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Patch Testing of Ceramic Barrier Filters

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Patch Testing of Ceramic Barrier Filters

CONTRACT INFORMATION

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Schedule and Milestones

The patch testing apparatus has been constructed and tested in the SRI laboratories. There have been substantial delays in proceeding with the field testing part of this program for contractual, rather than technical reasons. When the difficulty has been resolved, the schedule will be revised accordingly.

OBJECTIVES

The objectives of this work are to construct, install, and operate a patch testing unit on a hot gas stream at a coal-fired fluidized-bed boiler. Long-term "patch tests" will be conducted on ceramic disks of the same materials used in the fabrication of ceramic candles and ceramic cross-flow filters. The primary issues to be addressed in these tests are the long-term physical, thermal, and chemical stability of the ceramic materials; long-term pressure drop and filtration characteristics of the ceramic filters; potential for irreversible clogging of filter elements; and long-term performance and reliability of auxiliary hardware, such as the tube sheet and pulse-cleaning systems. Each long-term patch test will require about 3 to 4 months of nearly continuous operation.

BACKGROUND INFORMATION

Ceramic filters are among the primary candidates for particulate removal from gas streams at high temperature and high pressure. There are, however, some concerns about the durability of such filters and their vulnerability to plugging or fouling by the deposition of fine particles in the pores of the material. Because there are many possible combinations of sources, operating conditions and filter configurations, tests of full-scale or pilot-scale filter systems are not well suited to screening for optimal filter characteristics. Small-scale tests can be very effective, however, if care is taken to ensure that realistic gas and particulate characteristics are provided.

Laboratory experiments are useful for some purposes, but they have some significant weaknesses, especially where particles smaller than about 1 μm in diameter are involved. The central problem is that clusters and agglomerates of submicron particles cannot be effectively separated by aerodynamic shear forces. As a general rule, smaller particles have a larger ratio of surface area to mass than larger particles, which results in larger forces of cohesion compared to inertial forces for smaller particles. Furthermore, because the distances between the centers of submicron particles are very small, the gradient of an aerodynamic shear force must be extremely large to provide a great enough differential within the dimensions of an agglomerate to effect a separation of particles.

Laboratory tests of filtration with resuspended dust are especially questionable because the particles that would be the most challenging in practical applications are absent in such a test. There is little doubt that particles much larger than the pore size of a filter can be trapped on the surface of the filter and later be removed by aerodynamic or mechanical cleaning processes. The particles of real concern, however, are those smaller than the pores of the filter material.

Consider, for example, a filter having a mean pore diameter of 2 μm. Then particles of smaller diameter can enter the pores, and most of them will be deposited on the pore walls by various mechanisms, such as impaction, interception, and turbulent diffusion for the larger particles and thermal diffusion for the ultra-fine particles. Once attached to the pore walls, these particles would be very difficult to remove by any cleaning process for the same reasons agglomerates of submicron particles are so tenacious–relatively strong adhesive forces, and the requirement for extremely large shear forces to break them loose.

Patch tests on sidestreams of operating systems in the field have proved effective for many studies that have been carried out on conventional plants. By taking an isokinetic sample from a process stream and using methods similar to those used for extractive sampling, it is possible to simulate the behavior of a filter in a specific application. This approach can be used to develop very useful correlations among coal and ash properties, types of filter material, operating conditions, and filter performance.

PROJECT DESCRIPTION

Two approaches were considered in designing the patch tester. One was an in-situ method, in which the filters patches to be tested and their holder would be entirely inside the source duct. The alternative method is

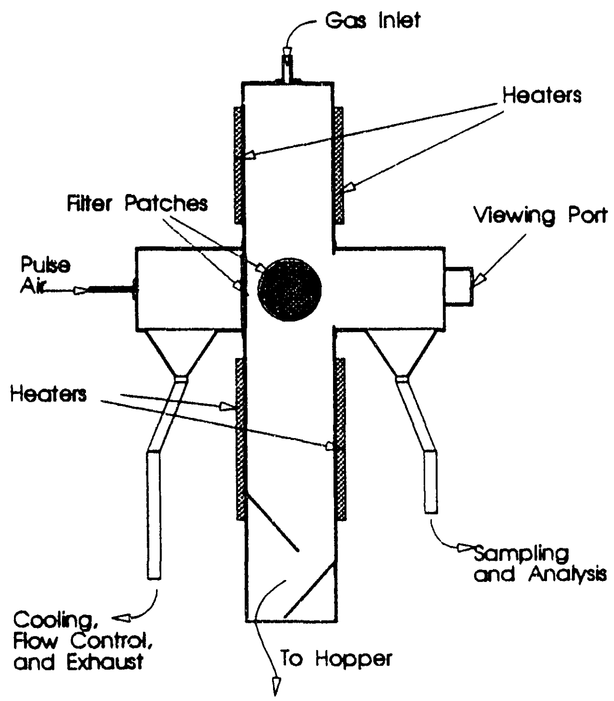

Figure 1. Layout Of Patch Tester, Vertical Section

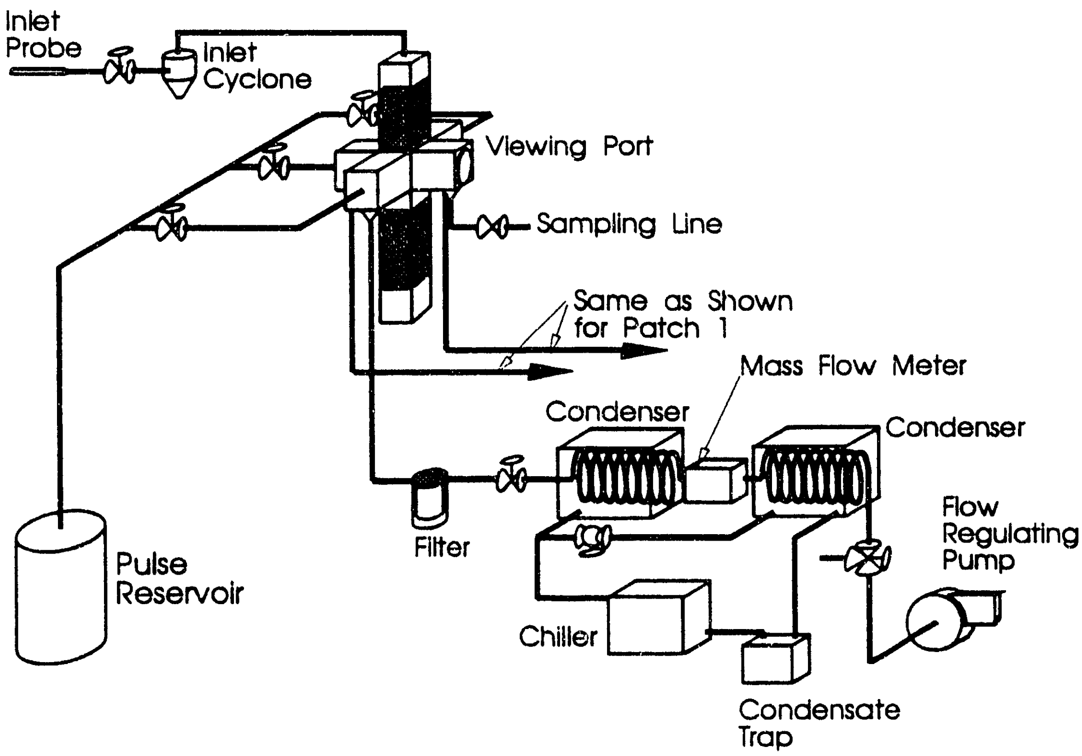

Figure 2. Isometric Piping Diagram For Patch Testing System

extractive, which involves drawing a small flow of gas from the duct into an apparatus that would maintain the filter at the process operating temperature.

The in-situ method has advantages in simplicity, because it is not necessary to transport the suspended particles to the filter. This approach is less flexible, however, in terms of inlet mass loading, temperature, accessibility, and instrumentation. For these reasons, an extractive system was designed for the patch test program.

Description of the Apparatus

The configuration of the patch tester is based upon a vertical orientation for each filter, as indicated in figure 1. It is designed to test three ceramic filter samples simultaneously and independently on a gas stream extracted from a full-scale system. The samples, or patches, are ceramic disks, nominally 102 mm in diameter, mounted on three sides of a rectangular stack, as shown in figure 2. The fourth branch is used for making measurements of the inlet particle loading and size distribution. It is also equipped with an viewing port for observing the formation of the dust cake and the action of the cleaning pulse.

The inlet side of the system is kept at the required temperature by a set of ceramic heaters. Because of the small filtration area, the total gas flow rate required to operate all three filters at a face velocity of 10 ft/min is only about 2.6 ft^3/min (actual). The inlet gas contributes very little to the overall heat requirements to keep the system at the required operating temperature.

Independent flow controllers, flow meters, and positive displacement pumps are provided on all four branches of the patch tester. A heat exchanger and back-up filter is provided on each line to protect the moving parts from hot or dirty gases. The filters are cleaned by separate reverse pulses taken from a common pressure reservoir.

The fourth, or test, branch of the system will be used for monitoring and sampling. When the gas flow rate in the test branch is set to match that of any of the other three branches, the flow patterns of the two will be nearly the same. So the particle size distribution entering the fourth branch will be nearly identical with that approaching the filter in the other branch. By inserting a cascade impactor, series cyclone system, or other analytical device in the outlet stream of the test branch, we can measure the particle size distribution on the inlet side of the matching filtered branch.

The system is designed to operate automatically and unattended, and a dedicated computer system is included in the setup for continuous data acquisition. Remote access to the data is available by modem connection to a dedicated telephone line. The design of the data acquisition and control system was based on the following considerations:

- Reliable sensors with high resolution
- Continuous record of data
- Adequate sensitivity for diagnosis
- Valve control linked to alarms or sensor values
- Orderly and safe automatic shutdown routines
- Remote access to data and control set points

We have tested the system in the laboratory. We have achieved temperatures above 1600° F in the inlet piping and in the main stack. We have exercised the automatic data acquisition and control system. The system is now ready for operation in the field.

Plans for Future Work

The patch tester will be set up at the circulating atmospheric fluidized-bed combustor on the campus of Iowa State University. The extraction of a sidestream will be by methods similar to those used for stack sampling. A probe inserted into the gas stream will be used to draw a sample of gas at approximately isokinetic conditions. Using extractive sampling methods as described above, augmented by a battery of laboratory tests on bulk samples, we will characterize the suspended particulate material in terms of

- Particle size distribution
- True density of particles
- Bulk porosity as a function of compacting stress
- Specific surface area (B.E.T.)
- Tensile strength of agglomerates
- Relative gas flow resistance of the dust cake

Upon completion of the test, each filter will be subjected to a battery of tests and analyses to determine what physical and chemical changes have occurred. Of specific interest will be any irreversible decreases in permeability and any significant changes in the strength of the material. Examples of the kinds of tests that will be performed on the filters include:

- Gas permeability
- Porosity
- SEM; EDX
- 4-point bend test
- Thermal expansion
- Heat capacity
- Thermal conductivity
- Differential thermal analysis
- Computer-aided tomography
- X-ray densitometry
- X-ray diffraction

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