Contract No. DE-AC21-94MC31160--33

PARTICULATE HOT GAS STREAM CLEANUP TECHNICAL ISSUES

QUARTERLY REPORT

April 1999 - June 1999

Prepared for

UNITED STATES DEPARTMENT OF ENERGY
Federal Energy Technology Center - Morgantown
Post Office Box 880, 3610 Collins Ferry Road
Morgantown, West Virginia 26505

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for

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Contract No. DE-AC21-94MC31160--33
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Abstract

This quarterly report describes technical activities performed under Contract No. DE-AC21-94MC31160. The analyses of hot gas stream cleanup (HGCU) ashes and descriptions of filter performance studied under Task 1 of this contract are designed to address problems with filter operation that are apparently linked to characteristics of the collected ash. This report reviews the status of the HGCU data bank of ash and char characteristics, including the interactive querying of measured particulate properties. Task 1 plans for the remainder of the project include completion and delivery of the HGCU data bank, and issuance of a comprehensive final report on activities conducted under Task 1.

GET NEW FROM JACK

Task 2 of this project concerns the testing and failure analyses of new and used filter elements and filter materials. Task 2 work during the past quarter included preliminary testing of two materials. One material tested was the soft candle filter manufactured by CGC and supplied by ABB. The other material was N610/mullite manufactured by Albany International (AIT).

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EXECUTIVE SUMMARY

This quarterly report describes technical activities performed under Contract No. DE-AC21-94MC31160. The analyses of Hot Gas Stream Cleanup (HGCU) ashes and descriptions of filter performance studied under this contract are designed to address problems with filter operation that are apparently linked to characteristics of the collected ash. Task 1 is designed to generate a data bank of the key characteristics of ashes collected from operating advanced particle filters (APFs) and to relate these ash properties to the operation and performance of these filters and their components. APF operations have also been limited by the strength and durability of the ceramic materials that have served as barrier filters for the capture of entrained HGCU ashes. Task 2 concerns testing and failure analyses of ceramic filter elements currently used in operating APFs and the characterization and evaluation of new ceramic materials.

Task 1 research activities during the past quarter included enhancement of the draft version of the HGCU data bank of ash and char characteristics. This report reviews the status of this data bank, and its ability to provide interactive querying of measured particulate properties.

Under Task 2 during the past quarter, three different candle filter materials were received for testing after operation in the Southern Company Services (SCS) Power Systems Development Facility (PSDF) in Wilsonville, Alabama. The candles received were AlliedSignal PRD-66C, McDermott ceramic composite, and Albany International (AIT) N610/mullite. To date, machining of test specimens from these candles is complete and testing is in progress.

INTRODUCTION

This quarterly report describes technical activities performed under Contract No. DE-AC21-94MC31160. Task 1 of this contract concerns analyses of HGCU ashes and descriptions of filter performance that are designed to address problems with filter operation linked to characteristics of the collected ash. Much of the work planned for Task 1 builds directly on work performed under a prior contract (No. DE-AC21-89MC26239) with the Department of Energy's Federal Energy Technology Center in Morgantown, WV (DOE/FETC-MGN). Task 2 of this contract includes characterization of new and used filter elements. Some of the problems observed at PFBC facilities include excessive filtering pressure drop, the formation of large, tenacious ash deposits within the filter vessel, and bent or broken candle filter elements. These problems have been attributed to ash characteristics, durability of the ceramic filter elements, and specific limitations of the filter design. In addition to the problems related to the characteristics of PFBC ashes, laboratory characterizations of gasifier and carbonizer particulates have shown that these ashes and chars also have characteristics that might negatively affect filtration. Specifically, gasifier particulates may form filter cakes that accumulate in thickness quite rapidly and also may reentrain following cleaning pulses. Recent measurements suggest that these gasifier char filter cakes may be compressed by the filtering pressure drop across their structure, thereby increasing their strength and the pressure losses incurred during filtration.

To identify which particulate characteristics can lead to problems with filtration, 384 particulate samples from fourteen facilities involved in FETC's HGCU program have been assembled. Three samples from gasification studies being carried out by Herman Research Pty. Ltd. (HRL) of Melbourne, Australia have also been included in the data bank. The most recent facility included in the data bank is the Westinghouse filter at Sierra Pacific Power Company's Piñon Pine Power Project. Many of the samples in the data bank have been analyzed with a variety of laboratory tests. Physical attributes of the particles that have been examined include size distribution, specific surface area, particle morphology, and bulk ash cohesivity and permeability. A range of chemical analyses of these samples, as well as characterizations of agglomerates of particles removed from filter vessels at Tidd, Karhula and Foster Wheeler's pilot-scale combustion facility located in Livingston, New Jersey have also been performed. The data obtained in these studies are being assembled into an interactive data bank which will help the manufacturers and operators of high-temperature barrier filters tailor their designs and operations to the specific characteristics of the particulate materials they are collecting.

Under Task 2, one AlliedSignal PRD-66C, two McDermott ceramic composite, and one AIT N610/mullite candles were received after operation in the SCS PSDF. The candles received and the hours of operation are as follows:

Manufacturer/Type	Candle	Hours of Operation
AlliedSignal PRD-66C	C732	636
McDermott ceramic composite	8-2-2-1	1360
McDermott ceramic composite	8-2-3-2	1535
AIT N610/mullite		784

The hoop tensile strength will be measured on nine specimens from each candle filter. Hoop tensile strength has previously been measured on each of these materials in as-manufactured condition. The strengths measured after operation will be compared to the as-manufactured strengths to see if degradation during operation is evident.

OBJECTIVES

Task 1 of this project is explicitly designed to address aspects of filter operation that are linked to the characteristics of the collected particles. This task has two primary objectives. The first is the generation of an interactive computerized data bank of the key characteristics of HGCU ashes collected from operating high-temperature, high-pressure, particle filters. The data bank is structured to identify, when possible, relationships between HGCU particulate properties and the operation and performance of these filters. Construction of the data bank is intended to help manufacturers and operators of high-temperature barrier filters tailor process design and operation to the specific characteristics of the particulate materials they are collecting. The second objective is to relate these measured properties and the contents of the data bank to the operation and performance of the advanced particle filters and filter components. The first objective includes formatting the data bank and collecting, analyzing, and maintaining particulate samples from operating HGCU facilities. The second objective of this task involves the collection of operating histories from advanced particle filters, correlating these histories with sample characteristics, interpreting these correlations, and communicating results in the various venues prescribed by DOE/FETC-MGN.

The objectives of the Task 2 test program at Southern Research are as follows:

- Provide material characterization to develop an understanding of the physical, mechanical, and thermal behavior of hot gas filter materials.

- Develop a material property data base from which the behavior of materials in the hot gas cleanup environment may be predicted.

- Perform testing and analysis of filter elements after exposure to actual operating conditions to determine the effects of the thermal and chemical environments in hot gas filtration on material properties.

- Explore the glass-like nature of the matrix material.

TASK 1 ASSESSMENT OF ASH CHARACTERISTICS

Task 1 research activities during the past quarter included enhancement of the draft version of the HGCU data bank of ash and char characteristics. This report reviews the status of this data bank, and its ability to provide interactive querying of measured particulate properties.

ASH DATA BANK DEVELOPMENT

The data bank is currently being modified to include the features described below. Although many of these features have not yet been fully implemented, the final form of the data bank should closely resemble this discussion.

To date, SRI has accumulated 387 HGCU particulate samples and has performed various analyses on over 150 of these samples. The results of all of these analyses are included in the data bank. The data bank accomplishes two principal functions. In addition to archiving the results of laboratory analyses of HGCU samples for interactive access (shown schematically in Figure 1), the data bank is structured to identify relationships between the HGCU particulate properties that have been measured and the performance of the HGCU filters. Upon activating the data bank, the user initially views a title page and then a page that provides some instructions for properly using and interpreting the information and constructing comparisons between data. (On-line help for the various options is available throughout the data bank.) The user is then directed to a screen that serves both as a main navigation screen, and as an invitation for the user to contribute samples and/or data to the data bank. The first of the principal functions of the data bank is accessed through this main navigation screen and allows the user to perform interactive queries on the data that were measured to physically and chemically characterize the HGCU samples. Parameters available to specify the sample population in this user-controlled querying include the HGCU facility where the sample was generated, the conversion process used, and the type of sample (including the location in the process where the sample was obtained). During querying, the user assembles the specifying parameters in a stepwise process. After the user sets each parameter, the data bank processes the query and displays the number of samples with measured data that satisfy the specification. If the user desires, parameters can be modified. In addition to allowing the user to build customized sets of parameters to constrain the sample population, the data bank also offers the user several preexisting sets of parameters from which analytical data can be selected and plotted.

After defining all the parameters that will be used to specify the samples that will be included in the data comparison, the user has three options: outputting the population with its associated data set to the operating system's clipboard, examining all available data for any specific sample in the population (including scanning electron micrographs, and any specialized analyses performed on the sample), or proceeding to select analytical quantities for a plotted display of the data. The analytical quantities that have been measured and can be plotted are listed in Table 1. When the user selects the analytical quantities that will be plotted, a running summary is provided of the number of samples in the sample population that contain numerical values for the quantities the user has selected. Depending on whether one or two quantities are selected for the data population, this plot will be displayed either as the distribution and range of values measured for a single quantity, or as data pairs

(independent variable value, dependent variable value) for two different quantities. Once data from the specified sample population is selected and graphed on the screen by the data bank, the user has the option of obtaining a hard copy of the plot, or of returning to the data bank for further comparisons.

The second principal function of the data bank is utilized when sufficient operating data, samples, and sample analyses were available for SRI to draw conclusions about system or process behavior. This portion of the data bank is shown schematically in Figure 2. In this case, the data bank includes prepackaged discussions of these conclusions. The user can select from a list of in-depth discussions of ash behavior and/or analyses procedures. The first of these discussions presents one of the principal findings of Contract No. DE-AC21-94MC31160 - a coherent mechanism describing how and why consolidated ash deposits form in PFBC filter vessels. This description is based on site observations made at the Tidd PFBC, field and laboratory analyses of ashes and nodules collected from Grimethorpe, Tidd and Karhula, and a review of literature describing eutectic formation, sintering, and consolidation of boiler tube deposits. The next three in-depth discussions review the factors in a PFBC that contribute to filter system failure, inertial particle collection in barrier filter vessels, and the potential for rapid increases in the thickness of transient IGCC filter cakes. The fifth and sixth discussions accessible for review from this screen detail the procedures and sampling protocol used during site visits, and the techniques used in the laboratory to characterize particulate samples. The seventh discussion describes laboratory equipment constructed to allow fragile filter cakes to be hardened with cynoacrylate vapor while still on the surface of the filter element.

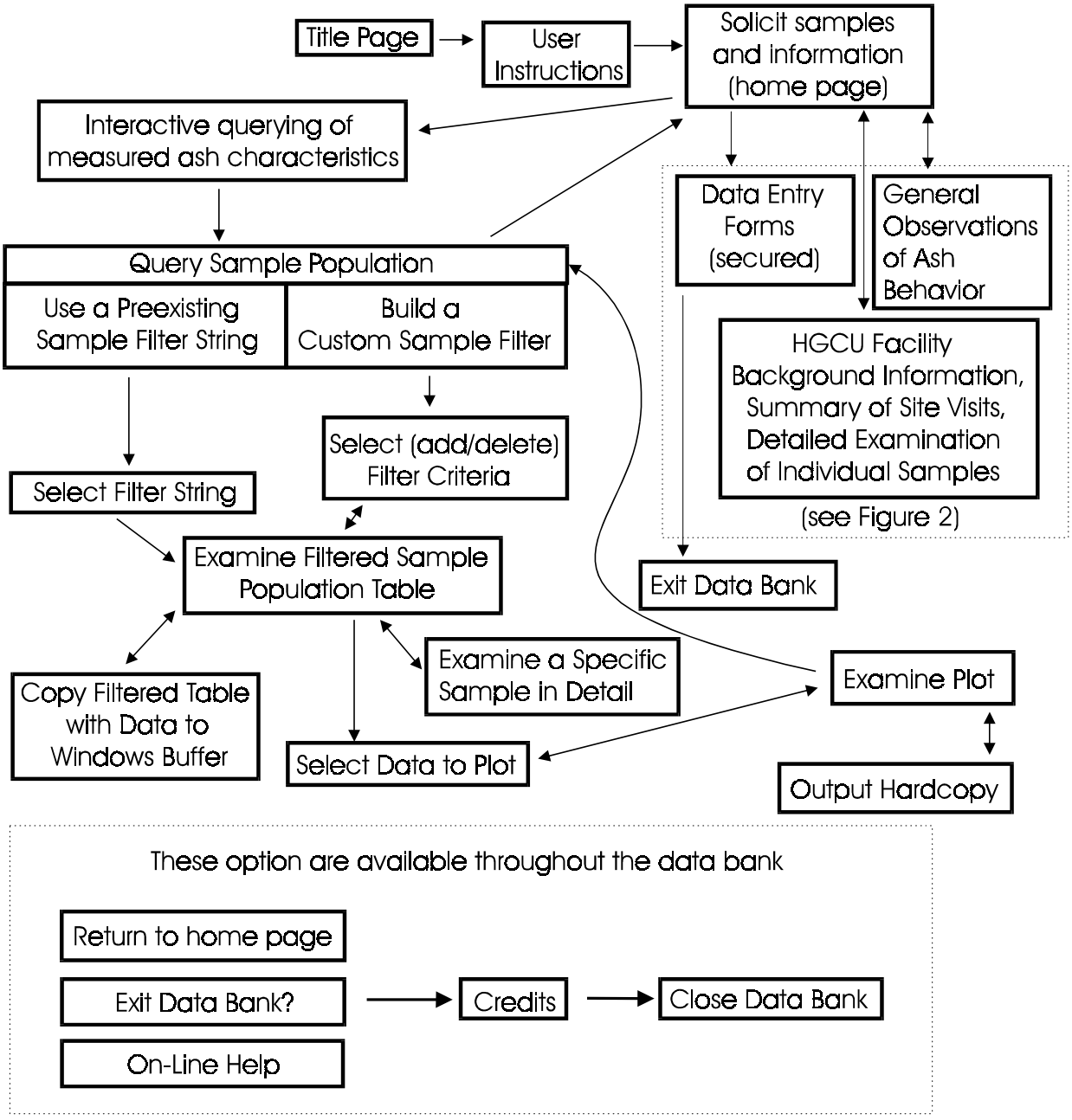

Figure 1. Schematic representation of the portion of the data bank controlling the interactive querying and plotting of sample analyses data.

Table 1
Analytical Quantities that can be Selected and Plotted as part of Interactive Querying

Analytical Quantity	units
Stokes' Mass Median Diameter	µm
true particle density	g/cm^3
specific surface area	m^2/g
uncompacted bulk porosity	dimensionless (expressed as a %)
morphology factor	dimensionless
drag-equivalent diameter	µm
specific gas-flow resistance	in H_2O·min·ft/lb
tensile strength	N/m^2
Li_2O content in ashed sample	% wt.
Na_2O content in ashed sample	% wt.
K_2O content in ashed sample	% wt.
MgO content in ashed sample	% wt.
CaO content in ashed sample	% wt.
Fe_2O_3 content in ashed sample	% wt.
Al_2O_3 content in ashed sample	% wt.
SiO_2 content in ashed sample	% wt.
TiO_2 content in ashed sample	% wt.
P_2O_5 content in ashed sample	% wt.
SO_3 content in ashed sample	% wt.
loss-on-ignition during ashing of sample	% wt.
soluble sulfate content of as-received sample	% wt.
equilibrium pH of as-received sample	dimensionless
porosity of ash deposit	dimensionless (expressed as a %)

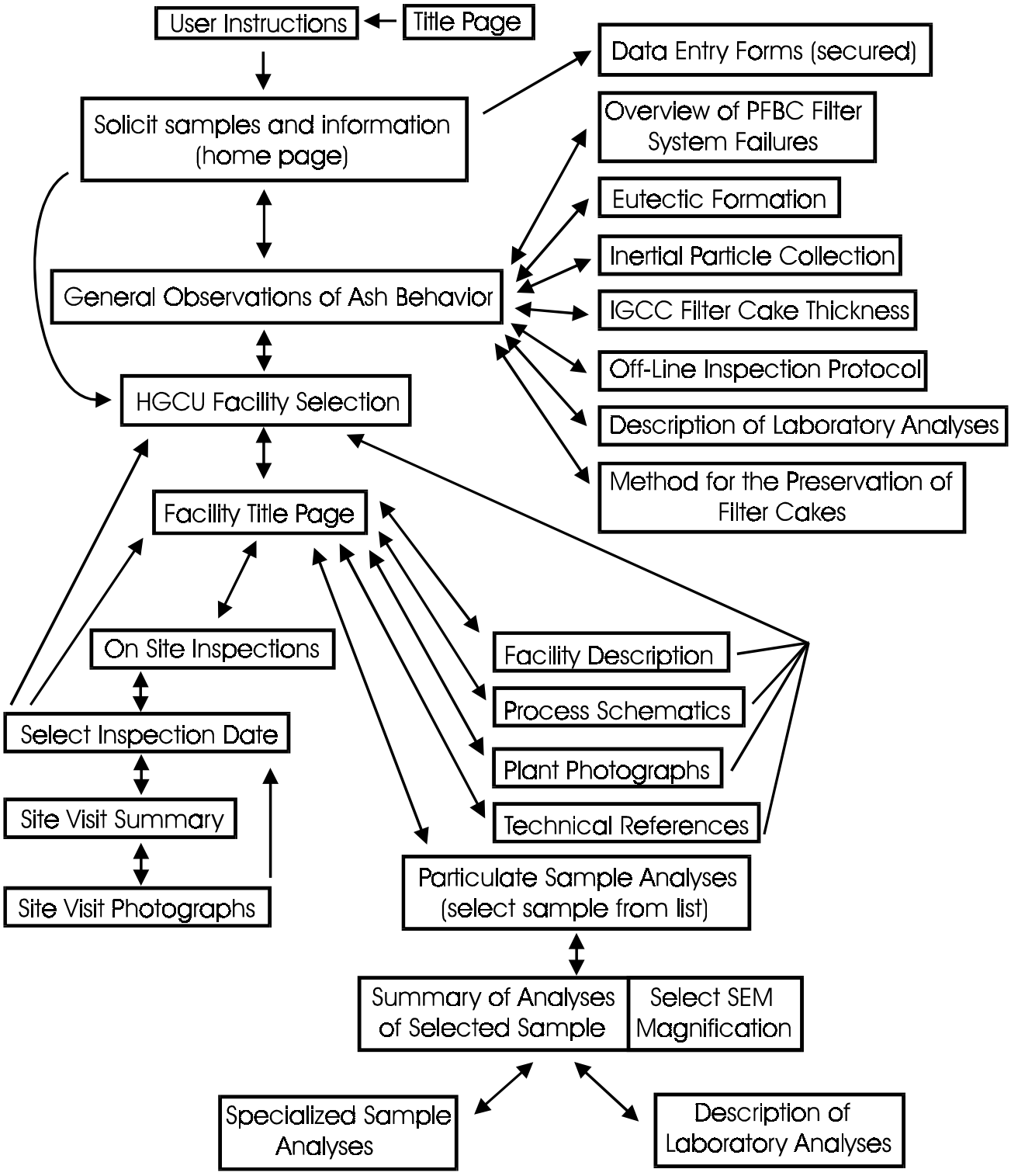

Figure 2. Schematic representation of the portion of the data bank controlling the review of project findings, site visits, background information on the HGCU facilities, and detailed analyses of individual samples.

From the main navigation screen, the user may also proceed to examine data and samples for specific facilities. If this option is selected, the user chooses one of the fifteen HGCU facilities to examine. Once a facility has been selected, the data bank lists the primary participating organizations and principal contact personnel for the facility. The user can then select and review one of the six categories listed: brief description of the facility; process schematics; plant photographs; technical references; on-site inspections; or particulate sample analyses. Under the first category, brief descriptions (up to two pages of text) are provided for each of the facilities in the data bank from which the various particulate samples were obtained. Series of process schematics and plant photographs can be scrolled through by selecting the second or third category. The fourth category provides the user with references to more detailed information about the facility. The category for on-site inspections contains information gathered during filter inspection and sampling trips made by Southern Research Institute personnel. Information in this category covers four site visits to the Tidd PFBC, one visit to the MGCR at Morgantown, and six inspection and sampling trips to the PSDF. After selecting a particular site visit to review, the data bank provides a brief summary of the condition of the filter, the sampling procedures and the particulate samples obtained, and some of the key data obtained during the visit. A series of photographs of the filter cakes and ash deposits observed during the visit can also be reviewed.

When the user wishes to review the analyses of samples obtained from a particular facility, a scroll-down list of the samples from that facility is displayed. Included with this listing are brief descriptions of the samples, and where and when they were obtained. After a sample is selected to examine in detail, a screen is displayed that summarizes the physical and chemical analyses that have been performed on that sample. Physical attributes that have been measured and are included in this display include median particle size, specific surface area, particle morphology, bulk ash cohesivity, permeability, and tensile strength. This screen also provides access to scanning electron micrographs of many of the samples in the data bank. In general, these micrographs were obtained and can be viewed at four different magnifications. Chemical analyses of the selected sample are also summarized on this screen. Some of the samples collected which have unusual histories or unique characteristics have been analyzed with specialized techniques. When specialized analyses have been performed on the selected sample, the results of these analyses can also be accessed from this screen. This screen also provides a direct link to descriptions and explanations of the various analyses used to characterize the samples.

Another option available through the main navigation screen is the entry of additional data obtained during the analysis of particulate samples. This option is password-protected so the integrity of data included in the data bank can be maintained. The entry of additional data into the data bank can be accomplished using forms customized to accept sample identification information and the results of the analyses listed in Table 1.

TASK 2 FILTER MATERIAL CHARACTERIZATION

Test specimens have been machined from each of the candles received after operation in the SCS PSDF. Nine hoop tensile specimens were taken from each candle with three of the specimens from the flanged end of the candle, three from the closed end, and three from the middle. Therefore, the strengths measured will reveal if any differences exist along the length of the candle. Individual cutting plans are shown in Figures 3 - 6. All of the specimens have been machined and are currently in testing. A data package summarizing the results will be provided upon completion of the testing. These results will give an indication of whether any strength degradation has occurred during operation at the PSDF.

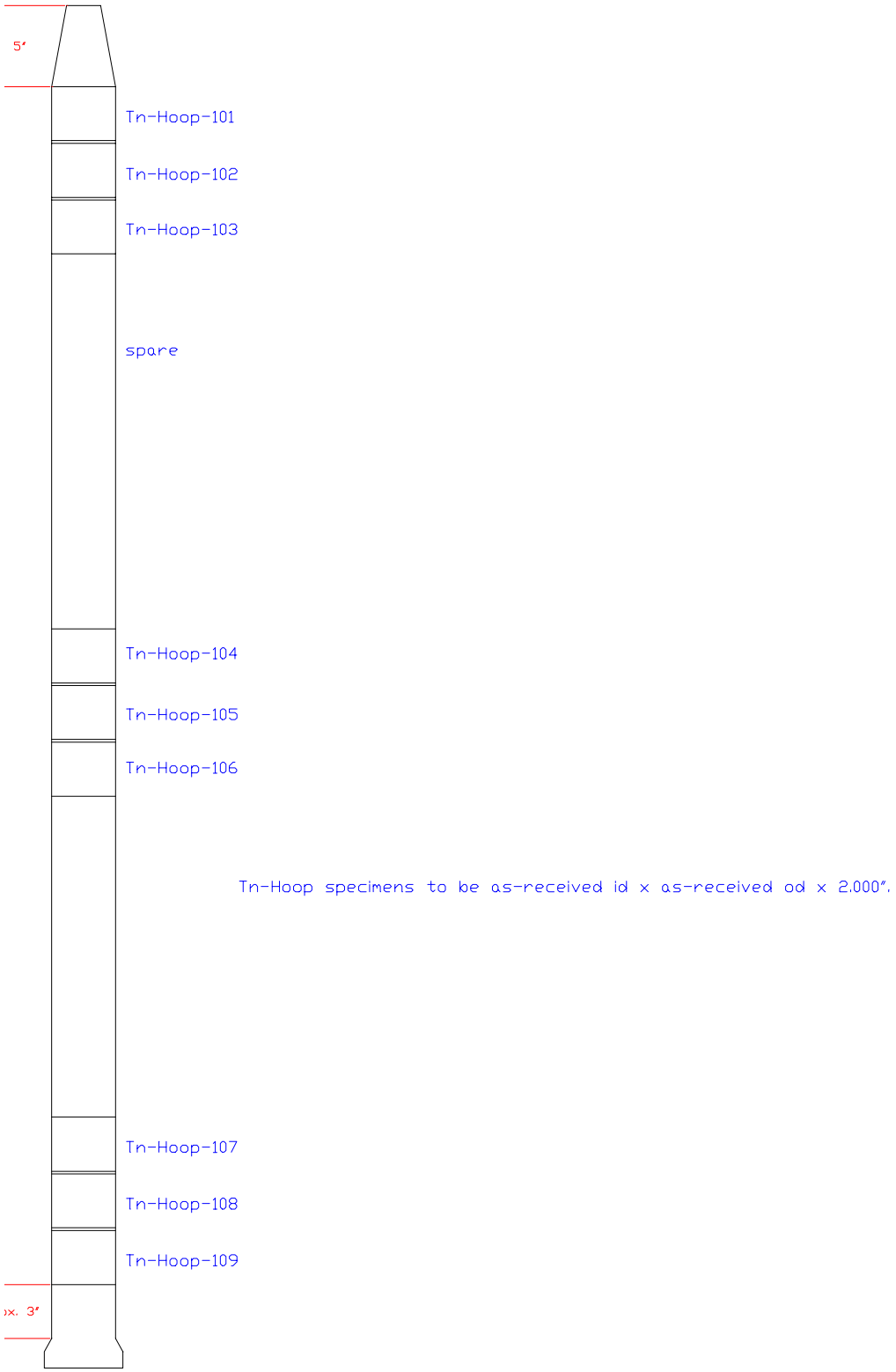

Figure 3. AlliedSignal PRD-66C Filter C732, 636 hours on-coal operation.

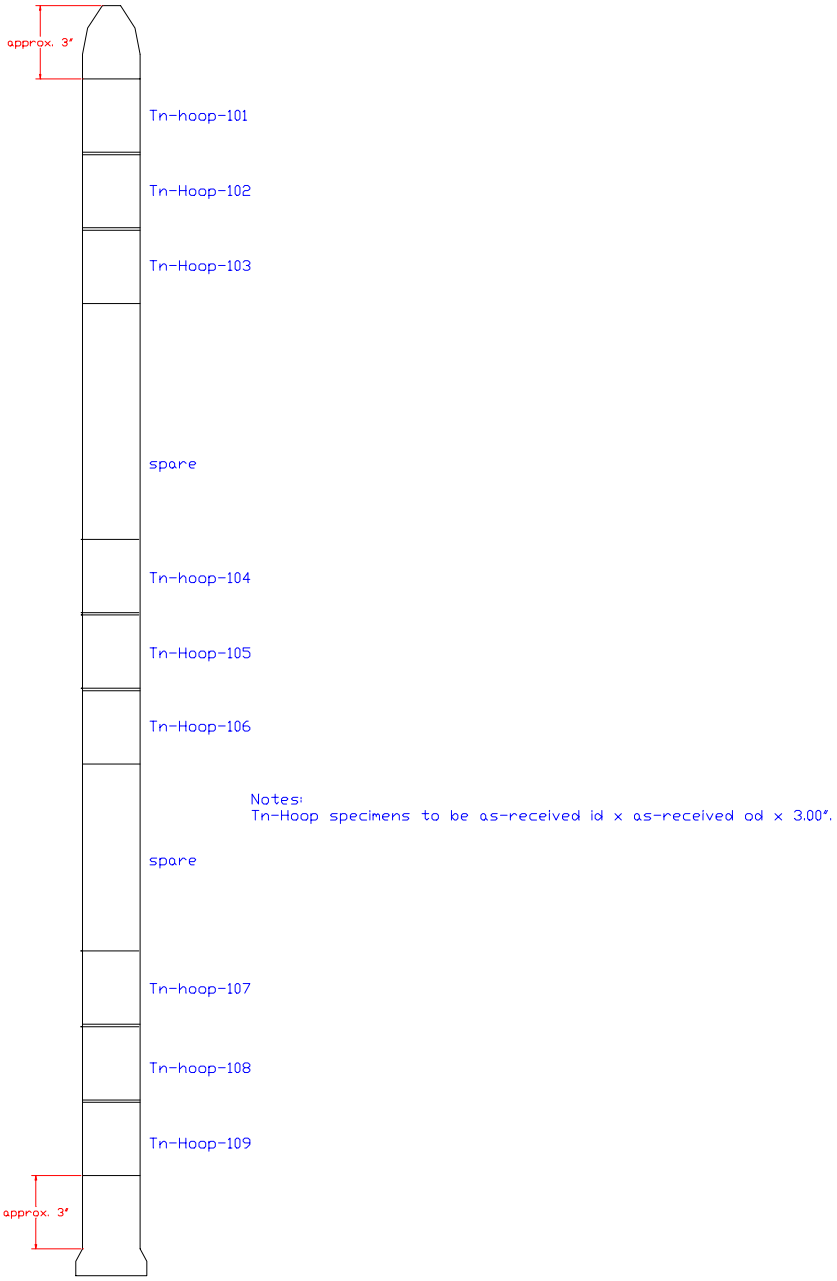

Figure 4. McDermott Filter 8-2-2-1, 1360 hours on-coal operation.

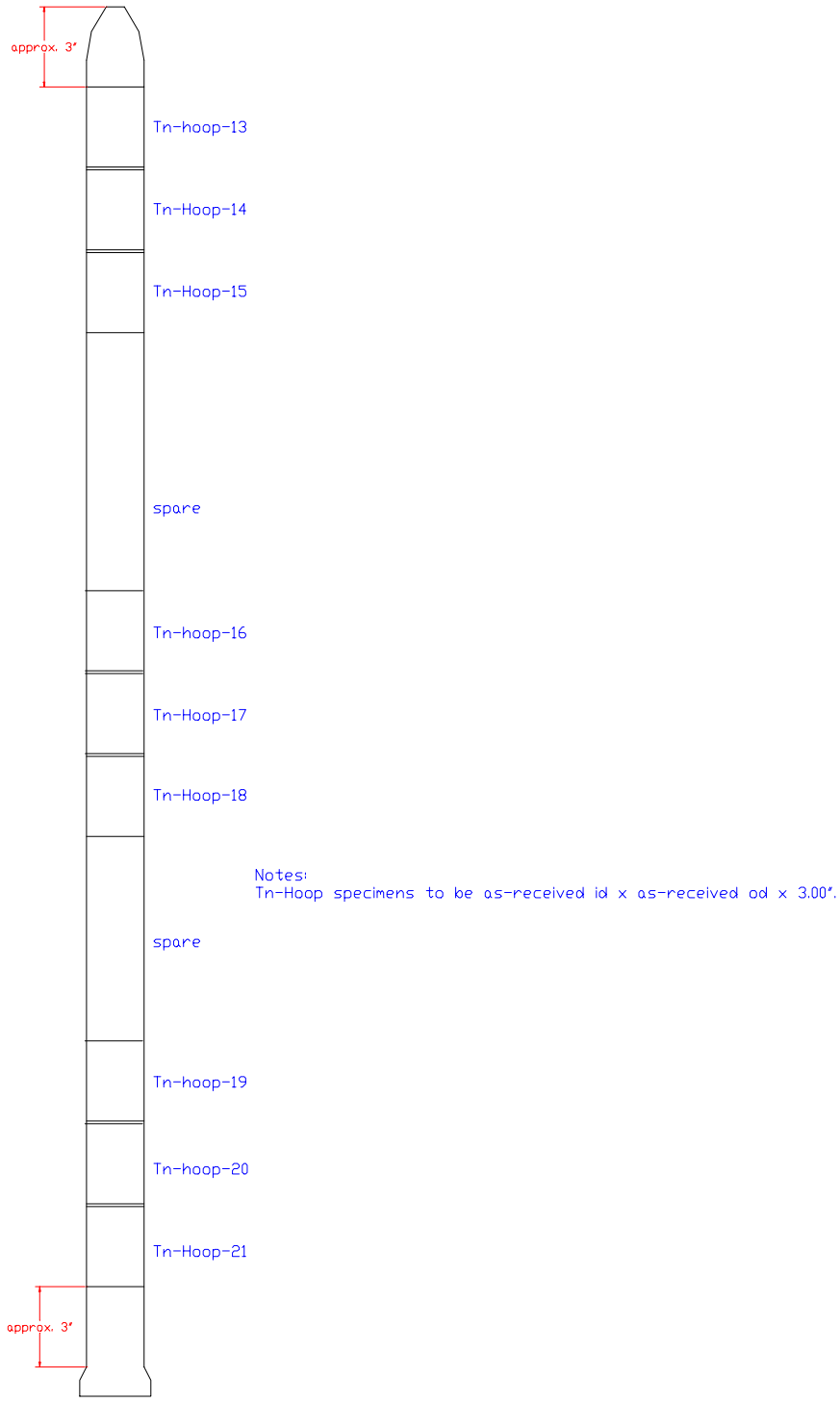

Figure 5. McDermott Filter 8-2-3-2.

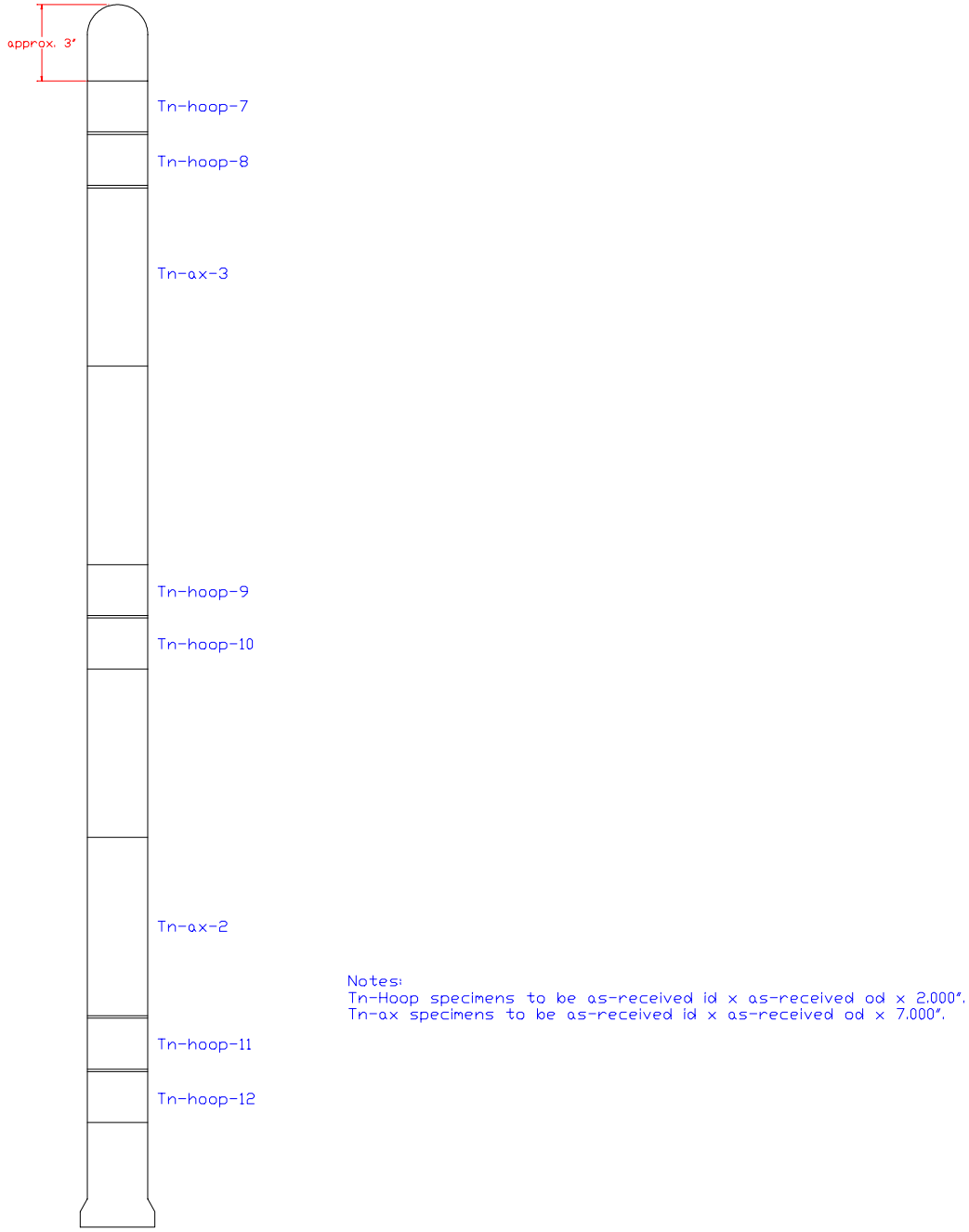

Figure 6. Cutting Plan for Techniweave Candle PSDF1247.

FUTURE WORK

Task 1 plans for the remainder of the project include completion and delivery of the HGCU data bank, and issuance of a comprehensive final report on activities conducted under Task 1. Under Task 2, the testing currently in progress will be completed and the results will be provided. Work is also beginning on the final report of all research activities throughout the contract.

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Approved by

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