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

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Author: Bruce W. Noel

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Submitted by
FluoreScience, Inc.
1010 Commerce Park Drive, Suite B
Oak Ridge, TN 37830

Participating Organization

Tennessee Technological University
Center for Electric Power
Box 5032
Cookeville, TN 38505

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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 received and studied new samples of an important thermographic phosphor, YAG:Dy. We studied the brightness as a function of dopant concentration and the relative brightnesses of the pertinent thermographic emission lines, both with respect to each other and among the phosphors.

With the previously reported failure of the binder method for coatings, we are setting up a plasma-spray facility in cooperation with a subcontractor.

We have been forming a network of people and organizations that may help us with various aspects of the problems at hand. This period, we approached a company with commercially successful probes, met with Tennessee Valley Authority staff (codes and coatings), and added a new faculty member to the team with materials expertise.

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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 second 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

A university subcontractor has agreed to set up a facility for experimental plasma spraying. This appears to be the best current candidate for production-level deposition of

TPs onto the inside tip end of ceramic probe housings. We expect the main challenge to lie in achieving intact crystal structure after deposition. The reason this is a challenge is that the plasma spraying melts the TP during the deposition, so that careful monitoring of conditions is necessary. We think we know why recrystallization may occur incorrectly. If we are right, then the problem lies in how to control the conditions properly.

We received and tested, for relative brightness, new batches of YAG:Dy made by two vendors. Our previous vendor is no longer in business. We chose concentrations of 2, 3, 4, and 5 mol % Dy, based on theoretical estimates.

We are setting up a calibration experiment that is required because we cannot be certain, without testing, that the batches from the new vendors do indeed have the same calibration curves as the original TPs.

Results and Discussion

We found that both new batches of YAG:Dy give peak relative brightness at 4 mol % Dy concentration.

The testing showed that the new samples are, overall, slightly brighter than equivalent-concentration samples made by the traditional method. The results are actually interestingly complicated. The principal thermographic emission lines are at 455 nm and 577 nm. The 455-nm line clearly has two components: a short one and a long one. The short component of the new-process phosphor's 455-nm line is about three times as bright as that of the standard phosphor. On the other hand, the long component of the standard phosphor is slightly brighter than that of the new-process phosphor. Physically, this tells us there are two parallel radiative-decay processes occurring. Which of these is the "correct" one, thermographically, will be discovered when we test them at operating temperature.

With regard to the 577-nm line, the original phosphor is slightly brighter than the new one.

Delta Controls Corporation manufactures high-temperature probes for Claus thermal reactors used in the processing of sulfur. These reactors have a similar high-temperature and corrosive environment as the coal gasifier, but operate at atmospheric pressure. Their design is an innovative, proven one. We have approached Delta Controls to see if they are interested in working with us on the development of the coal gasifier probe that can survive a high-pressure environment.

Because the installation of a temperature probe in a coal gasifier requires the penetration of the vessel's code-rated pressure boundary, a thorough understanding of the pressure-vessel codes is necessary. We met with several Tennessee Valley Authority (TVA) technical staff members knowledgeable with the relevant codes to discuss the probe design and related code issues. Subsequent to the meeting, we have obtained copies of the relevant code sections and are incorporating all code requirements into our probe design.

We learned that one of the TVA staff is a coatings expert who may be able to help us in the future. Meanwhile, a new member of the Mechanical Engineering department faculty at TTU is a materials expert who worked at Oak Ridge National Laboratory. We expect him to help with the materials selection for the probe.

Conclusions

Following our visit to the Texaco gasifier in Kingsport, TN, which we reported previously,² we obtained partial answers to some of the questions raised in (1) in the Introduction. For the sake of proceeding, we are going 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. We know very little about the currently used probe's construction.

We are still exploring the questions in (2) of the Introduction. We still have very little information. We are starting to suspect that no ceramic exists that will meet the temperature specification, the diffusivity specification, and the need to survive a slagging environment, but we are still looking vigorously.

The results discussed above show that we are a long way from answering (3) of the Introduction. This area is a focus of our work.

In addition to the good relationships with Texaco, Tennessee Eastman, and Oak Ridge National Laboratory we discussed last time,² we believe we have established a good relationship with a respected probe manufacturer, Delta Controls, whose technology could play an important role in the success of the project.

The finite-element modeling is on hold until we find out how to determine the exterior loads placed on the probe by shifting of the refractory.

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.

² B. W. Noel, "A Development of On-Line Temperature Measurement Instrumentation for Gasification Process Control," DOE Semi-Annual Report D40686R01, 4/1/99 to 9/31/00.