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ABSTRACT

A distributed monitoring and control system is proposed for a plasma hearth. The plasma hearth will be installed at Argonne National Laboratory-West with the assistance of Science Applications International Corporation. Real-time monitoring of the off-gas system is accomplished using a Sun Workstation and embedded PC's. LabWindows/CVI software serves as the graphical user interface.

I. INTRODUCTION

The Plasma Hearth Process (PHP) goal is to decompose hazardous organic materials, encapsulate actinide waste in an obsidian-like slag, and reduce storage volume of actinide waste. A plasma torch will generate a plasma with a peak temperature of 10,000 °F. The thermal energy imparted by the plasma torch heats gases within the torch chamber and then the gases melt the waste. A hydraulic ram pushes 55 gallon drums of organic and actinide contaminated waste close to the plasma torch, causing the waste to drip-melt into the crucible (Figure 1). Organic materials (e.g., PVC, $C_6H_4Cl_2$, etc.) decompose in the thermal environment of the plasma torch. Possible actinides in the waste will preferentially migrate to the slag phase of the melt (e.g., a mixture of Alumina, Magnesia, and Silica) and are captured in this slag once the material cools and hardens.[1] The slag, similar to obsidian, provides a good material to encapsulate the actinides. Since the slag may occupy a smaller volume of the entire melt, the effective waste storage volume of actinides may be reduced.

The PHP has a special off-gas system capable of accepting radioactive, contaminated particulate streams. As in Figure 1, the off-gas system consists of a secondary combustion chamber, a quench, a HEPA filter system, and an acid scrubber system. The secondary combustion chamber contains a propane fueled torch which thermally decomposes any residual organics emanating from the plasma hearth. The HEPA filter bank system consists of a dust filter and a secondary HEPA filter which removes radioactive contaminated particles from the off-gas prior to the wet scrubber. The acid scrubber system absorbs acid gasses, such as HCl, before the off-gases flow into the facility stack.

II. OFF-GAS MONITORING

As in Figure 1, the off-gas system is monitored using a laser induced breakdown spectroscopy system (LIBS), a Fourier-transform interferometer (FTIR), and a non-dispersive detector. The detectors monitor for actinides, inorganics and organic compounds contained in the off-gases.

The LIBS system detects actinides, such as U, Pu, and Am, prior to filtration by the HEPA filters. The LIBS system consists of a Charge-Coupled Detector (CCD) camera (Princeton Instruments) and a pulsed Nd:YAG laser (Big Sky Laser Corporation). The laser is focused in the center of the off-gas flow and induces dielectric breakdown of the off-gas. The laser plasma excites analyte atoms which emit photons characteristic to each analyte. The photons are collected by the spectrometer and are detected using the CCD camera. WinSpec software from

Princeton Instruments converts the raw spectrum into concentration data.

The FTIR provides on-line concentration data for the products of waste combustion, namely CO, H_2O, CO_2, NO_x, SO_2 and HCl. The FTIR detector consists of a Midac interferometer and a SiC light source. The SiC light source produces photons which travel though the off-gas flow and impinge upon the Midac interferometer. The Midac interferometer produces an interferogram which is converted into an absorbance spectrum and related to concentration by using a partial-least squares (PLS) routine.

The non-dispersive detector (ND) also uses a SiC light source to produce photons. The photons pass though the gas and then though a band-pass optical filter. The resulting light intensity emanating from the filter is proportional to the amount of HCl in the off-gas flow. The ND detector provides a redundant indication of the HCl content in the off-gas flow. The redundant indication of HCl content is compared with the FTIR detector to check the proper operation of both detectors.

III. STANDARD ADDITION SYSTEM

The standard addition system provides a calibrated gas flow of HCl, NO and CO. The gas flows are stepped from 0 to 25%, 50%, 75% and 100% of full flow. A measurement is taken by the FTIR and ND detectors at each fixed flow rate. The resulting measurements are used to calibrate the FTIR and ND detectors.

IV. CONTROL AND I/O EQUIPMENT

The overall layout of the control and data analysis system is shown in Figure 2. The Sun computer acts as a supervisor over the embedded PC computers. Four embedded PC computers provide low-level control, data-acquisition and display tasks. The control, data-acquisition and display tasks operating on the PCs communicate with the Sun supervisor using TCP/IP communication protocol.

A. Sun Controller

The Sun computer coordinates the control, data-acquisition and signal-processing tasks for the overall system. The Sun collects data from the embedded PCs and sends control commands to the embedded PCs. The Sun computer provides local displays for on-line and historical data trending as well as control screens. The Sun computer has software socket capability to allow remote clients to receive on-line and historical data over the ethernet. The Sun computer uses MATLAB software, on-line, to convert the raw data from the FTIR, LIBS, and ND detectors into concentrations.

B. Embedded LIBS/FIR PC

The embedded FTIR/LIBS PC's function is to acquire raw data from the FTIR and LIBS detectors and pass the data to the Sun computer. In addition, remote control over the FTIR and LIBS detectors in possible from a local configuration screen.

The GRAMS/386 software package is used to acquire data from the Midac interferometer for the FTIR system. A basic macro in the GRAMS/386 software acquires and averages 50 interferograms. The averaged interferogram is passed to the LabWindows/CVI program using DDE calls. The LabWindows/CVI program receives the interferogram and passes the interferogram to the Sun computer using TCP/IP communication protocol over a local ethernet connection.

A LabWindows/CVI program aquires data from the LIBS detector using C-language commands. The C-language commands are used to talk to the LIBS detector through DLL calls. The DLL calls are part of a software library delivered from Princeton Instruments.

C. Embedded Control PC

The embedded controller PC handles the control and acquisition of low-level analog and digital I/O's. The embedded controller PC controls the gate, purge and standard addition valves in the system using digital outputs and senses the position of the valves using digital inputs. The embedded controller PC aquires analog inputs for each viewport temperature and for the non-dispersive detector on the off-gas system. The embedded PC controls the flow rate of the standard addition system using 0-5 Volt analog outputs. The embedded PC aquires mass flow rate information for the purge gas line using RS-232 serial communication.

1. Gate and Purge Valves. Each detector assembly contains two gate and two purge valves. The gate valves provide isolation between the off-gas system and the radiation boundary window to the analyzers. The purge valves inject an N_2 purge into the light pipe assembly. The light pipe assembly links the SiC light source to the off-gas system and links the detectors to the off-gas system. The light detection pipes are purged with N_2 to reduce background absorbance due to atmospheric CO_2 and H_2O in the output of the analyzers.

2. Thermocouples. Type-J thermocouples are instrumented for each detector system. Thermocouples are attached to the detector piping near the junction of the detector piping and the off-gas piping. The thermocouples-couples measure the temperatures of the detector piping. An indication of temperature is needed since the design temperature of the gates valves must not be exceeded.

D. Remote monitors

Two remote monitors are located in the main control room and in a visitor trailer to provide on-line display of the off-gas monitoring system. The monitor in the control room aids operators by providing concentration information for Pu, U, and Am. The concentrations for $S0_2$, $C0_2$, CO, NO, HCl are also provided in a on-line and historical trend. The monitor in the trailer provides on-line concentration information for visitors.

V. CONCLUSION

A real-time distributed monitoring and control system is being designed for the off-gas system of a Plasma Hearth (PH) process. The PH is located at the Argonne National Laboratory-West site. The overall system contains LabWindows/CVI graphical user interface software which monitors off-gas concentrations of organics and actinides in the off-gas flow.

Future work may use the FTIR and LIBS detectors for closed-loop control. Since the FTIR detector determines the concentrations of the products of combustion, the detector can be used to optimize burner efficiency. Since the LIBS detector measures actinide entrainment in the off-gas, this measure may be used to control the waste feedrate and plasma torch flows in order to minimize the entrainment of actinides in the off-gasses.

REFERENCES

1. G.R. Hassel, et.al., *Evaluation of the Test Results from the Plasma Hearth Process Mixed Waste Treatment Applications Demonstration*, SAIC Document # SAIC-94/1095, Idaho Falls, ID (1994).

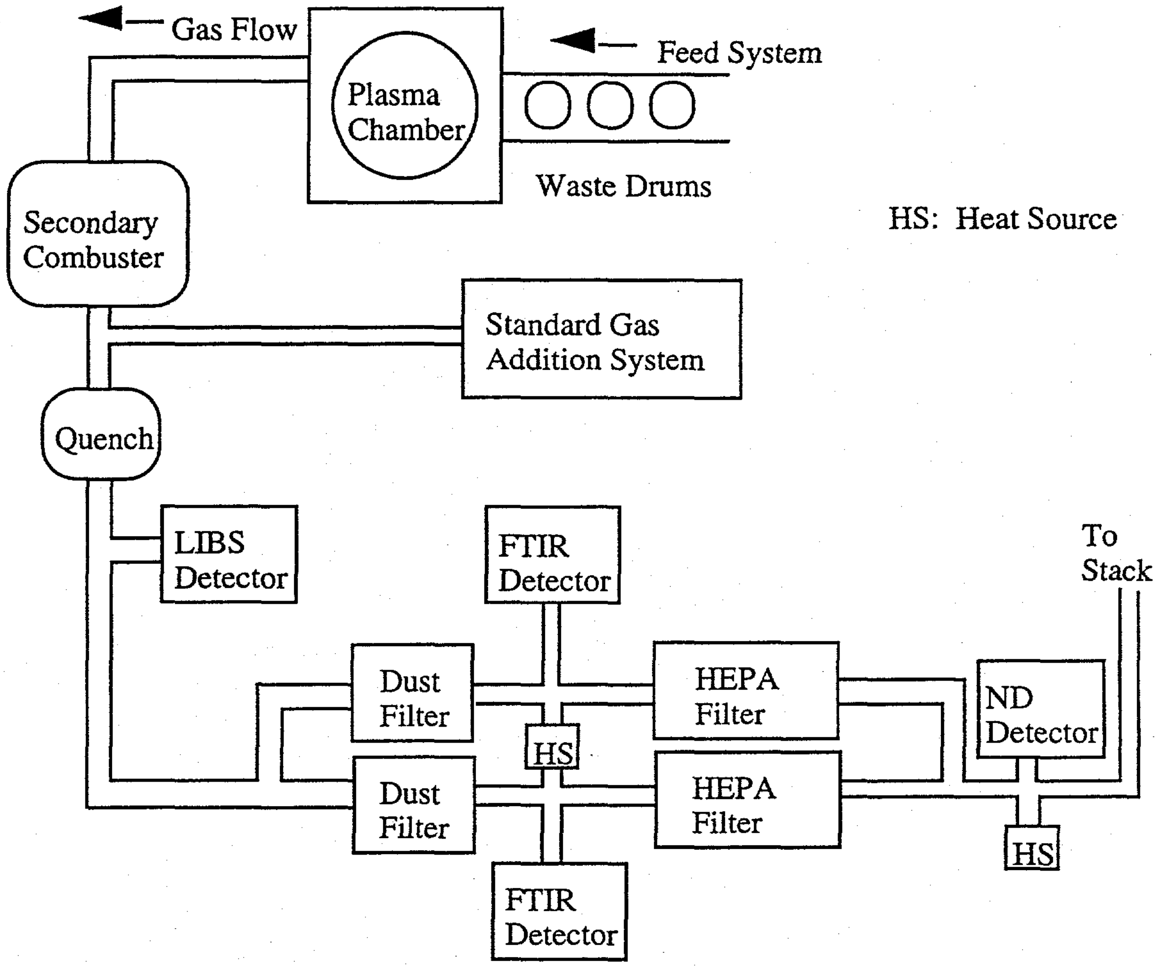

Figure 1 - Off-Gas Monitoring System for the Plasma Hearth

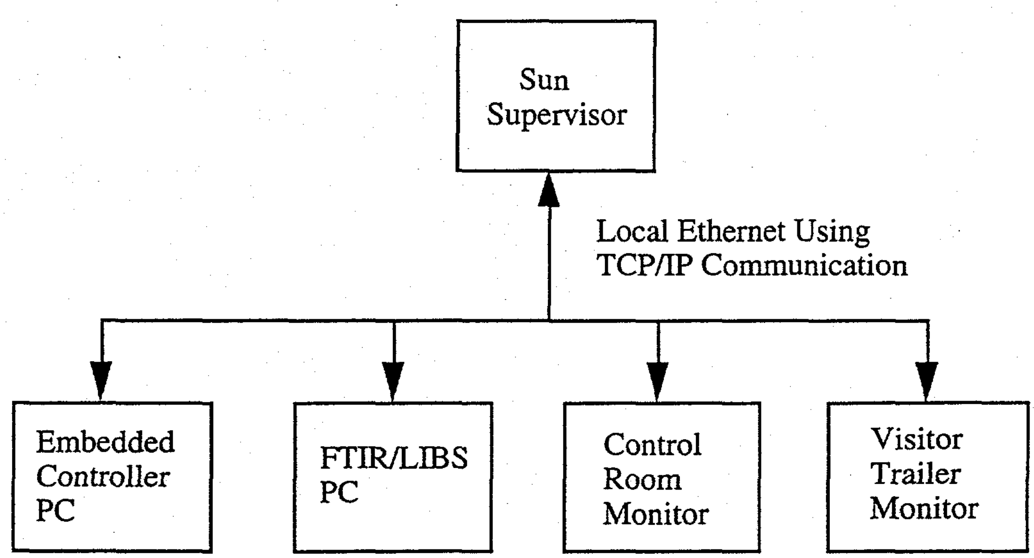

Figure 2 - Network Configuration