Renewable Energy Testing Center

Accelerating the Marketplace for Renewable Technologies

RETC

US Army Contract W15QKN-05-D-0030
Task 5 RETC, WBS # 4.6.0

Final Technical Report

Technikon # 1602-460 NA

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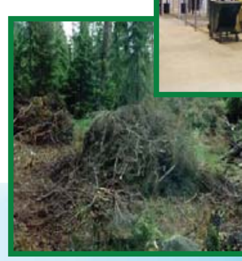

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14. ABSTRACT
Research for the Renewable Energy Testing Center is intended to provide validation of advanced processes that generate renewable energy and reduce energy usage compared to conventional processes. This report covers the work performed under Task #5 of contract W15QKN-05-D-0030. Specific areas covered includes the evaluation of three alternative energy technologies on the conversion of biomass to synthetic gas and liquid fuels. This includes a Red Lion gasifier, ACTI gasification and liquid fuel system, and Pacific Renewable Fuels diesel production system.

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This report has been reviewed for completeness and accuracy and approved for release by the following:

Project Manager	//Original Signed// Jodie Crandell	Date
Vice President	//Original Signed// George Crandell	Date

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ABSTRACT

Research on this project is intended to provide validation of advanced processes that generate renewable energy and reduce energy usage compared to conventional processes for metal casting and other defense applications. This work is a continuation of the work started under the Casting Emission Reduction Program (CERP) CRADA in June 1994 (USAF CRADA Number 94-SM-16), and which is now being conducted under a U.S. Army CRADA with an effective date of 31 March 2003, now expired.

This project had four (4) Research Tasks that included:

- Specific research to evaluate materials, processes and equipment required to generate renewable energy and renewable fuels for their potential to a) produce renewable energy and fuels b) determine the cost effectiveness of technologies and c) determine the environmental emissions from the processes and equipment. The results of these efforts were provided in separate technical reports.
- Perform Emission Measurement Technology research and development that expands the capabilities to measure air emissions for alternative energy processes. The results of these efforts were provided in separate technical reports.
- Provide Technology Transfer, Knowledge Transfer and Outreach to the DOD, EPA, DOE, and other stakeholders to share the results of the research effort. Present papers at Industry and DOD conferences, have exhibits at conferences, and participate in Industry and DOD workshops, seminars, technical conferences, and standards committees. Provide access to results of the research effort by maintaining a website with both secure and public sections on the World Wide Web. The results of these efforts were provided in one (1) technical report.
- Program Management, including Quarterly Reports and this Final Technical report.

The majority of work performed on this Task was conducted by Technikon, LLC at its 60,000 square foot facility containing a fully operational foundry. Emission testing, laboratory research and process development activities were also completed for this project at

this site and by Technikon and authorized subcontractors at off-site locations.

During the performance of the Task 5 the following were completed: a) Evaluations of three (3) alternative energy technologies; b) RETC overview report; c) A technical review of small scale energy technologies; d) A report on the development of the Technikon facility as an alternative energy test site; e) An evaluation of emission measurement technologies required for renewable energy testing; f) an intercomparison of condensable particulate sampling methods – this report documents a test that was performed under a prior CERP contract; g) technology transfer and outreach.

Executive Summary

During the next decade, our Nation's ability to reduce its dependence on foreign oil requires that it maintain its technical capabilities and to provide leadership in technological innovations. The cost of manufacturing to support DOD requirements in industries such as Metal Casting will be challenged by declining research and development resources. Meeting this challenge will require a greater reliance on cooperation among Government, industry, and research organizations.

The development of Renewable Energy Technologies presents a major opportunity for such cooperation. The DOD and industry share the goals of reducing energy and fuel costs needed to support manufacturing. The metal casting industry is very energy intensive and DOD is in need of reducing its energy requirements for both manufacturing and transport. Many new processes are in development that would support these goals, but they are all relatively new and untested. The RETC fulfills the need for a renewable energy testing and validation program that supports DOD and industry requirements. The program would continue with the CERP mission to prevent further loss of metal casting facilities due to noncompetitive processes, energy costs and environmental regulations. Domestic control of this basic industry is critical for national security (military vehicles, ordnance, and ship components) and for U.S. competitiveness of the automobile and heavy vehicles industry.

The Casting Emission Reduction Program was created to respond to these requirements, and the Renewable Energy Testing Center (RETC) is a component of these efforts. The focus of this project is to validate new energy technologies that support the American metal casting industry so that it can continue to deliver quality cost competitive products while having a reduced impact on the environment and reduced energy usage. The Renewable Energy Testing Center (RETC) program is based on the concept of testing and validation of renewable energy technologies related to biomass feedstock with a particular focus on biofuels for transportation. Technikon has a world-class research, demonstration and deployment facility located in the greater Sacramento, California region that is being utilized for this initiative. The RETC program focuses on support of relevant and emerging renewable energy technologies in the area of cellulosic waste and biomass to energy and fuel conversion technologies that would support Department of Defense (DOD) needs for compliance

to Executive Order 13423 that sets goals for the DOD to increase alternative fuel consumption at least 10% annually.

In recent years, the need to produce a lighter, more highly-mobile fighting force has become evident. Critical to this effort is lightweight metals and improved fuel efficiencies. In response to this need, the RETC is focusing efforts on new technologies such as cellulosic energy conversion technologies for the reduction in fuel costs, reduction of air emissions and energy consumption in the production of casting lightweight metals.

The scope of this effort is to provide for the testing, evaluation, qualification, and modification of renewable energy generation equipment and processes, as well as the testing of the hazardous air emissions from these processes. The selected processes would be tested and validated for efficiency in producing energy (electricity & heat) and liquid or gaseous fuels that are required for the metal casting industry and DOD applications. The existing CERP evaluation methodology will be continued throughout the Project and new refinements and enhancements will be added. An existing emission measurement standards and instrumentation protocol will be continued, with new refinements and enhancements added. Technikon will provide engineering, demonstration work, and project management to accomplish the execution of approved tasks through the end of the contract period.

This report covers four (4) major research tasks that were completed during a period of performance from July 2008 through December 2009.

Research Task 1 –*Renewable Energy Technology Validation* – This research task conducted evaluations of alternative energy technologies, produced an RETC overview report, performed a technical review of small scale energy technologies and summarized the development of the Technikon facility as an alternative energy test site.

Research Task 2 – *Emission Measurement Technology* - This task provided an evaluation of emission measurement technologies required for renewable energy testing and an intercomparison of condensable particulate sampling methods

Research Task 3 – *Technology Transfer of Research and Development Efforts* - This task promoted the transfer of technology and knowledge gained in this project.

Following is a summary of major results by research task.

<u>Research Task 1</u> – Three (3) Subtasks were completed:

- 3 Vendor tests – a) Red Lion Gasifier b) ACTI gasification and liquid fuel system, c) Pacific Renewable Fuels diesel production system
- 2 reports: a) Outside technical review of small scale renewable energy systems b) Overview of the Renewable Energy Testing Center (RETC)
- Documentation of site development to accomplish the RETC mission

<u>Research Task 2</u> – Two (2) Subtasks were completed:

- Evaluation of two emission measurement devices for renewable energy testing
- Report on Inter-comparison of condensable particulate measurement methods

<u>Research Task 3</u> - Two (2) Subtasks were completed:

1. Technology and Knowledge Transfer
2. Outreach

<u>Research Task 4</u> – Program Management Activities

1. Six (6) Quarterly Reports
2. One Final Technical Report

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FINAL TECHNICAL REPORT FORMAT

This report describes the technical activities that occurred under Technikon Contract Number W15QKN-05-D-0030, Engineering and Technical Services for Casting Emission Reduction Program (CERP): Renewable Energy Testing Center Task 5. There were four (4) major Research Tasks and seven (7) Subtasks performed under this Task Number. Per DI-MISC-80508, this report follows the guidance provided in the “American National Standard for Scientific and Technical Reports – Elements, Organization and Design.” Since readers may be only interested in a particular Subtask, each of these sections is written as an independent narrative (except where noted). This may result in some built-in redundancy between the Subtask sections.

The first section of the report contains an **Executive Summary**, a brief discussion of the research and results delivered under this project. The second section is the **Introduction and Program Management Overview**, which contains Program Management information as well as a general description for the Research Tasks. For each of the Subtasks, this report contains the following sections:

- Summary – A discussion of the research and results delivered under the Subtask, with emphasis on the findings of the research.
- Introduction – Introduces the subject, the purpose and the scope of the Subtask.
- Methods, Assumptions and Procedures – Discussion of the types of research, methods and operating procedures, by Subtask.
- Results and Discussion – Includes descriptions for the Subtask, a table summarizing Subtask results information, and a discussion of the impact of the results.
- Conclusions – Summarizes interpretations of the Results and Discussions sections.

The end of the report contains an **Appendix** that contains the full Gantt chart and Schedule for this Task Number, and a listing of **Acronyms and Abbreviations** utilized throughout this report.

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INTRODUCTION AND PROGRAM MANAGEMENT OVERVIEW

This project consisted of four (4) Research Tasks and seven (7) Subtasks under which various types of research and activities were conducted. The Research Tasks as directed under the approved scope of work for this Task were as follows:

1.0 RESEARCH TASK – RENEWABLE ENERGY TECHNOLOGY VALIDATION

Technikon will perform specific research to evaluate materials, processes and equipment required to generate renewable energy and renewable fuels for their potential to a) produce a renewable energy and fuels b) determine the cost effectiveness of technologies and c) determine the environmental emissions from the processes and equipment. The results from this research will allow for an evaluation of new suppliers and vendors in the area of renewable energy technologies to determine the extent to which they reduce the environmental impact when compared to current processes used by industry. Technikon will conduct process capability testing that will advance the knowledge base in the area of renewable energy production. The results of these efforts will be provided in separate technical reports corresponding to each of the following subtasks.

Subtasks

1.1 Vendor Test

From evaluation of renewable energy technologies completed under the FY2006 Tasks CERP Energy deliverable, Technikon will provide recommendations to select viable equipment and processes for comparative testing. Technikon will determine cost effectiveness and measure/test air emissions from these new processes and provide a comparison of the selected new processes with industry baseline data.

NOTE: Original PMP proposed 2 tests; 3 tests were performed.

1.2 Baseline Library

Technikon will perform a literature review and conduct research and additional testing as may be necessary to add to or update the Baseline Emission Level Library for conventional energy generation technologies.

NOTE: Original PMP proposed one baseline performance evaluation – RETC overview; a report on "Technical Review of Small Scale Systems" was added.

1.3 New Equipment or Process Development

Technikon will work with suppliers to optimize new technology and provide a demonstration site for renewable energy equipment. This may require modification of test facilities: power, gases, ventilation, etc., that are required to install demonstration or test equipment. As appropriate, Technikon will develop additional processes for renewable energy production. Technikon will test and evaluate the capabilities of these technologies to produce renewable sources of energy.

2.0 RESEARCH TASK – EMISSION MEASUREMENT TECHNOLOGY

Technikon will perform Emission Measurement Technology research and development that expands the capabilities to measure air emissions for all sources that require continuing accuracy improvement. The results of these efforts will be provided in one technical report covering to the following subtask.

Subtask

2.1 Evaluation of Emission Measurement Technologies required for Renewable Energy Testing

Technikon will test, evaluate and validate the operation, bias, and repeatability of laboratory and real time measurement devices for volatile organic compounds, hazardous air pollutants, criteria pollutants, and particulates. This will require a modification to the existing developed CERP measurement hardware and software to measure inputs to and outputs from the process.

2.2 Intercomparison of Condensable Particulate Matter Methods Summary

This Subtask was added in PMP Revision 1, to document the results of a test that was performed under a prior Task.

3.0 RESEARCH TASK – TECHNOLOGY TRANSFER OF RESEARCH AND DEVELOPMENT EFFORTS

Technikon will proactively provide Technology Transfer, Knowledge Transfer and Outreach to the DOD, EPA, DOE, the metal casting industry, and other stakeholders to share the results of the research effort. Technikon will present papers at Industry and DOD conferences (such as the AFS Environmental Conference and SERDP), have exhibits at conferences, and participate in Industry and DOD workshops, seminars, technical conferences, and standards committees. Technikon will provide access to results of the research effort by maintaining a website with both secure and public sections on the World Wide Web. The results of these efforts shall be provided in a technical report corresponding to the following subtasks.

Subtasks

3.1 Technology & Knowledge Transfer

Technikon will seek to deploy materials, products, processes, test methods, and technology results to appropriate DOD and commercial sites supporting the defense industrial base, and to those industries that have an interest in emissions measurement and control. Technikon will conduct seminars, make presentations, produce publications, maintain a CERP Internet website, and conduct other forms of information transfer to facilitate technology and knowledge transfer. Technikon will use multimedia tools as appropriate to support these activities; e.g., printed materials, photographic images, electronic presentations, videos, and CD-ROMs. To help accomplish this, a repository will be established that will be accessible through the Internet as a worldwide web site. Information contained in the repository will consist of technical papers, reports, results and test data, presentations, and briefings. This site will have a secure section for reports for Army approval and a public section for information that is approved for the release to the public.

NOTE: Original PMP proposed 2 conference presentations; 3 conference presentations were made.

3.2 Outreach

Actively participate in technical conferences, workshops, and symposia and interact with environmental associations & organizations and technical societies germane to this Project, to raise the level of public and private sector awareness. Participation will allow the contractor to share findings from this Project, identify possible stakeholders for technology transitioning, and learn firsthand about energy, alternative energy technologies and issues.

NOTE: Original PMP proposed 2 conferences; 6 conferences were attended.

Subtask Details

1.0 Renewable Energy Testing Validation

1.1 Subtask – Vendor Test

Summary

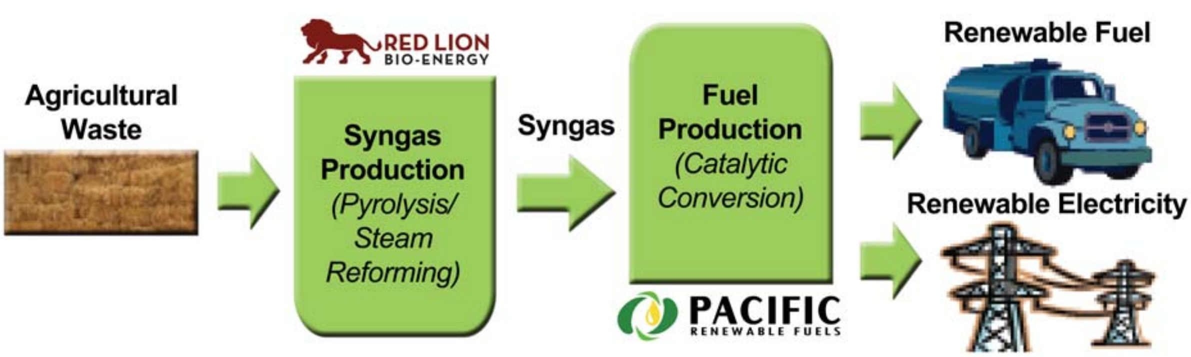
The objective of this Subtask was to assess the operation of renewable energy technologies that would be utilized in a waste to liquid fuel system. Three technologies were reviewed under this task included: 1.1.1 – Red Lion Bioenergy gasification system, 1.1.2 – Pacific Renewable Fuels syngas to diesel fuel system and 1.1.3 – ACTI gasification and liquid fuel system.

Subtask 1.1.1

Introduction

This report contains the results of an assessment of a gasification technology to thermally convert biomass to a clean usable synthetic gas (syngas), that could be utilized to produce a synthetic fuel fed into a generator to make electricity (Figure 1.1-1). Technikon, operators of the Renewable Energy Testing Center (RETC) for the Department of Defense (DOD), was part of a team that analyzed the performance of a pilot thermochemical conversion system owned by the Red Lion Bio-Energy (RLB) Company.

Figure 1.1-1 Process Flow of Integrated Bio-Refinery utilizing the Red Lion System



Methods, Assumptions and Procedures

The primary goal of the RETC subtask 1.1.1 effort is to determine the primary and trace constituents in syngas generated from a commercial scale thermochemical conversion (TCC) system. This 300 dry ton per day (dtpd) system was developed and built by Thermo Conversions, LLC (T.CON) and is currently being operated by Red Lion Bioenergy (RLB) at the University of Toledo. The Desert Research Institute (DRI) had the primary responsibility for the sampling analysis of the syngas in collaboration with Renewable Energy Institute International (REII), Pacific Renewable Fuels (PRF) and Technikon.

This report is the result of multiple test runs over a period of three (3) months (November 2008 through February 2009). Funding for these measurements was supplemented by these other organizations.

Results and Discussion

The results of multiple test runs show that the technical approach being utilized by Red Lion Bio-Energy is producing a higher quality syngas than any historically documented gasification system.

Table 1.1-1 displays the composition of syngas generated from the RLB system compared to the syngas generated from other thermochemical conversion systems using cellulosic biomass feedstocks.

Table 1.1-1 Summary of Comparison of RLB System Syngas to Other Thermochemical Conversion Systems

System and Output Descriptions	Output H_2 (Vol. %)	Output CO (Vol. %)	Output H_2/CO Ratio	Output CH_4 (Vol. %)	Output CO_2 (Vol. %)	Output N_2, Ar (Vol. %)
RLB System (1,000-1,800 °F)	**47 ± 5**	**23 ± 3**	**2.1± 0.4**	**12 ± 2**	**15 ± 2**	**<1**
Circulating Fluidized Bed Air Blown System (from Gasifier) (1,650 °F) *	6	13	**0.46**	6	13	62
Circulating Fluidized Bed Air Blown System (with gas Cleaning/ Enrichment (1,650 °F) *	29	27	**1.1**	<0.01	29	15
Downdraft Air Blown System (1,560 °F) *	22	19	**0.86**	ND	9	50
Fluidized Bed Air Blown System (1,560 °F) *	21	23	**0.91**	<1	10	42
Circulating Fluidized Bed Oxygen Blown System (1,700 °F) *	15	47	**0.32**	18	15	<1
Plasma Arc Air Blown System (>3,000 °F) *	8	22	**0.36**	<1	20	50

*** Note:** Historical data supplied by the Renewable Energy Institute International.

Table 1.1-2 is a compilation of syngas outputs generated from the thermochemical conversion of cellulosic biomass feedstocks using pyrolysis/steam reforming without oxygen (<0.9 volume % o2 input) tested in the RLB system (supplied by RLB from tests performed subsequently to the RETC test).

Table 1.1-2 Composition of Syngas from Thermochemical Conversion

Sample Description	Output H_2 (Vol. %)	Output CO (Vol. %)	Output H_2/CO	Output CH_4 (Vol. %)	Output CO_2 (Vol. %)
Rice Hulls	54	20	**2.7**	12	14
Rice Hulls	51	20	**2.6**	10	17
Wood (Oak)	45	29	**1.6**	13	13
Wood (Oak)	44	24	**1.8**	10	17
Rice Straw	38	22	**1.7**	15	23
Wood (Juniper)	46	23	**2.0**	11	18
Wood (Pine)	47	20	**2.4**	12	20
Wood (Pine)	52	26	**2.0**	6	17
Switch Grass	43	26	**1.7**	12	18

Additional tests performed by RLB indicate the sensitivity of the containment output to the amount oxygen that is allowed to be fed into the system. This is a difficult process variable to control; air leaks need to be minimized. Table 1.1-3 reflects these data.

Table 1.1-3 Effect of Oxygen Input on Syngas Contaminant Levels

Input O_2 (Vol. %)	Output Particulate Organic Carbon (ug/m3)	Output Particulate Sulfates (ug/m3)	Output SO_2 (ug/m3)	Output HCl (ug/m3)	Output Benzene (ppm)	Output Methyl-Napth-alenes (ug/m3)	Output 1,3-Butadiene (ppm)	Output Acet-aldehyde (ppb)
< 0.2	~1,000	2.5	<1.0	<5.0	119	< 1.0	ND*	ND*
0.7	6,400	5.6	3.8	26	960	14	30	47
1.2	57,000	8.1	13	141	1,350	311	84	109
1.8	194,000	27	18	179	1,260	__	9	199
3.0	122,000	201	240	665	__	892	--	368

Table 1.1-4 reflects the published data of other common gasifier systems compared to the RLB results.

Table 1.1-4 Comparison of RLB Syngas Contaminants with Other Gasifiers

Thermo-Chemical Technology	Particulate Organic Carbon (ug/m3)	Particulate Elemental Carbon (ug/m3)	Particulate Sulfates (ug/m3)	Particulate Chlorides (ug/m3)	H_2S (ppb)	NH_3 (ug/m3)	HCl (ug/m3)
RLB System	~1,000	~1,000	2.5	<5	~1,000	760	<5
CFB Air Blown System B (without control)	6,280,000	NT	NT	NT	150,000	2,200,000	130,000
CFB Air Blown System B (with 98% control)	125,600	NT	NT	NT	3,000	44,000	2,600

NT – not tested

Conclusions

The testing of the Red Lion Bio-Energy gasification system has produced promising results. This design shows significant improvement over the previous generations of gasification systems. Testing results support that:

The pyrolysis/steam reforming (without oxygen) system could produce a syngas from a wide variety of biomass resources that has an ideal composition for the production of fuels and the co-production of electricity:

- High quality syngas can be generated from a wide variety of feedstocks
- The ration of H2/CO is in the ideal range of 1.8 to 2.5 for diesel and alcohol fuel production
- The concentrations of contaminants in the syngas are much lower than the concentration of contaminants generated from thermochemical systems that use oxygen or air. This significantly reduces the cost of syngas purification systems
- Several contaminants level specifications have been met.

Subtask 1.1.2

Introduction

This report contains a description of the development and performance testing of the Pacific Renewable Fuels, Inc. (PRF) Synergy™ system. Included in this report is a description of the following:

- History of the Fischer-Tropsch (F-T) chemical process on which the Synergy™ system is based.
- Pacific Renewable Fuels Synergy™ system process.
- Assembly and installation of the PRF Synergy™ system at the Technikon Renewable Energy Testing Center (RETC) facility.
- Testing and validation of the PRF Synergy™ system process.
- Next phase of testing

Methods, Assumptions and Procedures

The objectives of the testing on the PRF system were to:

- Validate the PRF Synergy™ system process design.
- Test the PRF Synergy™ adaptive control system.
- Test PRF's proprietary diesel Terra™ fuel catalysts to determine that the fuel produced meets specifications as a transportation diesel fuel.

The ultimate goal of this demonstration is to provide data that will lead to integration of a Thermochemical Biorefinery system that would be able to efficiently and economically convert a wide variety of agriculture biomass residues to renewable fuels and electricity. This integration will allow distributed commercial-scale bio-refinery plants which will reduce the environmental, health and ecological effects associated with traditional fuel and energy production technologies and reduce reliance on foreign oil.

Results and Discussion

The Fischer-Tropsch (F-T) process is one of the advanced biofuel conversion technologies that comprise gasification of biomass feed stocks, cleaning and conditioning of the produced synthesis gas, and subsequent synthesis to liquid (or gaseous) biofuels. The F-T process has been known since the 1920s in Germany, but in the past it was mainly used for the production of liquid fuels from coal or natural gas. However, the process using biomass as feedstock is still under development. Any type of biomass can be used as a feedstock, including woody and grassy materials and agricultural and forestry residues. The biomass is gasified to produce synthesis gas, which is a mixture of carbon monoxide (CO) and hydrogen (H_2). Prior to synthesis, this gas can be conditioned using water gas shift to achieve the required H_2/CO ratio for the synthesis if this is necessary. The liquids produced from the syngas, which comprise various hydrocarbon fractions, are very clean (sulphur free) straight-chain hydrocarbons, and can be converted further to automotive fuels. F-T diesel is similar to fossil diesel with regard to its energy content, density and viscosity and it can be blended with fossil diesel in any proportion without the need for engine or infrastructure modifications. Regarding some fuel characteristics, F-T diesel is even more favorable, i.e. a higher cetane number (better auto-ignition qualities) and lower aromatic content, which results in lower NOx and particle emissions.

The PRF Synergy™ system (Figure 1.1-2) is designed to convert a mixture of gases into a liquid fuel using a proprietary patent pending catalyst. PRF is developing a series of catalysts designed for a variety of liquid fuels: ethanol, diesel, etc. This unit is to verify at a pilot scale the performance of their technologies. Upon completion of testing at Technikon, LLC the Synergy™ system will be moved to a live gasifier facility in Toledo Ohio where the PRF Synergy™ system will be integrated with the live gasifier syngas production system for field testing.

Figure 1.1-2 PRF Synergy™ System

Gases used in testing PRF systems were compressed Hydrogen and Carbon Monoxide: See Figure 1.1-3.

Figure 1.1-3 Gases Used in Testing PRF system.

The testing conducted at the RETC used bottled hydrogen and carbon monoxide gas to simulate the syngas produced from a biomass gasifier. Dozens of limited test runs were conducted to check out sub-system processes and procedures. Many extended runs were conducted on the pilot plant. Diesel Terra™ fuel was produced that meets California Diesel #2 fuel specifications. The diesel fuel is similar to a traditional F-T diesel fuel which exhibits high cetane values, contains no sulfur and has been shown to reduce NOx and particulates when consumed in existing diesel engines. In lab studies on PRF's Terra™ catalysts, it has been shown that with adaptations to process conditions, a military JP-8 fuel can also be produced.

The results of multiple test runs show that the Synergy™ system produces clean, synthetic diesel that meets specification for a California Diesel #2. Unlike bio-diesel or ethanol, the diesel fuel (Terra™ fuel) produced from the Synergy™ process can be used directly in the transportation infrastructure. Further, when produced from biomass, this diesel fuel results in a dramatic decrease in greenhouse gas production over petroleum derived diesel fuel. A sample of Terra™ Diesel Fuel produced by the PRF synergy process is shown in Figure 1.1-4.

Figure 1.1-4 Diesel (Terra™ Fuel) Sample Produced by the PRF Synergy™ Process Prepared for Chemical Analysis

Conclusions

The PRF Synergy™ system is complete, tested and ready for integration testing with an offsite gasification system. All testing objectives were met to validate the overall design of the PRF Synergy™ adaptive control system, and run PRF's proprietary diesel fuel catalysts in a commercially sized reactor system. Based on testing the PRF Terra™ catalyst diesel fuel meets specifications as a transportation diesel fuel. The ultimate goal of this demonstration was to provide data that will lead to the integration of the PRF Synergy™ system and the gasification system into a thermochemical biorefinery system that will be able to efficiently and economically convert a wide variety of agriculture biomass residues to renewable fuels and electricity.

Subtask 1.1.3

Introduction

This report summarizes a test program to assess the performance of a biomass-to-liquid-fuel technology designed to thermally convert biomass to a hydrocarbon fuel suitable for use in DOD multi-fuel power plants. Technikon, operators of the Renewable Energy Testing Center (RETC) for the Department of Defense (DOD), and American Combustion Technologies Incorporated (ACTI) conducted the test during the week of May 11, 2009 at ACTI's demonstration facility in Paramount, California.

The results of multiple test runs show that the ACTI pyrolysis gasification unit and steam reforming unit can convert biomass into a gas that can be theoretically upgraded to a hydrocarbon liquid through the catalytic Fischer-Tropsch (FT) synthesis process. The FT synthesis could not be demonstrated due to mechanical and processing difficulties. Hence, the operation of the liquid conversion steps is discussed in general terms only.

Methods, Assumptions and Procedures

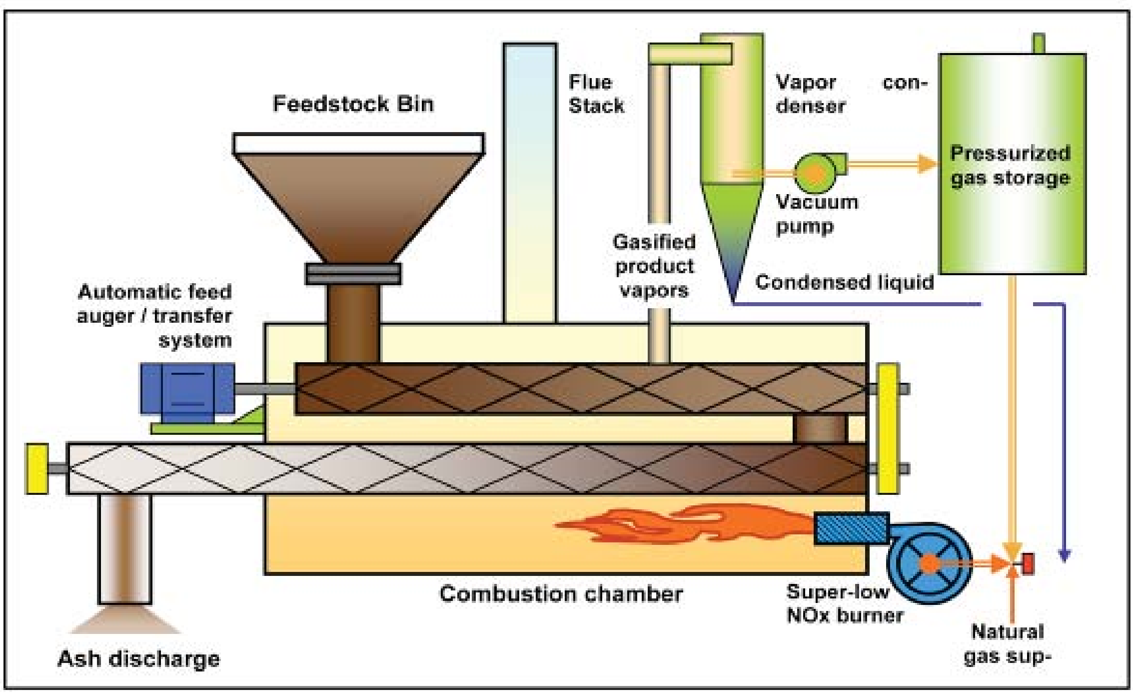
This report has been designed to document the methodology and results of a specific test plan that was used to evaluate the performance of a system employing thermochemical conversion (pyrolysis) and catalytic steam reforming to convert redwood chips to synthesis gas followed by catalytic (FT) hydrogenation/polymerization of the synthesis gas to yield a liquid hydrocarbon fuel. The test plan was designed to determine if the technology demonstrated by ACTI could produce synthesis gas that could be used for the production of liquid fuels and to assess the performance of the subsequent liquid fuel conversion steps.

The primary goal of this RETC Subtask effort is to determine the rate and composition of pyrolysis gas generated in the ACTI gasifier and of the synthesis gas produced in the catalytic reformer. A secondary goal is to determine the composition and production rate of any hydrocarbon fuel fraction suitable for use in military multi-fuel (internal combustion and gas turbine) power plants.

The test program was carried out at ACTI's 22 dry pound per hour (Figure 1.1-5 & 6) development/demonstration facility in Paramount, California, over a period of four (4) consecutive days.

Figure 1.1-5 ACTI Gasifier

Figure 1.1-6 ACTI Gasification System Diagram



The preliminary test samples that were collected by the test team, transferred by chain of custody and analyzed at approved outside labs. The resulting data were reviewed by Technikon team members to ensure completeness, consistency with the test plan, and adherence to the prescribed quality analysis/quality control (QA/QC) procedures. Appropriate observations, conclusions and recommendations were added to the report to produce a draft report. The draft report was then reviewed by senior management and comments incorporated into a draft final report prior to final signature approval and distribution.

Results and Discussion

The major pyrolysis gas constituents that were measured are summarized in Table 1.1-5.

Table 1.1-5 Measurement of Major Pyrolysis Gas Constituents

Component	Average Concentration (vol %)	Concentration Range
H_2	22.9	22.1 - 23.8
CO	29.4	27.6 - 30.9
CO_2	17.5	17.2 – 18.0
CH_4	12.4	12.1 - 12.8
C_2H_6	1.6	1.5 - 1.6
C_2H_4	4.1	3.8 – 4.4
C_2+	3.5	3.2 - 3.9
N_2	8.0	4.8 - 10.1
Ar/O_2	0.7	0.7 - 0.7

Table 1.1-6 summarizes the synthesis gas constituents that were measured. This data was obtained from gas analysis using bag samples sent to an outside lab. The original test plan called for gas sampling, and analysis, in real time using a Nova Analytical Systems Multi-Gas Analyzer. However, the Nova analyzer experienced calibration and stability problems that could not be solved in a timely fashion.

Table 1.1-6 Measurement of Synthesis Gas Constituents

Component	Average Concentration (vol %)	Concentration Range
H_2	47.4	39.2 - 55.5
CO	35.6	24.3 - 46.9
CO_2	9.0	3.9 - 14.1
CH_4	1.6	0.6 - 2.5
C_2H_6	0.1	0.0 - 0.1
C_2H_4	0	0
C_2+	0	0
N_2	6.2	5.2 - 7.1
Ar/O_2	0.2	0.0 - 0.3

Table 1.1-7 summarizes the liquid hydrocarbon components to be measured from the ACTI Slurry FT reactor (Figure 1.1-7). Note that due to inability to stabilize the system, no liquid fuel was produced during the test period.

Table 1.1-7 Liquid Components

Component	Concentration
Iso-Butane	Not available
n-Butane	Not available
Butene	Not available
Iso-Pentane	Not available
n-Pentane	Not available
C_6 –C_8+ Hydrocarbon	Not available

Synthesis gas from the reformer is combined with H_2, CO and light hydrocarbons recycled from the product recovery stage then compressed to approximately 450 psig by CP-3 and introduced to the bottom of the slurry reactor. The ascending gas bubbles commingle with solid catalyst pellets suspended in a high-molecular weight reaction fluid at approximately 475 °F. Liquid dispersion and gas contacting are enhanced by mechanical agitation. The Fischer-Tropsch reaction can be generally characterized: CO + catalyst => -CO*; -CO* + $2H_2$ => $-CH_2-$ + H_2O. Carbons continue to add to the growing $-CH_2-$ chain until the molecule desorbs from the catalyst surface. The distribution of molecular weights in the hydrocarbon product is strongly dependent on the properties of the catalyst. Hydrocarbon vapors leaving the slurry reactor (Figure 1.1-7) are separated in the hydrocarbon recovery section and higher molecular weight wax products are recovered from the reaction medium through a sintered metal filter.

Figure 1.1-7 Fischer-Tropsch Slurry Reactor

Conclusions

- The ACTI pyrolysis gasifier is well designed and is fully serviceable for the proposed mission. The performance of ACTI's follow-on gas-to-liquid conversion unit could not be assessed directly due to operational problems experienced during the test.
- ACTI's approach to the gas-to-liquids conversion process emphasizes simplicity

above efficiency and operability. This is not unusual in demonstration facilities. However, potential customers need to ensure that philosophy is not carried over into units designed and constructed for operation in the field.

- The selection of slurry reactor technology offers the best FT synthesis option for the ACTI target market. It accepts a wider range of H2 to CO feed mixtures, offers better temperature control and allows simpler catalyst maintenance than does the alternative fixed bed reactor technology.
- Because a combination of factors the ACTI system was not capable of demonstrating the conversion of syngas to a liquid fuel. The manufacturer has since been refining his design and potentially will solve his production problems.

1.2 Subtask – Baseline Library

Summary

The role of RETC in this development process is to provide the industry with an independent measurement laboratory for evaluating the performance of renewable energy and renewable fuels technologies with respect to robustness, safety, energy efficiency, environmental effectiveness and other key performance specifications. The RETC, and the oversight of the RETC staff, brings together technology developers, government entities and universities in a facility that allows the kind of testing needed to bring renewable energy systems to the commercialization phase. It also allows developers to integrate technologies that are needed to supply a complete waste to energy system at an accelerated pace and at a significant cost reduction. Present state and federal grant structures are relatively inflexible and make it difficult for the smaller developers to submit applications since they do not have the data needed to prove the effectiveness of their technologies. The RETC fills this gap in funding and accelerates renewable energy commercialization.

A major roadblock to commercialization of renewable energy technologies is that the smaller manufacturers need a place to demonstrate their pilot units and validate energy and environmental data. Smaller manufacturers are very important to the overall renewable energy initiative since they can frequently meet the needs of both the DOD and other energy consumers on a smaller scale than larger energy producers. Smaller renewable en-

ergy production facilities can be located closer to the "point-of-use" of the energy produced or at the "point-of-generation" of the biomass feedstock. The DOD can use the smaller renewable energy facilities at the location of the deployed forces, using locally available biomass feedstock, rather than transporting fossil fuels to those locations. Municipalities, agriculture, and industry can likewise locate the smaller scale units closer to the point-of-use or point-of-generation to gain additional energy savings not possible with larger scale centralized energy production facilities.

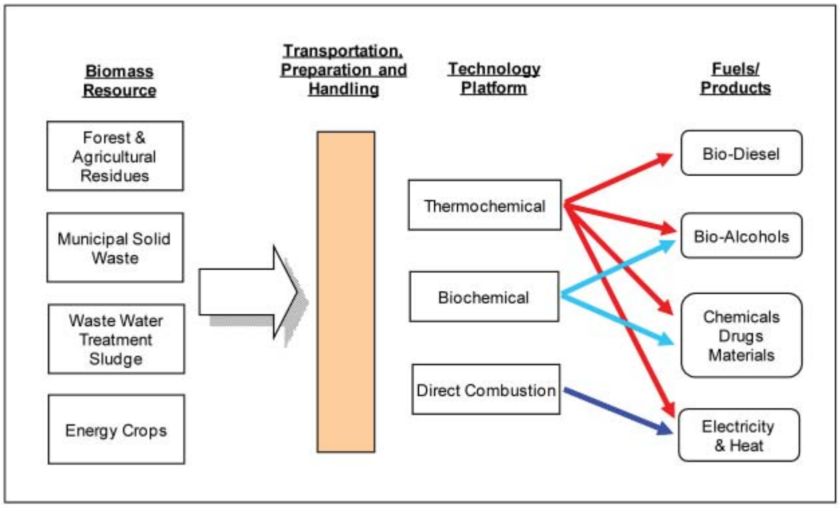
Under this subtask the goal was to document the historical and current biomass to energy technology platforms available to determine which technologies meet the requirements of being used for the production of biofuels from a variety of biomass feedstock. The results of this research are presented as two studies of available biomass to energy technologies. The actual process of producing biofuels from biomass involves two distinct process steps. The first is the production of a syngas of the required quality and composition and the second step is a process to convert the syngas to a liquid fuel. The second step is typically performed by a catalytic liquefaction process.

Introduction

Using funds from a previous DOD contract, Technikon commissioned a research study into the existing and historical renewable biomass to biofuel technologies and published the results of the study in April 2008. This report "Biofuel from Biomass", 1413-540 NA, US Army Contract W15QKN-05-D-0030, summarized the potential viability of various technical approaches used for the production of biofuels from renewable biomass (cellulosic) resources.

This report stated that an estimated 450 organizations worldwide have developed technologies for the conversion of biomass to biopower and/or biofuels. These technologies were classified into three processes: thermochemical, biochemical, and integrated processes. These three processes, or pathways, are shown in Figure 1.2-1.

Figure 1.2-1 Biofuel and Bioenergy Pathways



The report concluded that the thermochemical pathway is the most promising for the production of biofuels and or/biopower from biomass.

Under this contract Technikon refined its review of technologies to identify thermochemical biorefinery technologies. The first report was commissioned to an outside expert organization; BBI International who also publishes the Biomass, Ethanol and Biodiesel magazines. A second report was done internally on the methods and technologies identified by the RETC for our first round of development and testing.

Methods, Assumptions and Procedures

For the first report BBI was charged with performing initial review on the companies and technologies that meet the criteria required by Technikon. This front-end vetting process is designed to improve the quality of, and reduce the timeframe associated with, technology supplier selection by Technikon.

The project scope was straightforward and had two major components:

- Identify companies conducting research or producing equipment that gasifies biomass, particularly wood chips, into high quality syngas and/or utilize Fischer-Tropsch catalytic liquefaction technology to convert syngas to liquid fuel for diesel vehicles; and

- Perform a review of available technologies to produce a vetted list of companies that meet the following criteria:
- Design / manufacture “small-scale” gasifier or F-T unit – capacity of 1-25 tons of feedstock input per day (tpd). 1 ton of biomass feedstock is approximately equivalent to 13 million Btu. A system with 25 tpd input can conceivably produce 4 MW of thermal power (MWth), 1.2 MW of electrical power (MWe), or 35 barrels of liquid fuel per day. Note that this is a generalized figure, and does not account for individual system inefficiencies.
- Has production-scale unit commercially available, or in latter stages of development.
- Demonstrates proficiency and knowledge of craft.
- Emphasis placed upon companies that produce integrated system in-house, or have developed a business relationship with a partner company to produce integrated systems.

In the second report (1602-121) Technikon defined the method and procedures for equipment to be reviewed for and accepted for testing. Additionally we defined our goals for the testing and validation procedure:

Suppliers or other outside parties can submit new technologies for testing at the RETC. The technology assessment/performance testing can take place at RETC, McClellan, CA or at remote locations within the United States. An application for testing is submitted to RETC for review. The applicant will agree to provide the following information, equipment, and technical support to RETC:

- Technology supplier will supply equipment, catalyst, or processes for testing. The testing may be performed either off site or at the RETC facility at McClellan, CA.
- Data to support the viability of the technology must be submitted to RETC prior to the technology being reviewed for testing. The supporting date should quantify all the inputs and outputs including biomass, air emissions, solid waste, energy, and water. These data will include the energy content of the biomass feedstock used for

the performance test. (Not all of these data may be available at this stage of development.)

- Nondisclosure agreements (NDA) will be signed by RETC reviewers if requested.
- Testing selection decisions and testing sequence will be determined by the RETC team.
- RETC may request that the technology supplier cover the cost to set up the equipment for testing at the RETC facility as well as its removal after the test is completed.

Once a test application is received by RETC, and approved for testing, the technology will be added to the list of technologies being scheduled for testing. The test schedule will depend on the availability of the equipment, available funds, and the number of suppliers accepted for testing. During the actual performance test the technology supplier will provide the following materials and support to RETC:

- The technology supplier will provide test input materials; wood waste, rice straw, etc for the technology test. The supplier will also be responsible for the cost of removal of all unused feedstock and byproducts.
- The test plan will be developed by the RETC team and approved by technology supplier prior to scheduling the performance test.
- Establish testing period and number of cycles for statistical repeatability.
- Establish equipment needed to meter inputs and outputs and establish protocols to measure or test other materials.
- Establish environmental testing requirements
- Air emissions
- Water quality
- Waste testing and measurement
- Intermediate and output product quality testing protocols.
- The technology supplier will supply support staffing for set up and testing periods for the equipment or process.

- The RETC staff will be responsible for measurement of all inputs and outputs from technology supplier's equipment or processes.

Once the performance testing is completed, RETC will complete a technology assessment for the technologies tested. The technology assessment will be written once all test results are returned to RETC and all QA/QC data validation procedures have been completed. The technology assessment will include the following:

- An RETC technology assessment will be prepared from each performance test completed.
- The report will describe the technology being tested.
- Include pictures and process schematics.
- The report will quantify all system inputs and the outputs during the testing period.
- The final and intermediate outputs of the process or equipment will also be analyzed. The syngas produced may be the final output or used to power a combined heat and power (CHP) system or used in an integrated process to produce liquid fuel.
- Gas stream analysis if a syngas is produced
- Analysis of the liquid fuel if produced as a primary or secondary product.
- Output from a CHP process when used.
- Energy efficiency – The report will include an energy balance and energy efficiency calculations.
- Environmental impact – The report will include all environmental data collected during the performance testing.
- Air emissions
- Water discharges
- Waste streams and by-products analysis
- GHG Emissions and/or offsets
- Economic Viability – Information related to the cost effectiveness of the processes

tested will be provided if RETC receives sufficient cost data to perform the analysis.

- Insertion Potential – An assessment will be made to determine the most viable commercial market for the technology being assessed.
- The report will be prepared by the RETC staff and reviewed by the Army prior to approval.
- The technology assessment will also be supplied to the technology supplier for review prior to being made public on the RETC website. The technology supplier has the right to remove any proprietary information that it does not want made public, including company name. The results will not be removed from the test report.

Every effort will be made to properly portray the technology supplier's processes and products in an objective manner. Test protocols will be reviewed with the technology supplier prior to the performance test and energy balances will be provided in the technology assessment with all information gathered during the performance tests.

Results and Discussion

In the BBI report they review over 100 technologies and came up with the three possible companies. While a range of technology options were reviewed for this study, the preferred candidates produce an integrated gasification and catalytic liquefaction system. At the current development stage of the industry, there are no commercially produced integrated systems of the scale required for a mobile, deployable unit. However, several companies have built pilot-scale units and are within 12-18 months of commercialization. Based upon the information received through the analysis process, the recommended suppliers are (in no particular order of rank):

Community Power Corporation

Founded in 1996, Community Power Corp. (CPC) has an extensive history of producing gasification/CHP units. CPC's most recent project was a field-deployable unit that gasifies encampment waste to produce fuel for power. The company has also developed and built a pilot-scale F-T liquid fuel production unit integrated to CPC's flagship 'BioMax' gasifier/CHP unit. Commercial availability of the technology is expected in 12-18 months. CPC is the only sole-source integrated system supplier in this analysis.

Emery Energy Company / Radian Materials and Selected F-T Partner Company

Emery became involved in the gasification field in the 1990's. The company built several commercial systems, and has recently launched a subsidiary, Radian Materials, to pursue biomass feedstocks. Neither the parent company nor the subsidiary currently produce a 25 tpd or smaller systems commercially, but have produced a modular, mobile gasifier/CHP unit in the past. The company is currently building pilot-scale units for F-T production with technical assistance from several companies and organizations. Commercialization of the technology is expected within a 2-3 year timeframe.

Velocys, Inc. and Diversified Energy Corporation or Selected Gasifier Partner Company

Velocys, Inc. is one of a very few catalyst companies focusing on the small-scale liquid fuel production arena. The company has developed and recently completed testing on a 'micro-channel' F-T catalytic liquefaction unit. The company has announced a partnership with Diversified Energy Corporation to produce integrated systems, but is also working with other gasifier suppliers. Diversified Energy is still in the R&D stage with its technology. Commercial units from any type of partnership are expected within 2-3 years.

None of these technologies was past the pilot stage and none were interested in moving their pilot systems to the RETC. We continue to monitor their progress, and to date none have a commercial product.

The RETC tested three technologies under the initial RETC contract.

- Red Lion Bio- Energy – Toledo, Ohio
- American Combustion Technology, Inc – Los Angeles, CA
- Pacific Renewable Fuels – Sacramento, CA

The RETC accepted and started testing on three new technologies under the follow on contract (Task 6):

- PEAT International Plasma Pyrolysis System - Northbrook, IL
- Sierra Energy FASTOX Gasifier - Davis, CA
- Ternion BioFuels – San Jose, CA

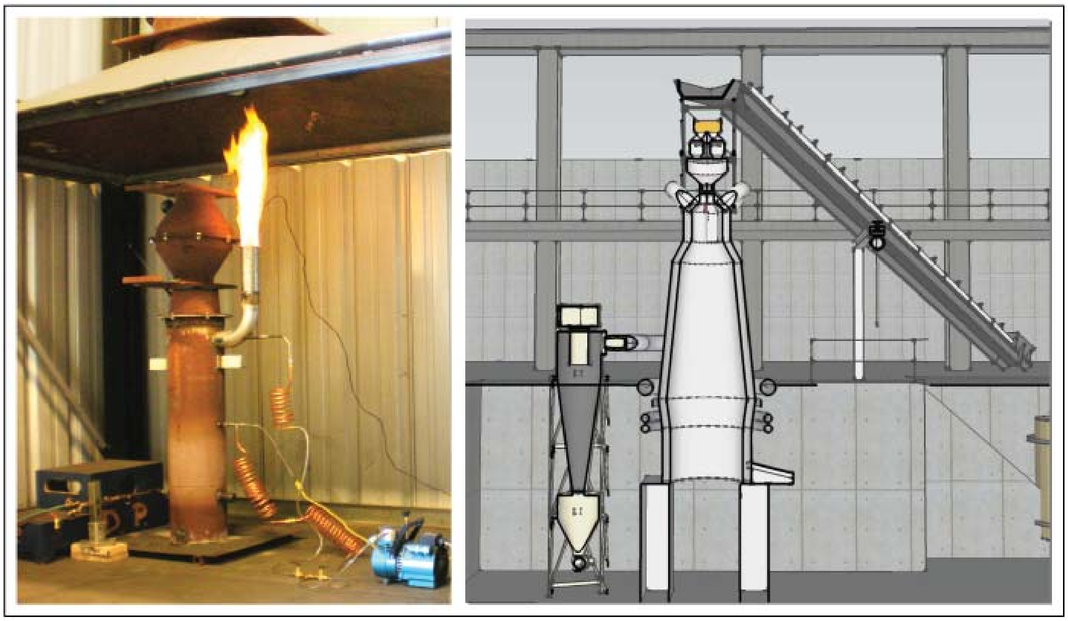
These technologies are in preliminary testing phases and results will be reported as testing is completed.

The PEAT International Plasma System is a pyrolysis technology (see Figure 1.2-2) using a plasma torch to provide the high temperature environment necessary to dissociating molecules into individual atoms. Organic or mixed organic and inorganic feedstock can be fed into the plasma system to produce syngas and a glass or glassy-ceramic matrix, depending on the feedstock.

Figure 1.2-2 The PEAT System Installed at the RETC

The Sierra Energy FASTOX gasifier (see Figure 1.2-3) is a modified blast furnace design that is capable of accepting municipal waste consisting of organic and inorganic materials. The gasifier operates similar to a blast furnace and is very robust in its ability to accept a wide range of charge materials while producing a syngas of acceptable quality to produce liquid fuels or generate electricity.

Figure 1.2-3 Sierra Energy FASTOX Gasifier – Present Test Unit and Proposed Unit at the RETC



Ternion Bio Industries, San Jose, California, has developed a photo bioreactor system (see Figure 1.2-4) using algae to capture carbon dioxide and producing oxygen as an off-gas. The algae grown have a very high Btu content and can be used as a feedstock for producing renewable energy. A technology assessment of the photo bioreactor will consist of determining process specifications, such as ability to absorb CO_2 and algae output. This will include the Btu values for different types of algae and determination of the most energy efficient use of the biomass produced.

Figure 1.2-4 Ternion Bio Industries Pilot System Installed at the RETC

Future Technology Assessments

RETC will evaluate future technology assessment candidates based on the need to fill "data gaps" as well as the availability of qualifying renewable energy process technologies. As additional technologies are evaluated by RETC a matrix of technologies and performance characteristics will be developed to allow RETC to determine which technologies are best suited for a particular application. Technologies that have not yet been tested will be solicited to fill the data gaps identified in this matrix.

Conclusions

The objective of RETC is to provide DOD and industry with an independent measurement laboratory for evaluating the performance of renewable energy and renewable fuels technologies with respect to robustness, safety, energy efficiency, environmental effectiveness and other key performance specifications. It brings together technology developers, government entities, and universities, with the oversight of the RETC staff, in a facility that allows the kind of testing needed to advance renewable energy systems to the commercialization phase. It also allows developers to integrate technologies that are needed to supply a complete waste to energy system at an accelerated pace and at a significant cost reduction. Present State and Federal grant structures are less flexible and almost exclude the smaller developers from making applications since they do not have the data needed to get awarded. The RETC fills this gap in funding and accelerates renewable energy commercialization.

Within the first months of the RETC program, Technikon reviewed the state of the technologies in the waste to energy area. This review revealed that there were no commercial biomass to fuel installations built to date, but there were a multitude of emerging companies that had gotten past the research phase and had or were building pilot systems.

Many of these companies were faced with the same obstacles that prevented them from getting their technology recognized and funded for the commercialization phase:

- The technology was only one of the components needed for a complete commercial plant. A complete green waste to liquid fuel facility contains multiple components that have to be integrated to operate as a plant.

- They needed testing data to validate the performance of the technology.
- They do not have permitted demonstration facility to install and showcase equipment.
- The do not possess trained staff that can operate and test performance of systems.
- The Absence of relationships with other technology providers to accelerate integration needed to produce a complete commercial package for the market.

The approach developed by the RETC team is a missing link in the current funding cycle for renewable energy technologies. Presently only the few companies attracting early venture capital funding are getting past the pilot stage and getting DOE grants. Additionally, many of these are failing prior to any major demonstration of their technology, absorbing a disproportionate amount of federal dollars. The RETC approach leverages government funds and is a means of validating technologies prior to any major commercial or government funding.

1.3 Subtask – New Equipment or Process Development – Development of Test Site

Summary

The Renewable Energy Testing Center mission is to support development, testing and validation of emerging green energy technologies with a particular emphasis on waste to liquid fuel. Most company's technologies that are accepted into the RETC for installation will require support to complete the installation. This can include; a) permitting support b) supplying power to equipment, c) compressed air, b) city or cooling water, d) water drainage, e) exhaust stack, f) supply gases and g) etc. This subtask tracks the work RETC has done under this contract for installation support.

Introduction

This report contains the results of facility preparation efforts to support the testing program for:

- PEAT plasma thermal destruction & recovery (PTDR) -100 plasma gasification system

- Pacific Renewable Fuels' synthetic gas (syngas) to liquid fuel system production demonstration unit (PDU)

Facility preparation includes:

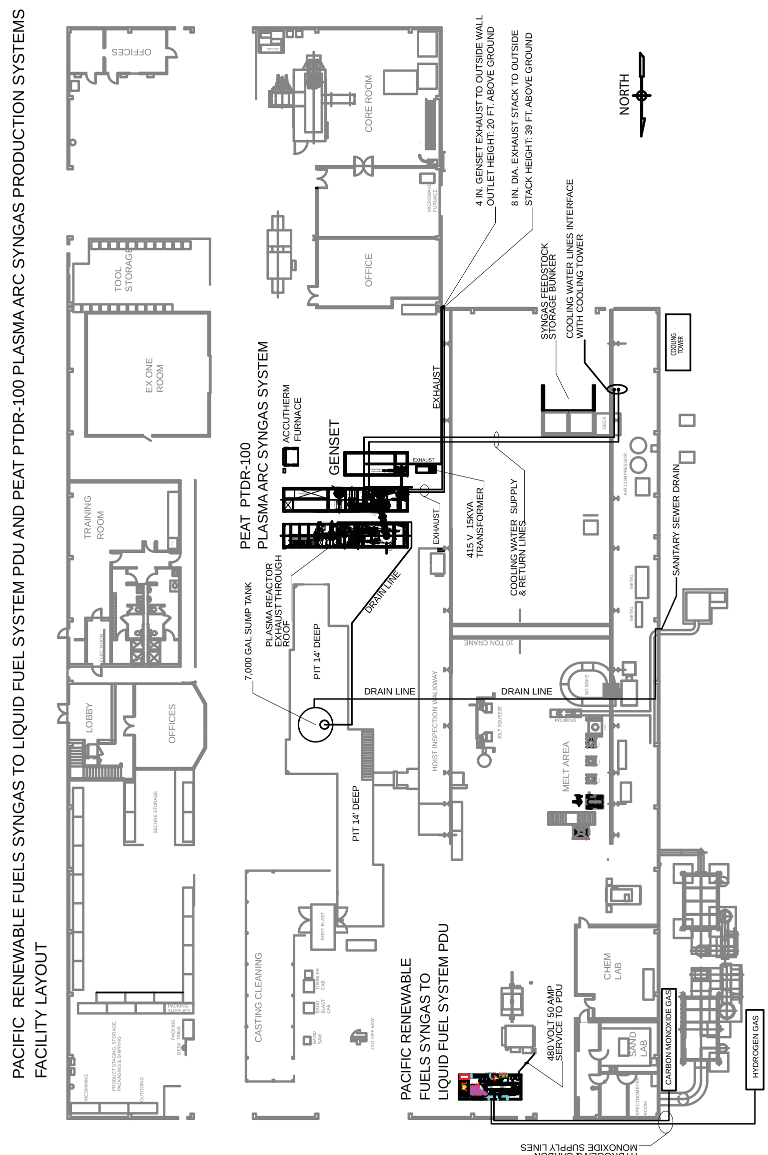
- Equipment staging and assembly areas for the PTDR-100 and the PDU.
- Installation of utilities:
- Electricity for the PEAT PTDR-100 and the Pacific Renewable Fuels PDU including energy monitoring kilowatt hour meters for the PEAT PTDR-100
- City water for the PEAT PTDR-100
- Chilled water for the PEAT PTDR-100
- Waste water drain lines and collection sump tank for the PEAT PTDR-100
- Temporary storage and plumbing for hydrogen and carbon monoxide gases for the Pacific Renewable Fuels PDU

- Exhaust ducting and work platforms for the PEAT PTDR-100:
- Reactor emergency exhaust duct
- Scrubber exhaust duct
- Diesel gas engine driven electrical generator (genset) exhaust duct
- Plasma Reactor Work Platforms

Methods, Assumptions and Procedures

Technikon first has to determine the best location for the proposed equipment based on: Access required b) location of utilities c) operations requirements and d) available room. The layout below shows our 60,000 sq. ft foundry and the relative location of the equipment installed under this contract.

Figure 1.3-1 Project Site Plan for Pacific Renewable Fuels Syngas to Liquid Fuel System PDU and PEAT PTDR-100 Plasma Gasification System



Results and Discussion

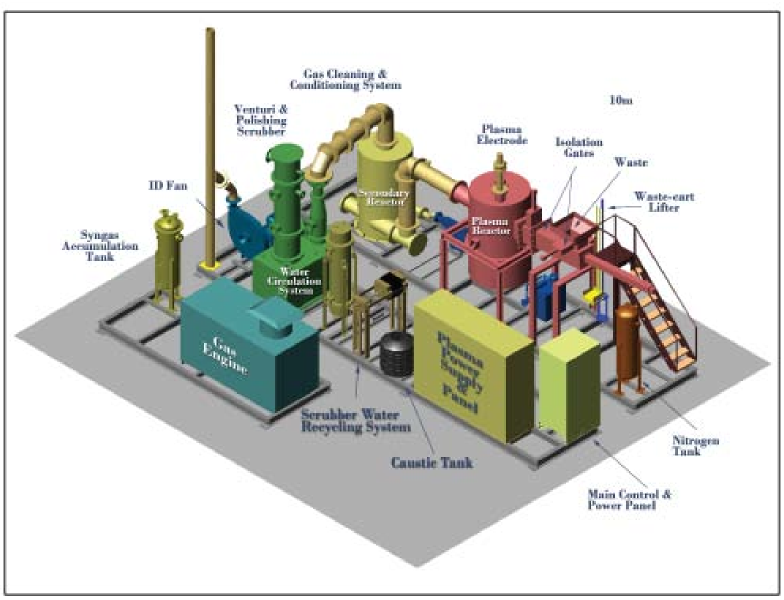
Both the PEAT and the PRF unit were successful installed and operated during the projects period of performance. One lesson learned was that the equipment suppliers required more support than was initially anticipated. This will be a common problem when dealing with going from the drawing board to the pilot unit. Meeting EPA and OSHA requirements also was an area that we needed to support both PEAT and PRF.

PEAT Plasma Furnace and Gas Cleaning System

The PEAT system is designed to reduce materials to their basic building block elements using a high temperature plasma field. Organic or mixed materials feedstock is hand fed into unit at up to 130 lbs per hour. The output is a synthesis gas (CO, H_2) and small volumes of miscellaneous gases that can be processed to provide electricity or liquid fuel. All inorganic materials are converted into a glass slag. Generated syngas then has three options for processing:

- Exhaust mode – syngas goes to thermal oxidizer to burn off all VOCs, CO and Hydrogen, then passes thru a wet scrubber system for particulate removal and then to atmosphere (worst case and numbers used in emission calculations).
- Power Mode – bypassing thermal oxidizer but going thru wet scrubber and then to genset for electrical production; minor exhaust from genset operation (mostly CO2). Electricity will be fed to existing heat treat furnace which will act as a load bank.
- Liquid Fuel Production Mode - bypassing thermal oxidizer but going thru wet scrubber and feeding syngas to the Pacific Renewable Fuels' catalytic fuel conversion system; output varies with catalyst used: ethanol, methanol, diesel, etc. Unconverted gases return to thermal oxidizer before exhaust.

Figure 1.3-2 Peat PTDR Diagram



Pacific Renewable Fuels' Systems

The Pacific Renewable Fuels' (PRF) Synergy™ system produces clean, synthetic diesel fuel from a variety of feedstocks including biomass, coal, and natural gas. The process includes two stages, first the production of syngas (H_2 and CO) from biomass, coal or natural gas which can be accomplished by gasification (for coal or biomass) or steam reforming processes (for natural gas). Next, the Synergy™ system catalytically converts the syngas into clean, synthetic diesel fuel.

Pacific Renewable Fuels has developed a pilot plant called the Process Development Unit (PDU) system to validate commercial designs. The results of multiple test runs show that the Synergy™ system produces clean, synthetic diesel that meets specification for a California diesel #2. Unlike bio-diesel or ethanol, the diesel fuel produced from the Synergy™ process can be used directly in the transportation infrastructure. Further, when produced from biomass, this diesel fuel results in a dramatic decrease in greenhouse gas production over petroleum derived diesel fuel.

The PRF PDU is designed to convert a mixture of gases into a liquid fuel using a catalyst. PRF is developing a series of catalysts designed for a variety of liquid fuels: ethanol, methanol, diesel, etc. This unit is to verify at a pilot scale the performance of their technologies. Sources of syngas to be tested include various options:

- Proprietary syngas generator that converts natural gas and water to produce a clean syngas (no particulate or other contaminants).
- Syngas from bottled hydrogen and carbon monoxide gases.
- Syngas generated by a gasification unit (PEAT Plasma unit). The syngas from a gasifier may contain elements that affect the life of the catalyst bed. This allows testing and improvements of the system to optimize catalyst life.

Figure 1.3-3 Examples of Gasses being Stored

Conclusion

Facility preparation for the PEAT PTDR-100 and the PRF Process Development Unit is complete. Both systems are 100% operational. Additionally many of the modifications made to the facility will be reusable for future technologies and equipment reducing the cost to the program.

2.0 Emission Measurement Technology

2.1 Subtask – Evaluation of Emission Measurement Technologies required for Renewable Energy Testing

Summary

Emission Measurement Equipment and methodologies is needed to support the mission of the RETC in supplying accurate data on technologies being validated. Under this subtask two pieces equipment were purchased (by Technikon) and accuracy determined. In one case, the Nova Analytical Systems Model 7904CRM, the equipment was returned because of its inability to perform successfully.

Introduction

<u>Nova Analytical System</u>

A report was completed to document the results of a specific test plan that was used to evaluate the suitability of Nova Analytical Systems' Model 7904CRM-AC Multi-Gas Analyzer to acquire thermochemical conversion (TCC) technology data. The test plan was designed to determine whether the Nova analyzer demonstrated acceptable accuracy, stability and repeatability in measuring synthesis gas components (H_2, CO_2, CO and CH_4) in both the laboratory and field environments.

The primary goal of this RETC Subtask effort is to test analytical equipment needed in the measurement of syngas being generated by various gasification technologies. The first piece of equipment tested was the Nova Analytical Systems' Model 7904CRM-AC Multi-Gas Analyzer to acquire thermochemical conversion technology data.

This report is the result of numerous calibration and test runs made over a period of 4 months. The tests were carried out at Technikon's McClellan Park facility and at the American Combustion Technologies Inc. (ACTI) Paramount California site.

Diablo Analytical 5000A Real Time Gas Analyzer

A report was prepared to document the results of specific tests to evaluate the suitability of the Diablo Analytical 5000A Real Time Gas Analyzer to acquire thermochemical conversion technology data. The tests were designed to determine whether the Diablo Analytical RTGA demonstrated acceptable accuracy, stability and repeatability in measuring synthesis gas components (H_2, CO, CO_2, CH_4, N_2, and O2).

Methods, Assumptions and Procedures

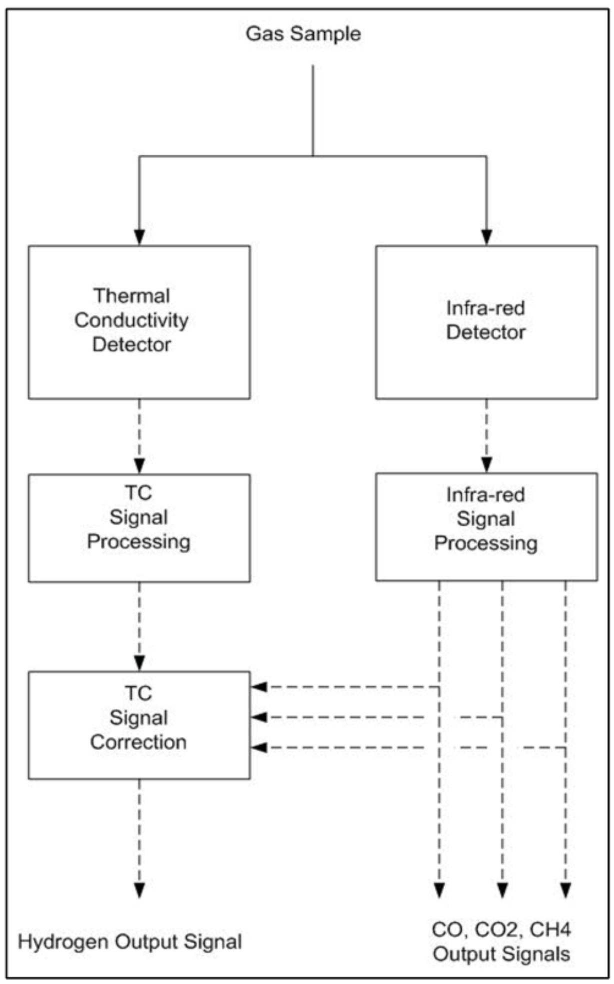
The resulting data on both instruments were reviewed by Technikon team members to ensure completeness, consistency with the test plan, and adherence to the prescribed quality analysis/quality control (QA/QC) procedures. Appropriate observations, conclusions and recommendations were added to the report to produce a draft report. The draft report was then reviewed by senior management and comments are incorporated into a draft final report prior to final signature approval and distribution.

Results and Discussion

Nova Analytical System

The Nova Multi-Gas Analyzer was designed primarily as a hydrogen analyzer employing a thermal conductivity (TC) cell. The instrument is used mainly in the metals processing industry to monitor the hydrogen concentrations during heat treating. In basic terms, a thermal conductivity cell consists of a heated wire whose resistance changes with temperature. When hydrogen flows through the cell the wire it is cooled by an amount proportional to the thermal conductivity of hydrogen. That temperature change is processed by the instrument to yield a hydrogen concentration. The hydrogen reading will be in error if other gases are present in the sample stream since each gas will have a different thermal conductivity. The Nova system compensates for the presence of CO, CO_2 and CH_4 by measuring these gases independently in an infrared (IR) absorption cell using notch filters to isolate the absorption wavelength of each gas. The thermal conductivity signal is then adjusted by the Nova software to compensate for the presence of these gases and a corrected hydrogen signal is output. This is shown schematically in Figure 2.1-1. Nova does not normally output the concentrations of CO, CO_2 and CH_4 to the user, but did so for the analyzer supplied to Technikon since these gases are of interest in synthesis gas production.

Figure 2.1-1 Conceptual Diagram of NOVA Signal Processing Scheme



The programmable logic controller in Nova's Multi-Gas analyzer automatically runs a single-point calibration of the infrared detector (span 1) and the thermal conductivity detector (span 2). At Nova's recommendation, Technikon purchased a certified gas mixture (33% CO, 33% CH_4, and 34% CO_2) to calibrate the infrared detector and a second cylinder of ultra-pure hydrogen was purchased to calibrate the thermal conductivity detector.

In addition to the single-point calibration, Technikon applied serial dilutions of the four component gases (in nitrogen) to permit multi-point calibration of the analyzer as a function of gas concentration for each component gas. The multipoint calibrations generated curves of concentration versus output voltage. These calibration curves were quite linear and the equations describing them were programmed into data logging software to convert the analyzer's raw output voltages into real-time gas concentrations.

During the period in which Technikon had custody of the instrument it did not meet the minimum operational requirements for stability and reproducibility for incorporation into the company's testing programs. Specifically, two difficulties were experienced with the analyzer that could not be resolved by Nova:

- The analyzer output for known test mixtures drifted from the calibration curves at a rapid and unacceptable rate;
- Following software adjustments by the factory, the response of the infrared detector evinced a continuous drift when a gas of known composition was placed on the sample port – or removed from the sample port – not reaching a stable, steady level after 15 minutes.

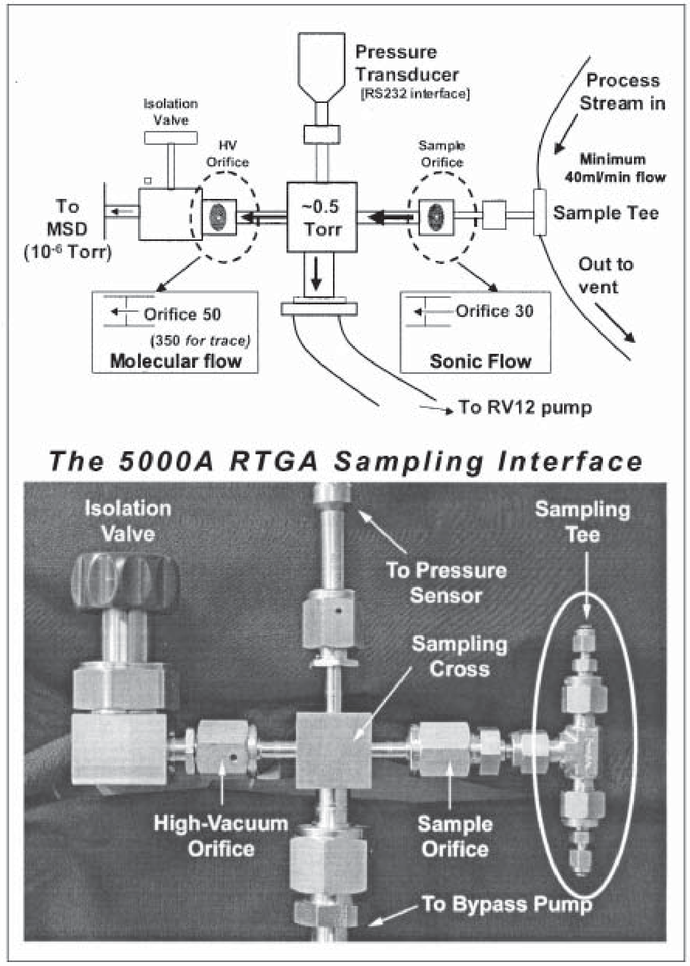
Diablo Analytical 5000A Real Time Gas Analyzer

The Diablo Real-Time Gas Analyzer System consists of three major components:

- an Agilent Technologies model 5975 Mass Selective Detector (MSD)
- the Diablo Analytical 5000A sampling interface and
- The instrument control and data processing software.

The Agilent mass selective detector is an OEM mass spectroscopy (MS) quadrapole-style detector. The detector is supported by a high-vacuum pump and a vacuum controller that maintains the detector in a pressure range of 10^{-6} Torr. The Diablo RTGA sampling interface consists of a heated "cross" that connects an external sample line to the MSD via two restriction orifices with a low pressure plenum between them. The plenum is held at 0.5 Torr by a roughing pump and provides a necessary "intermediate state" between the ambient sample and the high vacuum MS detector. The sample interface is shown schematically in Figure 2.1-1. The Agilent MSD is controlled directly by "ChemStation" software. Analytical method creation and data processing are controlled by Diablo's proprietary MS Sensor 3.0 software.

Figure 2.1-2 Sample Interface Shown Schematically



Conclusion

Nova Analytical System

The Nova Model 7904CRM-AC Multi-Gas Analyzer did not meet Technikon's requirements for real-time laboratory and field measurement of thermo-chemical gasification equipment performance. Specifically, the Nova analyzer did not exhibit consistent accuracy and stability during the calibration phase or the calibration check phase of its operation. Nova Analytical Systems attempted to correct these deficiencies over a period of 4 months without success at which time Technikon elected not to accept the instrument and returned it to Nova Analytical Systems.

Diablo Analytical 5000A Real Time Gas Analyzer

The Diablo Analytical 5000A Real Time Gas Analyzer does meet Technikon's requirements for real-time laboratory measurement of thermochemical gasification technology performance provided the inherent limitations of mass spectroscopy are understood. The Diablo Analytical software, however, is problematic and needs to be improved. The Diablo RTGA is not appropriate for testing in the field.

2.2 Subtask – Intercomparison of Condensable Particulate Matter Sampling Methods

Summary

Measurement of particulate matter (PM) from stationary sources is required for compliance to the Clean Air Act. There are several existing methods promulgated by the EPA for sampling PM emissions from industrial stacks, with efforts underway for updating and improving them.

For capturing emitted PM, current methods employ filters and impinger trains for the filterable and condensable particulates, respectively. An alternative method for measuring PM is through the use of a dilution tunnel. In dilution methods, the hot stack gases are rapidly cooled and mixed with cleaned ambient air. Dilution tunnel methods are thought to reproduce the conditions experienced by emissions as they exit a stack, and more accurately measure emitted PM. The sampling methodology of a dilution tunnel permits simultaneous collection of both filterable and condensable PM.

Introduction

The impinger methods are generally thought to overestimate condensable particulate matter (PM) and particulate matter with a mean aerodynamic diameter less than 2.5 microns (PM2.5) emissions because dissolved gases and condensed particles are collected in the impinger train in addition to condensable gases. These methods positively bias the mass emission rate because the impinger solution contains water-soluble gases as well as condensable PM. It is also believed that filter methods that use filters taken at stack temperatures generally underestimate PM because they do not account for vapors that can nucleate or grow upon cooling and dilution after emission from the stack. A previous study showed that an impinger based method gave results 2 to 3 times higher than a dilution tunnel on a metal foundry stack.

Methods, Assumptions and Procedures

The research foundry used for the comparative testing was located at Technikon LLC, in

McClellan Park, CA. Testing was from July 28-31, 2008.

Eight replicate test pours on individual molds, each containing four gear cavities, were conducted. A single mold was placed on a test stand that was enclosed in an emission hood that meets EPA Method 204 requirements for a total temporary enclosure (TTE). The initial sand temperature was maintained at 26–32 °C and the system process air temperature in the hood enclosure was kept at 43 °C. Furfuryl alcohol no-bake type sand molds were poured with Class 30 gray iron at 1427–1482 °C through an opening in the top of the enclosure. At the conclusion of the pouring time, the opening was covered for the duration of the test. A complete casting cycle consisted of a 45-min period that included the metal pouring and cooling processes, a 15-min shakeout of the mold, and an additional 15-min cooling period following shakeout. The total casting cycle and sampling time was 75 min.

Method EPA OTM-027, which combines PM10 and PM2.5 cyclones, was used as the front half for the two impinger methods for collection of the filterable particulate, and the EPA CTM-039 dilution tunnel. The condensable PM was collected by two different impinger based methods. One method used was the standard EPA Method 202 wherein hot, filtered sample air passes through a series of four impingers containing deionized distilled water that is surrounded by ice water. The second impinger method tested was EPA OTM-028. This so-called "dry" impinger method utilizes a condenser prior to dry impingers, which are in a water bath kept at 29°C.

Two dilution systems were run concurrently with the impinger methods. One system was a prototype dilution tunnel called the Atmospheric Dispersion System (ADS), by Baldwin Environmental Inc and Desert Research Institute. In this system, there is immediate 20:1 dilution of stack gas with filtered and cleaned ambient air. Particulate size fractionation occurs after dilution using sharp-cut cyclones for both PM10 and PM2.5. There is a 10 second particle formation residence time at 85 °F for formation of condensable particulate.

In the EPA CTM-039 dilution system, fractionation of the particulate is accomplished prior to the dilution tunnel through the use of EPA OTM-027. The PM10 and PM2.5 free sample then travels through a heated probe. In the tunnel it is diluted 20:1 with dry air, mixed and filtered. There is a 0.5 second particle formation residence time at 29°C for condensable particulate.

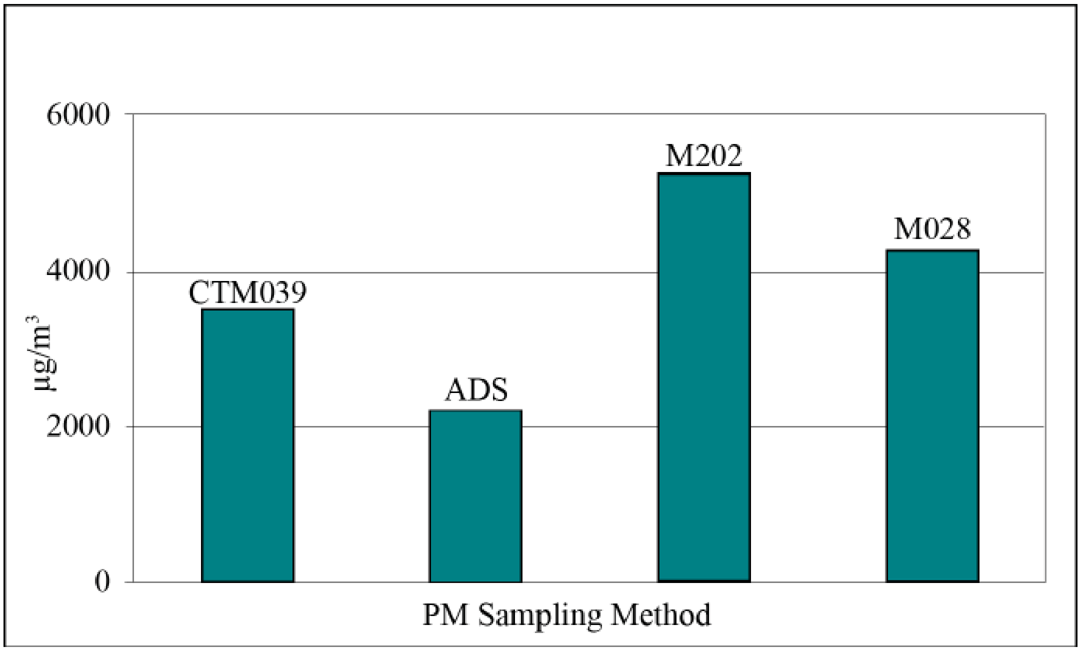
These four methods were collocated in a single plane of the horizontal 6 in. insulated duct located downstream from the TTE and prior to the baghouse. Standard buttonhook-type sampling probes of ¼ in. inner diameter were used to isokinetically remove stack gas samples.

The method of analysis for collected filterable particulate and condensable particulate included gravimetry, organic carbon and elemental carbon (OC/EC), and ion chromatography. In addition, laser desorption time-of-flight mass spectrometry (LD-TOFMS) was conducted for organic characterization by particle size from the DRUM samples. This paper will discuss the gravimetric results

Results and Discussion

Average PM2.5 concentration expressed as $\mu g/m^3$ for all runs for each method are shown in Figure 2.2-1. Both impinger methods result in higher mass concentrations than the dilution tunnel methods, with the ice water impinger method (Method 202) giving a concentration of 5300 $\mu g/m^3$. The difference can be explained by water soluble organic and inorganic gases, such as sulfur dioxide, collected by the ice impinger train. Both Method 202 and OTM-028 were purged immediately after each test run with high purity nitrogen, although it did not seem to remove the positive bias.

Figure 2.2-1 Average PM2.5 Concentrations for Two Impinger and Two Dilution Sampling Methods



In contrast, the ADS resulted in the lowest concentration of PM2.5 at 2200 μg/m^3. Particulate from the walls of the ADS were not recovered, which may explain the low result compared to CTM-039.

Conclusion

The PM mass obtained from stack-sampling is method dependent, with methods that use a hot filter and either a cold or "dry" impinger train to measure condensable PM from stationary sources giving higher emitted particulate mass than dilution based methods. The two dilution methods tested resulted in mass concentrations that correlated well with each other, with the ADS method showing the least variance in the data.

Technikon continues participation with the American Society for Testing and Materials (ASTM) committee trying to establish the condensable PM standards to be used by the EPA. This data is being added to other tests from various industries. The type of dilution tunnel approach is yet to be agreed to by this committee.

3.0 Technology Transfer of Research and Development Effort

Summary

With input from the Contracting Officer's Representative (COR), Technikon identified opportunities for Outreach so that the RETC is better known and more widely recognized than at the beginning of Task 5. This Research Task also included activities responsible for maintaining the CERP web site.

Introduction

Two important Subtasks under the Task 5 are contained under the Research Task – Technology Transfer of Research and Development Effort. Under this Research Task, Technikon was directed to proactively provide Technology Transfer, Knowledge Transfer and Outreach to the Department of Defense (DOD), the Environmental Protection Agency (EPA), the Department of Energy (DOE), and other stakeholders to share the results of the

RETC research effort. The task required Technikon to present papers at Industry and DOD conferences, have exhibits at conferences, and participate in Industry and DOD workshops, seminars, technical conferences, and standards committees. The task also required Technikon to provide access to results of the research effort by maintaining a website with both secure and public sections on the World Wide Web.

The following directives were given to Technikon in the subtasks for this task:

3.1 Subtask - Technology & Knowledge Transfer: Seek to deploy materials, products, processes, test methods, and technology results to appropriate DOD and commercial sites supporting the defense industrial base, and to those industries that have an interest in emissions measurement and control. Conduct seminars, make presentations, produce publications, maintain a CERP Internet website, and conduct other forms of information transfer to facilitate technology and knowledge transfer. Use multimedia tools as appropriate to support these activities; e.g., printed materials, photographic images, electronic presentations, videos, and CD-ROMs. To help accomplish this, a repository will be established that will be accessible through the Internet as a worldwide web site. Information contained in the repository will consist of technical papers, reports, results and test data, presentations, and briefings. This site will have a public section for information that is approved for the release to the public. The site's web address is www.cerp-us.org.

3.2 Subtask – Outreach: Actively participate in technical conferences, workshops, and symposia and shall interact with environmental associations & organizations and technical societies germane to this Project, to raise the level of public and private sector awareness. Participation will allow Technikon to share findings from this Project, identify possible stakeholders for technology transitioning, and learn firsthand about high priority emission control and measurement issues. Technikon will conduct on-site assessments of selected foundries (not more than three) to identify the gaps between existing capabilities/practices and available technologies, and shall recommend improvements for modernization and compliance with Clean Air Act requirements.

Methods, Assumptions and Procedures

This Subtask utilized electronic and digital technology to maintain a World Wide Web Site. Technikon employees maintained, and updated the web site on monthly basis.

Technikon personnel prepared presentations for the purposes of communicating information and results from RETC activities at technical conferences.

Results and Discussion

3.1 Subtask – Technology and Knowledge Transfer

During the execution of Task 5, Technikon delivered the following reports to the US Army CERP Contracting Officer's Representative:

Table 3.1-1 Summary of Reports Delivered

WBS #	Description	Test Date *Scheduled/* Completed	Report *Scheduled/* Completed*	Date *Scheduled/* Delivered*
1.1.1	Gasification Unit Test	11/14/08	6/5/09	6/9/09
1.1.2	PRF Synergy System – Production of Liquid Fuel from Syngas	8/14/09	11/27/09	11/30/09
1.1.3	ACTI Unit Test (Southern CA)	5/15/09	10/2/09	10/5/09
1.2.1	Energy Technologies – Baseline Performance Evaluation	*No tests*	8/5/09	8/7/09
1.2.2	BBI Report: Technical Review of Small Scale Systems	*No tests*	11/20/08	11/26/08
1.3	New Equipment of Process Development – Development of Test Site	*No tests*	11/6/09	11/9/09
2.1	Evaluation of Emission Measurement Technologies required for Renewable Energy Testing – Diablo	*No tests*	10/19/09	10/20/09
2.1	Evaluation of Emission Measurement Technologies required for Renewable Energy Testing – Nova	*No tests*	10/19/09	10/20/09
2.2	Intercomparison of Condensable PM Test Summary	*Performed under another contract*	4/23/09	4/27/09
3.1/3.2	Technical report for Outreach	*No tests*	12/14/09	12/14/09
9.0	Final Technical Report for Task 5	*No tests*	12/10/09	12/10/09

*Note: Underlined dates are completed. Italicized dates are scheduled.

In addition, Technikon updated the web site totally dedicated to CERP/RETC and its activities (www.cerp-us.org). This web site hosts all the reports delivered under all CERP/ RETC contracts and approved for unlimited distribution by the Contracting Officer's Representative and, if appropriate the CERP Steering Committee, which is no longer in existence. See Table 3.1-2 for the public reports that were posted on the CERP web site during the execution of Task 5:

Table 3.1-2 Summary of Reports Posted to CERP Web Site

Test or ID	Task Number	WBS #	Report Title	Date Posted to Web Site
HM	FY2006	1.1.6	Pouring, Cooling and Shakeout Emissions from Shell Step Cored poured with Iron	6/12/08
HRa	FY2005	1.2.4	Mold Making Emissions from ProMetal S-15 Digital Printing Machine	6/16/08
HRb	FY2005	1.2.4	Pouring, Cooling and Shakeout Emissions from Digitally Printed Molds	6/16/08
NA	FY2006	2.2.1	Sampling and Measurement of Methane from Metal Foundry Process Emissions	6/18/08
HV	FY2006	1.1.8	Pouring, Cooling and Shakeout Emissions from Coated Molds Poured with Iron	8/25/08
NA	FY2006	1.4.5	Inorganic Binder Properties Study	8/26/08
HO	FY2006	1.1.5	Emissions from Shell Core Making and Storage	8/28/08
HT	FY2006	2.1.1	CO/CO2 Emission Variability in PCS Operations	10/24/08
NA	FY2006	2.2.2	Particulate Matter Sampling Method Comparison Proposed Test Plan	10/24/08

Finally, under Subtask 3.1, Technikon conducted seminars and made presentations regarding CERP and its research. See Table 3.1-4 for these seminars and presentations.

Table 3.1-3 Summary of Seminars and Presentations

Conference/Meeting Name	Location	Seminar or Presentation	Month and Year
AFS EHS Conference	St. Louis, MO	The Renewable Energy Testing Center	August 2008
AFS Environmental 101	Nashville, TN	The Renewable Energy Testing Center	February 2009
SES Stationary Source Sampling and Analysis for Air Pollutants	Panama City Beach, FL	Results from condensable particulate testing at CERP.	March 2009
Clean Technology Showcase	Sacramento, CA	Exhibit booth	October 2009

3.2 Subtask – Outreach

Under Subtask 3.2, Technikon participated in technical conferences, workshops, symposia and other key meetings in order to interact with various organizations regarding CERP/RETC and its research and to identify potential joint venture projects. Numerous contacts were made to identify additional stakeholders in further CERP/RETC research and in potential transitioning of CERP/RETC research outcomes and technology. See Table 3.2-1 for a summary of the conference participation.

Table 3.2-1 Summary of Conference Participation

Conference/Meeting Name	Location	Contacts/Information	Month and Year
AFS EHS Conference	St. Louis, MO	Foundry clients interested in renewable energy technologies.	August 2008
DMC 2008	Orlando, FL	Numerous – separate follow-up file maintained and available upon request.	December 2008
Tactical Wheeled Vehicle Conference	Monterey, CA	Support of light weighting, energy reduction and rapid prototyping mission.	February 2009
TMS 2009	San Francisco, CA	Support of light weighting, energy reduction and rapid prototyping mission.	February 2009
AFS Metal Casting Congress	Las Vegas, NV	Network with organizations regarding supply chain issues and DoD mission sustainability, which involve energy choices.	April 2009
Strategic Materials Conference	Cleveland, OH	Network with organizations regarding supply chain issues and DoD mission sustainability, which involve energy choices.	April 2009
Cast Metals Coalition Annual Meeting	Sacramento, CA	Network with organizations regarding supply chain issues and DoD mission sustainability, which involve energy choices.	May 2009

Conclusions

With input from the COR, Technikon identified opportunities for Outreach so that the CERP/RETC is better known and more widely known than at the beginning of the Task 5.

APPENDIX 1: EXPLODED GANTT CHART FOR FY2006 TASKS

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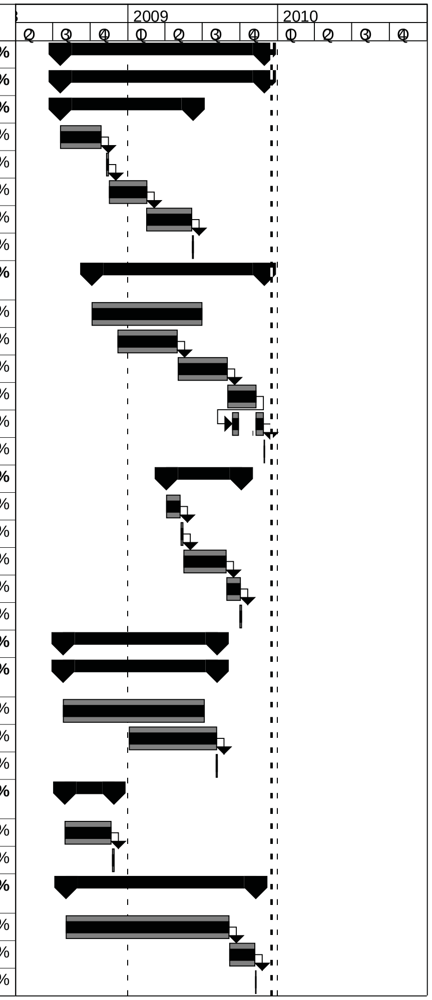
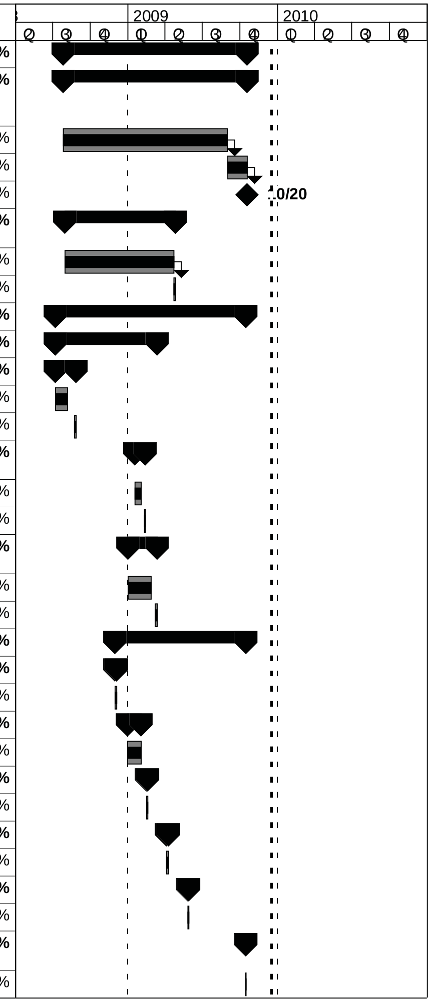
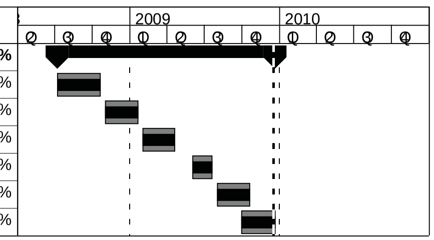
D	WBS	Renewable Energy Testing Center	Baseline Start	Actual Start	Baseline Finish	Actual Finish	% Complete
1	**1**	**Renewable Energy Technology Validation**	**Mon 7/21/08**	**Mon 7/21/08**	**Tue 11/3/09**	**Mon 11/30/09**	**100%**
2	**1.1**	**Vendor Test**	**Mon 7/21/08**	**Mon 7/21/08**	**Tue 11/3/09**	**Mon 11/30/09**	**100%**
3	**1.1.1**	**Gasification Unit Test (TCC Unit)**	**Mon 7/21/08**	**Mon 7/21/08**	**Thu 7/16/09**	**Tue 6/9/09**	**100%**
4	1.1.1.1	Test Preparation	Mon 7/21/08	Mon 7/21/08	Fri 9/5/08	Mon 10/27/08	100%
5	1.1.1.2	Perform Test	Mon 9/8/08	Mon 11/10/08	Fri 12/26/08	Fri 11/14/08	100%
6	1.1.1.3	Test Data Validation	Mon 12/29/08	Mon 11/17/08	Fri 2/6/09	Mon 2/16/09	100%
7	1.1.1.4	Write Report	Mon 12/29/08	Mon 2/16/09	Fri 7/10/09	Fri 6/5/09	100%
8	1.1.1.5	Deliver Report	Mon 7/13/09	Mon 6/8/09	Thu 7/16/09	Tue 6/9/09	100%
9	**1.1.2**	**Syngas to Liquid Fuel Unit Test (Liquid fuels Process Development Unit)**	**Mon 10/6/08**	**Mon 10/6/08**	**Tue 11/3/09**	**Mon 11/30/09**	**100%**
10	1.1.2.1	Install Equipment	Mon 10/6/08	Mon 10/6/08	Fri 3/27/09	Tue 6/30/09	100%
11	1.1.2.2	Develop Test Plan	Mon 12/8/08	Mon 12/8/08	Fri 3/27/09	Fri 5/1/09	100%
12	1.1.2.3	Perform Test	Mon 3/30/09	Mon 5/4/09	Fri 8/14/09	Mon 8/31/09	100%
13	1.1.2.4	Test Data Validation	Mon 8/17/09	Wed 9/2/09	Fri 9/11/09	Mon 11/9/09	100%
14	1.1.2.5	Write Report	Mon 9/14/09	Mon 9/14/09	Fri 10/30/09	Fri 11/27/09	100%
15	1.1.2.6	Deliver Report	Mon 11/2/09	Mon 11/30/09	Tue 11/3/09	Mon 11/30/09	100%
16	**1.1.3**	**ACTi Unit Test (Southern CA)**	**Fri 1/2/09**	**Mon 4/6/09**	**Mon 10/5/09**	**Mon 10/5/09**	**100%**
17	1.1.3.1	Test Preparation	Fri 1/2/09	Mon 4/6/09	Fri 5/8/09	Fri 5/8/09	100%
18	1.1.3.2	Perform Test	Mon 5/11/09	Mon 5/11/09	Fri 5/15/09	Fri 5/15/09	100%
19	1.1.3.3	Test Data Validation	Mon 5/18/09	Mon 5/18/09	Fri 8/28/09	Fri 8/28/09	100%
20	1.1.3.4	Write Report	Mon 8/31/09	Mon 8/31/09	Fri 10/2/09	Fri 10/2/09	100%
21	1.1.3.5	Deliver Report	Mon 10/5/09	Fri 10/2/09	Mon 10/5/09	Mon 10/5/09	100%
22	**1.2**	**Baseline Library**	**Mon 7/28/08**	**Mon 7/28/08**	**Fri 7/24/09**	**Fri 8/7/09**	**100%**
23	**1.2.1**	**Energy Technologies - Baseline Performance Evaluation**	**Mon 7/28/08**	**Mon 7/28/08**	**Fri 7/24/09**	**Fri 8/7/09**	**100%**
24	1.2.1.1	Perform Evaluation	Mon 7/28/08	Mon 7/28/08	Fri 5/1/09	Mon 7/6/09	100%
25	1.2.1.2	Write Report	Mon 1/5/09	Mon 1/5/09	Fri 7/17/09	Wed 8/5/09	100%
26	1.2.1.3	Deliver Report	Mon 7/20/09	Wed 8/5/09	Fri 7/24/09	Fri 8/7/09	100%
27	**1.2.2**	**BBI Report: Technical Review of Small Scale Systems**	**Fri 8/1/08**	**Fri 8/1/08**	**Wed 11/26/08**	**Fri 11/28/08**	**100%**
28	1.2.2.1	Write Report	Fri 8/1/08	Fri 8/1/08	Thu 11/20/08	Thu 11/20/08	100%
29	1.2.2.2	Deliver Report	Fri 11/21/08	Tue 11/25/08	Wed 11/26/08	Fri 11/28/08	100%
30	**1.3**	**New Equipment or Process Development - Development of Test Site**	**Mon 8/4/08**	**Mon 8/4/08**	**Fri 10/16/09**	**Mon 11/9/09**	**100%**
31	1.3.1	Revise Facility for Testing	Mon 8/4/08	Mon 8/4/08	Fri 8/14/09	Fri 9/4/09	100%
32	1.3.2	Write Report	Mon 8/17/09	Mon 9/7/09	Fri 10/9/09	Fri 11/6/09	100%
33	1.3.3	Deliver Report	Mon 10/12/09	Mon 11/9/09	Fri 10/16/09	Mon 11/9/09	100%



D	WBS	Renewable Energy Testing Center	Baseline Start	Actual Start	Baseline Finish	Actual Finish	% Complete
3	2	**Emission Measurement Technology**	**Mon 7/28/08**	**Mon 7/28/08**	**Fri 9/18/09**	**Tue 10/20/09**	**100%**
5	**2.1**	**Evaluation of Emission Measurement Technologies required for Renewable Energy Testing - 2 reports**	**Mon 7/28/08**	**Mon 7/28/08**	**Fri 9/18/09**	**Tue 10/20/09**	**100%**
6	2.1.1	Perform Evaluation	Mon 7/28/08	Mon 7/28/08	Fri 7/10/09	Mon 8/31/09	100%
7	2.1.2	Write Report	Mon 7/13/09	Wed 9/2/09	Fri 9/11/09	Mon 10/19/09	100%
8	2.1.3	Deliver Report	Mon 9/14/09	Tue 10/20/09	Fri 9/18/09	Tue 10/20/09	100%
9	**2.2**	**Intercomparison of Condensable PM Test Summary**	**Fri 8/1/08**	**Fri 8/1/08**	**Mon 4/27/09**	**Mon 4/27/09**	**100%**
0	2.2.1	Write Paper	Fri 8/1/08	Fri 8/1/08	Thu 4/23/09	Thu 4/23/09	100%
1	2.2.2	Deliver Paper	Fri 4/24/09	Fri 4/24/09	Mon 4/27/09	Mon 4/27/09	100%
2	3	**Technology Transfer**	**Wed 7/9/08**	**Wed 7/9/08**	**Fri 5/29/09**	**Fri 10/16/09**	**100%**
3	3.1	**Technology and Knowledge Transfer**	**Wed 7/9/08**	**Wed 7/9/08**	**Fri 4/10/09**	**Fri 3/13/09**	**100%**
4	**3.1.1**	**First Conference Presentation (AFS EHS)**	**Wed 7/9/08**	**Wed 7/9/08**	**Wed 8/27/08**	**Wed 8/27/08**	**100%**
5	3.1.1.1	Prepare Materials for Conference	Wed 7/9/08	Wed 7/9/08	Tue 8/12/08	Wed 8/6/08	100%
6	3.1.1.2	Attend Conference	Mon 8/25/08	Sun 8/24/08	Wed 8/27/08	Wed 8/27/08	100%
7	**3.1.2**	**Second Conference Presentation (AFS Env'l 101)**	**Mon 2/2/09**	**Mon 1/19/09**	**Fri 4/10/09**	**Thu 2/12/09**	**100%**
8	3.1.2.1	Prepare Materials for Conference	Mon 2/2/09	Mon 1/19/09	Fri 3/6/09	Mon 2/2/09	100%
9	3.1.2.2	Attend Conference	Mon 4/6/09	Wed 2/11/09	Fri 4/10/09	Thu 2/12/09	100%
0	**3.1.3**	**Third Conference Presentation (SES Conf.)**	**Fri 1/2/09**	**Fri 1/2/09**	**Thu 3/12/09**	**Fri 3/13/09**	**100%**
1	3.1.3.1	Prepare Materials for Conference	Fri 1/2/09	Fri 1/2/09	Thu 3/5/09	Thu 2/26/09	100%
2	3.1.3.2	Attend Conference	Mon 3/9/09	Mon 3/9/09	Thu 3/12/09	Fri 3/13/09	100%
3	**3.2**	**Outreach**	**Mon 10/6/08**	**Mon 12/1/08**	**Fri 5/29/09**	**Fri 10/16/09**	**100%**
4	**3.2.1**	**First Conference (DMC2008)**	**Mon 10/6/08**	**Mon 12/1/08**	**Fri 10/10/08**	**Thu 12/4/08**	**100%**
5	3.2.1.1	Attend Conference	Mon 10/6/08	Mon 12/1/08	Fri 10/10/08	Thu 12/4/08	100%
6	**3.2.2**	**Second Conference (Tactical Wheeled Vehicles**	**Mon 2/2/09**	**Thu 1/1/09**	**Fri 2/6/09**	**Mon 2/2/09**	**100%**
7	3.2.2.1	Attend Conference	Mon 2/2/09	Thu 1/1/09	Fri 2/6/09	Mon 2/2/09	100%
8	**3.2.3**	**Third Conference (TMS 2009)**	**Mon 2/16/09**	**Mon 2/16/09**	**Wed 2/18/09**	**Wed 2/18/09**	**100%**
9	3.2.3.1	Attend Conference	Mon 2/16/09	Mon 2/16/09	Wed 2/18/09	Wed 2/18/09	100%
0	**3.2.4**	**Fourth Conference (AFS Metalcasting Congress**	**Mon 4/6/09**	**Mon 4/6/09**	**Fri 4/10/09**	**Fri 4/10/09**	**100%**
1	3.2.4.1	Attend Conference	Mon 4/6/09	Mon 4/6/09	Fri 4/10/09	Fri 4/10/09	100%
2	**3.2.5**	**Fifth Conference (CMC)**	**Thu 5/28/09**	**Thu 5/28/09**	**Fri 5/29/09**	**Fri 5/29/09**	**100%**
3	3.2.5.1	Attend Conference	Thu 5/28/09	Thu 5/28/09	Fri 5/29/09	Fri 5/29/09	100%
4	**3.2.6**	**Sixth Conference (SARTA Clean Tech Showcase)**	**Thu 5/28/09**	**Fri 10/16/09**	**Fri 5/29/09**	**Fri 10/16/09**	**100%**
5	3.2.6.1	Attend Conference	Thu 5/28/09	Fri 10/16/09	Fri 5/29/09	Fri 10/16/09	100%



ID	WBS	Renewable Energy Testing Center	Baseline Start	Actual Start	Baseline Finish	Actual Finish	% Complete
66	**4**	**Program Management**	**Wed 7/9/08**	**Wed 7/9/08**	**Fri 11/20/09**	**Mon 12/21/09**	**100%**
[illegible]	4.1	Quarterly Report	Wed 7/9/08	Wed 7/9/08	Mon 10/20/08	Mon 10/20/08	100%
[illegible]	4.2	Quarterly Report	Mon 11/3/08	Mon 11/3/08	Tue 1/20/09	Tue 1/20/09	100%
[illegible]	4.3	Quarterly Report	Mon 2/2/09	Mon 2/2/09	Mon 4/20/09	Mon 4/20/09	100%
[illegible]	4.4	Quarterly Report	Mon 5/4/09	Thu 6/4/09	Mon 7/20/09	Mon 7/20/09	100%
[illegible]	4.5	Quarterly Report	Mon 8/3/09	Mon 8/3/09	Tue 10/20/09	Tue 10/20/09	100%
[illegible]	4.6	Final Technical Report	Tue 9/1/09	Thu 10/1/09	Fri 11/20/09	Mon 12/21/09	100%



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APPENDIX 2: ACRONYMS AND ABBREVIATIONS

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Acronyms and Abbreviations

ACTI	American Combustible Technology, Inc.
ADS	Atmospheric Dispersion System
AFS	American Foundry Society
AIHA	American Industrial Hygiene Association
API	Application Program Interface
ARDEC	U.S. Army Armament Research, Development and Engineering Center
ASAM	Association for the Standardization of Automation and Measuring Systems
ASTM	American Society for Testing and Materials
CAAA	Clean Air Act Amendments of 1990
CARB	California Air Resources Board
CEM	Continuous Emission Monitor
CERP	Casting Emission Reduction Program
CERP	Casting Emission Reduction Program
CHP	combined heat and power
CISA	Casting Industry Suppliers Association
COR	Contracting Officer's Representative
CPC	Community Power Corp
CRADA	Cooperative Research And Development Agreement
CSOW	Contract Statement of Work
CTM	Chemical Transport Model
DOD	Department of Defense
DOE	Department of Energy
DRI	Desert Research Institute
DSPC	Direct Shell Production Casting
DTPD	Dry Ton Per Day
EBL	Emissions Baseline Library
EPA	Environmental Protection Agency
FID	Flame Ionization Detector
F-T	Fischer-Tropsch

Acronyms and Abbreviations

FY	Fiscal Year
GC	Gas Chromatograph
Genset	Electrical Generator
GHG	Green House Gases
HAP	Hazardous Air Pollutant
IR	Infrared
ISO	International Standards Organization
LD-TOFMS	Laser Desorption Time-Of-Flight Mass Spectrometry
MDS	Mass Selective Detector
MS	Mass Spectroscopy
NCMS	National Center for Manufacturing Science
NDA	Nondisclosure agreements
OC/EC	Organic Carbon and Elemental Carbon
OEM	Optical Emission Spectroscopy
OSHA	Occupational Safety and Health Administration
OTM	OSHA Technical Manual
PDF	Portable Data File
PDU	production demonstration unit
PEL	Permissible Exposure Limit
PM	Particulate Matter
PMP	Program Management Plan
POM	Polycyclic Organic Matter
PRF	Pacific Renewable Fuels
Psig	Pounds Per Square Inch Gauge
PTDR	Plasma Thermal Destruction & Recovery
QA/QC	Quality Assurance/Quality Control
REII	Renewable Energy Institute International
RETC	Renewable Energy Testing Center
RLB	Red Lion Bio-Energy
RSD	Relative Standard Deviation
RTGA	Real-Time Gas Analyzer

Acronyms and Abbreviations

SERDP	Strategic Environmental Research and Development Program
STEL	Short Term Exposure Limits
STLC	Soluble Threshold Limit Concentration
Syngas	Synthetic Gas
T.CON	Thermo Conversions, LLC
TC	Thermal Conductivity
TCC	Thermochemical Conversion
TEA	Triethylamine
TGOC	Total Gaseous Organic Concentration
THC	Total Hydrocarbon
TTE	Total Temporary Enclosure
US EPA	U.S. Environmental Protection Agency
USCAR	U.S. Council for Automotive Research
UV	Ultraviolet
VOC	Volatile Organic Compound
WBS	Work Breakdown Structure

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