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

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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 designed, assembled, and tested a portable test fixture that can give relative quantitative data on the condition of phosphors. It needs a more-sensitive detector for optimum performance. We ordered an appropriate detector.

A second experimental test of the survivability of thermographic phosphor in a high-pressure, high-temperature reducing environment showed no substantial deterioration of the phosphor. This very important result further confirmed the results reported last time. We arranged for one more test as evidence that there is no effect or, if there is, then the data will give us a deterioration rate. That third test is underway at the time of this report.

We aligned and tested the prototype probe. It works as expected.

The DOE/NETL arranged for a test bed to test the probe and the measurement system in a real environment. We visited the facility to learn what will be required to do the field test.

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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 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?
4. At the beginning of the project, we did not suspect – because we had insufficient information about the about the products of combustion in a gasifier – that there might be a materials issue with our phosphors. Now we know that this is a possibility. The question then is, can any of the products of combustion have a chemical effect on the normally inert phosphors such that it would render them nonoperative in the combustor environment?

Any of these questions could be of the “go/no-go” variety.

Experimental

Work continued at a very low level during this reporting period because of the pending results of the phosphor-survivability test and the subsequent contract extension.

We installed the more-sensitive detector for the portable test fixture and the higher-voltage power supply it required.

The second run of the phosphor-survivability test took place at the DOE's Power Systems Development Facility (PSDF) operated by the Southern Company. As in the first run, the test box resided inside the gasifier in an ambient of high pressure, high temperature, and a combination of product gases, including the chemically reducing H_2S. The run lasted 447 h at temperatures ranging from 850ºC to 925ºC (1550ºF to 1700ºF). When the test box returned to our laboratory, we repeated the visual inspection and brightness measurement of the first run. This time we did the relative brightness measurements with both the laboratory simulator – as before – and the revised portable tester for comparison and to normalize the data. We then once again returned the package to the PSDF for a third run, which is scheduled to occur during the next reporting period.

After much experimentation, we developed a straightforward method for rapidly aligning the probe. Because it required several innovations, we are treating the technique as proprietary for the present. One additional optical component probably will be custom-fabricated because we have not found it in any catalog so far.

After properly aligning the probe, we verified that it works as expected. We measured the room-temperature brightness of the probe and compared it with that of the phosphor powder to get a brightness-calibration coefficient.

Faced with the probable success of the phosphor-survivability test and a functional probe, we arrive at the point where we must have a test bed to proceed to the project's intended conclusion. The DOE/NETL arranged a possible collaboration with the Southern Company to test our measurement-system prototype at the PSDF. Although the PSDF is not a slagging gasifier that operates at the originally proposed temperature and pressure, it nevertheless can provide a good test of many of the system's concepts.

We visited the PSDF to determine possible probe locations, determine what other problems may have to be solved to do a field test there, and to evaluate the main logistics involved.

Results and Discussion

Our portable test fixture can now accommodate a much larger range of phosphor brightnesses, including the YAG:Dy that is essential in the slagging-gasifier probe. We can calibrate it for any phosphor that we normally use and can normalize the results to the laboratory-prototype simulator.

Comparing the data from the first and second runs of the test box containing YAG:Dy showed little difference when compared with the change that occurred between the pre-test virgin phosphor and the same phosphor after the first test.

The probe assembly proceeded quickly and easily. The alignment did not. It proved frustratingly slow because of what might be thought of as a parallax problem. However, once that problem was solved in a straightforward and easily repeatable way, the alignment became easy.

Upon visiting the PSDF, we found several locations in the tower that might be suitable. Installing the probe appears to be a simple matter. The PSDF personnel will have merely to install another flange; all existing flanges are currently either in use or assigned for use. We found that, because of the plant layout, the tower's location relative to the control room, and lack of sufficient space in the control room, that placing the data-generation part of our equipment in the control room is nor practical. Of course this means that the prototype instrument for this field test will be in the tower. We therefore sought a suitable location. We found several that might be suitable, although each presents some problems in handling, protection (some very expensive equipment will be open to weather and uncontrolled temperature), equipment and material handling considerations, personnel access, power availability, safety, and so on. Reaching any conclusion about the location will require input and coordination between FSI and PSDF personnel.

Conclusions

Now that it is fully functional, the portable test fixture provides a rapid and easy assessment of many properties of phosphors and measurement geometries in a simple, compact unit. The data normalization mentioned in the "Experimental" section will allow us to freely substitute the-easy-to-use, fixed-alignment portable test unit easily, even in the field.

The small difference in brightness after the second run of the phosphor in the test box suggests one of two causes for the somewhat larger initial difference. (1) The phosphor is remarkably stable in a reducing environment after an initial decay. If this is true, then the initial decay could be caused by "cleanup" of noncrystalline or imperfectly crystalline defects in the as-grown material. (2) The "surface dirt, probably from unburned carbon (graphite form) or unburned hydrocarbons, had the initial effect of occluding some of the visible luminescence, which increases only slightly after that initial effect. The third run should be definitive in establishing if either of these two assertions is valid.

The probe is correctly aligned. Its calibration is, except for a known amplitude factor, the same as that of the original (unused) phosphor. All of the necessary data are at hand. If time permits, we may run the probe at temperature in the simulator as a cross-check and verification that no unforeseen problems develop at high temperature. The completion of the probe unit awaits its integration into its supporting structure, part of which includes the mounting flange that is to be specified in the design of the field experiment.

PSDF personnel will have to install a flange to accept our probe housing. The flange will be a standard one, of a type and size already in use for thermocouple access.

The fact that we cannot place our data-generation equipment in the control room has important implications for both this experiment and the design of a commercially marketable version. Those implications require considerable thought and experimental investigation, so it is premature to discuss them in this report.

Reference

[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.