Thermocouple-Instrumented Promoted Combustion Test Sample

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A standard test for determining metals flammability in enriched oxygen is American Society for Testing and Materials (ASTM) G124, *Standard Test Method for Determining the Combustion Behavior of Metallic Materials in Oxygen-Enriched Atmospheres.* The results of the tests are generally published as threshold pressures, or the lowest pressure in 100% oxygen that supports combustion of a metal test sample. Currently, the standard defines combustion as consumption of an entire 150-mm-long, 3.2-mm-diameter rod. However, questions have been raised as to the credibility of an entire rod burning to determine flammability. Differences in interpretation of the burn criteria led to inconsistent ranking of materials at various test facilities. Therefore, White Sands Test Facility initiated a study to help define the burn-length criteria used for determining threshold pressures.

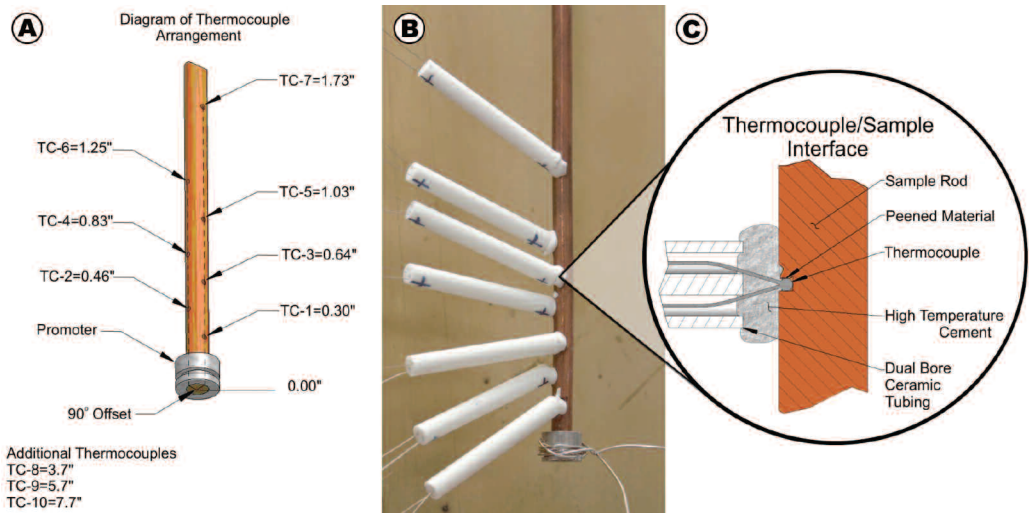

Fig. 1. *Thermocouple placement (A), shielding (B), and sample interface (C).*

The primary concern in establishing burn-length pass/fail criteria is the extent of the preheating effect on the rod caused by the promoter. The promoter (typically aluminum or magnesium) is applied to the bottom of the rod to start combustion of the material. To examine this promoter affected zone (PAZ), sample rods were instrumented with thermocouples and tested at multiple conditions where the sample material was not flammable.

Sample rods were instrumented with 10 type-K thermocouples, arranged as shown in figure 1A. The interface between the thermocouple and sample can be seen in figure 1C. Small-diameter beaded-type thermocouple junctions were used for rapid temperature response. The thermocouple beads were placed into holes drilled in the sample rods. The beads were then crimped in place (see figure 1C, "Peened material"), thus eliminating the possibility of thermally insulating the thermocouple junctions when applying high-temperature cement shielding. The high-temperature cement and dual-bore ceramic tubing (figure 1B) were applied to at least the lower eight thermocouples. Such shielding protected the thermocouples from burn-through and prevented reading any gas or flame temperatures rather than the sample temperatures.

The promoters were applied to the samples, which were then mounted to a sample stand fitted with a thermocouple plug connector rack with female high-temperature connectors. These plug-style connectors had screws to hold the positive and negative thermocouple leads from the sample.

Once in the test chamber, male high-temperature connectors were mated at the correct positions. The thermocouples were introduced into the test chamber via a single 24-wire thermocouple feedthrough, rated at 5,000 psi. The thermocouple leads were insulated with Teflon and, because of the flammability of Teflon in oxygen, it became obvious that protective measures had to be taken. Initially, the thermocouples were simply bundled. The leads ignited and were consumed after five tests. In an attempt to shield the second feedthrough, a brass plate was installed between the sample and thermocouple leads to divert any molten metal. Even with the plate in place, the thermocouples were

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continued

consumed after several additional tests. Finally, the thermocouple leads were sheathed in Nextel, and a Nextel-sheathed jumper wire was made and attached to the igniter lead, fed below the plate, and reattached to the promoter wire.

Tests were conducted in this configuration at 100, 500, 1,000, and 5,000 psia with both aluminum and magnesium promoters. Temperature and pressure data were captured at 50 or 100 Hz. High-speed video of the promoter event, taken at 1,000 frames per second, was used to synchronize test events with specific data points. *Note: The thermocouple response time had to be calculated and adjusted to correctly synchronize the video and data.*

In initial tests, several thermocouples exhibited unrealistic temperatures (figure 2). Hypothesizing that the thermocouples were picking up ground noise through the sample stand, the sample rod was electrically isolated from the stand, effectively creating floating thermocouples. This configuration eliminated the erratic and undesirable false readings (figure 3).

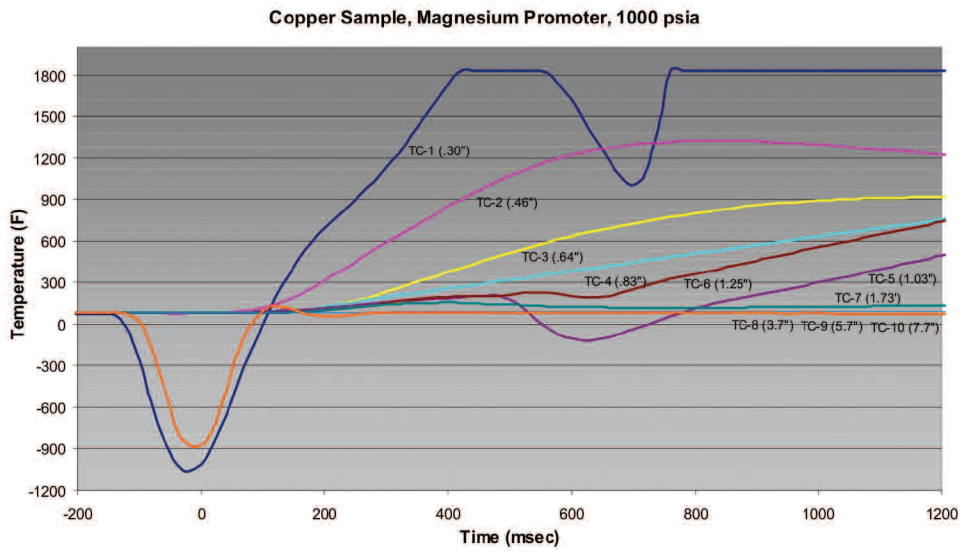

Fig. 2. Thermocouple temperatures before isolation.

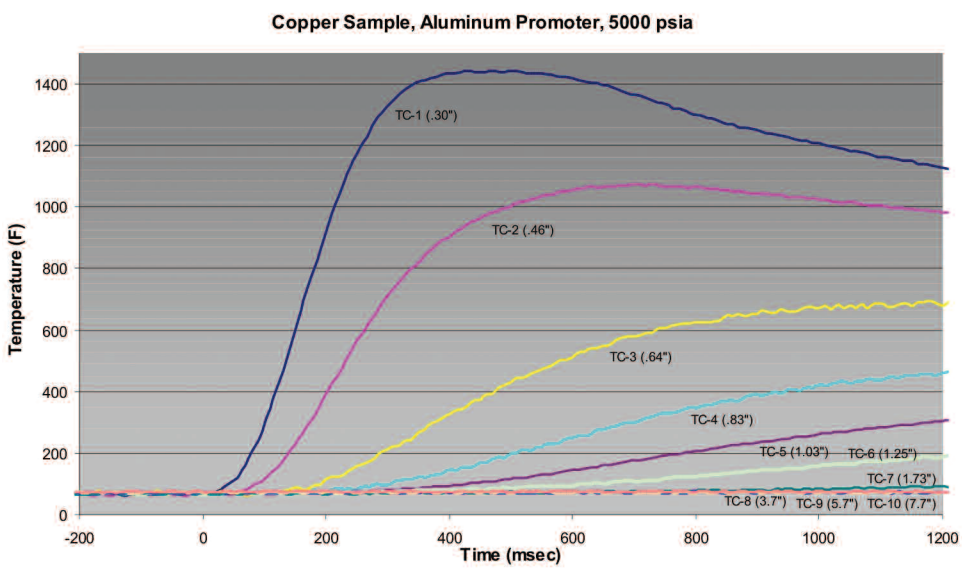

Fig. 3. Thermocouple temperatures after isolation.

Configuring the samples and test apparatus, as described, protected the thermocouples and data so that the results were interpretable and repeatable. The test results were repeatable with small standard deviations, providing the critical data needed for the determination of the PAZ.