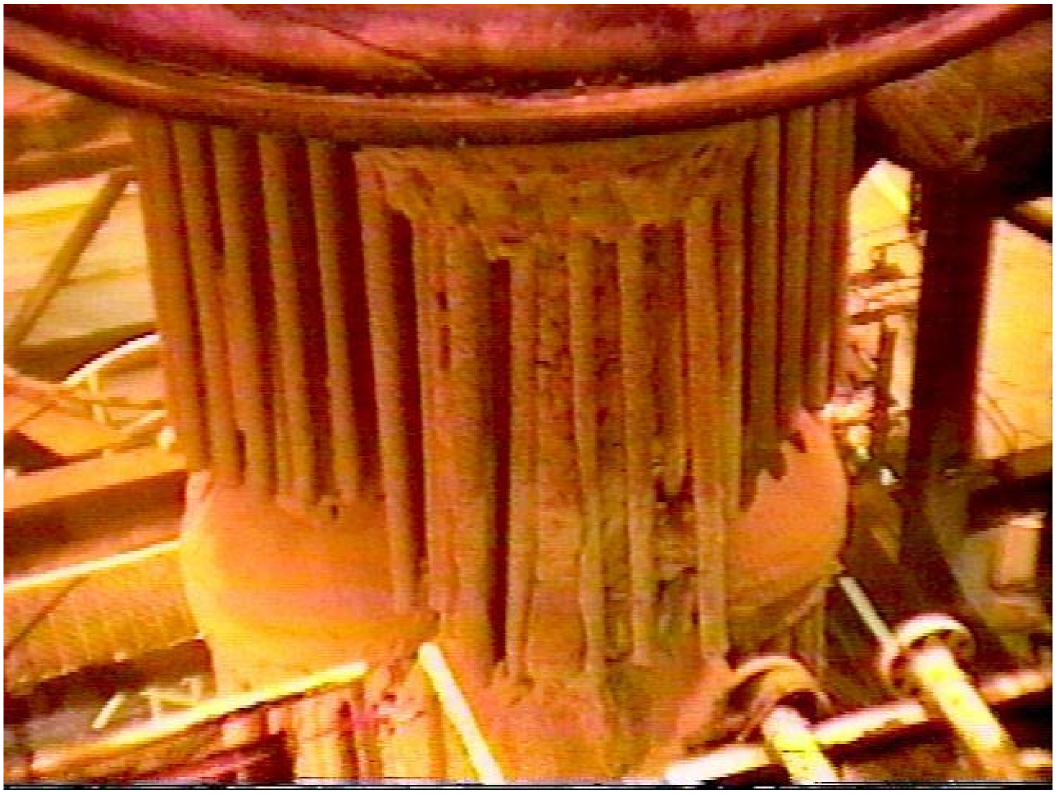

Figure 3-7. Severe bridging and candle deformation in the top plenum.

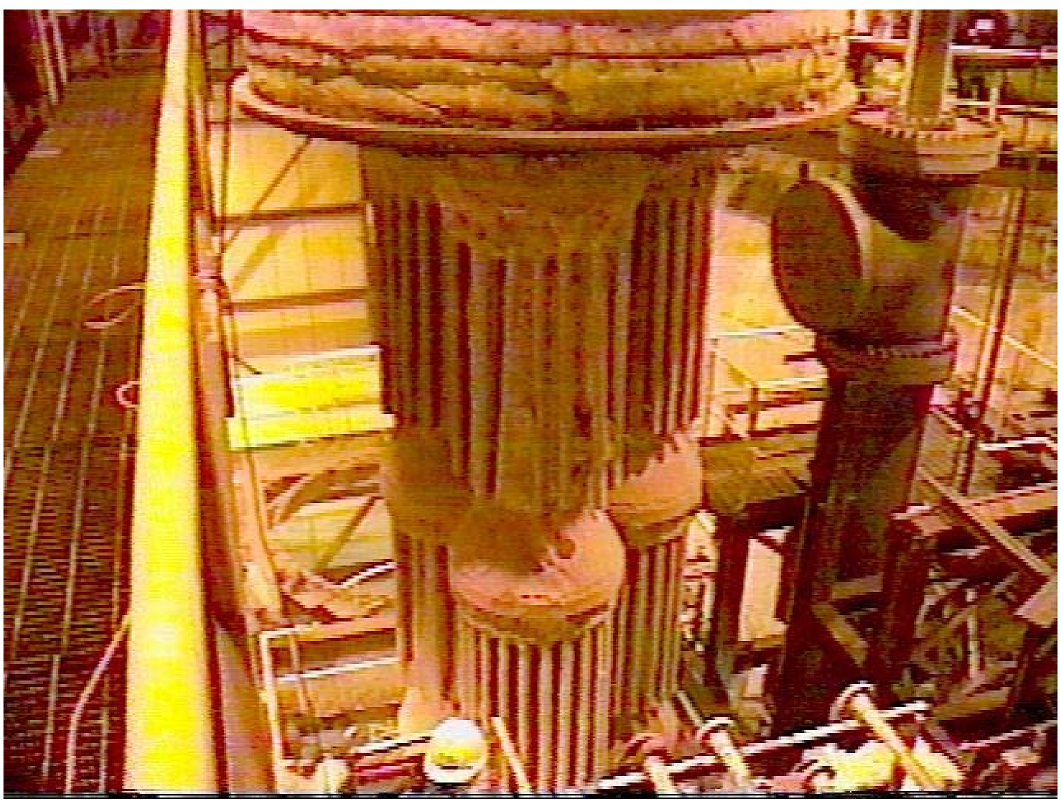

Figure 3-8. A view of the top and middle plenums as the assembly was lifted from the filter vessel.

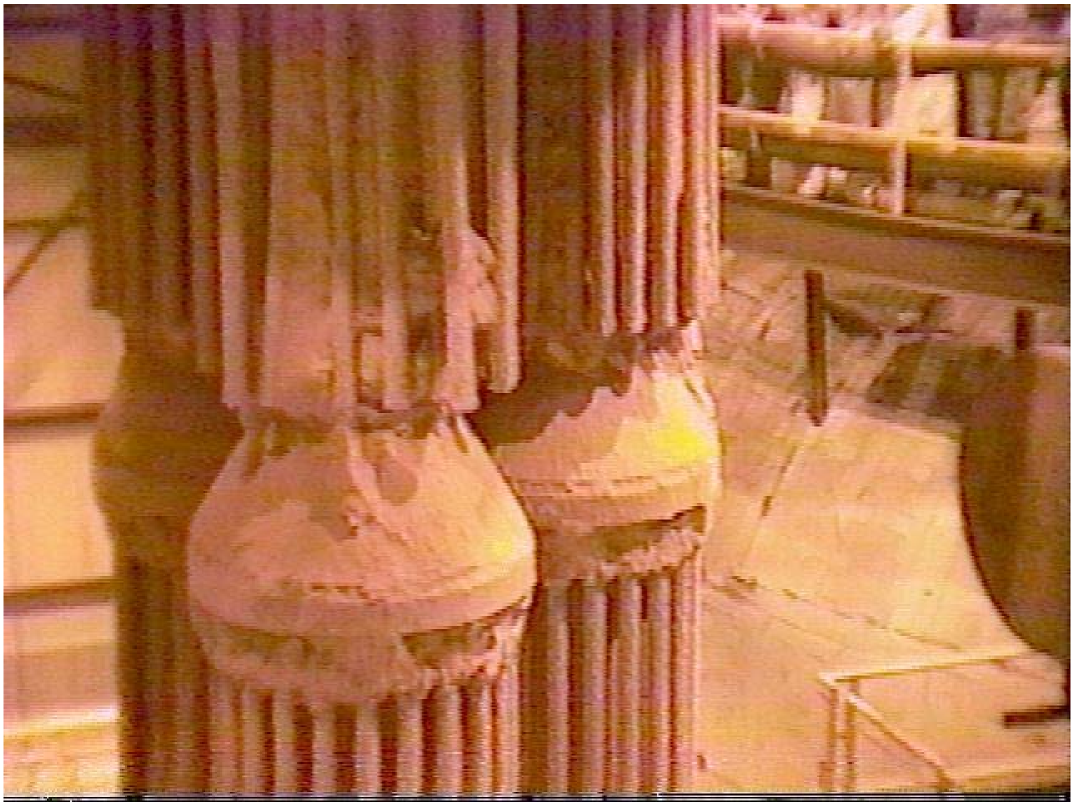

Figure 3-9. Portions of the top and middle plenums are visible in this photograph.

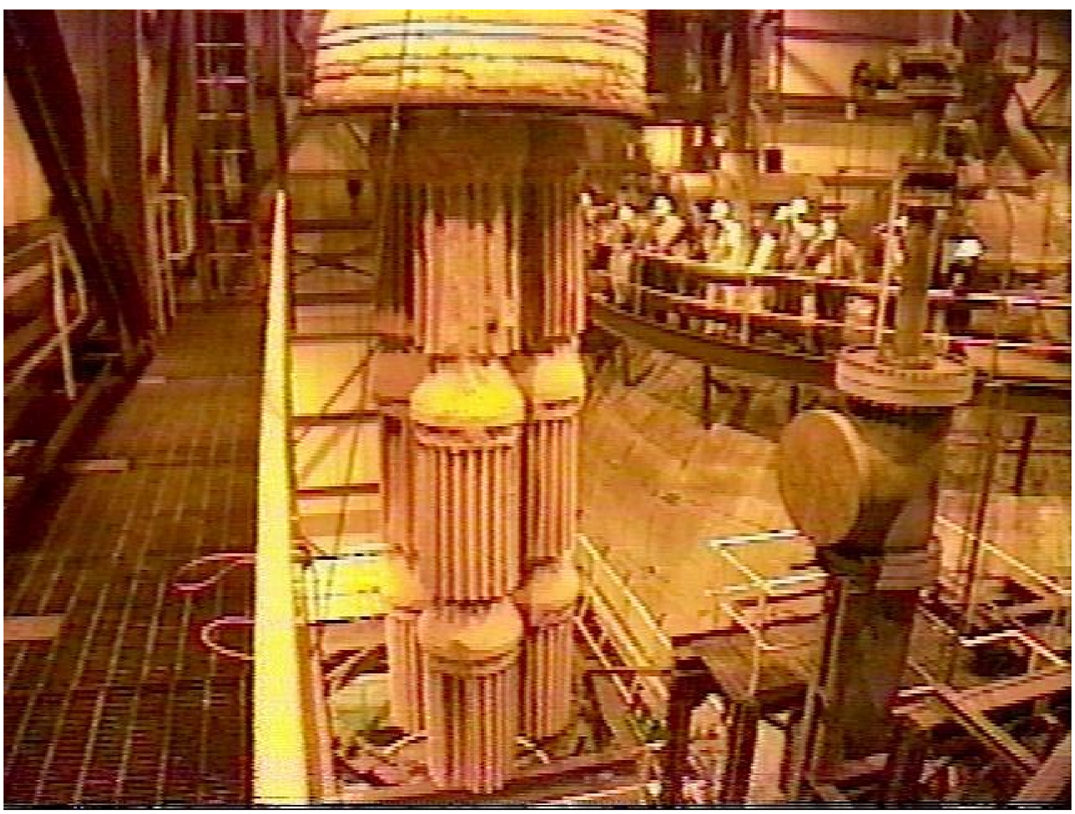

Figure 3-10. The entire plenum assembly being transported to the inspection platform.

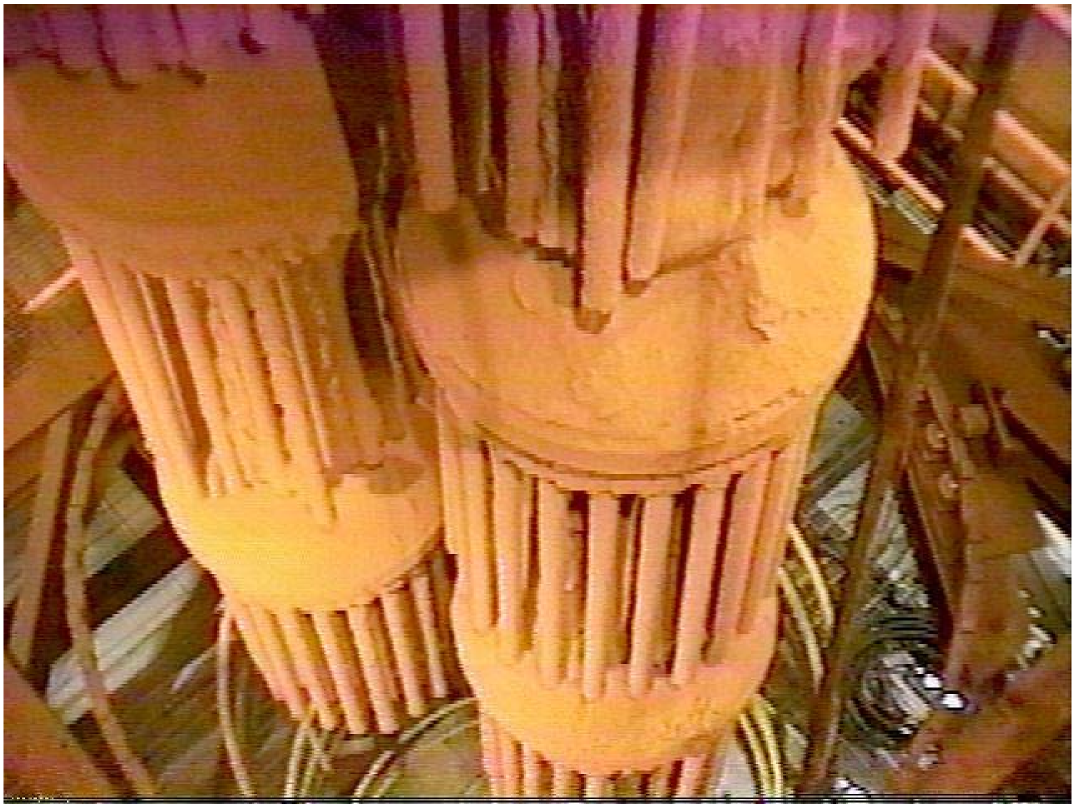

Figure 3-11. Plenums being lowered into the inspection platform.

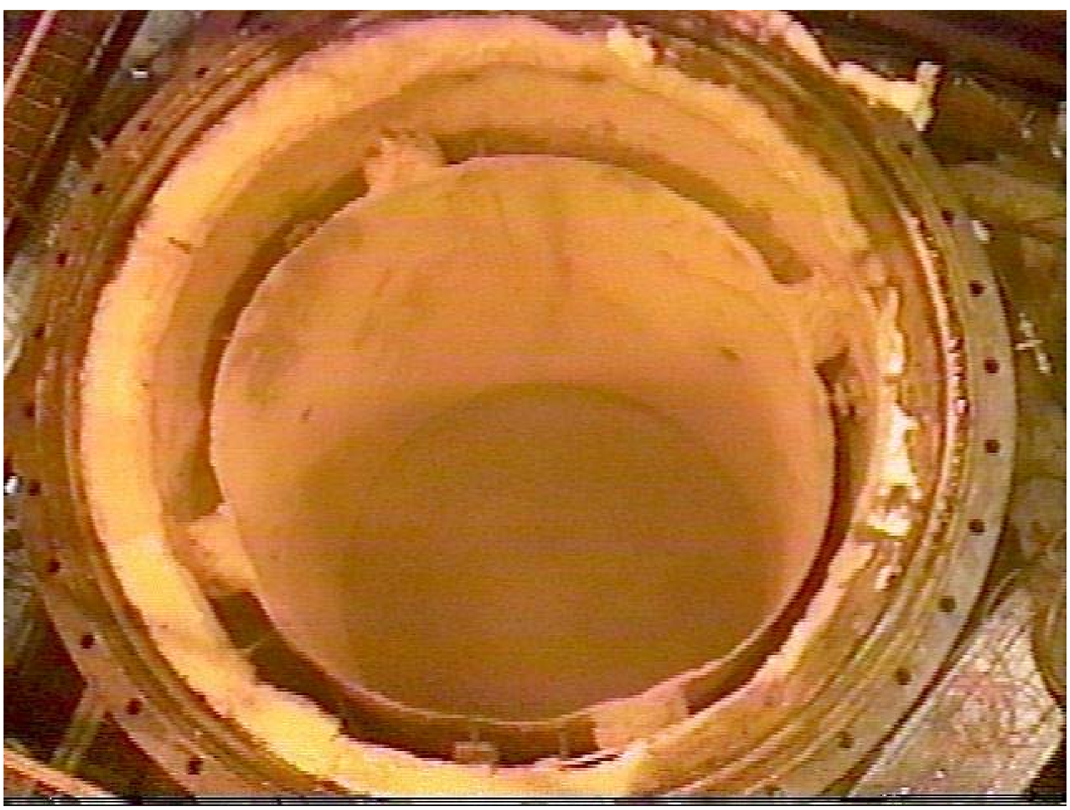

Figure 3-12. The interior of the filter vessel and the shroud after removal of the plenum assembly.

Figure 3-13. Close up of ash bridges and tubesheet deposits.

Figure 3-14. Bridging was especially severe adjacent to the central support column.

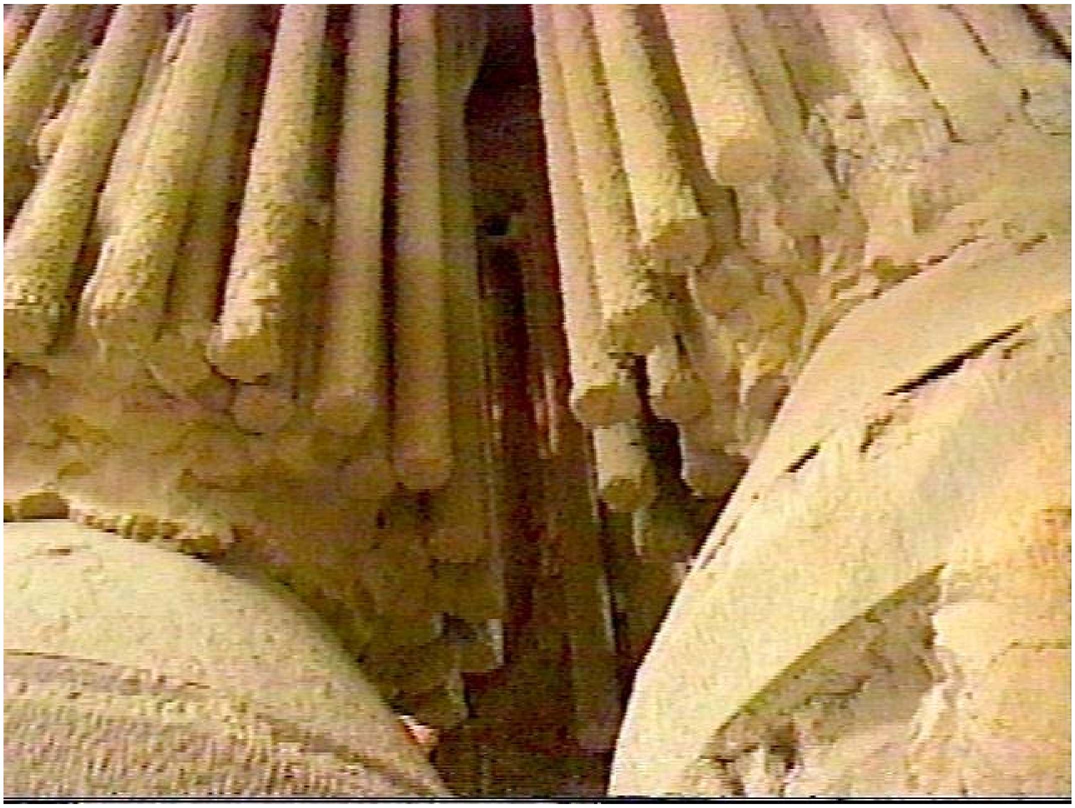

Figure 3-15. Bridging adjacent to the central support columns was pervasive.

Figure 3-16. In addition to deposits adjacent to the support columns, large, strong agglomerates formed around the regions where the candles were attached to the tubesheet.

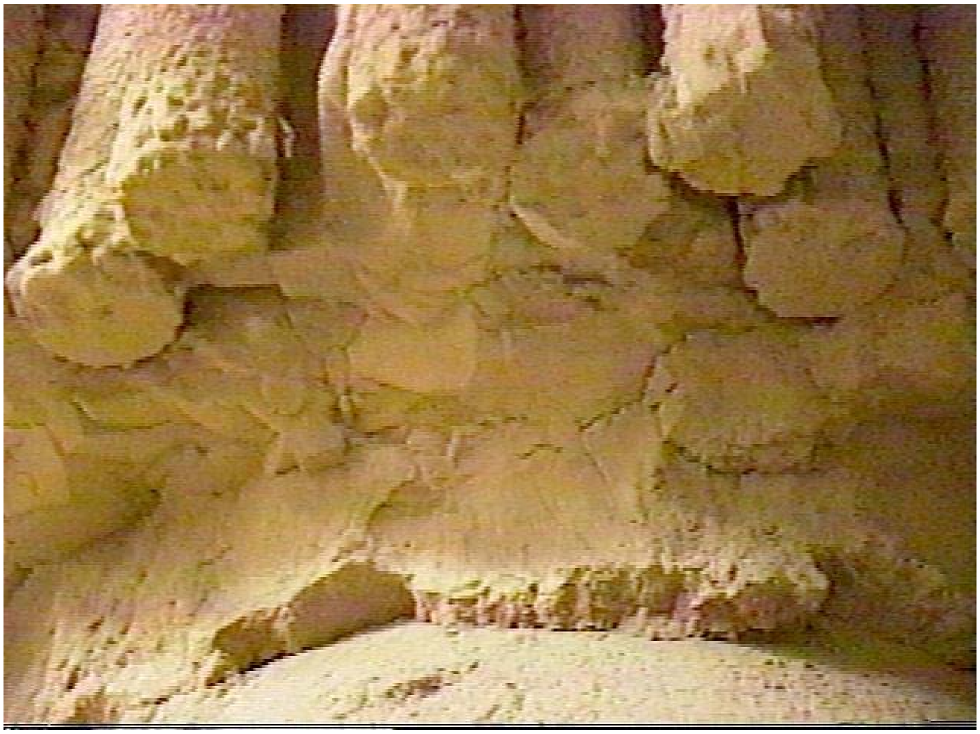

Figure 3-17. Close up of ash bridges.

Figure 3-18. Two types of fracture surfaces are seen here. The relatively clean fracture surfaces on the two elements in the foreground indicate that these elements broke following operation. The ash-covered fracture surface of the element just to the right of the aforementioned elements indicates that this element broke before operation was discontinued.

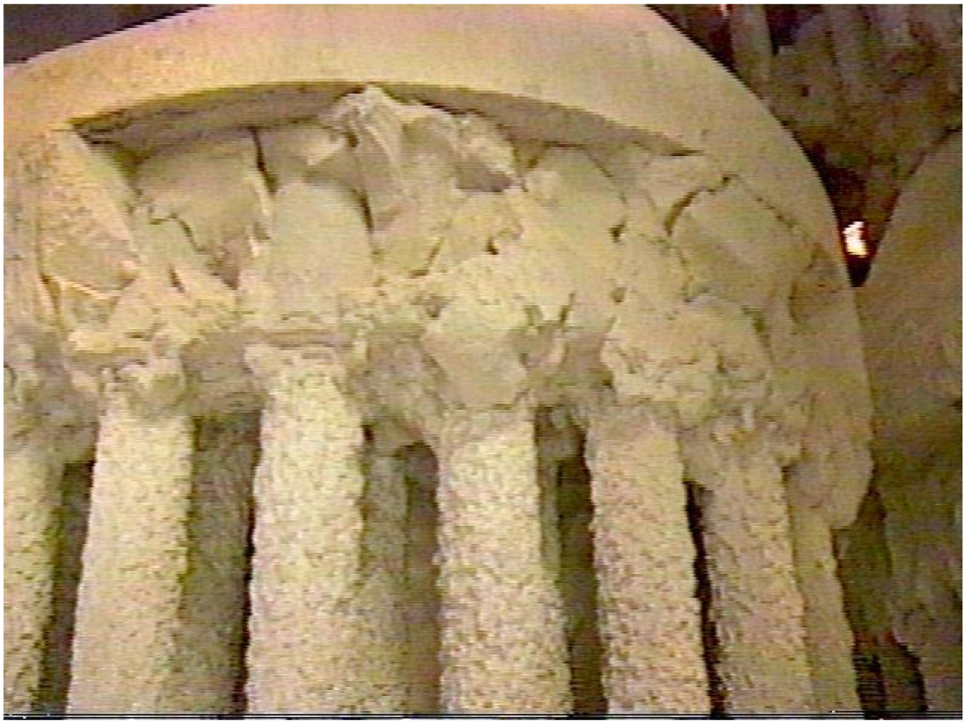
Figure 3-19. Large ash deposits were common under the tubesheet. This photograph also shows the general appearance of the filter cakes.

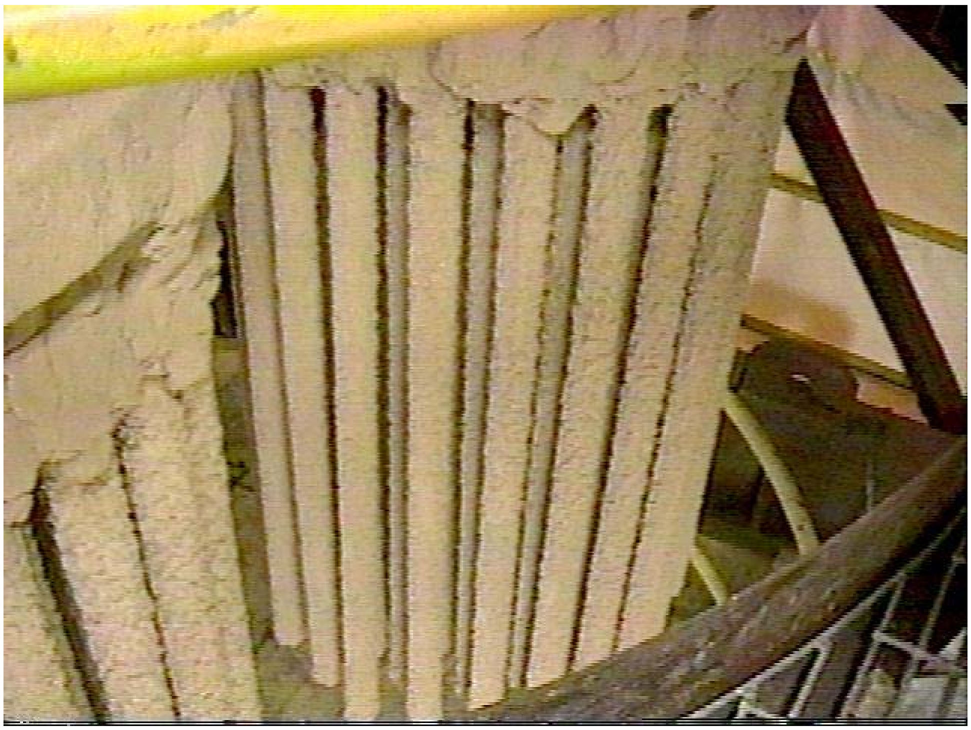
Figure 3-20. The candles in the bottom plenums were relatively free of bridges, presumably because these plenums had no support columns in the center of the arrays of elements. (Deposits formed by turbulent diffusion on the central columns in the upper plenums. These deposits grew unabated, and significantly contributed to the problems that were common in the upper plenums.)

Figure 3-21. The bottom plenum was not entirely free of bridging between candles. This photograph shows a chunk of ash stuck between candles in the bottom plenum. This chunk is believed to have originated under the tubesheet in the bottom plenum.

Figure 3-22. Close up of the filter cakes in the bottom plenum.

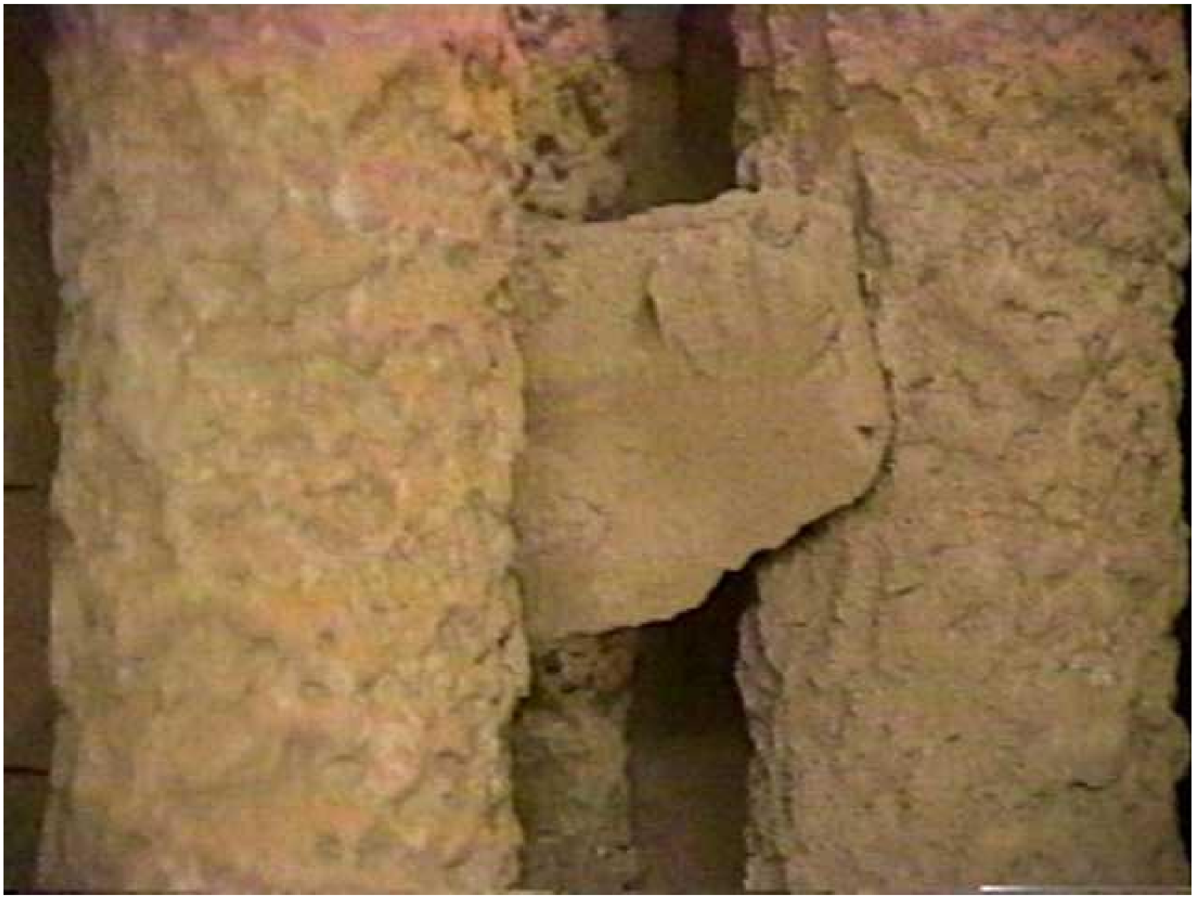
Figure 3-23. At various places large ash deposits were found lodged between filter elements.

3.1.3 October 27, 1994

From May 1994 until the shutdown of the facility in the spring of 1995, operation of the APF focused on two separate approaches to eliminating the ash bridges previously formed between candle filter elements and nearby surfaces. The first approach involved increasing the mean size of the entrained particles entering the filter vessel by spoiling, and later bypassing, the cyclone located just upstream of the filter. The other approach was to remove the inner ring of candle filter elements from the top and middle plenum assemblies. Although this latter approach involved removing 25 % of the ceramic candle filter elements, and consequently 25 % of the active surface area, it was implemented to increase the separation between the candle filter elements and the ash sheds and plenum support conduits, reducing the likelihood that ash bridges would form at these locations.

When the APF was opened on October 27, 1994 a significant number of candle filter elements were broken, and ash deposits were present at various locations throughout the filter assembly. Figures 3-24 through 3-36 illustrate the condition of the APF. As observed in two previous site visits, the region under each tube sheet where the candle filter elements were mounted was completely packed with ash deposits. Although the number of ash bridges adjacent to the filter elements was reduced compared to the two prior site visits, there were still a few large ash bridges formed between the lower portion of filter elements in the top and middle plenum assemblies and the ash sheds and/or the plenum support conduits. In general, the filtering surfaces of the intact filter elements were relatively clean, except for regions of the candles just below the tube sheet deposits mentioned above. The surfaces of the plenum support conduits and the ash sheds were cleaner than previously observed; however, several thick ash deposits were present on portions of these surfaces. Bridging of ash between filter elements in the bottom plenum assembly did not seem to be a serious problem.

Figure 3-24. General appearance of the top plenum as it was being transported to the inspection platform.


Figure 3-25. The top plenum experienced some bridging and broken elements.


Figure 3-26. This photograph shows a cover that was installed to minimize the growth of ash deposits around the tubesheet.

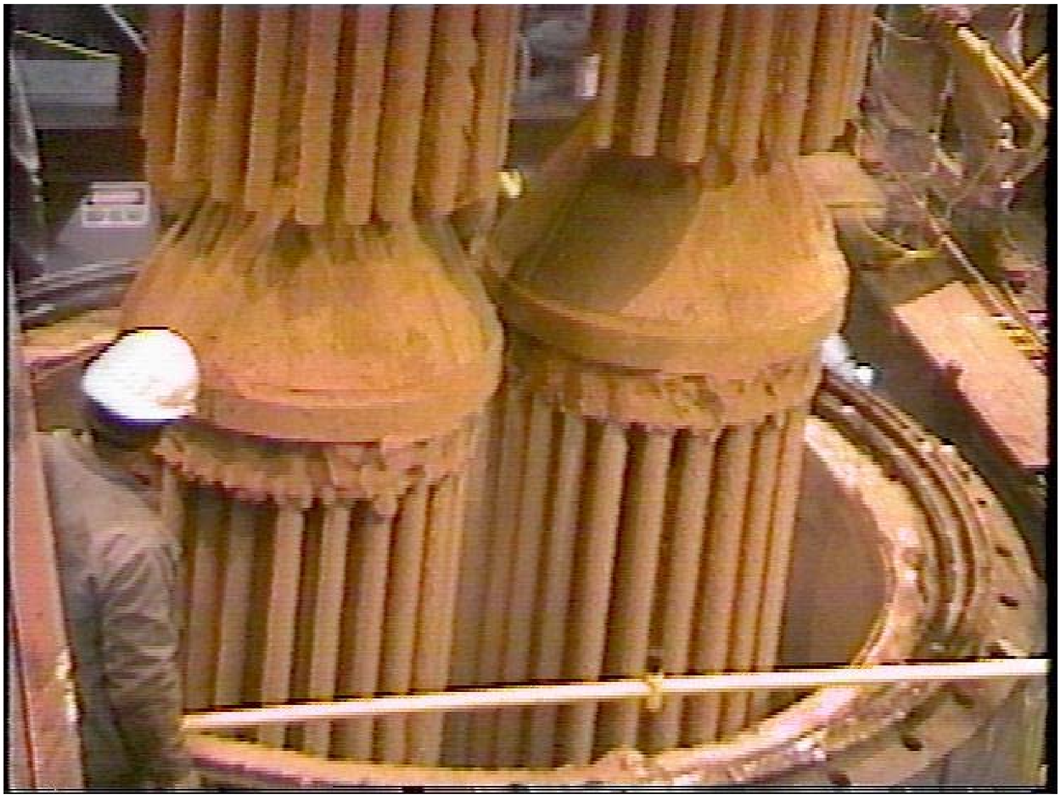

Figure 3-27. This photograph shows the general condition of the bottom and middle plenums as they were lifted from the filter vessel.

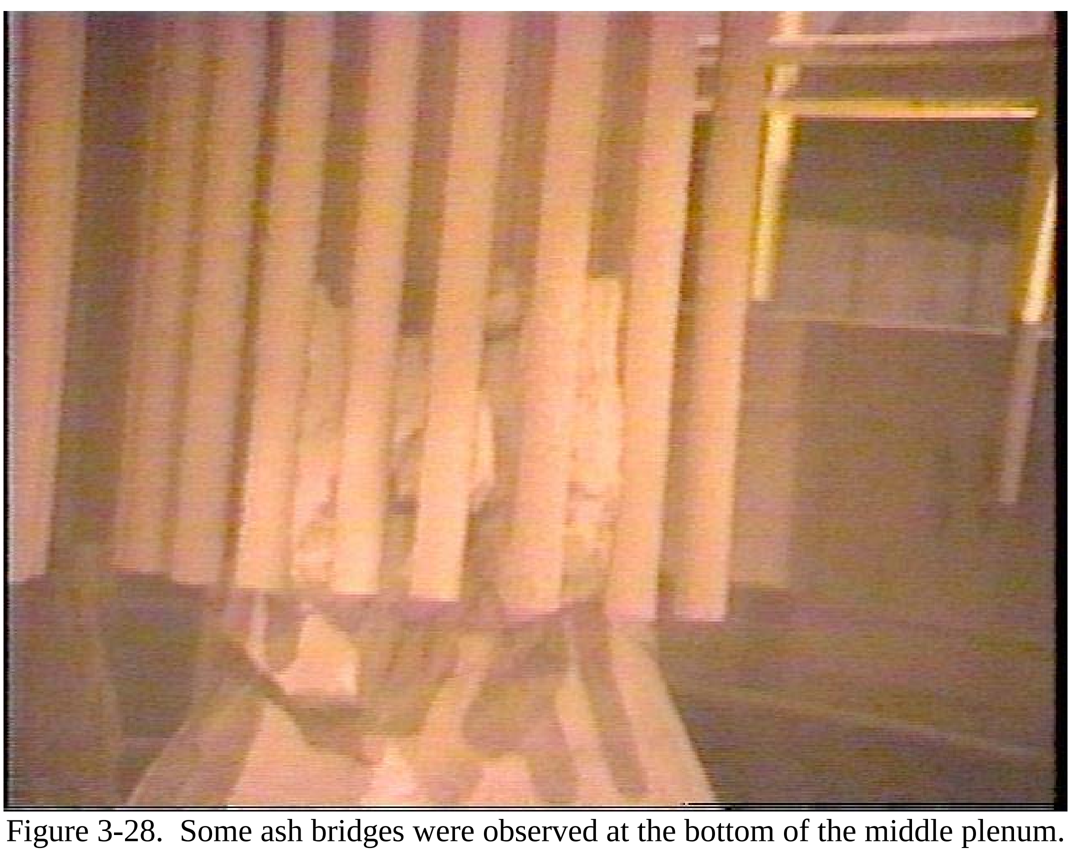

Figure 3-28. Some ash bridges were observed at the bottom of the middle plenum.

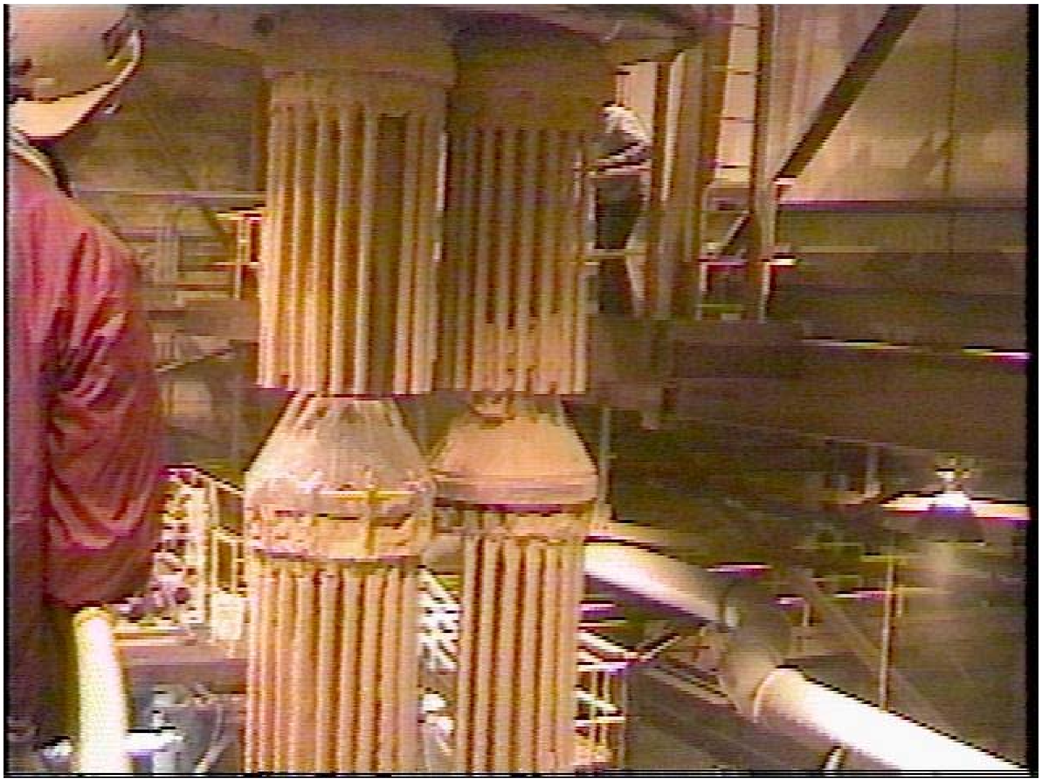

Figure 3-29. General condition of top and middle plenums as they were transported to the inspection platform.

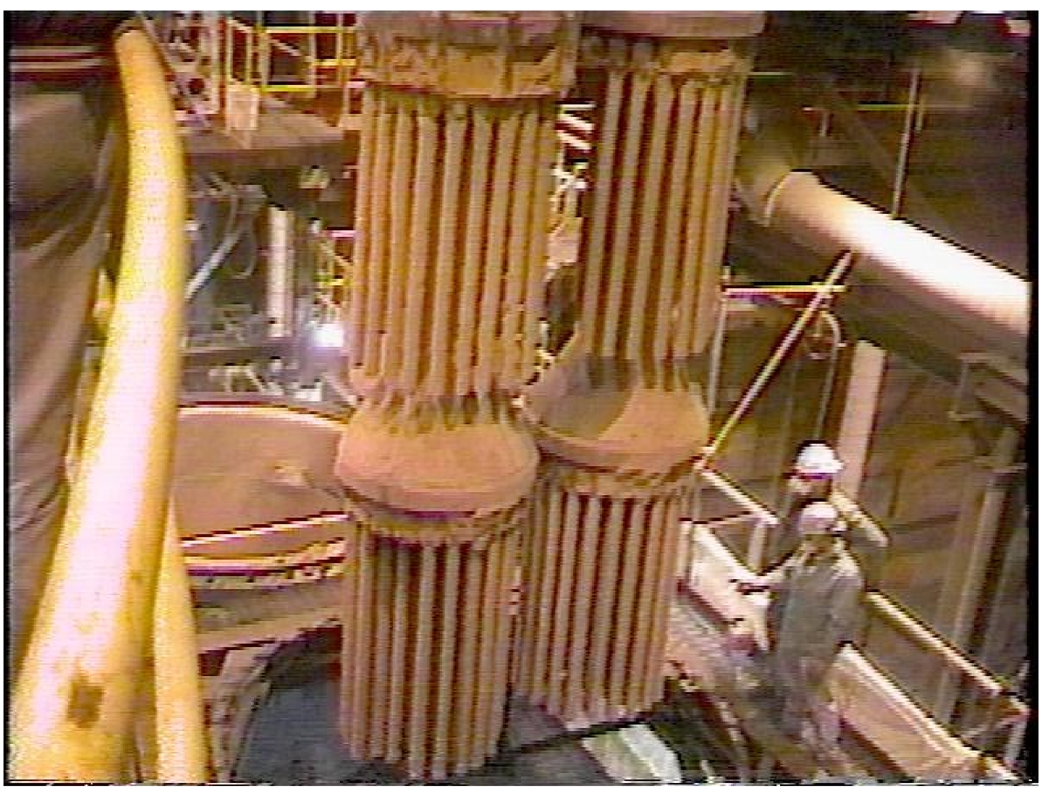

Figure 3-30. General condition of middle and bottom plenums as they were transported to the inspection platform.

Figure 3-31. View of a tubesheet ash deposit on the bottom plenum.

Figure 3-32. View of a tubesheet ash deposit on the top plenum.

Figure 3-33. Condition of the tubesheet and top portion of the top plenum.

Figure 3-34. This morphology of this large ash bridge supports the conclusion that loose ash falling from above can be blocked and retained by chunks of ash previously lodged against the candles. This bridge was located near the lower end of the filter elements just above the conical surface of the ash shed.

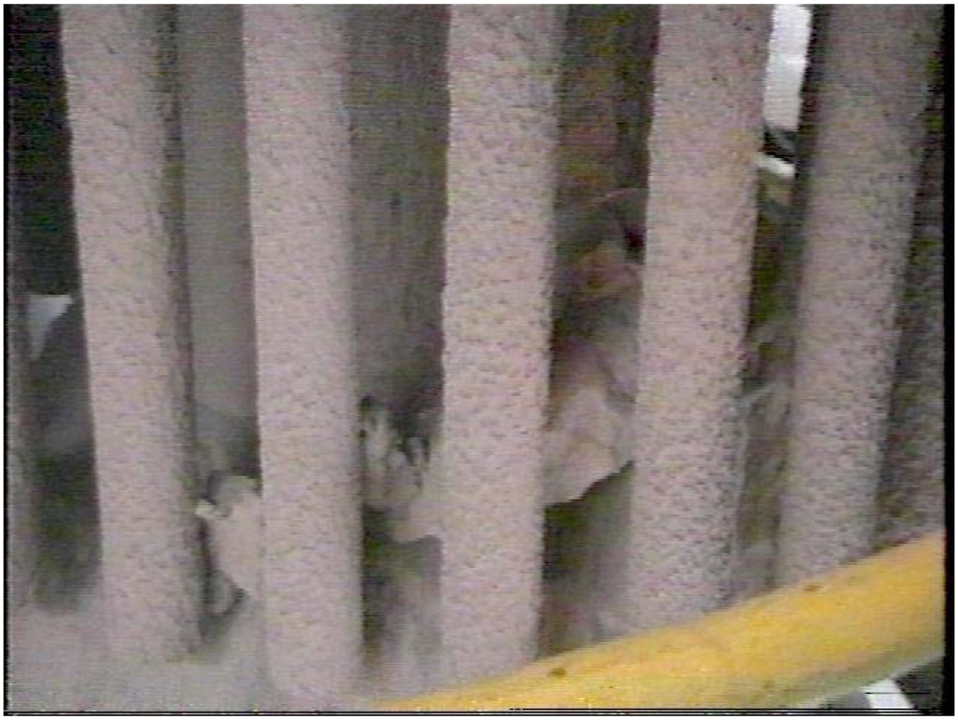

Figure 3-35. Chunks of ash that get trapped between candles (as shown here) appear to provide the initial conditions for development of bridges between adjacent filter elements. Ash removed during cleaning pulses piles on top of these trapped chunks instead of falling into the hopper for removal.

Figure 3-36. This view looking up at the middle plenum shows six candles that broke during operation. The appearance of the central support column suggests that cleaning pulses passing downward through these six locations scoured the column clean.

3.1.4 May 11, 1995

The APF was opened once more on May 11, 1995 after the final shutdown of the Tidd Demonstration Plant. During this last operating period, the cyclone upstream of the APF was entirely bypassed to get as many relatively large particles into the filter vessel as possible. In general, the filter assembly was quite clean. The only significant deposits of ash were on the underside of the tube sheets, much like the deposits found in these locations during prior inspections. Most of the broken candle filter elements were of a particular experimental design. Most of the other filter elements were intact. Figures 3-37 through 3-50 present a variety of views of the APF following the final shutdown of the facility.

Figure 3-37. The filter assembly was basically free of bridges and most of the elements were intact when the assembly was removed from the filtration vessel.

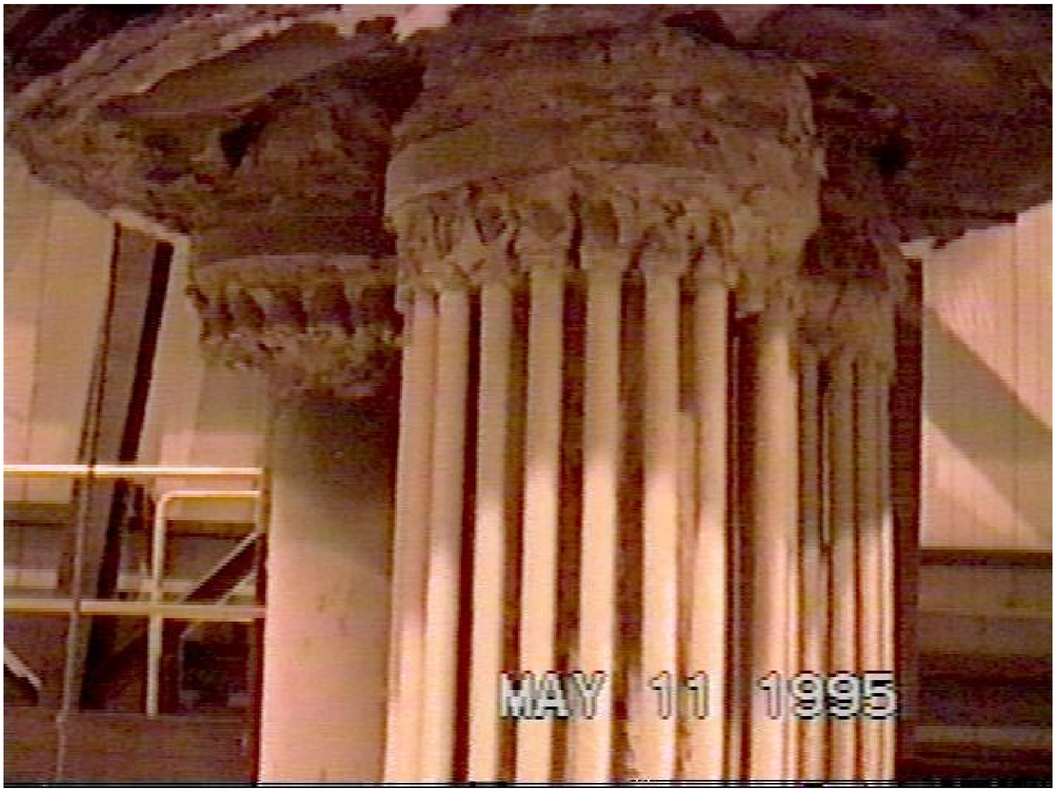

Figure 3-38. Breakages in the plenum on the left were attributed to factors other than ash characteristics.

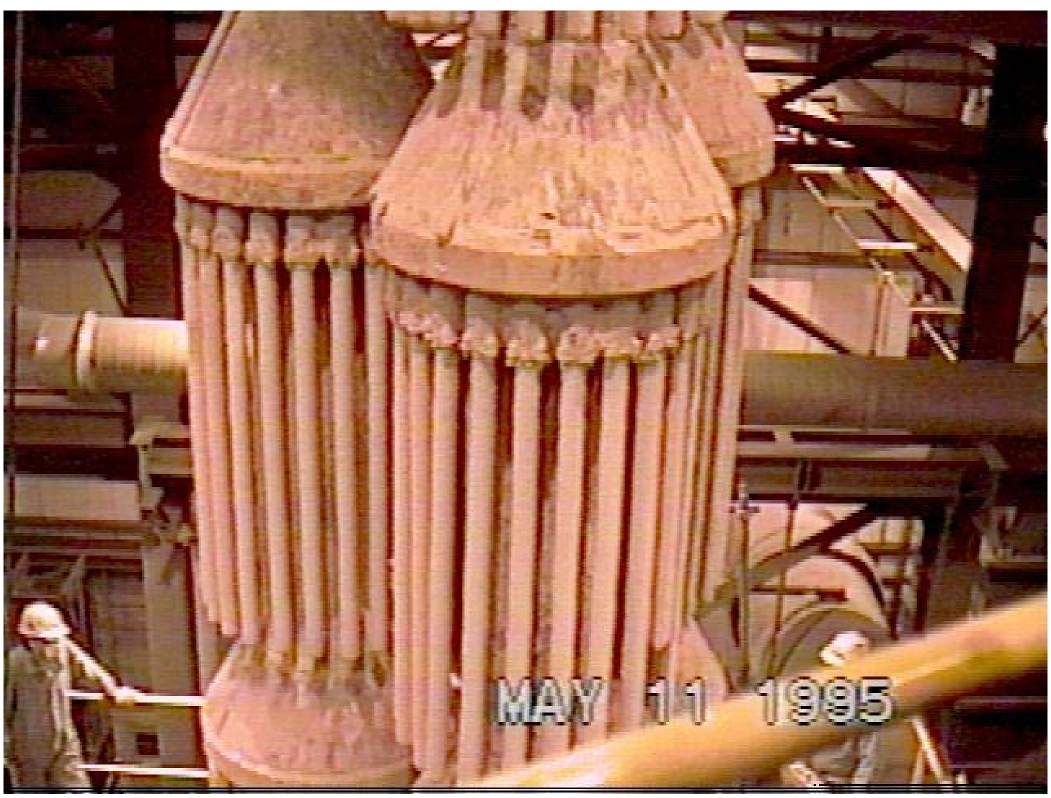

Figure 3-39. The middle plenum assembly was clean and the filter elements were intact.

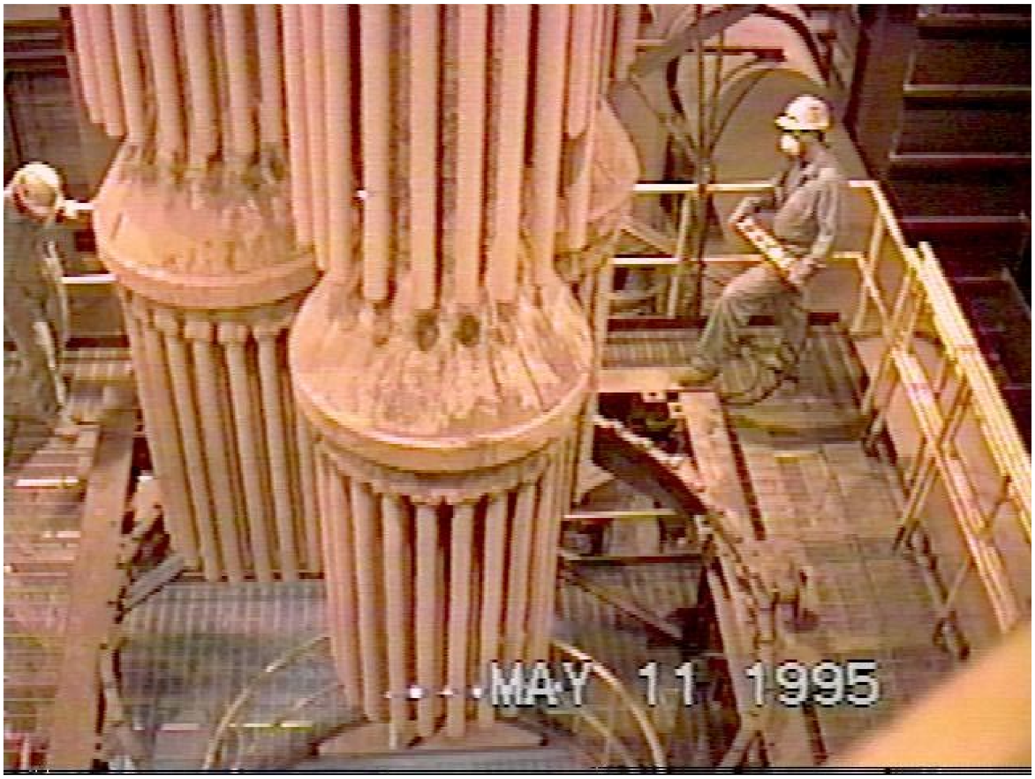

Figure 3-40. The bottom plenum was clean and the filter elements were intact. The filter assembly is being lowered onto the inspection platform.

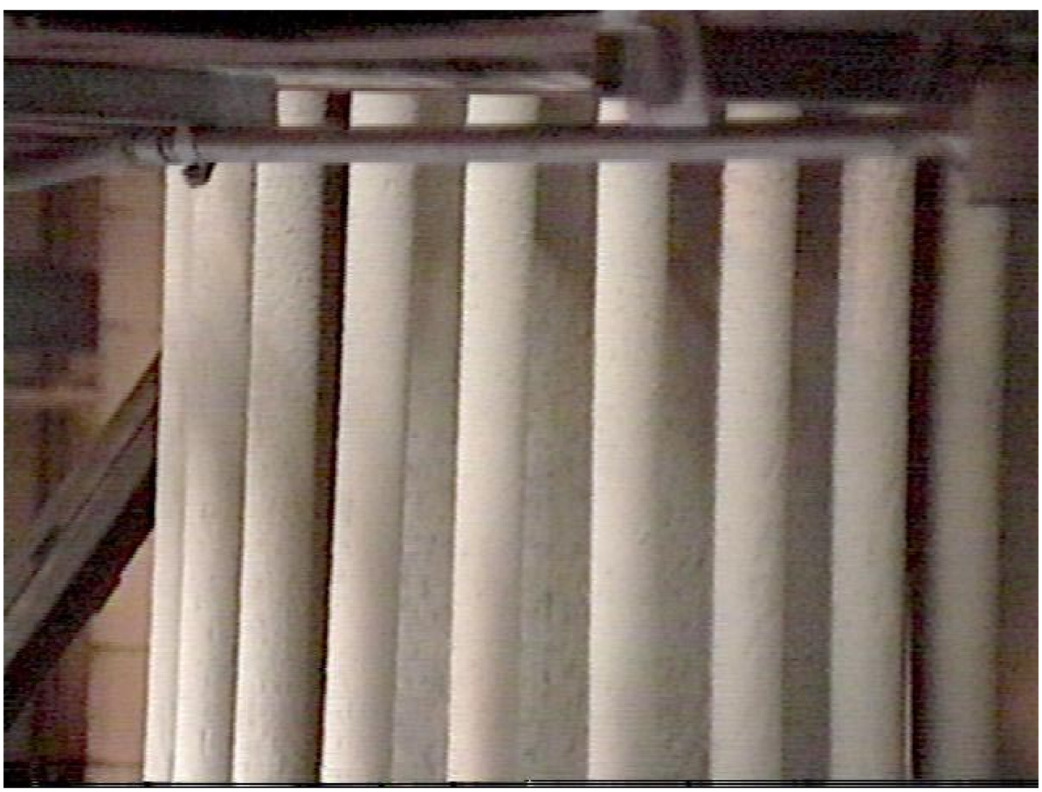

Figure 3-41. The intact candles in the top plenum were very clean.

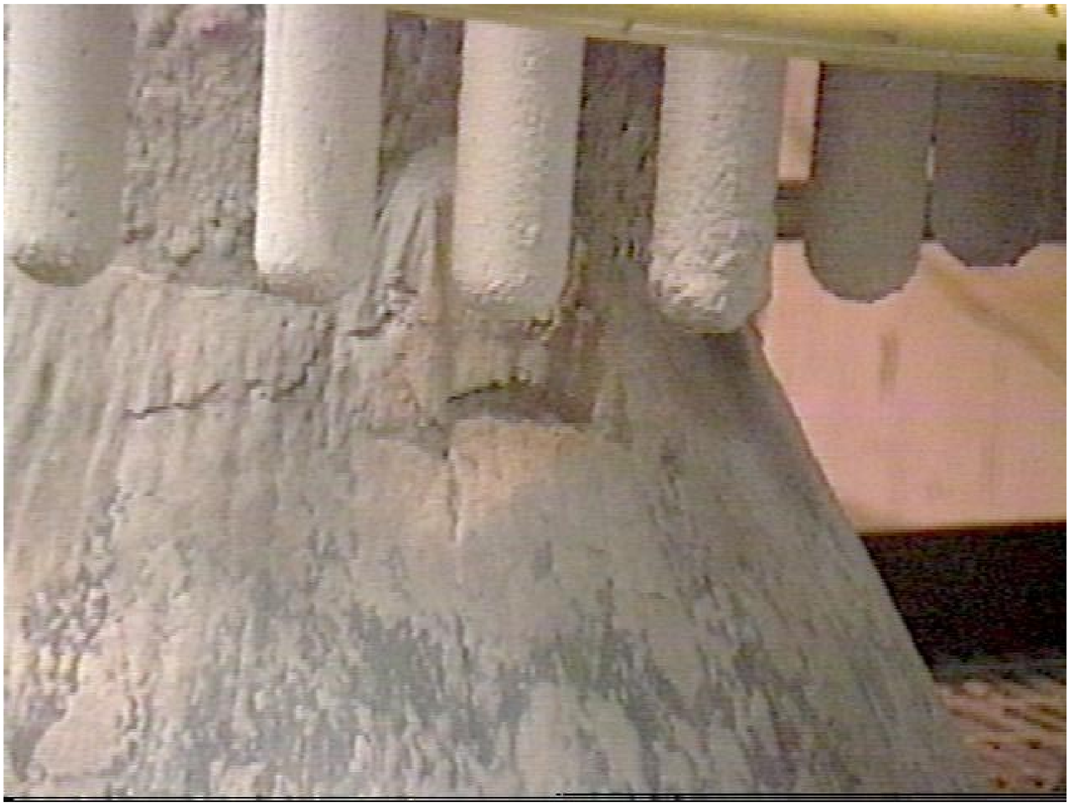

Figure 3-42. Only minor deposits were present on the ash shed below the top plenum.

Figure 3-43. The distinctly different appearances of the filter cakes on these two filter arrays in the bottom plenum are believed to be a result of different element types.

Figure 3-44. Close up of filter cakes in the bottom plenum.

Figure 3-45. Many of the filter cakes were moderately thick and irregular in shape.


Figure 3-46. Tubesheet region of the bottom plenum.

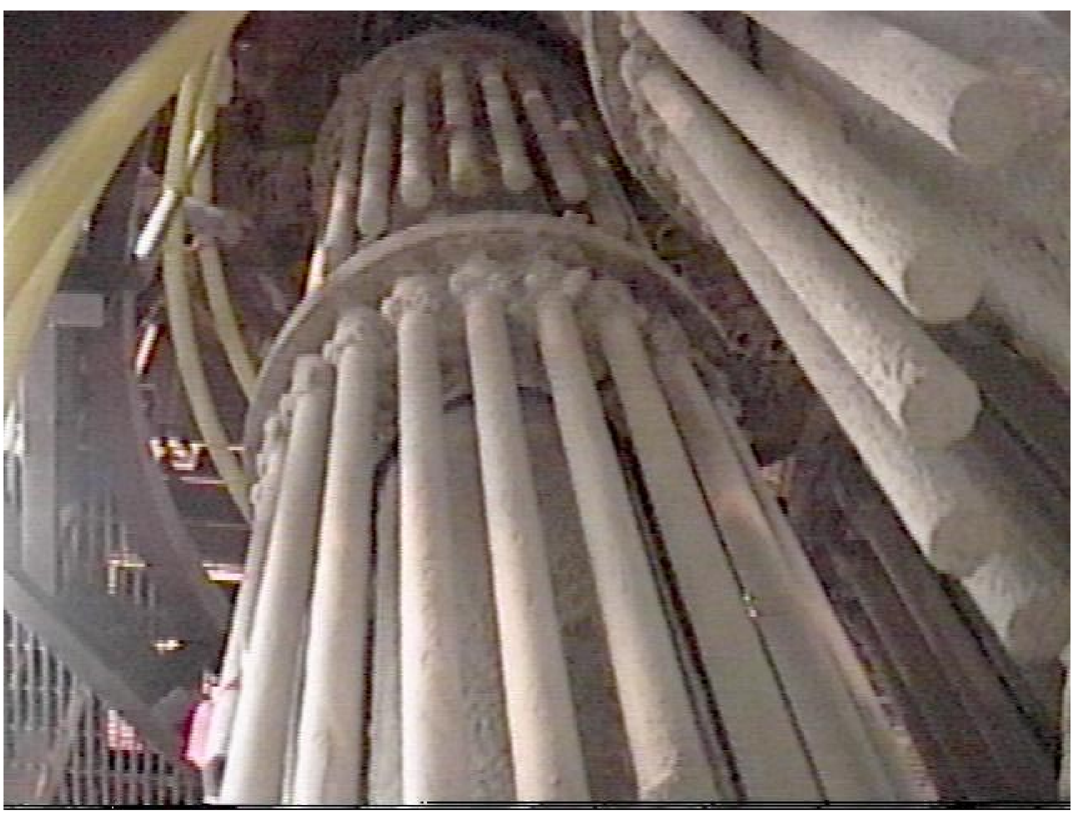
Figure 3-47. This view looking up at the top two plenums shows how the inner ring of elements was removed prior to this run, and how the elements remained relatively clean.

Figure 3-48. The ash sheds remained relatively clean during this run.

Figure 3-49. The intact elements in the top plenum remained clean.

Figure 3-50. The ash sheds and the central support columns remained free of significant ash deposits.

3.2 DOE/FETC MODULAR GAS CLEANUP RIG

FETC has performed a number of tests with its one ton-per-day fluidized-bed gasifier to analyze and develop high-pressure, high-temperature components and processes in reducing and oxidizing environments. The 10-inch diameter Fluid Bed Gasifier provides 300 lb/hr of particle-laden coal gas at 1000 °F and 425 psig for cleanup in a barrier filter. The coal gas pressure is reduced to 285 psig before entering the four-candle Modular Gas Cleanup Rig (MGCR) for particulate removal. Several gasification particulate samples collected in the MGCR were analyzed under this task.

3.2.1 October 29, 1996

A site visit was made to the MGCR for inspection and sampling on October 29, 1996. All four filter elements were covered with nearly uniform thin cakes (Figure 3-51). The thickness of the filter cakes on candles A, B, and D was about 0.76 mm, and the filter cake on candle C was about 0.51 mm thick. Figure 3-52 shows these thickness measurements being performed. Porosity values of 94.2 and 95.3 % were measured with a core sampler for the filter cake on candle A. The same method applied to the filter cake on candle C yielded values of 94.6 and 94.9 %.

Filter cake porosity was also measured by impregnating weighed filter cake nodules with ethanol. Five measurements were performed using this technique on nodules from candle B.

The results of these measurements varied from 90.8 to 91.8 %. Another method based on the impregnation of nodules with low viscosity epoxy failed because the viscosity of the epoxy was still too high to allow it to penetrate the ultrafine pores in the filter cake nodules. It is not certain whether the porosity of the filter cakes on all four candles is closer to 91 or 95 % because the thinness and fragility of the cake challenged both methods. Further analyses of samples from the MGCR are discussed under the section *Analyses of Particulate Samples*.

Figure 3-51. Lower portion of the four candles removed from the MGCR filter vessel. Each element was covered with a thin, black filter cake that was smooth and fluffy.

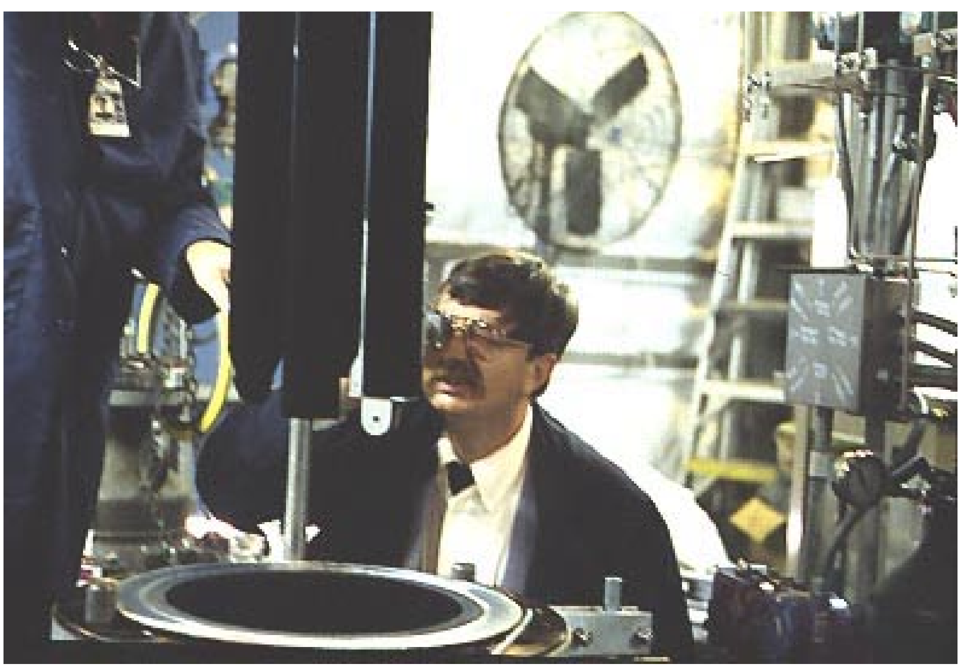

Figure 3-52. Microscopic examination of the filter cakes was used to determine their thickness.

3.3 POWER SYSTEMS DEVELOPMENT FACILITY

The Power Systems Development Facility is an engineering scale demonstration of two advanced coal-fired power systems including hot gas cleanup.[9] The project is sponsored by Southern Company Services, Inc., and by the U.S. Department of Energy's Federal Energy Technology Center, under contract DE-FC21- 90MC25140. The first system placed on line was the Kellogg Brown & Root transport reactor, which is an advanced circulating fluidized bed reactor designed to operate as either a combustor or a gasifier. (All the samples from the PSDF that were analyzed under this task were generated by this transport reactor operating in combustion mode.) The transport reactor uses one of two possible hot gas cleanup filter technologies (particulate control devices or PCDs) at a component size readily scaleable to commercial systems. The second system to be demonstrated, Foster Wheeler's topped pressurized fluidized bed combustor (PFBC), incorporates a bubbling-bed carbonizer and a circulating PFBC and will also employ high-temperature PCDs.

The objectives of the PSDF are to develop advanced coal-fired power generation technologies through testing and evaluation of hot gas cleanup systems and other major components at the pilot scale and to assess and demonstrate the performance of the components in an integrated mode of operation. The facility is sized to test the components at capacities that are readily scaleable to commercial systems. The primary focus of the PSDF project is to demonstrate and evaluate high temperature PCDs that are the single most important component required for successful development of advanced power generation systems.[10] High temperature PCDs are a common component of advanced gasification and APFBC technologies, both of which will be evaluated at the facility.

The Kellogg Brown & Root transport reactor technology, under development at the PSDF at a scale of about 2 tons/hour of coal feed, can operate either as a gasifier or combustor. Tests can be conducted in both configurations. In the gasifier mode, coal is introduced and burned substoichiometrically. The coal devolatilizes, the volatiles pyrolize and the residual char is steam gasified. This staging of the gasification reaction forces oxygen to react with char rather than with the volatiles, as is characteristic in fluid bed gasifiers. As a result, the size of the gasifier (and the capital cost) is reduced below that of conventional gasification because the amount of char to be gasified by reaction with steam (which is slow at the expected operating temperature) is reduced substantially. Operation in the combustion mode is similar, but the reactor is fired with excess air and a fluidized bed heat exchanger is included in the reactor loop to remove the heat released from the system.[10]

The transport reactor train is sized to process sufficient coal to generate 1,000 acfm of gas to test the PCDs. Indirect cooling of the gas from the transport reactor will allow testing of the PCDs with inlet temperatures between 650 °F and 1,500 °F and at pressures in the range 100 psia to 280 psia. The PCD in this train will receive exhaust gas from the transport reactor operating in either gasification or combustion mode. The gas exiting the PCDs will be thermally oxidized in the gasification mode, cooled and filtered in the baghouse before discharge from the stack. The ash/char mixture produced in the gasification mode will be oxidized in the Sulfator prior to disposal. A Siemens Westinghouse-supplied filter system was used during commissioning of the transport train. The dirty gas enters the PCD below the tube sheet and flows through the candle filters, and the ash collects on the outside of the filters. The clean gas passes from the plenum/candle assembly through the plenum pipe to the outlet pipe. As the ash collects on the outside surface of the candle filters, there is a gradual increase in the pressure drop across the filter system. The filter cake is periodically dislodged by injecting high pressure gas pulse to the clean side of the candles. The cake then falls to the discharge hopper. When the transport reactor is operated in the combustion mode, the pulse gas is high pressure air. The pulse gas is routed individually to the two plenum/candle assemblies via injection tubes mounted on the top head of the PCD vessel. The pulse duration is typically 100-500 milliseconds. All operation to date has been with the Siemens Westinghouse FL0301 filter vessel. This vessel has a tangential inlet, and holds up to 91 filter elements in two plenums. The top and bottom plenum are pulse-cleaned separately.[11]

A number of shutdowns of the PSDF transport reactor took place during the execution of this task. Six of these shutdowns afforded opportunities for direct observation of ash deposits in the Siemens Westinghouse FL0301 filter vessel when it was taken off line and opened for inspection and refitting. In general, the site visits conducted at these times included video and still photography to document the condition of the vessel, followed by measurements of the thickness and areal density of the filter cakes at various locations in the assembly. On each site visit, sufficient ash was removed from at least one candle filter element for detailed analyses. In the following discussions, the general condition of the vessel, and the data and samples obtained while on site are described. The detailed laboratory analyses of selected ash samples are discussed under the section entitled *4.0 Analyses of Particulate Samples*.

3.3.1 April 9, 1997

The Siemens Westinghouse FL0301 filter vessel installed on the transport reactor train at the PSDF was opened because of indications of filter element breakage on April 9, 1997 following a brief run (CCT4C) without added sorbent. A site visit was made to the PSDF on that date to observe, document and characterize the filter cakes present on the candle filter elements and other filter vessel deposits. Photographs of the condition of the filter vessel taken during this site visit are presented in Figures 3-53 through 3-60. All of the candle filter elements were covered with patchy, thin cakes. The thickness of the filter cakes ranged from about 0.1 to 1 mm. (Because the filter was extensively pulse-cleaned prior to shutdown, the thickness of these cakes does not necessarily represent the condition of the cakes during operation.) Analyses were performed on filter cake ash that was collected from the surfaces of the candles before they were removed from the tubesheet. Two complete candles with deposited filter cakes were also set aside for ash analysis.

Because no sorbents were added to the process stream prior to this site visit, the concentrations of calcium and magnesium in filter cake ash collected on this site visit are relatively low (as compared with pressurized, fluidized-bed combustion ashes from fully implemented processes). Because operation of the PSDF combustor was still in its early stages in April 1997, the chemical and physical characteristics of PSDF ashes produced in later operation differ significantly from the filter cake ash collected on this site visit. (The chemical and physical characteristics of filter cake ash collected on this site visit are presented in section *4.5 Power Systems Development Facility*.)

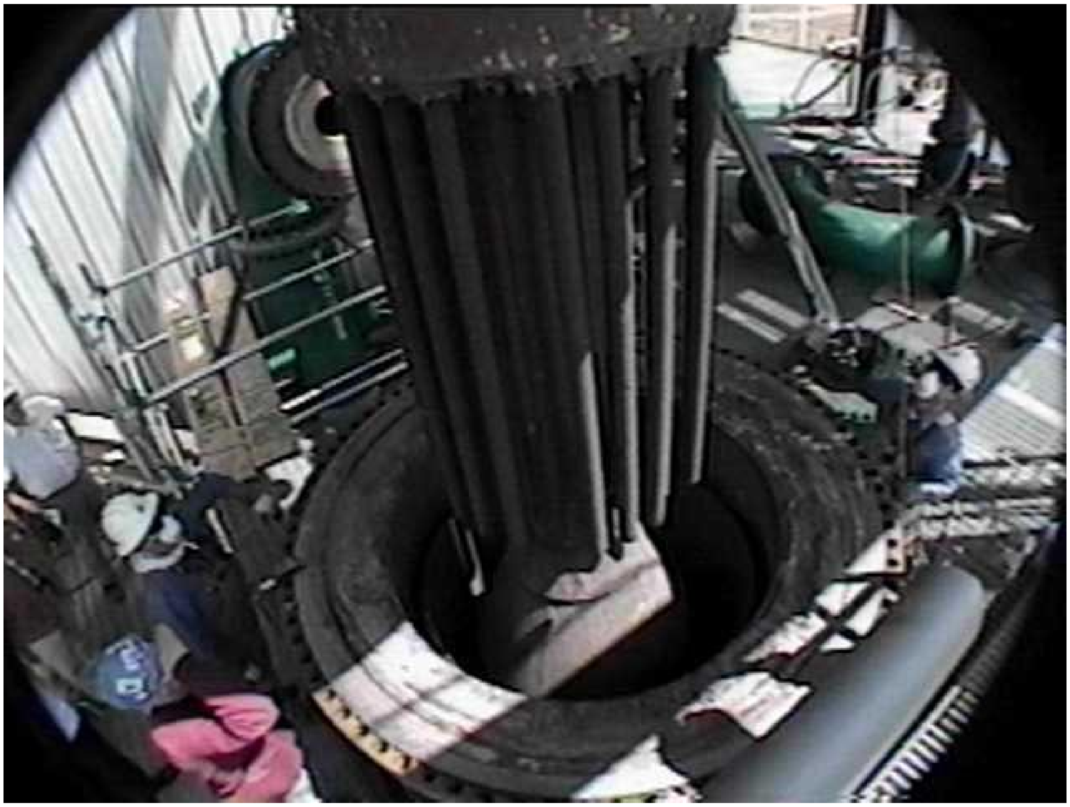

Figure 3-53. Removal of the filter assembly for inspection and refitting.

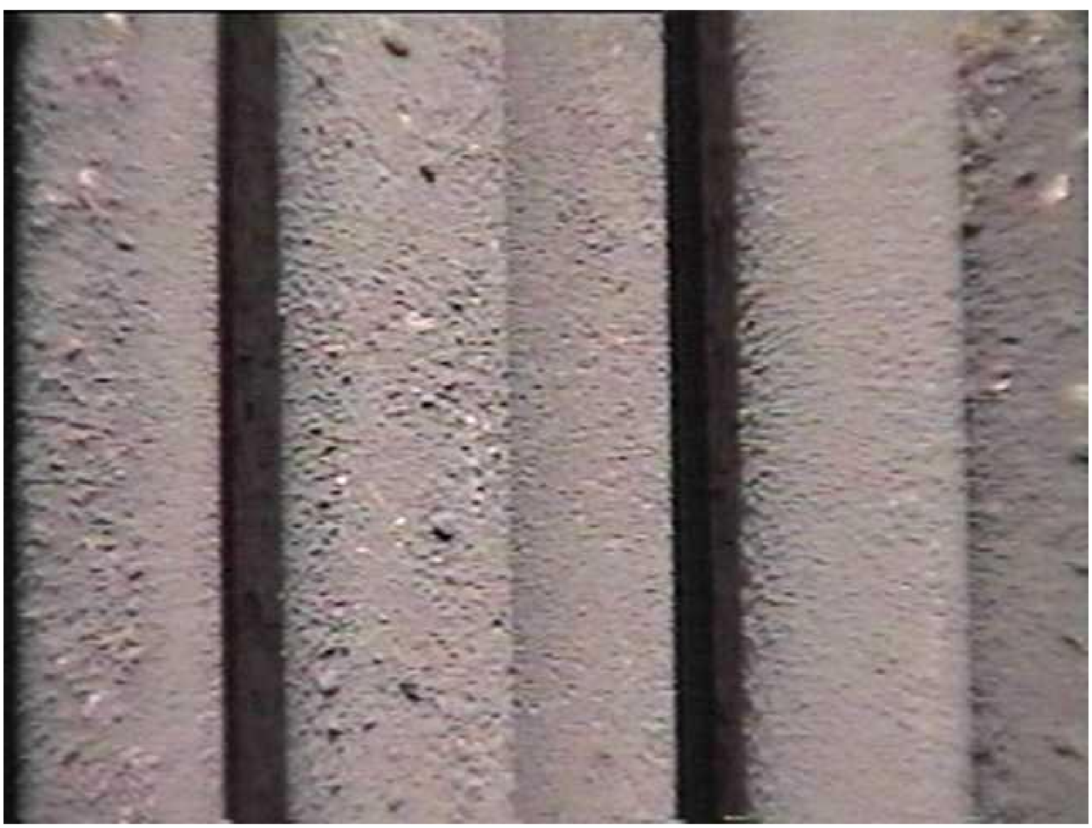

Figure 3-54. Typical condition of the filter cakes.

Figure 3-55. Lower plenum candles.

Figure 3-56. The lower plenum clearing the filtration vessel.


Figure 3-57. Typical deposits that formed around the filter element mounting assemblies.


Figure 3-58. Typical patchy cakes observed on the filter elements.

Figure 3-59. Upper portion of the top plenum assembly.

Figure 3-60. Lower portion of the top plenum assembly.

3.3.2 July 29, 1997

The purpose of the site visit to the PSDF on July 29, 1997 was to collect and analyze ash samples from the Siemens Westinghouse FL0301 filter vessel after run CCT6. Photographs were obtained of the filter when it was opened. Ash samples were gathered from a number of different filter elements in the upper and lower plenums. Filter cake thickness was measured at several points with a traversing transverse laser gauge. In general, the majority of the filter elements were covered with relatively smooth filter cakes that were from 1 to 2.5 mm thick. In addition, many of the filter cakes on filter elements on the outside of the arrays had what appeared to be impaction ridges. These ridges, seen in Figure 3-61, ran vertically along the candle filter elements with raised ash deposits facing into the gas flow that apparently swirled in the filter vessel around the plenums. The thicknesses of several of these swirl impaction ridges found in cakes present on filter elements in the bottom plenum were measured about six inches below the tops of the filter elements. These ridges were up to 24 mm thick. Core samples were taken at several locations where filter cake thickness had been measured to determine filter cake porosity. Porosities ranging from 84 to 89 %, with an average value of 87 %, were measured for filter cakes on the top plenum. Corresponding values measured for bottom plenum filter cakes ranged from 81 to 86 %, with an average value of 83 %. Figure 3-62 provides a view of the shroud that surrounds the filter assembly in the FL0301 filter vessel.

Figure 3-61. Upper portion of candles showing impaction ridges in the filter cakes.

Figure 3-62. Interior of the filter vessel showing the shroud that surrounds the plenums.

3.3.3 November 5, 1997

Another site visit was made on November 5, 1997 to the PSDF to characterize the condition of the filter and collect ash samples for analysis. This site visit followed run TC01G. The condition of the filter vessel is depicted in Figures 3-63 through 3-67. This unscheduled shutdown of the transport reactor was conducted because of indications of candle filter element breakage. The filter elements were pulse-cleaned repeatedly following the last filtration cycle. Although a few candle filter elements in the vessel were broken, the majority of the elements were intact and were covered with thin, uneven cakes. The candle breakages observed on this visit are not likely to have resulted from the characteristics of the collected ash, and are not discussed here.

Figure 3-63. Filter cakes and deposits at the top of the filter elements. The blue color in this photograph was caused by blue tarps surrounding the inspection platform.

Figure 3-64. Lower portion of some of the candles on the lower plenum. The blue color in this photograph was caused by blue tarps surrounding the inspection platform.

Figure 3-65. More deposits around the top of the filter elements. The blue color in this photograph was caused by blue tarps surrounding the inspection platform.

Figure 3-66. Upper half of the lower plenum assembly. The blue color in this photograph was caused by blue tarps surrounding the inspection platform.

Figure 3-67. Upper portion of filter elements. The blue color in this photograph was caused by blue tarps surrounding the inspection platform.

Core samples (for areal density determinations) were obtained from three candles in the top plenum and two candles in the bottom plenum. For each of these candles, measurements were made about 10 inches below the tubesheet and 10 inches above the bottom of the candle. The areal density measurements are summarized in Table 3-1.

Table 3-1
Filter Cake Areal Density Measurements (November 5, 1997)

location	areal density, lb/ft^2
top plenum	0.049
bottom plenum	0.047
near top of candles	0.039
near bottom of candles	0.057
overall average	0.047

The thickest region of the filter cake observed on candles in the top plenum was about 2 mm thick. On the bottom plenum a region of the filter cake was found that was about 2.5 mm thick. Filter cake thickness was measured at several points with a traversing transverse laser gauge. The data from these measurements are summarized in Table 3-2 but are probably not too meaningful because the cakes were very thin and had very irregular thickness.

Table 3-2
Filter Cake Thickness Measurements (November 5, 1997)

location	thickness, mm
top plenum (~10 inches below the top of the candle)	0.84
top plenum (~10 inches below the top of the candle)	1.40
top plenum (~10 inches above the bottom of the candle)	0.51
top plenum (~10 inches above the bottom of the candle)	0.64

During examination of the filter cakes on November 5, one nodule was large enough and strong enough for a porosity determination to be performed with the ethanol impregnation method. The value of porosity measured for this nodule taken from the flat roof over the top plenum was 80.5%. The actual porosity of the filter cakes formed in the PSDF can only be precisely determined if thicker or smoother filter cakes are present when the filter vessel is opened for inspection and sampling.

3.3.4 January 20, 1998

A fourth site visit was made to the PSDF on January 20, 1998 to characterize the condition of the filter and to collect ash samples. This visit followed the scheduled shutdown of the transport reactor at the conclusion of run TC01I [9] on December 9, 1997. The filter vessel was left closed and off-line until it was opened for inspection in mid-January 1998. All the filter elements were intact. The filter cakes covering the candles generally ranged in thickness from 1 to 7 mm.

The Figure 3-68 shows representative tubesheet pressure drop data obtained just prior to shutdown of the reactor on December 9, 1997.

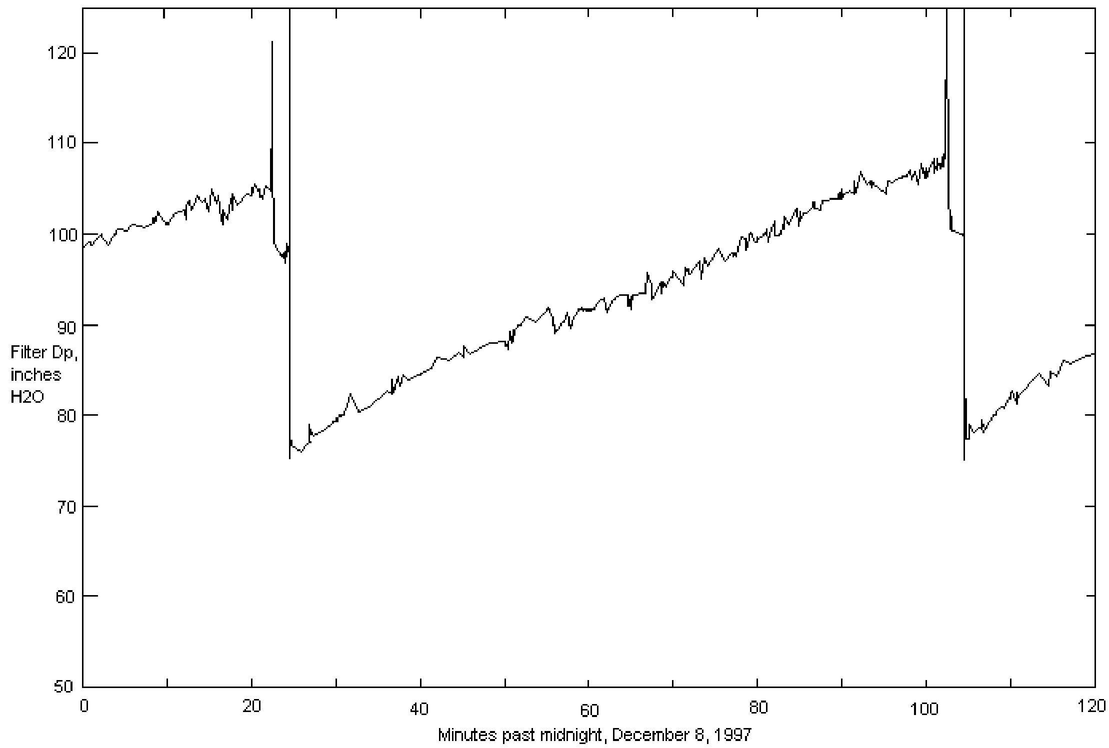

Figure 3-68. Pressure drop data from FL0301 operation early on December 8, 1997.

Core samples (for areal density determinations) were obtained from three candles in the top plenum and two candles in the bottom plenum. For each of these candles, measurements were made about 10 inches below the tube sheet and 10 inches above the bottom of the candle. Filter cake thicknesses were measured with the traversing transverse laser gauge at several points corresponding to the locations where the core samples were obtained. Data from the areal density and filter cake thickness measurements indicated that these characteristics were relatively consistent at the various points in the filter vessel where they were measured. These data are summarized in Table 3-3. The average cake thickness was 3.9 mm and the average areal density of the filter cake was 0.47 lb/ft^2. The average porosity of the PSDF filter cakes observed on this visit was 76 %. Two of the samples obtained during this site visit (ID # 4294 and ID # 4295) were selected for detailed laboratory measurements, which are discussed under section *4.0 Analyses of Particulate Samples*.

Table 3-3
Filter Cake Thickness and Areal Density Measurements (January 20, 1998)

ID #	plenum	location	core sample weight, g	average thickness, mm	areal density, lb/ft^2
4283	top	near top of candle	1.5233	3.4	0.43
4284	top	near bottom of candle	1.6702	4.7	0.47
4285	top	near top of candle	1.8306	4.4	0.51
4286	top	near bottom of candle	1.7111	3.6	0.48
4287	top	near top of candle	1.5126	3.5	0.42
4288	top	near bottom of candle	1.5542	3.8	0.44
4289	bottom	near top of candle	1.9073	4.1	0.53
4290	bottom	near bottom of candle	1.7668	3.2	0.49
4291	bottom	near top of candle	2.2918	5.1	0.64
4292	bottom	near bottom of candle	1.1176	2.7	0.31
avg	top	--	--	3.9	0.46
avg	bottom	--	--	3.8	0.50
avg	both	near top of candles	--	4.1	0.51
avg	both	near bottom of candles	--	3.6	0.44
avg	both	all locations	1.6878	3.9	0.47

The filter cakes that were observed on January 20 had experienced extensive back pulsing prior to the opening of the filter vessel. Therefore, they are not necessarily representative of the appearance of the cakes at the beginning of filtration cycles during normal operation. However, the general appearance of the cakes and the various cake structures that were observed suggest that some of the characteristics of the ash and the different filtering substrates may influence cake buildup and the effectiveness of pulse cleaning. A variety of filter elements were used in the PSDF in the operating period just prior to January, 1998. The photographs in Figures 3-69 through 3-76 taken on this site visit present the general condition of the filter cakes observed. The appearance of the filter cake may have depended on the type of candle substrate on which it formed. Although most of the candle filter elements were covered with filter cakes similar to the one shown in Figure 3-72, some of the cakes observed were lumpier, and others were smoother, than the typical cakes shown in Figure 3-72. Figure 3-73 shows an example of one of the lumpier cakes present on one of the candle filter elements. The degree of lumpiness of the filter cake was apparently not caused by the location of the elements in the filter array, because many of the filter elements adjacent to the one shown in Figure 3-73 were covered with significantly smoother cakes.

Figure 3-74 shows a filter cake that is somewhat smoother than the majority of cakes, and Figure 3-75 shows one of the smoothest cakes observed. In Figure 3-75, small pinholes are distributed over the surface of the cake. It is likely that these pinholes were formed by reverse flow during back pulsing; however, it is not known whether these pinholes were caused by the repeated pulses applied during shutdown, or whether they can be formed by a single back pulse. The appearance of the filter cakes shown in Figures 3-69 through 3-75 is quite different than the appearance of a passive ash deposit formed on a set of stacked samples of various filter element materials located within the array of candle filter elements (Figure 3-76). This passive ash deposit has a very rough surface in comparison with the various filter cakes.

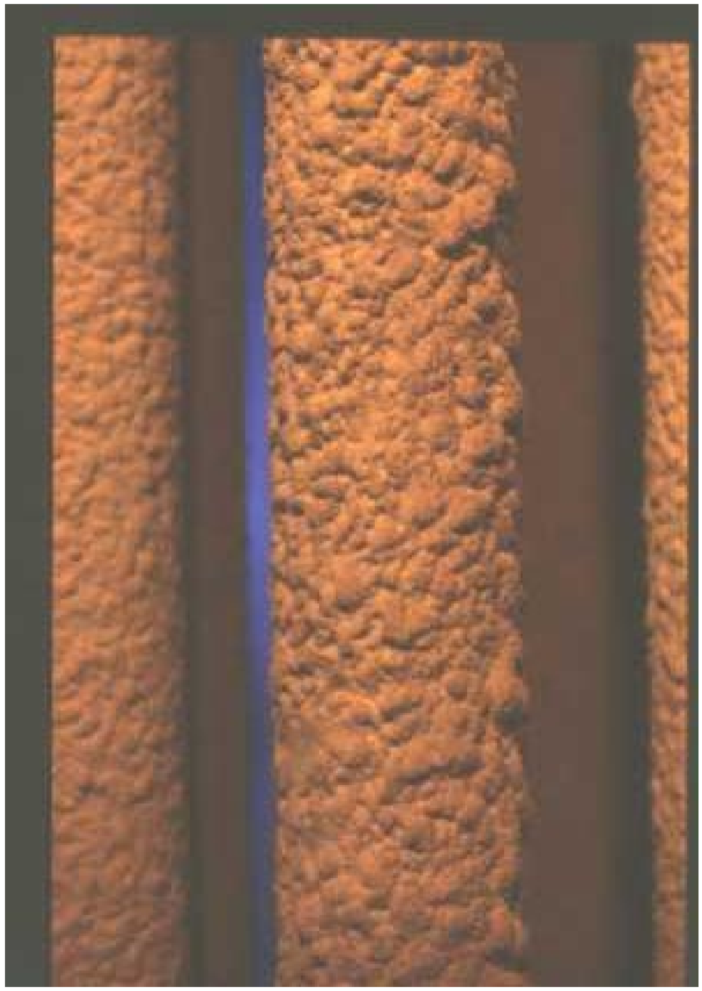

Figure 3-69. Many of the filter cakes observed on January 20, 1998 had a lumpy appearance.

Figure 3-70. Deposits observed around the top of the filter elements.

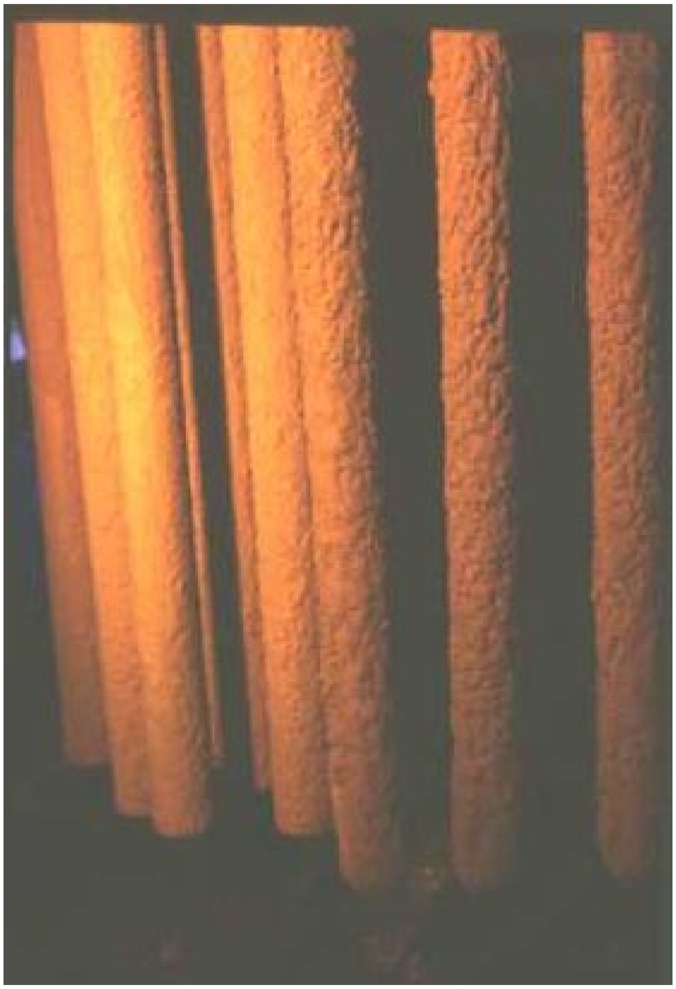

Figure 3-71. Typical appearance of the lower portion of the filter elements.

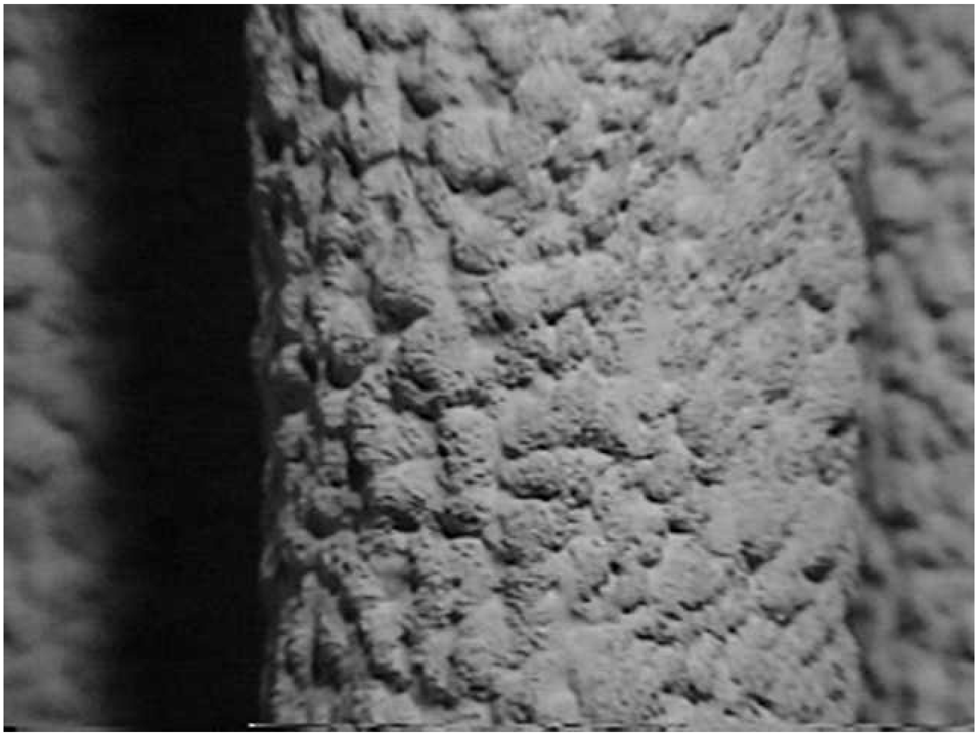

Figure 3-72. A representative photograph of the appearance of the majority of the filter cakes observed in the Siemens Westinghouse FL0301 filter at the PSDF on January 20, 1998.

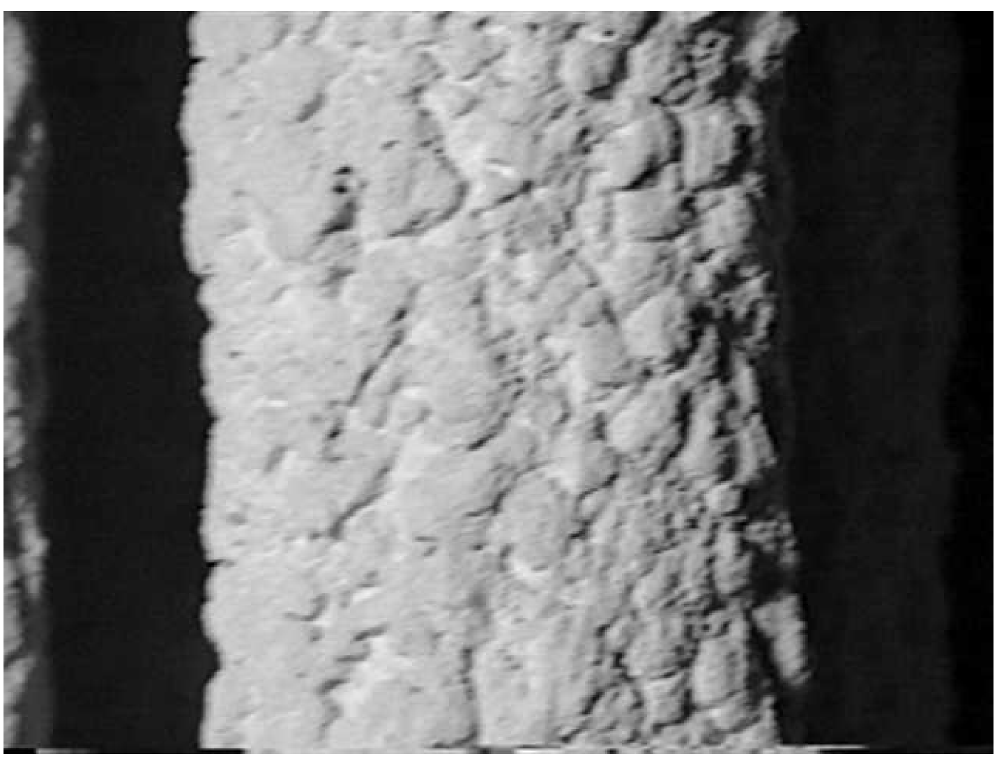

Figure 3-73. A representative photograph of the appearance of one of the lumpier filter cakes observed in the Siemens Westinghouse FL0301 filter at the PSDF on January 20, 1998.

Figure 3-74. A representative photograph of the appearance of a relatively smooth filter cake observed in the Siemens Westinghouse FL0301 filter at the PSDF on January 20, 1998.

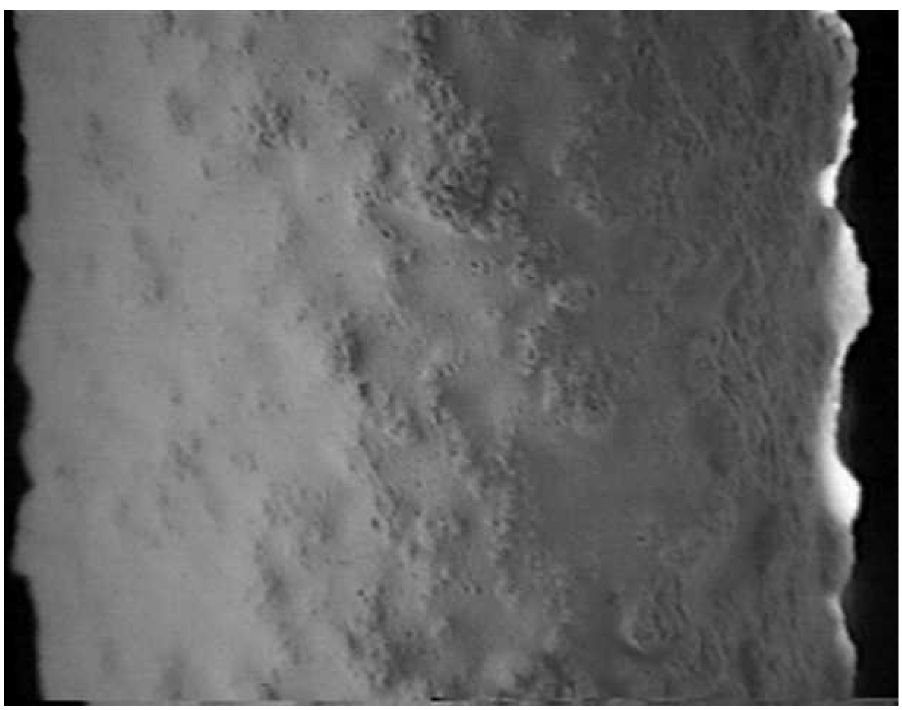

Figure 3-75. A representative photograph of the appearance of the smoothest filter cakes observed in the SiemensWestinghouse FL0301 filter at the PSDF on January 20, 1998. Small pinholes are distributed over the surface of the cake.

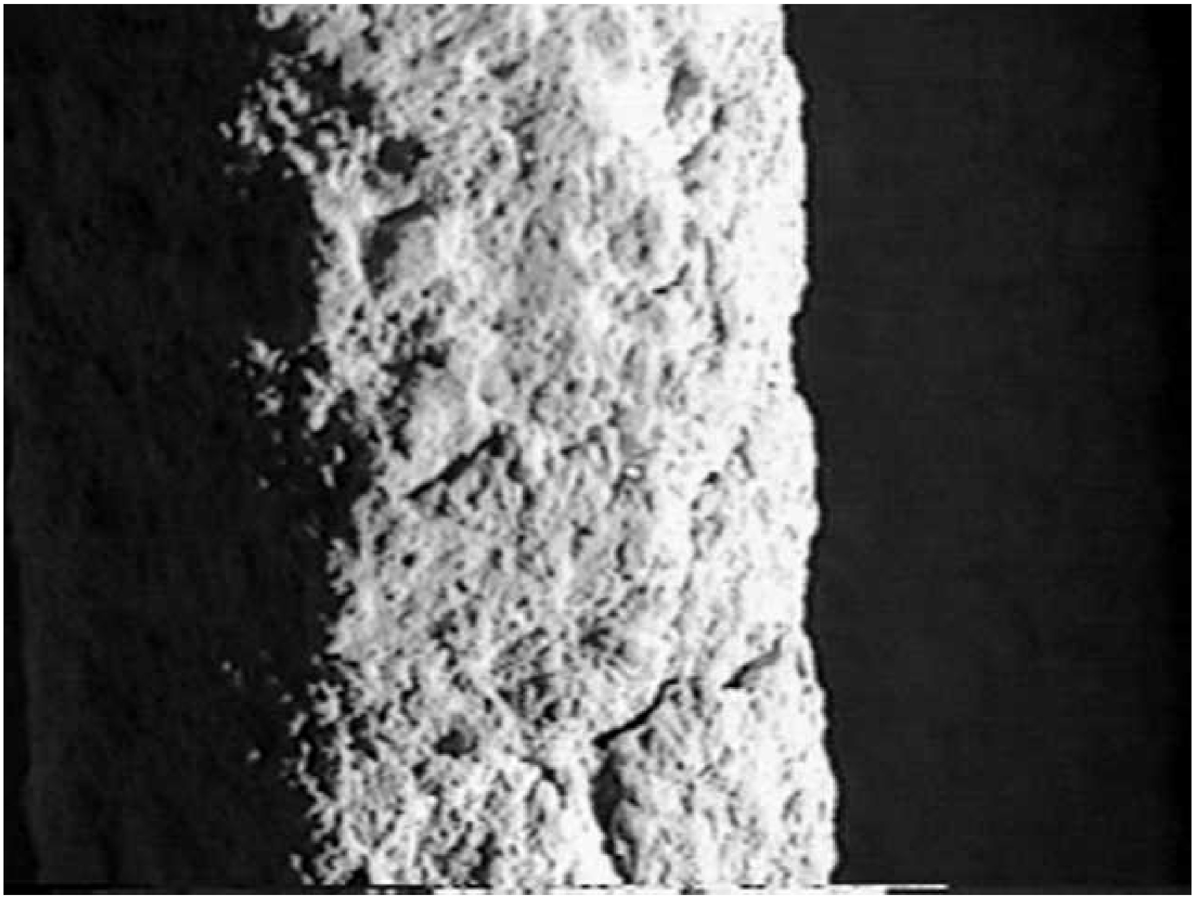

Figure 3-76. A representative photograph of the appearance of a passive ash deposit formed on a set of stacked samples of various filter element materials located within the array of candle filter elements. This deposit was observed in the Siemens Westinghouse FL0301 filter at the PSDF on January 20, 1998.

3.3.5 May 18, 1998

A site visit was made on May 18, 1998 to the PSDF to characterize the condition of the filter and to collect ash samples for analysis. This site visit followed the conclusion of run TC02. Because of the interest in obtaining filter cakes that were representative of filter operation during the filtering cycle, the Siemens Westinghouse FL0301 filter vessel was not pulse-cleaned just prior to the system shutdown that preceded the May 18 site visit and inspection. Following the last filtration cycle (approximately 38 minutes long) the coal feed was stopped and neither of the two plenum assemblies in the filter was back pulsed. (Both plenums were left uncleaned because it was thought that the force of the pulse in the filter vessel during the cleaning of one of the plenums would disturb and possibly compress the filter cakes on the uncleaned plenum.) Consequently, the filter cakes observed on May 18 were thicker than those observed on prior site visits. The cakes also seemed to comprise two regions: a reddish, rough, thin portion adjacent to the surface of the filter elements, and brownish, thicker outer layer that generally was relatively smooth. One of the objectives of the dirty shutdown procedure was to allow differences in residual and transient cakes to be assessed. Because these two regions of the filter cake may have represented residual and transient filter cake, samples of these regions were obtained and analyzed by Southern Company

Services under Contract No. DE-FC21-90MC25140. Results of these analyses are not reported here.

Figures 3-77 through 3-82 review the appearance of the filter vessel and the various filter cakes observed. All the filter elements were intact and most were covered with relatively smooth filter cakes. One of the samples obtained during this site visit (ID # 4303) was selected for detailed laboratory measurements, which can be reviewed under section *4.0 Analyses of Particulate Samples*. Core samples (for areal density determinations) were obtained from ten candles in the bottom plenum and one candle in the top plenum. For each of these candles, measurements were made midway along the length of the candle. Filter cake thicknesses were measured with the traversing transverse laser gauge at several points corresponding to the locations where the core samples were obtained. These measurements are summarized in Table 3-4. The filter cakes present on some of the filter elements seemed to comprise a smooth, soft outer layer over a somewhat lumpier, inner layer. Most of these somewhat lumpier filter cakes were located on the top plenum assembly. The lumpier filter cakes ranged in thickness from 3.7 to 7.9 mm. The average cake thickness was 5.3 mm and the average areal density of the filter cake was 0.55 lb/ft^2. The average porosity of the PSDF filter cakes observed on May 18 was 79.3 %. Three of the measured porosity values (the first three entries in the Table 3-4) deviated significantly from this average value. These deviations were probably caused by the degree of irregularity of the surface of the filter element which would affect the measurements of filter cake thickness and/or the completeness with which ash was collected by the core sampler.

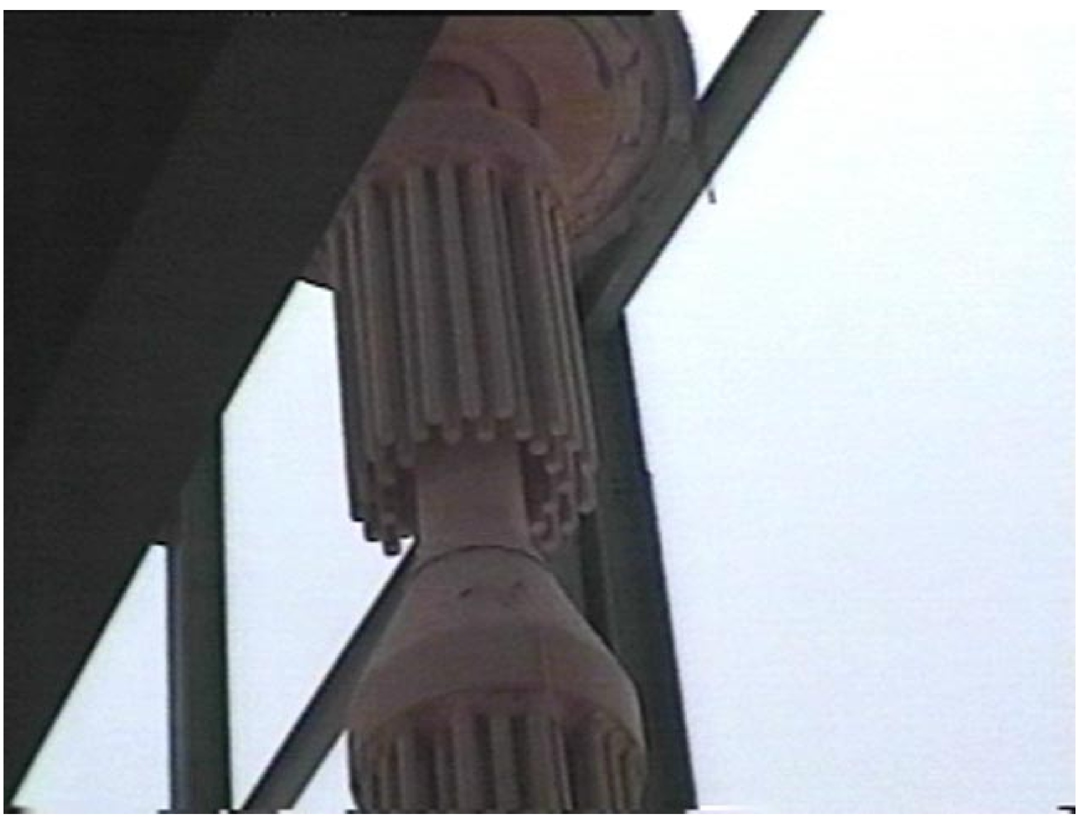

Figure 3-77. Appearance of the entire filter assembly on May 18, 1998 during removal from the filter vessel.

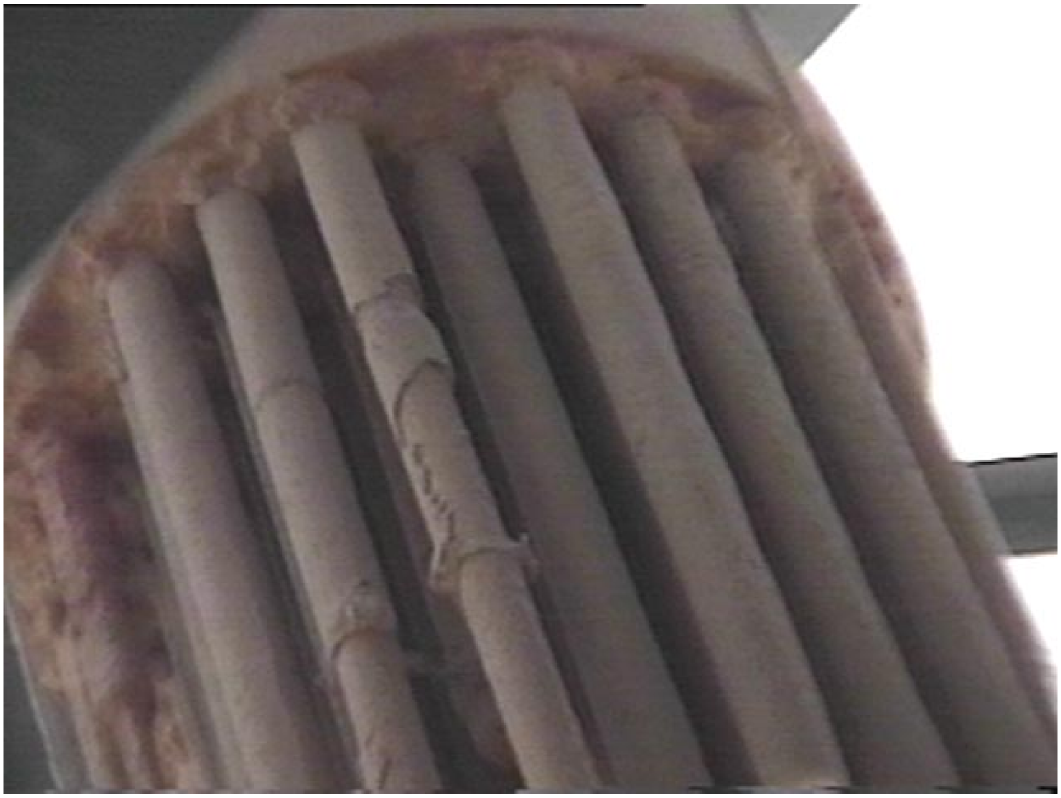

Figure 3-78. Close up of plenum assembly during transport to the inspection platform.

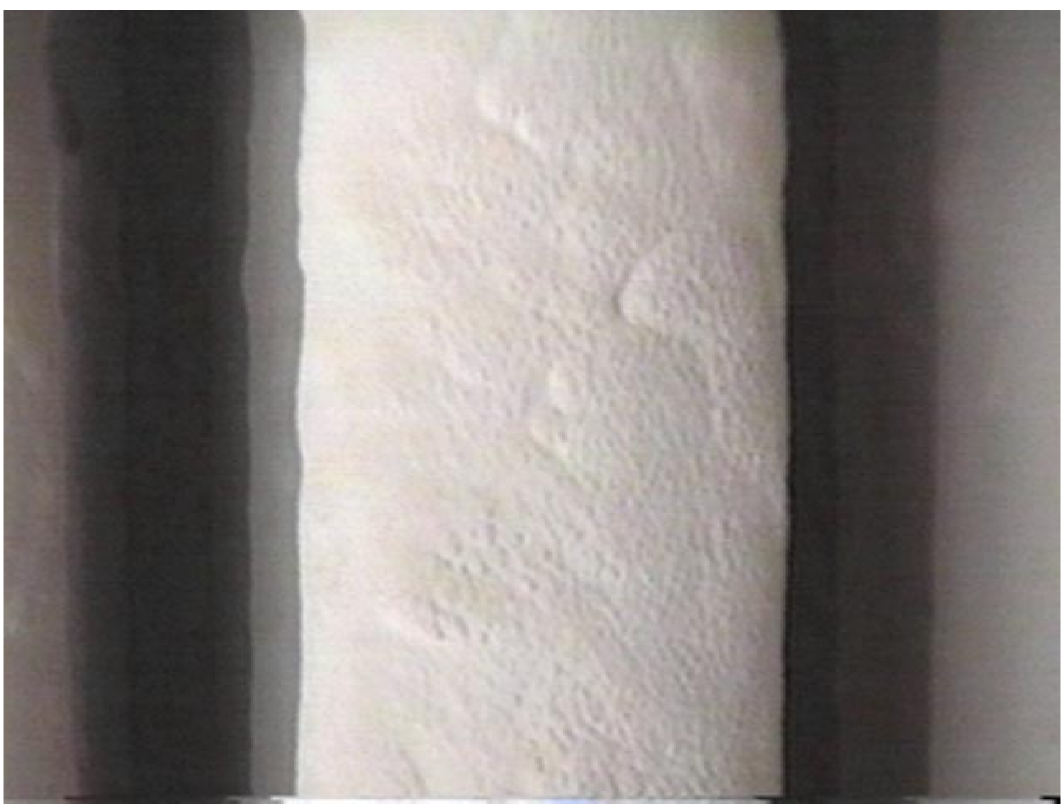

Figure 3-79. Typical smooth filter cakes observed on the bottom filter plenum at the PSDF on May 18, 1998.

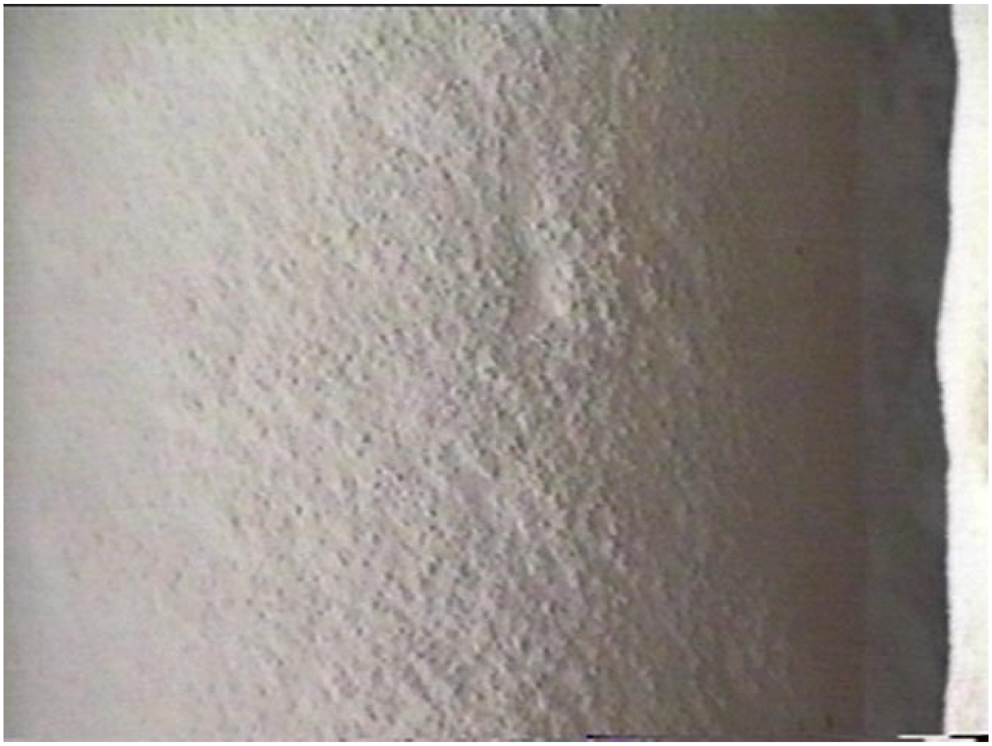

Figure 3-80. Close up of relatively smooth filter cake.

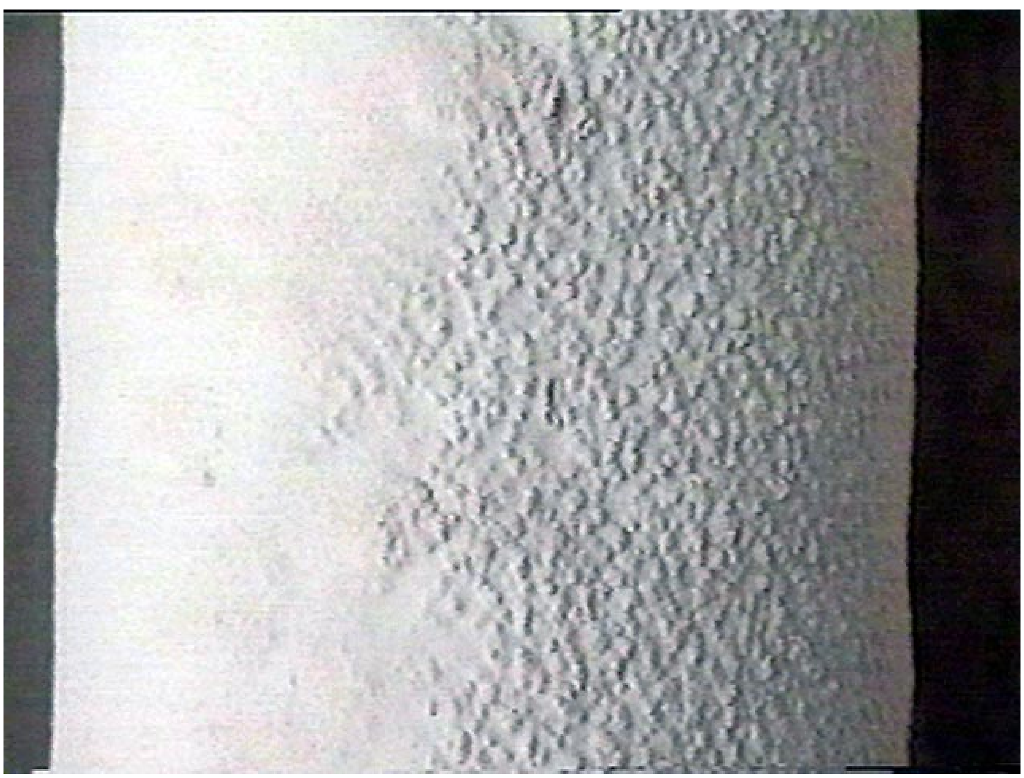

Figure 3-81. Another close up of relatively smooth filter cake.

Figure 3-82. This photograph shows the typical ash deposits formed around the mounting locations on the top filter plenum at the PSDF (May 18, 1998).

Table 3-4
Filter Cake Areal Density and Thickness Measurements

plenum	core sample weight, g	thicknes s, mm	areal density, lb/ft^2	porosity, %	comments
bottom	1.8646	3.7	0.52	72.9	cake easily released
bottom	2.2258	3.8	0.62	68.7	smooth cake
bottom	1.0811	5.2	0.30	88.9	cake easily released
bottom	1.6886	4.4	0.47	79.6	
bottom	2.3144	6.0	0.65	79.4	tenacious residual cake
bottom	1.8599	5.7	0.52	82.6	
bottom	2.0868	6.8	0.58	83.4	tenacious residual cake
bottom	2.1658	5.3	0.61	78.2	tenacious residual cake
bottom	2.2349	5.6	0.63	78.5	cake easily released
bottom	2.0010	4.1 to 7.9	0.56	--	lumpy, irregular thickness, residual cake embedded in weave
top	2.2886	6.2	0.64	80.4	smooth cake easily released
avg	1.9829	5.3	0.55	79.3	

3.3.6 January 26, 1999

A site visit was made on January 26, 1999 to the PSDF to characterize the condition of the filter and to collect ash samples for analysis. This site visit followed the conclusion of run TC05B. Figures 3-83 through 3-92 provide a review of the appearance of the various filter cakes observed. Selected element locations were blanked off so that the filter operated with a nominal face velocity of 8 ft/min prior to this site visit. Because of the interest in obtaining filter cakes that were representative of filter operation during the filtering cycle, the Siemens Westinghouse FL0301 filter vessel was not pulse cleaned just prior to the system shutdown that preceded this site visit. Following the last filtration cycle the coal feed was stopped and neither of the two plenum assemblies in the filter was back pulsed.

Figure 3-83. FL0301 filter assembly being transported to the inspection platform on January 26, 1999.

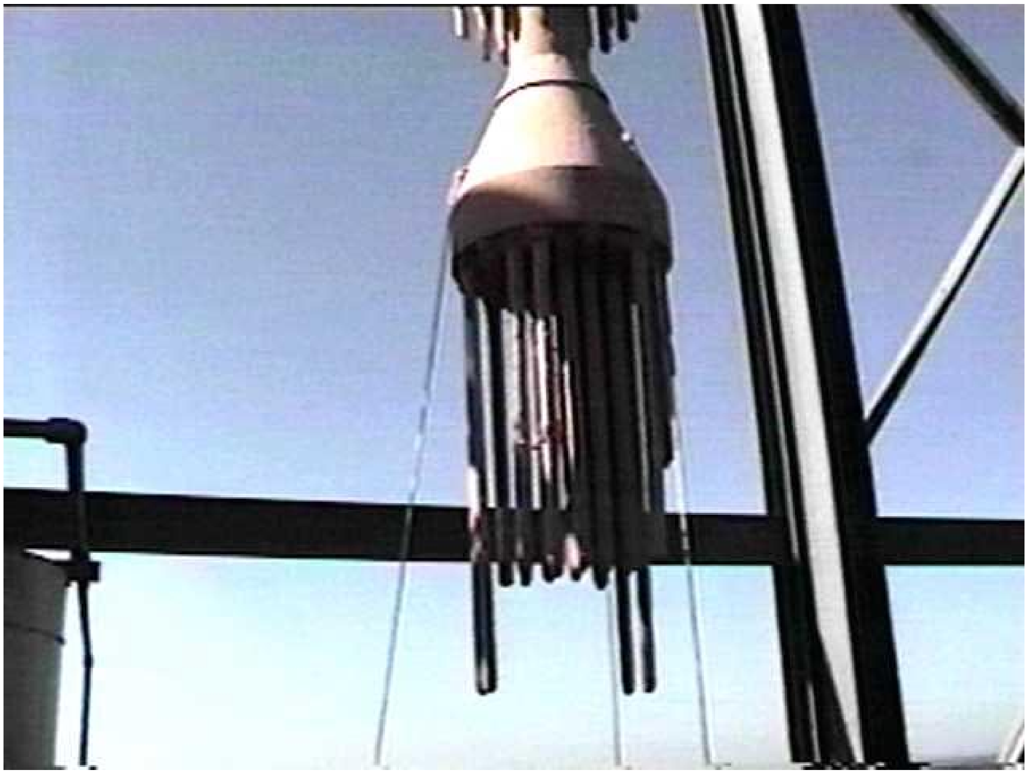

Figure 3-84. FL0301 filter assembly being transported to the inspection platform on January 26, 1999.

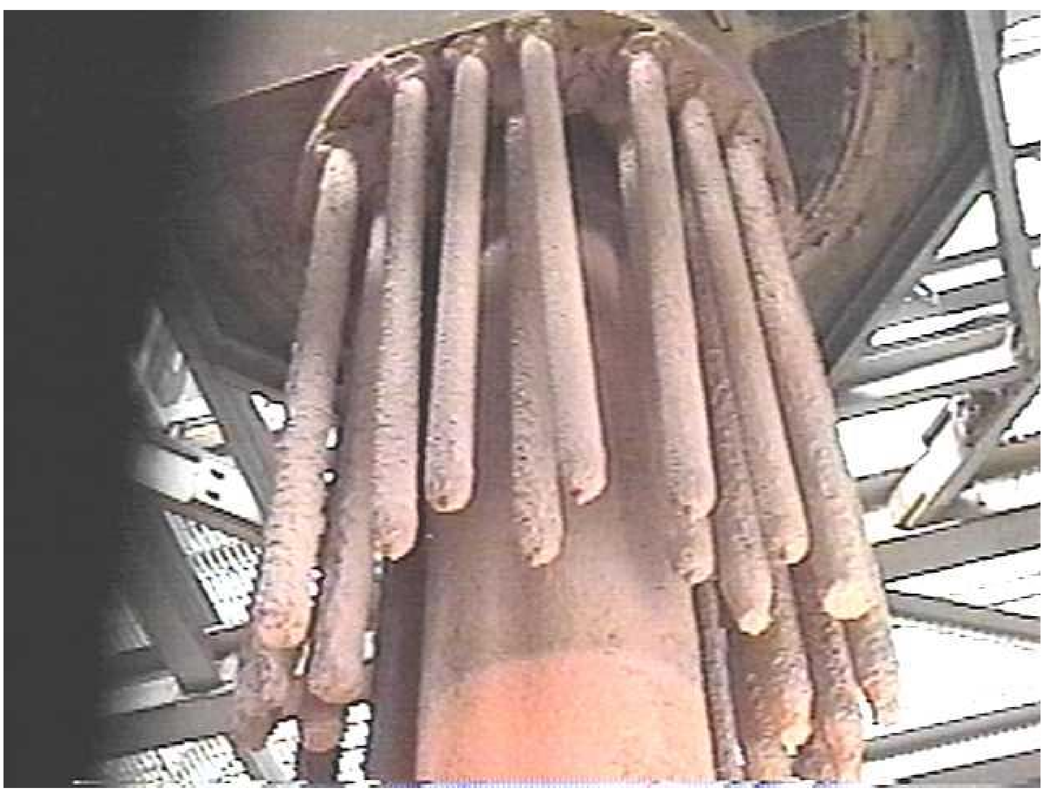

Figure 3-85. Overall view of candles in the top plenum (January 26, 1999).

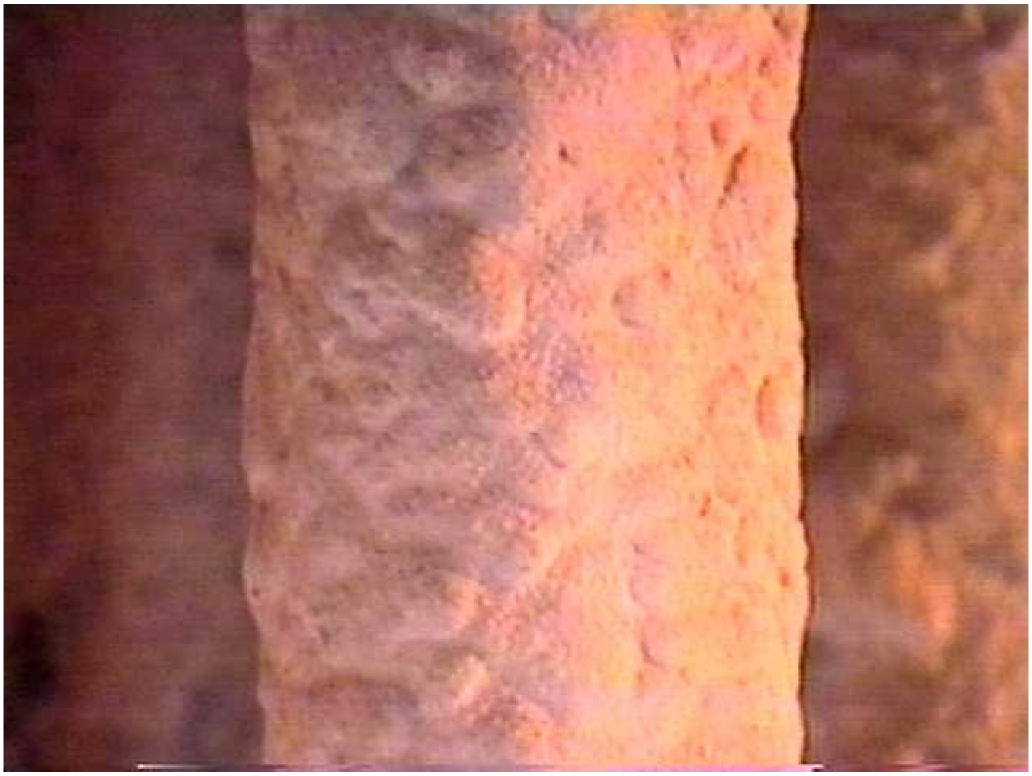

Figure 3-86. Close up of filter cake in the top plenum (January 26, 1999).

Figure 3-87. Typical deposits that formed around the filter element mounting assemblies (January 26, 1999).

Figure 3-88. Lower portion of filter elements in the top plenum (January 26, 1999).

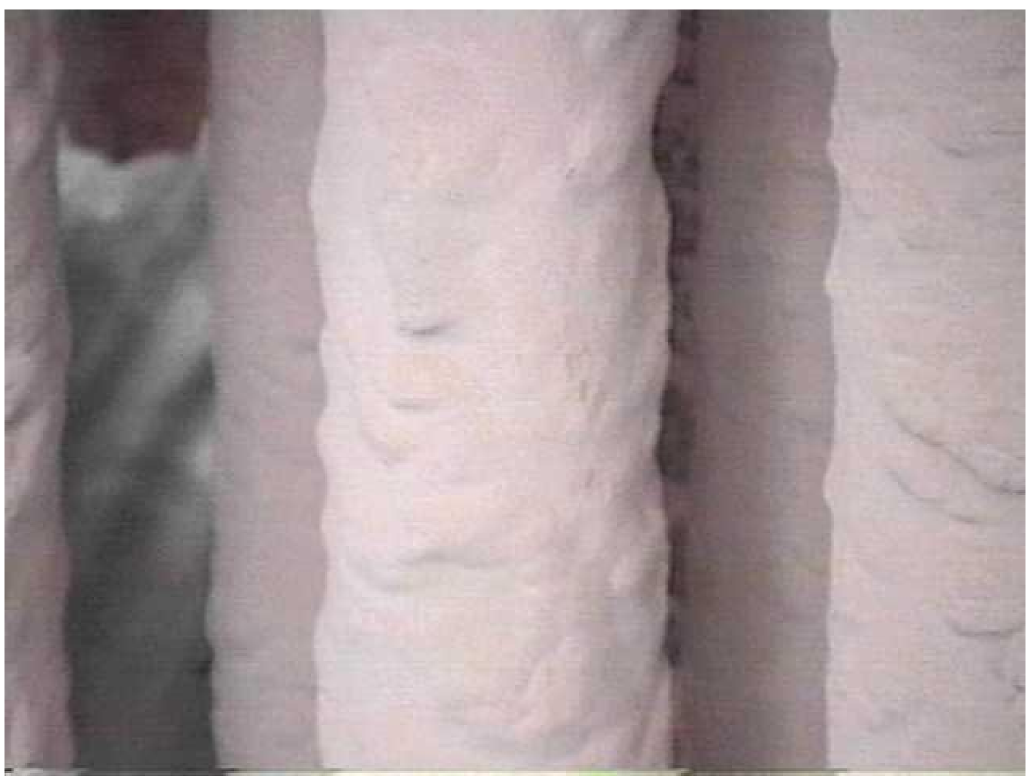

Figure 3-89. Close up of a filter cake in the top plenum (January 26, 1999).

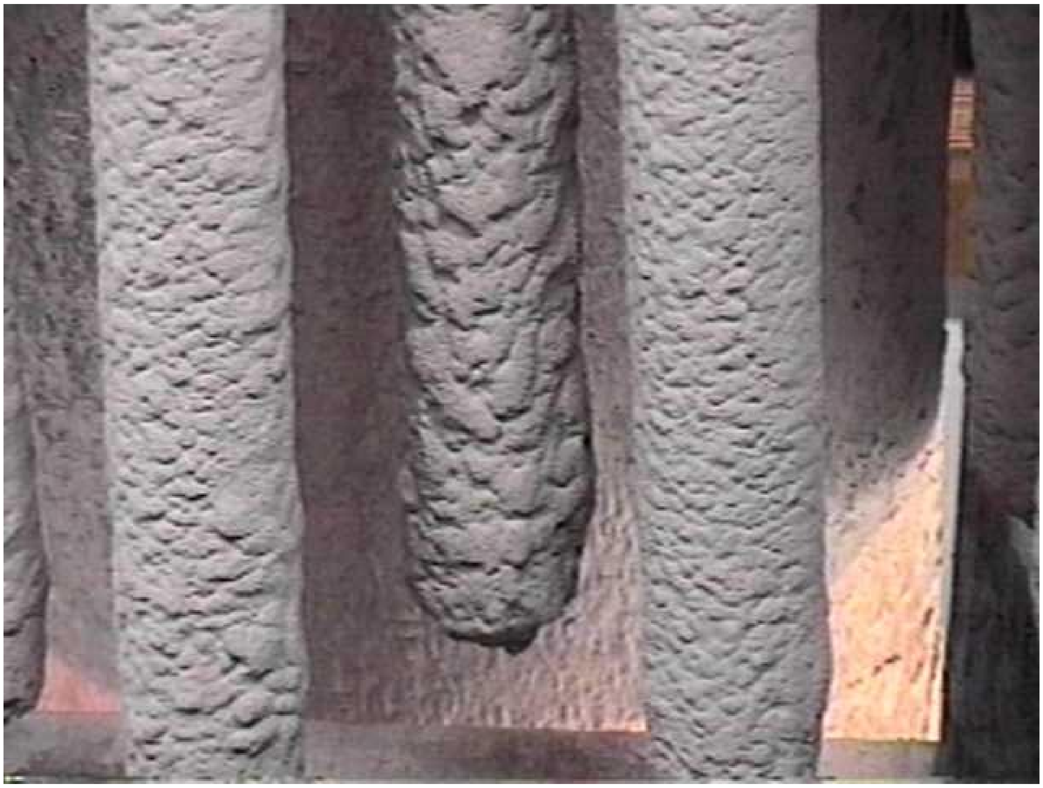

Figure 3-90. Lower portion of the filter elements in the top plenum (January 26, 1999).

Figure 3-91. Many of the filter cakes observed in the top plenum on January 26, 1999 had a lumpy appearance.

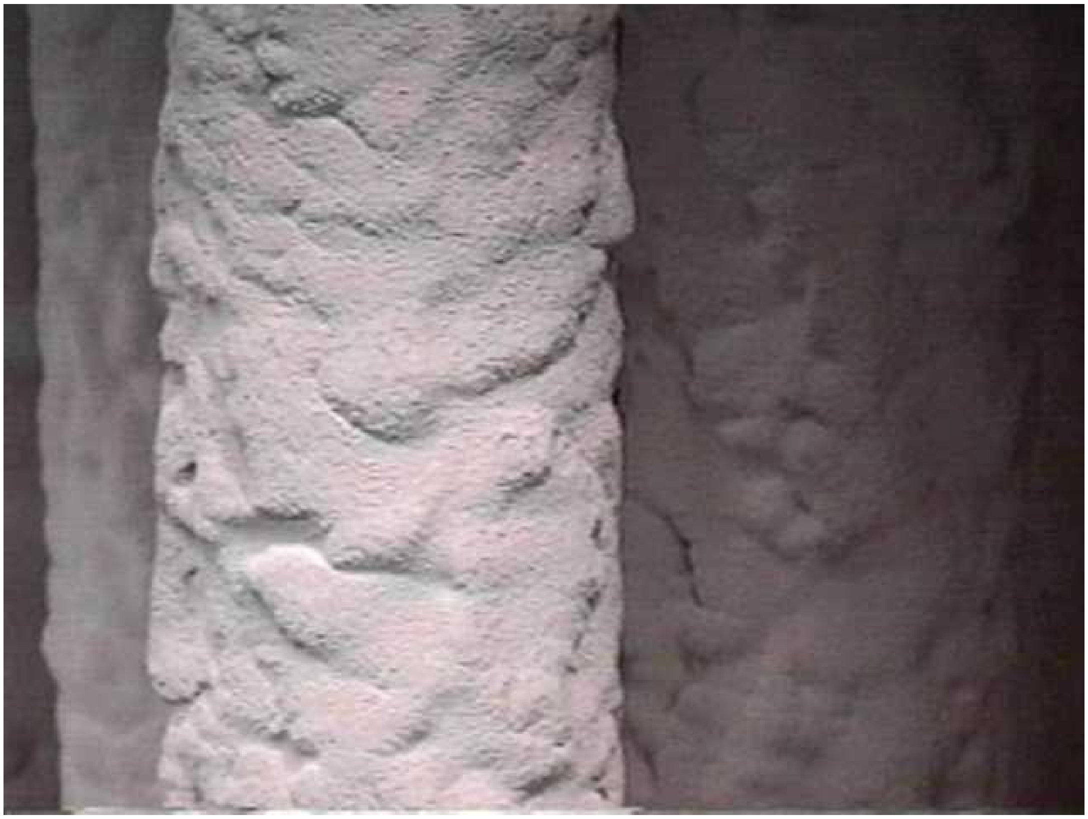

Figure 3-92. Another view of lumpy filter cakes observed in the top plenum on January 26, 1999.

All of the filter elements were intact and most were covered with relatively lumpy filter cakes. Filter cake ash samples were collected from the surfaces of eight different elements. One of the samples obtained during this site visit (ID # 4347) was selected for detailed laboratory measurements, which can be reviewed in section *4.0 Analyses* of *Particulate Samples*. Core samples (for areal density determinations) were obtained from six candles in the top plenum and one candle in the bottom plenum. For each of these candles, measurements were made about 12 inches from the top of the candle and on the outermost surface of the candles (furthest from the center of the plenum). Filter cake thicknesses were measured with the traversing transverse laser gauge at points corresponding to the locations where the core samples were obtained. These measurements are summarized in Table 3-5. The filter cakes ranged in thickness from 3 to 8 mm. The average cake thickness was 5.9 mm and the average areal density of the filter cake was 0.67 lb/ft^2. The average porosity of the PSDF filter cakes observed on January 26 was 78.5 %.

Table 3-5
Filter Cake Areal Density and Thickness Measurements

plenum	core sample weight, g	thickness, mm	areal density, lb/ft^2	porosity, %
top	2.02	4.7	0.56	76.9
top	2.83	6.8	0.79	77.7
top	2.98	6.7	0.83	76.2
top	2.71	8.0	0.76	81.9
top	2.09	4.4	0.58	74.7
top	0.88	3.0	0.24	84.5
bottom	3.29	7.9	0.92	77.8
avg.		5.9	0.67	78.5

In addition to the sampling described above, a complete candle with its attached filter cake was obtained from the top plenum for subsequent preservation and study. A description of the preservation process, which utilizes cynoacrylate vapor and low-viscosity epoxy, can be found in *Appendix A Technique for Preserving Filter Cakes*.