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**QUARTERLY
TECHNICAL PROGRESS REPORT**

Report No. 4

Laser Ultrasonic Furnace Tube Coke Monitor

ERIP

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1.0 INTRODUCTION

This report summarizes the technical progress achieved during the fourth quarter of the ERIP project entitled, "Laser Ultrasonic Furnace Tube Coke Monitor." The focus of work during this reporting period was the construction of an electronic control module for the coke detector probe. The electronic control module supervises the actuation and data collection functions of the probe sensor. Basic operation of the probe controller was confirmed.

A 12-month no-cost extension to the original grant period was approved during the reporting period. Project expenditures at the time of this report were approximately \$42,000. These expenditures are consistent with the project progress.

2.0 BACKGROUND

The overall aim of the project is to demonstrate the performance and practical use of a probe for measuring the thickness of coke deposits located within the high temperature tubes of a thermal cracking furnace. This aim will be met by constructing a probe that will be tested using simulated coke deposits that are positioned inside of a bench-scale furnace. Successful development of the coke detector will provide industry with the only available method for on-line measurement of coke deposits.

3.0 PROJECT OBJECTIVES

A key project objective will be to verify that the coke detector can meet specific end-user criteria needed for successful commercialization of the device including the following:

1. Sensitive measurement of coke deposits ranging in thickness from 0-1/4"
2. Suitable for use on coils of 1 1/2"- 4" diameter
3. Suitable for use at coil temperatures up to 1050°C
4. Suitable for use on rough oxidized metal surfaces
5. Instrument reliability under practical operating environments
6. Measurement reproducibility
7. The instrument is operator safe
8. The probe can be used to make random measurements down the coil length at various access angles from available furnace ports
9. The probe can operate at stand-off distances of at least 10-20'
10. The instrument package can be assembled for less than \$50,000-\$75,000

4.0 PROJECT WORK

4.1 Probe Assembly

Conventional ultrasonic transducers used to investigate the internal structure of materials can not be directly exposed to high temperatures. High temperature ceramic stand-offs can be used to thermally isolate the transducer from the hot surface. However, effective transmission of energy from the stand-off to the hot surface requires the use of a gel-like couplant. Unfortunately, these couplants can not typically withstand temperatures above about 550 °C.

To overcome this problem, we have developed an automated device to introduce a mechanical wave into the material surface using a transducer standoff composed of a fusible alloy. This involves use of an automated probe that briefly contacts the sacrificial standoff against the hot surface, thereby melting the tip to form a molten metal couplant. The device requires timing circuits to initiate recording of the pulse echoes at the proper time interval following initial contact. The probe must have the following features:

1. Provide a standoff to thermally isolate the transducer from the hot tube surface.
2. Provide a couplant media capable of withstanding 1000°C for intermittent use.
3. Automatically conform to a rough, convex, tube surface, even at an angle of attack that is not perfectly normal to the tube surface.
4. Initiate contact and pulse echo recording at desired time intervals.

An integrated probe tip was fabricated that incorporates the high temperature pulser/receiver device. The mechanical design of the probe tip is shown in Figure 1. The probe tip consists of the transducer and the sacrificial standoff, which is housed in a spring-loaded body. The transducer is connected to a miniature air cylinder that is actuated to push the transducer outward for a controlled period of time to initiate contact with the target object.

Figure 1. Schematic of integrated probe tip

A photograph of the assembled and disassembled probe tip is shown in Figures 2 and 3. Figure 4 shows the probe tip during a measurement.

Figure 2. Assembled probe

Figure 3. Disassembled probe

Figure 4. Probe tip during measurement

4.2 Electronic Control Module.

A functional schematic of the control system is shown in Figure 5. When a measurement is desired, a switch is thrown which activates a single shot timer. The timer opens an air solenoid to initiate contact of the sacrificial standoff with the hot surface. An air pressure regulator controls the force of the standoff against the hot surface. After a controlled time interval, a second single shot timer initiates data collection from the pulser/receiver module to the storage oscilloscope via a trigger signal. The recorded waveform is then processed in a computer using specialized software that identifies the pulse echoes and estimates the pulse time intervals. These pulse time intervals are then used to estimate material thickness, such as the coke layer.

Figure 5. Schematic of overall measurement system

The electronic control elements are housed in a control box as shown in Figure 6. The control box contains pressure regulators, relays and timers necessary for supervision of the probe actuation and data collection sequence.

Figure 6. Photograph of control box

4.2 Data Collection

The probe tip was tested using a heated metal plate to verify the basic operation of the assembly. Figure 6 shows a photograph of the overall test system. A recorded waveform is shown on the computer monitor. The first ultrasonic peak represents the echo from the sacrificial stand-off. The proceeding wave peaks represents echoes from the metal plate. The time difference between the wave peaks gives a measure of the plate thickness. Tests are now being conducted to reduce signal to noise ratio in order to resolve echoes from the coke layer.

Figure 6. Overall test system and recorded waveform from heated plate using automated probe

5.0 PROJECT SCHEDULE AND BUDGET

The project expenditures to date are approximately \$42,000 or about 42% of the total budget. During the next reporting period, the control system will be optimized to improve the signal to noise ratio and to verify the sensitivity of the probe to discriminate coke layers of varying thickness.