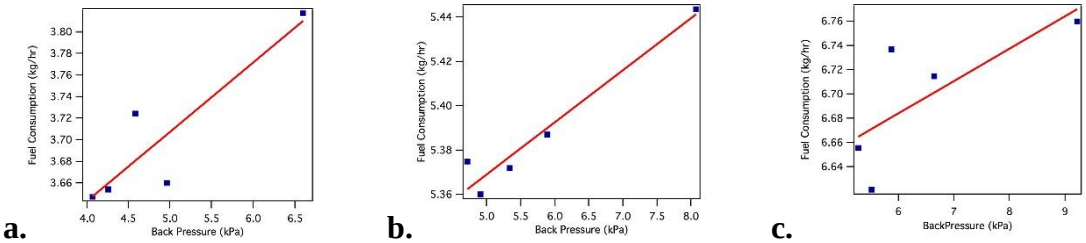


Figure 7: Modeling results for 0.5mm and 1mm graded interlayer in FGM TE materials

A flat plate heat exchanger, with continuously variable plate spacing, was installed on a Caterpillar C2.2 diesel genset. Tests characterizing the relationship between backpressure, heat-exchanger efficiency, engine performance and emissions were conducted with objective of fully characterizing the tradeoff between backpressure and exhaust heat transfer. Not surprisingly our results show that increasing backpressure has a negative effect on engine efficiency. Figure 8 shows a plot of average fuel consumption at various engine loads as the exhaust is constricted and backpressure is increased.



a. **b.** **c.**

Figure 8: Average diesel consumption vs. exhaust backpressure at a. 50% b. 80% and 100% engine load.

Emissions data is mixed. Increases in backpressure lead to increases in NO_x concentrations and decreases in CO and number of soot particles. The increase in backpressure, however, has a distinct positive effect on the energy flux through the heat exchanger. Figure 9 shows the total energy per unit area through the heat exchanger versus average backpressure. Future experiments will be run over an expanded range of backpressures and quantify total soot mass using METEL's new scanning electrical mobility spectrometer (SEMS).

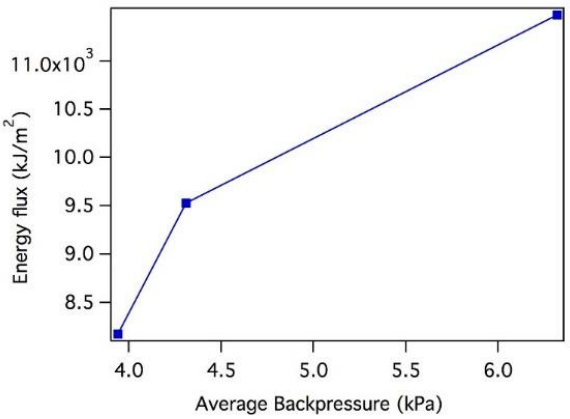


Figure 9: Heat exchanger energy flux as exhaust is constricted and backpressure is increased.

Project 5: Marine Engine Continuous Emissions Monitoring System

The summarized accomplishments for the reporting period are:

- Performance and emissions comparison of B20 biodiesel (RME)/diesel/glycerol emulsion fuels, B20, and diesel conducted on Quickwater and CAT C2.2 diesel generator
- Upgraded Condensation Particle Counter (CPC) and new Scanning Electrical Mobility Spectrometer (SEMS) received from BMI
- In cylinder monitoring post processing program completed

Results:

BMI SEMS

The BMI 2100 Scanning Electrical Mobility Spectrometer (SEMS) was received during this reporting period. The instrument is a first-of-its-kind, capable of achieving particle size distribution scans at a significantly faster rate than other particle mobility spectrometers currently on the market. The unit is additionally equipped with an x-ray particle charge neutralizer instead of a traditional radioactive neutralizer for ease of use and transport. A preliminary test of the instrument has been conducted for particulate emissions of certified diesel using the laboratory CAT C2.2 marine diesel generator. Figure 10 shows the SEMS derived total particulate number concentration measured over an ISO 8178 load cycle on the CAT C2.2 marine diesel generator. The particle mobility diameter distribution is also collected at each data point as illustrated in Fig. 1. The instrument enables METEL to identify detailed changes in particle mobility diameter distribution as a function of engine load and fuel. The instrument will also provide a real time measure of total soot mass with additional post processing. Comparisons of SEMS derived soot measurements with TEM and gravimetric soot samples are currently underway.

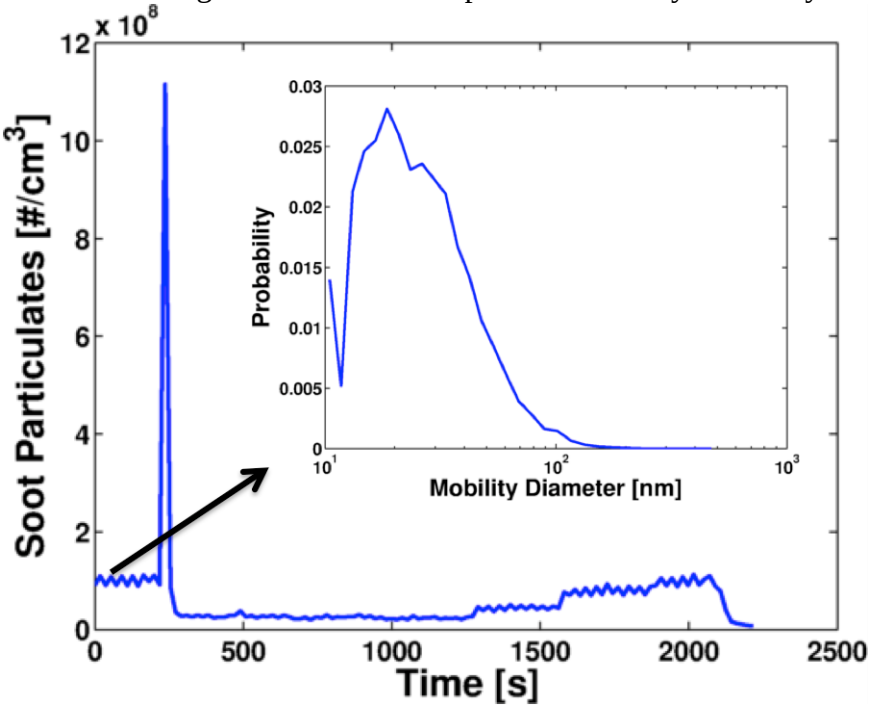


Figure 10: SEMS total particulate number concentration measured for an ISO 8178 load cycle on the laboratory CAT C2.2 marine diesel generator. An example of the particle mobility diameter distribution collected at each temporal data point is also illustrated.

In-Cylinder Monitoring Post Processing

Post processing functions for the in-cylinder monitoring data were completed during this reporting period. In-cylinder heat release rates, fuel burn rates, and other important properties can be calculated from the pressure vs. crank angle data. It was then discovered that the current CAT C2.2 is an indirect injection diesel engine, making in cylinder monitoring data difficult to interpret due to the use of multiple combustion chambers. As such, a request was sent out to Caterpillar for a direct injection diesel engine for testing. We plan to receive a direct injection C2.2 replacement during the next reporting period.

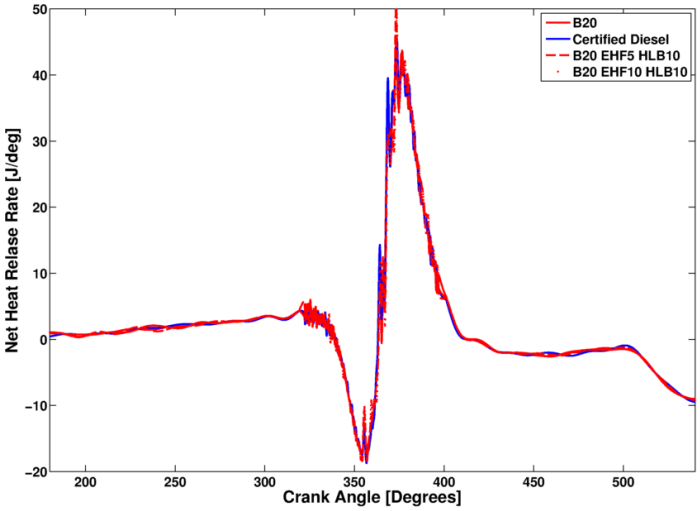


Figure 11: Net heat release rate calculated over 30 engine cycles of the CAT C2.2 marine diesel generator for B20 biodiesel (RME), certified diesel, B20 biodiesel/5% glycerol, and B20 biodiesel/10% glycerol.

Project 6: Algae based glycerin fuel project

The summarized accomplishments for the reporting period are:

- NMR quantification of small molecules in microalgae extracellular media
- Development of headspace CO2 sensor

Results:

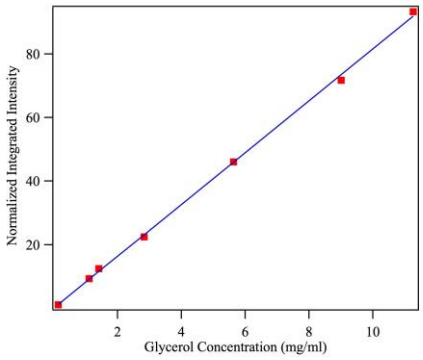


Figure 12. Normalized integrated intensity of peaks in NMR spectra attributable to glycerol versus

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 To that end we investigated both the conditions under which small molecule production is maximized and chemical techniques for detecting and separating those molecules. Figure 12 shows a calibration curve for Nuclear Magnetic Resonance (NMR)-based procedure for quantification of extracellular hydrocarbons.

Optimal environmental conditions for promoting the production of extracellular hydrocarbons in microalgae cultures remain elusive. Figure 13 shows a graph of glycerol production in two cultures of Dunaliella tertiolecta grown in L1 medias (https://ncma.bigelow.org/media/pdf/NCMA-algal-medium-L1.pdf) with differing nitrate and phosphate concentrations. However, even in fertilized cultures, glycerol concentrations have been inconsistent and significantly lower than what has been reported in the literature.ii Lack of control over dissolved CO2 concentrations in microalgae cultures is a concern in this respect. A team of undergraduate students at Maine Maritime Academy is working on the development of a dissolved CO2 sensor and dosing pump as part of their capstone project.

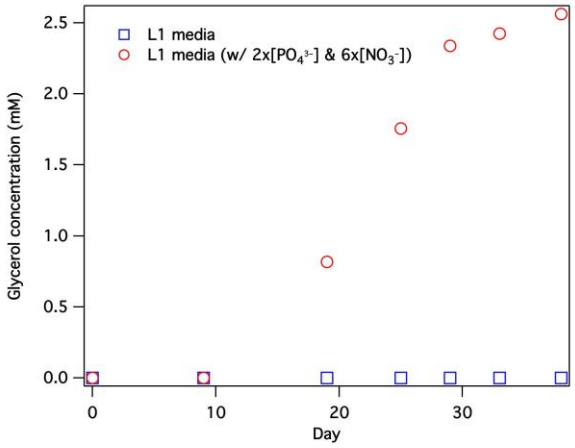


Figure 13. Concentration of extracellular glycerol versus age of microalgae culture (*Dunaliella tertiolecta)*

Project 7: Development of Medium Speed Engine Testing

The summarized accomplishments for the reporting period are:

- Space secured for lab development
- Preliminary system designs completed
- Engine and main equipment ordered

Results:

METEL has secured laboratory space on the MMA campus in Andrews Hall, which is currently under construction and seen below in figure 14 (left), to develop a medium speed heavy fuel test cell. This project will provide the unique capability of testing and evaluating novel fuels, including low sulfur heavy fuel, emulsion fuels, biofuels, and LNG, for performance and engine emissions in a medium speed diesel engine. To our knowledge this will be the only independent facility in the country with these capabilities. The rationale behind the development in this lab is to help the marine and power industry meet the regulatory requirements established under MARPOL ANNEX VI. A Wartsila 6L20, an inline 6 cylinder medium speed diesel generator set capable of burning heavy fuel seen in figure 14 (right), was sourced out to be the test engine for the laboratory. A number of support systems for the engine, including fuel, lubricating oil, and coolant, have been designed and the required equipment have been sourced out to be purchased.

Figure 14: (Left) Andrews Hall on MMA campus, the location of the medium speed engine lab under construction, (Right) Wartsila 6L20 diesel generator set on order for the lab

Education, Workforce development and STEM accomplishments

- $400,000 matching investment made by Maine Maritime Academy in undergraduate transportation engineering training labs. Particularly in power fluids, material testing and electronics.

- Environmental Science Minor developed including 6 new courses which have a transportation focus.. Courses include engine emissions, fuels and other key classes which realate to the environmental impacts of transportation modes. This initiative utilizes the new research and teaching labs developed with METEL's assistance as key

training tools for workforce development in transportation related environmental concerns. The first of these courses is scheduled to be offered in fall 2016.

STEM Events:

- Participated in Maine Engineers Week at University of Southern Maine.
- Contract issued to MMA from the Maine Mathematics and Science Alliance to develop maritime transportation related STEM activities for k-12 students. METEL is co-funding this effort.

Significant Results:

Evaluation work on Diesel/Glycerin Emulsion fuels assisted SCG in securing its 2nd technology patent.

Key Outcomes:

How have the results been disseminated?

Project 1: Diesel/Glycerin Emulsion fuel project

- Data has been included in white papers discussing the benefits and limitations of emulsion fuels and distributed through newsletters
- Data was used by Collaborating Institution (SeaChange Group LLC) to compete for the 2015 SAFE Clean energy Prize. Company was awarded 4th place.

Project 2: Hydrogen Injection Fuel Project

- Nothing to report for this period

Project 3: Forest Biomass Diesel fuel project

- One article was submitted to a refereed journal
- Student presentation at the International Bioenergy & Bioproducts Conference in Atlanta, GA won second place student paper award

Project 4: Thermoelectric Exhaust heat recovery generator project

- 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

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

- Complete engine and emissions performance testing on increasing biodiesel content (up to B100) and glycerol emulsion concentration (30 wt%).
- Complete durability testing campaign of emulsion fuels on the vessel Quickwater
- Determine the effects of emulsion particle size on engine and emissions performance

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
- Analyze distillate fractions and prepare diesel blends for engine testing
- Hydro-treat 10 L of TDO oil for fractionation and blending
- Recruit a graduate student to work on either TDO or pyrolysis

Project 4: Thermoelectric Exhaust heat recovery generator project
- Complete heat exchanger thermal characterization
- Complete back pressure and exhaust emissions relationship
- Create thermoelectric material to match heat exchanger available heat flux

Project 5: Continuous Emissions Monitoring System
- Continue integration of SMPS
- Equip medium speed engine with in-cylinder monitoring

Project 6: Algae Based Glycerin fuel project
- We are considering exporting some microalgae work to the National Center for Marine Algae and Microbiota (NCMA) at Bigelow Laboratories in East Boothbay Harbor, ME.

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

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
- One under review, two in preparation

Project 4: Thermoelectric Exhaust heat recovery generator project
- Paper published in the Journal of Electronic Materials entitled "Efficiency of a Sandwiched Thermoelectric Material with a Graded Interlayer and Temperature-Dependent Properties"

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:

Other publications, conference papers and presentations:
- Two conference abstracts submitted and accepted for oral presentation
    - International Association of Maritime Universities 2016 Meeting – Vietnam, July
    - Transportation Research Board Sail-to-Satellite – DC, June 2016

- Chi Truong, M. Clayton Wheeler, William J. DeSisto, Paige A. Case and Brian G. Frederick, Pressurized fast pyrolysis of calcium formate-pretreated pine, International Bioenergy & Bioproducts Conference in Atlanta, GA, 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
Harakas, G.N., Eaton, S.J., Kimball, R.W., Braley, B.G. and Ring, R.C. Biodiesel Glycerol Emulsion Fuel Mixtures US Patent #: 9,303,228. April 5th, 2016 Issued to SeaChange Group. METEL assisted in the evaluation of their technology.

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	0.25 Months
Contribution to Program/Project	Leading STEM efforts for program
Funding support	MMA Internal
Collaborated with individual in foreign country	No
Country of Foreign Collaborator	N/A
Travelled to Foreign Country	No
If travelled to foreign country(ies) duration of stay	N/A

Name	Thomas Lokocz
Program/Project Role	Research Engineer
# Hours worked during reporting period	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	Scott Eaton
Program/Project Role	METEL Research Engineer, all projects
# Hours worked during reporting period	540
Contribution to Program/Project	Mechanisms of TDO
Funding support	DOT UTC 0 month (UMaine)
Collaborated with individual in foreign country	No

Name	Patricia Dunford
Program/Project Role	Undergraduate researcher

# Hours worked during reporting period	240 hrs
Contribution to Program/Project	STEM Algae project
Funding support	DOT UTC
Collaborated with individual in foreign country	No
Country of Foreign Collaborator	N/A
Travelled to Foreign Country	No
If travelled to foreign country(ies) duration of stay	N/A

Name	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	Mubarak Khleewee
Program/Project Role	M.S. Student
# Hours worked during reporting period	1040
Contribution to Program/Project	HDO of FAsP oil
Funding support	6 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	1040
Contribution to Program/Project	HDO of phenol
Funding support	6 month (DOT) 0 months (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	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

Name	Karl Olson
Program/Project Role	M.S. Student
# Hours worked during reporting period	520
Contribution to Program/Project	Alternative uses for glycerol
Funding support	3 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.

Exxon Mobile has been working with METEL on the development of the Medium speed Diesel Laboaratory

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?
Environmental Minor adds a practical, hands-on based understanding of transportations emissions and how they are monitored and regulated vital for professional transportation workers understanding of Compliance and emission regulation.

What is the impact on physical, institutional, and information resources at the university or other partner institutions? METEL lab facilities allowed the development of the environmental minor and other educational opportunities for transportation related undergraduate students.

Physical resources such as facilities, laboratories, or instruments;
What is the impact on technology transfer? METEL work evaluating SCG's technology has resulted in a technology patent for them that progresses them closer to commercialization.

What is the impact on society beyond science and technology? Environmental minor also educates Transportation students on regulatory and compliance laws, both domestic and internationally.

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." Bioresource Technology. Vol. 136 pp. 550-555. 2013.