

**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 – March 31, 2019

Reporting Period End Date: March 31, 2019

Report Term or Frequency: This report covers the period from September 30, 2018 May 31, 2019, per the Grant Deliverables and Requirements for UTCs instructions

Signature of Submitting Official:



Richard Kimball

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. Project closed June 30 2018, final report issued.
- Project 2: At Sea testing of a hydrogen injection system on MMA Work Vessel for emissions reduction. Project closed July 2018 final report issued.
- 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 closed Mar 2019 final report issued.
- 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 closed Mar 2019 final report issued.
- 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 closed Mar 2019 final report issued.
- Project 6: Studies the capability of particular Algae strains to produce Glycerin fuel for use as a low cost low emissions transportation fuel. Project closed Mar 2019 final report issued.
- Project 7: Development of Medium Speed Engine Testing Laboratories for Efficiency Improvement and Emissions Reduction Technology Evaluation. Project closed Mar 2019 final report issued.
- Project 8: Sustainability Education and Laboratory Training for Workforce Enhancement Project closed Mar 2019 final report issued.
- Project 9: Efficiency Improvement of Workboats through Hull Form Optimization Develop a high efficiency, advanced hull form for application to the coastal fishing fleet. Project closed Mar 2019 final report issued.

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

What was accomplished under these goals?

Major Activities and Specific Objectives

General METEL accomplishments:

- Completed final report for Glycerin/Diesel Emulsion Fuel and Hydrogen Injection project July 2018
- Completed final report for all remaining METEL projects completed Apr 1 2019
- Delivery of thermal deoxygenation oils for upgrading blending research for testing in METEL diesel engine.
- Studies on salinity shocking to induce algae to excrete glycerin show positive results in increasing algae glycerin output. Results could be applied to increase output of algae farm fuel production.
- Completion of design and validation of a continuous cylinder pressure measurement system using an in-house developed air cooling system installed in medium speed diesel engine lab. System was used effectively for commercial contract test work.
- Completion of two major test contracts for a large oil company using the newly developed medium speed diesel lab total contract value \$275k. Results for client very positive w/ more test contracts coming for summer 2019
- Workforce Development: First two graduates of the environmental minor graduating May 4 2019
- Completion of experimental Work Boat hull at The Landing School in Arundel, Maine

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:

- Project closed and final report issued July 2018

Project 2: Hydrogen Injection Fuel Project

The summarized accomplishments for the reporting period are:

- Project closed and final report issued July 2018

Project 3: Forest Biomass Diesel fuel project

The summarized accomplishments for the reporting period are:

- Prepared 16 different fuel blends of thermal deoxygenation (TDO) oil, hydrotreated TDO (HDO) oil, TDO oil distillate, and HDO oil distillate for physicochemical and emission characterization.
- Completed chemical and physicochemical characterization of different TDO blend stocks and fuels blends in laboratory facilities at Maine Maritime Academy, UMaine's Technology Research Center, and a fuel testing laboratory in Chelsea, MA.

- Project closed and final report issued Apr 2019

Description of accomplishments for Forest Biomass Fuel Project:

Sixteen different diesel fuel blends were prepared by mixing thermal deoxygenation (TDO) oil, hydrotreated TDO (HDO) oil, TDO oil distillate, and HDO oil distillate with Ultra-Low Sulfur Diesel (ULSD). TDO oil blend stocks and different fuels blends were tested for density, viscosity, heat of combustion, carbon, hydrogen, and nitrogen content, cetane number, boiling range distribution, lubricity, carbon residue, acid and base number, and hydrocarbon types. A detailed description of methods and results can be found in the Forest Biomass Diesel Fuel Project's final report.

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

Summarized accomplishments:

- Project closed and final report issued Apr 2019

Project 5: Marine Engine Continuous Emissions Monitoring System

Summarized accomplishments:

- Designed and implemented Air cooled continuous monitored in cylinder pressure system
- Ran in cylinder pressure system successfully for client tests.
- Project closed and final report issued Apr 2019

Project 6: Algae based glycerin fuel project

Summarized accomplishments:

- Results completed for osmotic shocking experiments show significant extracellular glycerin production over non shocking growth.
- . Project closed and final report issued Apr 2019

Description of accomplishments for the Algae Glycerin Fuel project:

The final result of this project was the development and verification of salinity shocking on algae production of glycerol (fuel). The results, when compared to prior work for non-shocking growth showed potential for significant fuel production increase using low salinity growth with periodic salinity shocking could significantly increase production rate over a given period. Results showing about a twofold increase in production were observed and higher rates may be achieved through further optimization.

Project 7: Development of Medium Speed Engine Testing

Summarized accomplishments:

- Second client test contract completed and Customer satisfied stating the results made significant contribution to the direction of their R&D on Marine lube oils
- Currently \$275 of test contracts have been completed and another \$200k of test are planned for the remainder of 2019.
- Project closed and final report issued Apr 2019

Project 8: Sustainability Education and Laboratory Training for Workforce Enhancement

Summarized accomplishments:

- First two graduates of Environmental minor obtained the minor and are graduating May 4 2019. One of the students stated that her future employer cited the minor as a significant factor to distinguish her from other candidates resulting in a job offer.
- Project closed and final report issued Apr 2019

Project 9: Efficiency Improvement of Workboats through Hull Form Optimization

The summarized accomplishments for the reporting period are:

- Completion of model hull at Boat School
- Project closed and final report issued Apr 2019

Education, Workforce development and STEM accomplishments

Activities for this area are described in Project 8.

Significant Results:

Project 1: Diesel/Glycerin Emulsion fuel project

- Project Completed

Project 2: Hydrogen Injection Fuel Project

- Project completed

Project 3: Forest Biomass Diesel fuel project

- Overall, the chemical and physicochemical properties of HDO oil fuel blends and HDO oil distillate fuel blends are closer to the properties of ULSD.
- Project completed

Project 4:

Project 5: Marine Engine Continuous Emissions Monitoring System

- Air cooled continuously monitored in cylinder pressure system implemented and utilized successfully in client testing
- Project completed
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Project 6:

Project 7: Development of Medium Speed Engine Testing

Two large testing program completed for major industrial client; more contracts pending

Key Outcomes:

How have the results been disseminated?

Project 1: Diesel/Glycerin Emulsion fuel project

- TRID final report

Project 2: Hydrogen Injection Fuel Project

- TRID Final report

Project 3: Forest Biomass Diesel fuel project

- TRID Final report

Project 4: Thermoelectric Exhaust heat recovery generator project

- TRID Final report

Project 5: Continuous Emissions Monitoring System

- TRID Final report

Project 6: Algae Based Glycerin fuel project

- TRID Final report

Project 7: Development of Medium Speed Engine Testing

- TRID Final report

Project 8: Sustainability Education and Laboratory Training for Workforce Enhancement

- TRID Final report

Project 9: Efficiency Improvement of Workboats through Hull Form Optimization

- TRID Final report

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: Already completed

Project 2: Hydrogen Injection Fuel Project: Already completed

Project 3: Forest Biomass Diesel fuel project

- Project completed no further work under DOT UTC grant

Project 4: Thermoelectric Exhaust heat recovery generator project

- Project completed no further work under DOT UTC grant

Project 5: Continuous Emissions Monitoring System

- Project completed no further work under DOT UTC grant

Project 6: Algae Based Glycerin fuel project

- Project completed no further work under DOT UTC grant

Project 7: Development of Medium Speed Engine Testing

- Project completed no further work under DOT UTC grant

Project 8: Sustainability Education and Laboratory Training for Workforce Enhancement

- Project completed no further work under DOT UTC grant.

Project 9: Efficiency Improvement of Workboats through Hull Form Optimization

- Project completed no further work under DOT UTC grant

Education, Workforce development and STEM:

- See project 8 above

2. PRODUCTS: What has the program produced?

Publications, conference papers, and presentations

Journal publications:

Project 1: Diesel/Glycerin Emulsion fuel project

- Final report issued

Project 2: Hydrogen Injection Fuel Project

- Final report issued
- Project 3: Forest Biomass Diesel fuel project
- Final report issued

Project 4: Thermoelectric Exhaust heat recovery generator project

- Final report issued

Project 5: Continuous Emissions Monitoring System

- Final report issued

Project 6: Algae Based Glycerin fuel project

- Final report issued

Project 7: Development of Medium Speed Engine Testing

- Final report issued

Project 8: Sustainability Education and Laboratory Training for Workforce Enhancement

- Final report issued

Project 9: Efficiency Improvement of Workboats through Hull Form Optimization

- Final report issued

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

None to report

Other publications, conference papers and presentations:

Oral Presentations:

- None to report

Website(s) or other Internet site(s)

The METEL website can be found at: www.mainemaritime/metel

This is the main website for the DOT UTC Center, describing the center’s mission as well as the projects, key personnel and serves as a repository for the research reports generated by the project.

Technologies or techniques Development of an air cooled continuous in cylinder pressure measurement system. Final system tests completed and utilized for contract testing

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	1 months (Donated time)
Contribution to Program/Project	METEL Technical Director; final reports

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	Thomas Lokocz
Program/Project Role	Research Engineer
# Hours worked during reporting period	100 hrs No DOT UTC hours
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	Asst. Professor
# Hours worked during reporting period	100 hours No DOT UTC hours
Contribution to Program/Project	METEL Final report generation
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	Asst. Professor
# Hours worked during reporting period	100 hours no DOT UTC hurs
Contribution to Program/Project	METEL final reports
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	Clayton Wheeler
Program/Project Role	UMaine Co-P.I.
# Hours worked during reporting period	95.6 hrs
Contribution to Program/Project	Lead P.I. for UMaine effort; Leading the TDO/FAsP project at UMaine
Funding support	0 month (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	Mathew Kline
Program/Project Role	Graduate student
# Hours worked during reporting period	240 hrs
Contribution to Program/Project	HydroTreating of TDO Oil
Funding support	1.5 month (DOT)
Collaborated with individual in foreign country	No

Name	Sampath Karunaratne
Program/Project Role	UMaine Postdoctoral Researcher
# Hours worked during reporting period	346.77 hrs
Contribution to Program/Project	Production of TDO Blendstocks
Funding support	2.17 month (DOT) 0 month (UMaine)
Collaborated with individual in foreign country	No

What other organizations have been involved as partners?

None for this reporting period. Note: Test contract clients have requested anonymity due to the propriety nature of their products.

What other collaborators or contacts been involved?

Nothing to Report

4. IMPACT:

What is the impact on the development of the principal discipline(s) of the program?

The completion of the medium speed diesel lab, as a unique, world class test facility have only just begun to have impact on the R&D of fuels, lube oils and emissions reduction strategies. This

lab is engaged in several major test contracts with key companies in the marine industry, providing direct technology transfer to our industries. In addition, the lab has proven a major asset for the training of our marine engineering students and exposes them to state of the art research relevant to their future.

What is the impact on other disciplines?

Nothing to Report

What is the impact on the development of transportation workforce development?

The medium speed diesel lab is being used in key courses in the marine engineering program to improve the training of marine engineering students by direct, hands-on work on the medium speed diesel systems including maintenance and operation of the engine. Marine engineering students are licensed USCG officers upon graduation and enter the transportation workforce.

What is the impact on physical, institutional, and information resources at the university or other partner institutions? The METEL lab infrastructure has provided new training facilities and opportunities (described previously) as well as outreach to our industry through R&D test contracts.

The environmental minor, developed with funding from the DOT UTC program is complete and the first (2) graduates of this program completed the minor. The minor prepares students for environmental issues that they may face in their professions specifically in the areas of transportation and energy fields. Topics such as combustion emissions, pollution control biofuels are examples of courses which address environmental issues facing the transportation industry

Physical resources such as facilities, laboratories, or instruments;

What is the impact on technology transfer? The continued use of the medium speed diesel lab to support industry testing in new fuels, lube oils and emissions devices is having direct impact on the R&D efforts of our client companies. We have completed two major industrial test contracts to date with two more in the works for next year. The impact of this lab on the R&D efforts of companies is direct, with results directing the R&D efforts of these companies as they develop new products for the transportation industry and address such issues and environmental emission regulations and transportation efficiency. In addition the MSEL facility has the capacity to make significant contributions in the automation and development of autonomous ships, which is a major upcoming development area for the marine transportation industry.

What is the impact on society beyond science and technology? The work being done for industrial clients is in the development of new fuels and lube oils to reduce emissions and improve engine efficiency, addressing directly issues of pollution, climate change (reduction of NO_x and Sox and particulates) as well as economic productivity of the marine transportation industry. The marine industry as well as other transportation sectors are required to meet ever more stringent emissions standards and the METEL facilities are directly capable of contributing to these solutions.

5.CHANGES/PROBLEMS

Nothing to report

6. SPECIAL REPORTING REQUIREMENTS

Nothing to report