A Development of On-Line Temperature Measurement Instrumentation for Gasification Process Control

Semi-Annual Technical Report

For the period ending 10/1/01

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Issued Nov 15, 2001

DOE Award Number DE-PS26-99FT40686

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Abstract

This progress report covers continuing work to develop a temperature probe for a coal gasifier. A workable probe design requires finding answers to crucial questions involving the probe materials. We report on attempts to answer those questions.

We previously reported an apparent anomaly in the high-temperature behavior of fused-silica optical components. This time, we report on further anomalies in other components. These unexpected results impede or prevent acquiring data related to the project.

The commercial manufacturer of gasifier probes had agreed to lend us three ceramic inner sheaths and one outer sheath for experimentation. He subsequently sent us one inner sheath.

We designed a test fixture to be used in a proposed test of phosphor material in a reducing environment at a power company's test facility.

Funding delays outside our control caused a related project to be put on hold. Because the two projects shared travel funds, we are unable to continue experimental work until funding resumes. Meanwhile, we are doing some of the labor-intensive data reduction for our recent calibration curves.

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Introduction

FluoreScience, Inc. (FSI) is developing a probe to measure temperature in developmental slagging coal gasifiers. FSI is collaborating with faculty and graduate students from Tennessee Technological University (TTU) in this work. The temperature-measurement method uses thermographic phosphors (TPs) as the temperature sensors. The basis of the method and many of its applications are amply covered in the literature.[1] Reference 1 is a review article that includes references to other work.

The idea behind TP temperature measurements is conceptually straightforward. In practice, the method is complex. TPs are ceramics and similar materials that exhibit repeatable characteristics that are functions of temperature. One generates these characteristics by depositing the TPs on the surface whose temperature is to be measured, then subjecting the TPs to ultraviolet (UV) light. The resulting fluorescence, which exhibits the temperature-sensitive characteristics, is converted to an electrical signal by an appropriate photoelectronic detector. The electrical signal is directly related to the temperature. It is thus possible to build an instrument that measures temperature by using TPs as sensors.

For use in coal gasifiers, we have proposed using a probe with TP deposited on the inside of the tip. The probe would, like existing thermocouple probes, be inserted so that the probe tip projects into the interior of the gasifier. The biggest advantages of the TP probe would lie in the expected durability and low cost.

This third progress report covers further work intended to answer several crucial problems regarding the probe design and construction. One way to phrase these questions is as follows.

1. What numbers and/or conditions can we assign to the environmental parameters? The parameters include number and location of probes; type of materials used to construct the gasifier walls and their thermal characteristics; thickness of the walls; composition of the gases; and pressures, temperatures, etc.
2. Is there a suitable optimum ceramic material for the probe body? The ceramic will handle the stresses caused by temperature. It will be durable in the high-temperature-gas environment. It will sufficiently resist diffusion of high-pressure, hot gas such that a simple purge-gas technique can remove reactive gas from the interior.
3. Is there a satisfactory inexpensive method for coating TP durably onto the inside of the tip?

There are other crucial questions that we can address later, but these three could be “go/no-go” questions.

Experimental

Our experiment simulator was designed to achieve temperatures to 1700ºC for the in-laboratory simulation of field experiments of optical components. Because this simulator is a new concept, it has not yet been completely tested under all conditions. During this period, we attempted to extend the calibration data to higher temperatures. We ran into some problems that we discuss in the Results section.

Negotiations continue with a commercial maker of gasifier probes to share all the technology for purposes of manufacturing complete instruments based on our probe design, assuming it proves feasible. The manufacturer earlier agreed to lend us three ceramic inner sheaths and one outer sheath for experimentation. He subsequently sent us one inner sheath. The probe sheath is too long to fit into the oven cavity of our simulator. We therefore designed and obtained the materials needed to extend the oven cavity.

We designed a test fixture to be used in a proposed test of phosphor material in a reducing environment at a power company’s test facility. In a letter to our contact at SouthernCo, we outlined the proposed experiment. We received an acknowledgement, but no further communication as of the date of this report.

We have requested detailed dimensional drawings from Delta Controls Corporation, manufacturer of the probe. The drawings should let us do a finite-element simulation

We are looking into some new coatings that might go on the outside of the probe to reduce its diffusivity. We have contacted an expert on the subject.

Funding delays outside our control caused a related project to be put on hold. Because the two projects shared travel funds, we are unable to continue experimental work until funding resumes. The funding continuation had been approved as of the date of this report. Meanwhile, we are doing some of the labor-intensive data reduction for our recent calibration curves.

Results and Discussion

Because experimental work shut down nearly coincident with the beginning of this reporting period, few results are available.

At the beginning of the period, we were working on extending the use of our simulator to higher temperatures (above 1400ºC). Lately, we have been experiencing difficulty with some of the commercially supplied components and materials at high temperatures. Last time, for example, we reported on an apparent eutectic formation between our phosphors and fused-silica cuvettes used to hold them. This time, we uncovered more problems. We had previously designed and made ceramic test fixtures used to hold and position various optical components inside the simulator. We made them from ceramic that is supposedly usable continuously to 1700ºC. Contrary to what one would therefore expect, we have found that these ceramics fracture and distort at temperatures as low as 1450ºC. Furthermore, we have found that some of the lenses, which are *sapphire* and therefore rather expensive, are exhibiting problems somewhat similar to those of the fused-silica cuvettes. As with the previously reported case, we are working with the ceramics manufacturer and the lens manufacturer to find out what is wrong. We have no reason to believe that the oven calibration is off by any large amount. Besides, sapphire should not exhibit any sort of anomalous behavior until much higher temperatures (well over 2000ºC).

We applied a thin coating of one of our standard TPs to the inside of the probe tip, illuminated the TP with a hand-held nitrogen laser, and verified visually that the TP is emitting fluorescence. We will quantify this as soon as we get the simulator modified.

Some of the calibration points have been extracted from the large amount of data acquired with the simulator. Even with the aid of a powerful computer-assisted mathematical-analysis code, it goes fairly slowly.

Conclusions

We have no new information regarding Question 1 of the Introduction. We continue to assume that the Texaco gasifier is typical. We know the number and location of the probes and the wall thickness. We have enough information about the composition of the gases, and of the pressures and temperatures, to proceed. We have a rough idea of the gasifier's wall materials. In the Delta Controls Corporation probe, we have at hand an apparently durable design. We now need to discover, based on the results from a proposed reducing-gas-environment test, both if and how long the phosphors will survive such an environment. Once we know those results, we will be able to estimate the phosphor's durability with a purge gas, such as the Delta probe incorporates. This may be the most-important determinant in our probe's potential commercial success.

We are still exploring the questions in (2) of the Introduction and are somewhat more optimistic that the answers might all be positive. We are working with a probe that has been successful in somewhat similar applications. If the phosphors deteriorate slowly or not at all in a reducing-gas environment, then the purge-gas technique the probe uses might ensure long-term survivability in the atmosphere of the gasifier. A state-of-the-art coating could reduce the diffusivity even farther. Together with its superior mechanical features, we could have a winning combination.

We have no new information this period on Question 3.

References

[1] B. W. Noel, W. D. Turley, and S. W. Allison, "Thermographic-Phosphor Temperature Measurements: Commercial and Defense-Related Applications," Proc. 40th International Instrumentation Symposium (Instrument Society of America, 1994), pp. 271-288.