WRI 09-R014

DEVELOPMENT OF A THERMAL OXIDIZER FOR DISTRIBUTED MICROTURBINE BASED GENERATION

TOPICAL REPORT

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By
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TABLE OF CONTENTS

LIST OF FIGURES

DISCLAIMER

ABSTRACT

This project concerns the replacement of the catalytic bed in a microturbine with a thermal oxidizer. The advantage of a thermal oxidizer over a traditional combustion chamber is that the length and temperature of the device allows the volatile species to oxidize relatively slowly and without a flame front. With no flame, the temperature increase throughout the unit is spread over a much larger volume so there is no hot spot for thermal NO_x formation, and the gas Btu level does not have to be above the ignition concentration.

Project specific objectives included assessment of the materials and performance requirements of the thermal oxidizer, design the thermal oxidizer system, fabrication of the thermal oxidizer, testing of the oxidizer's performance in concert with the microturbine and comparison of the performance of the oxidizer with catalytic beds and traditional combustion chambers.

The thermal oxidizer was designed and fabricated with the assistance of High Country Fabrication of Casper, Wyoming. The design consists of a long set of tubes surrounded by a packed bed of loose ceramic material. The outer vessel containing the tubes and packing is a 3-foot diameter steel shell with multiple layers of thermal insulation. After the metal components were fabricated, the vessel was shipped to Denver where the insulation was poured. The unit was shipped to the cosponsor site for integration with the 100 kW microturbine device.

Connection of the thermal oxidizer to the Elliot microturbine turned out to be problematic. The high flow rate of gas tended to push the hot zone out of the oxidizer as assembled. The research team identified several approaches to improve the oxidizer performance including a longer gas path, increased residence time, higher surface area packing material and improved combustion catalysts. The cosponsor is working with an engineering form with oxidizer experience to reconfigure the hardware before moving to a field trial on landfill gas.

EXECUTIVE SUMMARY

This project concerns the replacement of the catalytic bed in a microturbine with a thermal oxidizer. The advantage of a thermal oxidizer over a traditional combustion chamber is that the length and temperature of the device allows the volatile species to oxidize relatively slowly and without a flame front. With no flame, the temperature increase throughout the unit is spread over a much larger volume so there is no hot spot for thermal NO_x formation, and the gas Btu level does not have to be above the ignition concentration.

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INTRODUCTION

The push to examine alternative energy production methods has grown stronger over the past few years. Due to rising energy costs, the potential national security issues with a limited petroleum production and the environmental concerns with coal-fired power plants, more emphasis is falling onto new sources of power production. Biomass, stranded gas, oil shale, wind and solar are all topics of frequent conferences and numerous proposals. The abundance of coal and natural gas in the western states in the past has led to the dismissal of the use of lower grade fossil fuels in energy production, which is why the oil shale has remained in the ground and waste gas has been flared. The use of those low-grade fuels will become more important as technologies are developed which can use them effectively to produce power for local consumption.

Western Research Institute has been working with Flex Energy for several years on a project (Task 59) that concerns the application of a catalytic combustion system that has been married to a micro-turbine device. The catalytic combustion system decomposes the VOC's and transmits these gases to the gas turbine. The turbine has been altered to operate on very low-level BTU fuels equivalent to 1.5% methane in air. The goal of the project has been to apply this catalytic microturbine VOC destruction approach to waste gases from oil storage, coal upgrading and farm waste. The testing to date has shown that the performance of the microturbine is very stable even at low Btu gas concentrations. Although the testing is not complete, the project is expected to wrap up within the next six months.

While the current catalytic microturbine performs as expected, there are some issues with the catalytic bed of the device that complicate its application universally. The bed is sensitive to particulates in the feed air as these particulates can coat the catalyst and degrade performance. Sulfur contamination is also a serious issue with the catalysts performance. Flex Energy has designed a new device to circumvent the weaknesses of their previous design and will work with Western Research Institute to develop this new form of microturbine.

This project will concern the replacement of the catalytic bed in the microturbine with a thermal oxidizer. The advantage of a thermal oxidizer over a traditional combustion chamber is that the length and temperature of the device allows the volatile species to oxidize relatively slowly and without a flame front. With no flame, the temperature increase throughout the unit is spread over a much larger volume so there is no hot spot for thermal NO_x formation, and the gas Btu level does not have to be above the ignition concentration.

The thermally oxidizing microturbine is designed to produce electrical power from Btu gas that would be otherwise wasted or flared. The applications for this unit include coalmine methane, landfill gas and digester waste gas. The size of this unit, a 100kW device is large enough to be used alone or as an array to produce significant power for local use. Another proven advantage of the microturbine approach to distributed power generation is the benefit to the local grid as a power controller as the inverter technology in the microturbine aids to control frequency, voltage and phase noise on the transmission lines. It has been shown that a microturbine array will improve overall power transmission behavior, particularly when the grid is heavily loaded during peak usage.

OBJECTIVES

The overall goal of the project was to develop the thermal oxidizer system to attach to the 100kW microturbine to produce power on low Btu gas. Project specific objectives included:

- Assess the materials and performance requirements of the thermal oxidizer.
- Design the thermal oxidizer system.
- Fabricate the thermal oxidizer.
- Test the oxidizer's performance in concert with the microturbine.
- Compare the performance of the oxidizer with catalytic beds and traditional combustion chambers.

WORK PLAN

Task 1 Design of the Thermal Oxidizer

There are preliminary drawings of the thermal oxidizer. The basis of the original drawing was to provide sufficient time and volume for the oxidation reaction to be completed based on the flow rate of the gas and the velocity generated. As the oxidizing gas provides the heat to begin the reaction of the following gas, there is a heat exchanger quality to the device. Also critical to the performance is the need for inert packing to provide thermal mass and surface area for deposition of contaminants that might otherwise effect turbine life. Within the design, there are issues with high temperature strength, corrosion resistance, insulation quality, and resistance to spalling or scaling. The scope of this task will be to define the details of the design with materials choices suitable for the temperature and conditions within the reactor as well as provide the strength required for sustained operation at high temperatures.

The initial design will use a mild steel shell with a refractory liner. Inside the refractory will be a thin alloy shied to prevent refractory particulates from reaching the turbine. Alloy internals will be used to resist the operating temperature in air that will run as high at 1500°F. An internal thermal mass consisting of alumina or mullite saddles is anticipated. A particulate separating device such as a small cyclone may be attached to the exit of the oxidizer, again as protection for the turbine. Exact sizes, alloys and wall thickness of components may be determined by availability of materials.

Following design choices of materials and layout, finished drawings will be produced for the fabricator. These drawings will include a materials list and specifications for alloys and component dimensions and wall thickness.

<u>Task 2 Fabrication of the Thermal Oxidizer</u>

Because of the complexity and size of the thermal oxidizer, WRI will require the assistance of a certified welder and perhaps an engineering shop. The device will be first fabricated as a shell, two end caps, the tube core, exit cyclone, and support structure. All items will be prepared in refractory lined carbon steel with the exception of the tube core that is anticipated to be fabricated out of 310 stainless steel. The tube core is the most complex item, but the outer shell will be the heaviest component and most difficult to handle. The device is not a pressure vessel and will not require ASM certification, though we expect to use a certified welder to minimize faults in fabrication. The welding of type 310 stainless steel is done commonly but again is best handled by an experienced welder with the correct welding equipment.

This thermal oxidizer will be the first tested of this scale for this application. Based on its performance some alterations or redesign may be necessary for later models. Ideally we would like to collaborate with an engineering shop that would be both capable and interested in a long-term relationship if this device becomes commercial. Time and availability of such a firm may be the ultimate decider whether that goal would be met, or whether we would have to choose a fabrication subcontractor less likely to be capable of large-scale production.

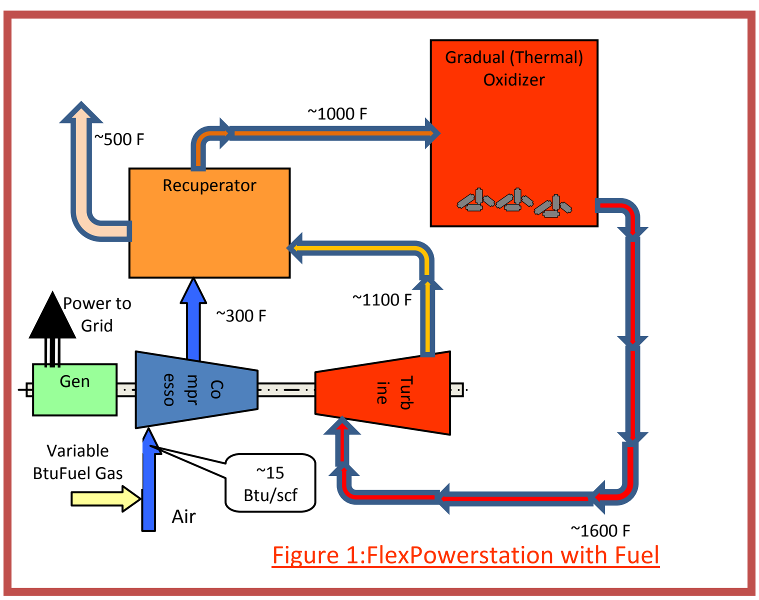

Figure 1:FlexPowerstation with Fuel

Figure 1 Diagram Showing Location of Thermal Oxidizer

Task 3 Operation and Testing of the Thermal Oxidizer Microturbine

Initial tests of the unit will include a 50-psig pressure-test to examine the unit for any leaks. Cold flow testing of the thermal oxidizer unit at working flow rates of air will then be conducted to measure pressure drop across the system. This test will take into account the change in flow due to anticipated heating rates of the air as it moves through the oxidizer. These flow measurements will be made with and without the inert thermal mass packing material.

On successful operation of the oxidizer during cold flow, the system will be shipped to the co-sponsor site for attachment to the 100 kW microturbine. Cold flow testing of the integrated system will then be conducted followed by thermal couple installation and burner installation. Hot flow tests with clean air will follow. Successful completion of tests to this stage will allow introduction of methane at increasing concentrations with careful monitoring of all temperature data and emission concentrations.

The final tests of the thermal oxidizer microturbine will be conducted on landfill gas on site.

RESULTS

The thermal oxidizer was designed and fabricated with the assistance of High Country Fabrication of Casper, Wyoming. The design consists of a long set of tubes surrounded by a packed bed of loose ceramic material. (Figure 2) The outer vessel containing the tubes and packing is a 3-foot diameter steel shell with multiple layers of thermal insulation. After the metal components were fabricated, the vessel was shipped to Denver where the insulation was poured. Figures 3, 4 and 5 show the principal components. The unit was shipped to the cosponsor site for integration with the 100 kW microturbine device.

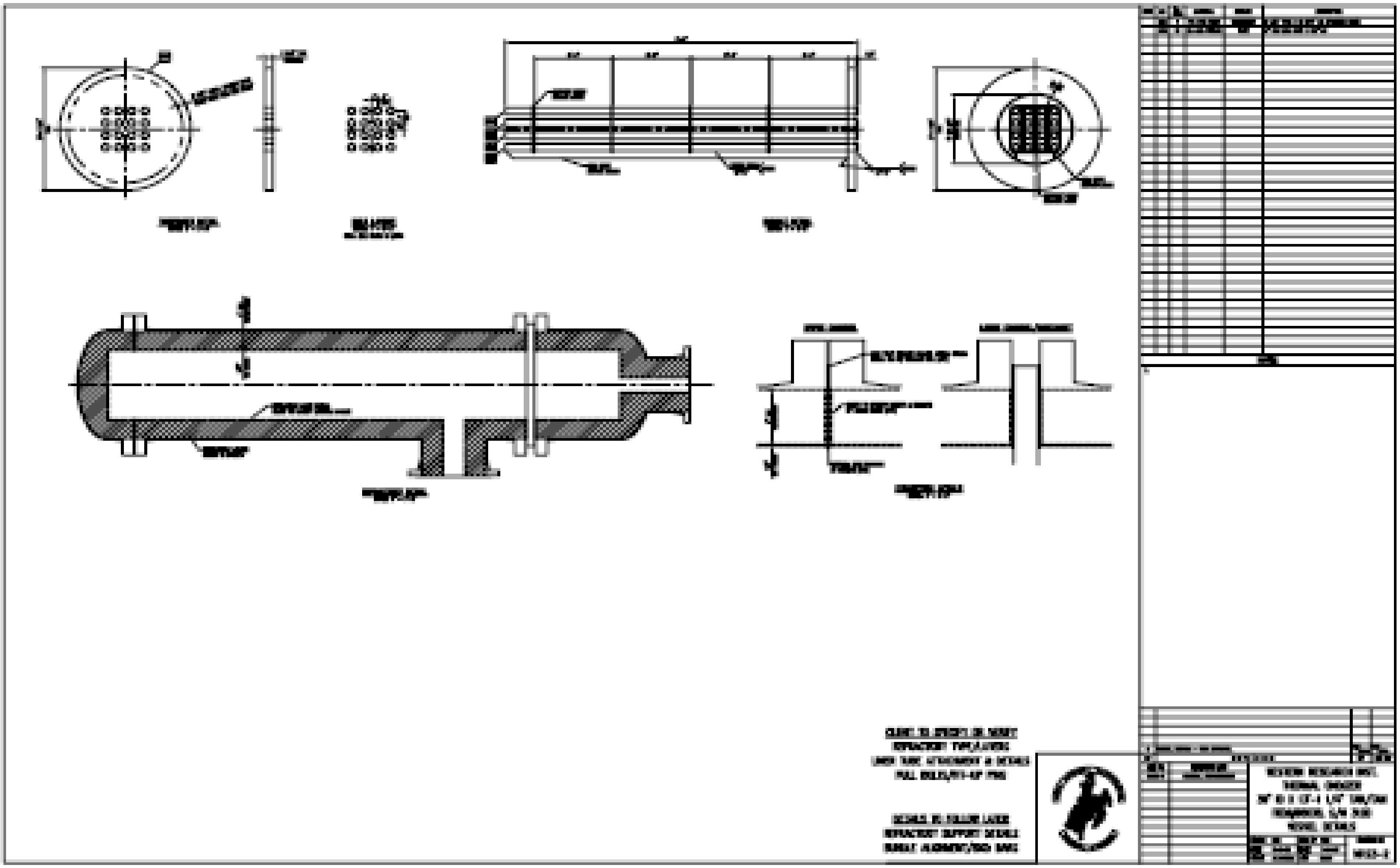

Figure 2 The Thermal Oxidizer Design

Figure 3 Base of Thermal Oxidizer

Figure 4 Thermal Oxidizer Core Tubes

Figure 5 Thermal Oxidizer Shell

Connection of the thermal oxidizer to the Elliot microturbine turned out to be problematic. (Figure 6) The high flow rate of gas tended to push the hot zone out of the oxidizer as assembled. The research team identified several approaches to improve the oxidizer performance including a longer gas path, increased residence time, higher surface area packing material and improved combustion catalysts. The cosponsor is working with an engineering form with oxidizer experience to reconfigure the hardware before moving to a field trial on landfill gas.

Figure 6 Thermal Oxidizer Attached to Elliot Microturbine

CONCLUSIONS

Although this project must close, the conclusions are not yet finalized.

- The thermal oxidizer was designed and fabricated successfully.
- The thermal oxidizer was shipped to the cosponsor site and integrated to the Elliot microturbine for testing.
- Initial testing showed that at high flow rates, the hot zone was forced through the oxidizer less than one hour after operation was begun.
- A redesign on the flow path and operational conditions is underway and should correct the hot zone problems.