

Development of a Coal Combustion Product (CCP) Database System

**Final Report
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DEVELOPMENT OF A COAL COMBUSTION PRODUCT (CCP) DATABASE SYSTEM

EXECUTIVE SUMMARY

Nearly 90 million tons of coal combustion products (CCPs) are produced annually in the United States. The value of CCPs is well established by research and commercial practice; however, only 25% of these products are utilized. The 1994 U.S. Department of Energy report to Congress, *Barriers to the Increased Utilization of Coal Combustion/Desulfurization Byproducts by Governmental and Commercial Sectors* (DOE Office of Fossil Energy), states that there are several major areas of institutional barriers to utilization. Two of these areas are 1) inadequate information, including both engineering and environmental data and 2) inefficient technology/information transfer to CCP producers, end users, regulators, or potential users of CCP technology.

The American Coal Ash Association (ACAA), dedicated to advancing the technically sound, commercially competitive, and environmentally safe use of CCPs, is striving to remove these barriers. CCPs commonly include fly ash, bottom ash, and boiler slag. These materials may vary widely by material type, coal feedstock, combustion conditions, collection systems, and other operational parameters. The characterization of CCPs provides valuable information relevant to the use of the materials. The ability to compare the material characterization on the basis of engineering and analytical data is beneficial in decisions related to CCP utilization.

The objective of this project was to develop a computer program containing a database of advanced analytical and comprehensive engineering information on CCPs, accessible through a user-friendly interface. Version 1.0 of the "ACAA CCP Data Manager" was specifically designed to:

- Perform multiple-criteria queries to produce a set of samples for in-depth study.
- View and print standard test reports, such as C618 reports.
- Compare and contrast analytical results in graphs and tables.
- Graph utilization information by application and region.
- Save data to a file for use in other computer applications, such as spreadsheet programs.

The program was designed to contain descriptive information about a given CCP sample, including sample formation data (material type, sample location, fuel type, collection device etc.), combustion system design data (steam generator type, furnace type, SO₂ and NO_x control information, ash-handling configurations), test data (chemical, mineralogical, and physical characterization data), and utilization potential of the CCP. The location of the plant is identified by region. The database has been initially populated with information on over 800 CCP samples, taken from the Coal Ash Resources Research Consortium (CARRC). An installation package and user's guide was developed for unlimited distribution by the ACAA.

The main features of the program are *query, select, view, report, and graph*. Query provides a way to reduce the database to a set of samples matching specific criteria; for example, "retrieve all samples where the material type is fly ash and the utilization potential is cement and concrete products and the samples were produced in Region 1." Select allows the user to further narrow the query by selecting specific samples returned from the query. View displays all of the available information on the samples. Report provides a variety of reports to view and print, including laboratory reports, C618 reports, and utilization reports. Graph provides a menu of predefined graphs to choose from, such as comparing test results of selected samples or displaying the total number of samples identified for selected utilization potential within each region.

The program has applications for a variety of users, including CCP producers, marketers, and researchers. CCP producers can compare CCPs produced at their plant(s) with CCPs produced under similar conditions at other plants. Producers can use the program to plan for changes in fuel sources or other physical changes in the plant that will affect the quality of their ash. Marketers will be able to examine product consistency over a period of time. CCP producers and marketers can compare CCP properties and elucidate new ways to utilize a particular CCP. Researchers can use the program to identify CCPs that may be specified for emerging technologies. Researchers could also use the program to study how production condition interactions affect the characterization of CCPs.

DEVELOPMENT OF A COAL COMBUSTION PRODUCT (CCP) DATABASE SYSTEM

1.0 BACKGROUND

Nearly 90 million tons of coal combustion products (CCPs) are produced annually in the United States. The value of CCPs is well established by research and commercial practice; however, only 25% of these products is utilized. The 1994 U.S. Department of Energy (DOE) report to Congress, *Barriers to the Increased Utilization of Coal Combustion/ Desulfurization Byproducts by Governmental and Commercial Sectors* (DOE Office of Fossil Energy), states that there are several major areas of institutional barriers to utilization. Two of these areas are 1) inadequate information, including both engineering and environmental data and 2) inefficient technology/information transfer to regulators or potential users of CCP utilization technology and among CCP producers, end users, and regulators.

The American Coal Ash Association (ACAA), dedicated to advancing the technically sound, commercially competitive, and environmentally safe use of CCPs, is striving to remove these barriers. Understanding the mechanisms involved in the formation and utilization of CCPs is a time-consuming and expensive task of compiling, processing, manipulating, and relating data. ACAA has contracted with the Energy & Environmental Research Center (EERC) to develop a database and computer program to assist ACAA members in the management and use of CCPs in a cost-effective manner. The program will incorporate information on fuel source, combustion conditions, collection and storage methods, analytical and empirical test results, and utilization potential. This will allow the user to assess interactions between sample generation and ash properties. The project was cofunded with ACAA and DOE through the EERC's Jointly Sponsored Research Program.

2.0 APPROACH

The overall goal of this project was to develop a computer program containing a database and user-friendly interface to find and interact with analytical and system engineering data on CCPs. This work was coordinated with ACAA staff and the ACAA technical committee. The program and user manual have been provided to the ACAA for unlimited distribution at its discretion. The program, "ACAA CCP Data Manager," was specifically designed with the features listed below:

- Perform multiple-criteria queries to produce a set of samples for in-depth study
- View and print standard reports, such as C618 reports, on selected samples
- Compare and contrast analytical and empirical test results of selected samples in graphs and tables
- Graph utilization information for selected parameters, regions, or samples
- Save data to a file for use with other computer software, such as spreadsheet programs

3.0 METHODS AND ACCOMPLISHMENTS

This work was accomplished through three main tasks: 1) identifying the data and relationships, 2) designing the database and interface, and 3) populating the database. Each task and the methods to accomplish the work are described below.

3.1 Identifying the Data and Relationships

Several meetings with the ACAA technical committee task force resulted in the identification of the kinds of information that was to be included in the database. It was determined that the database needed to be "CCP sample-oriented"; that is, all of the information collected for the database was to be related to a CCP sample. Information related to the design of the combustion system and the factors affecting the formation of the sample are included so that users can study relationships among sample formation, sample characterization, and sample utilization.

The database was designed to hold confidential information in tables outside of the main database. As copies of the database are created for individuals, their confidential data is included in their copy only. Thus the program gives users the ability to identify which samples are their own.

A form was developed for future use in collecting data and data input (Appendix A). The four main categories of related sample information are: sample formation, combustion system design, analytical data, and application.

3.1.1 *Sample Formation*

Sample formation data fields include fuel type, fuel rank, collection device, and significant operating conditions. There are also fields for general sample information such as material type and region (region is the location where the sample was produced; see the last page of the collection form in Appendix A for the list of regions).

3.1.2 *Combustion System Design*

Design features of the engineering system influence the type and quality of the CCPs produced. For example, ash properties can be affected by fuel and boiler type. A furnace designed to burn eastern bituminous coals but currently burning western subbituminous coals will exhibit different ash properties than a furnace designed for and burning western subbituminous coals even though both furnaces are burning the same fuel.

System design configuration data fields include furnace type and manufacturer, steam generator type and manufacturer, SO_2 and NO_x control information, and ash-handling configurations.

3.1.3 *Analytical Data*

Analytical data include chemical, mineralogical, and physical characterization data for the CCP. Standard units have been assigned to each parameter. Analytical data fields include the parameter analyzed, value (result), analytical method, technique, date analyzed, and QA/QC (quality assurance/quality control) comments.

3.1.4 Application

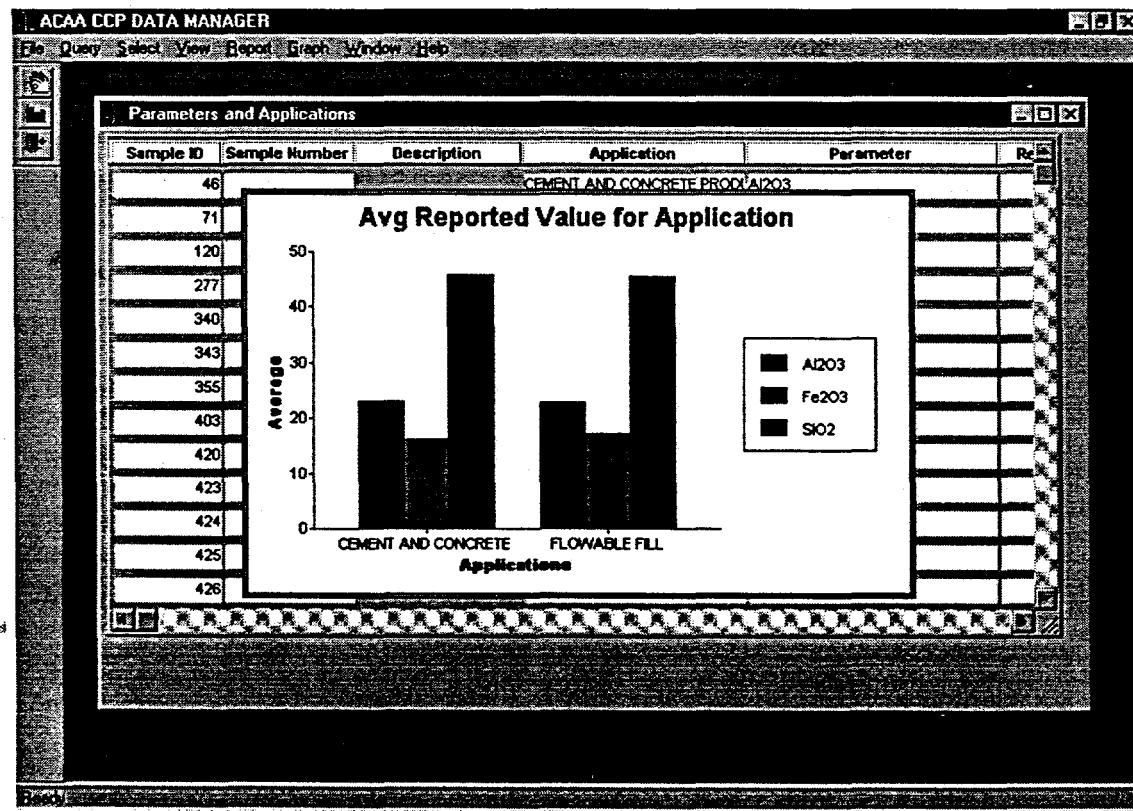
“Application” refers to the actual or potential utilization options that have been identified by the submitter of the sample as appropriate for the specific sample. The identified applications are not governed by the standards required for the utilization option or the characterization results of the sample. The common applications for CCPs are listed in the collection form (Appendix A).

3.2 Designing the Database and Interface

After the data types and relationships were defined, the physical database was created using traditional database management design strategies. The database engine software (structure and data) is Sybase SQL Anywhere, Version 5.0.02®, Sybase, Inc. The schematic of the database is in Appendix B.

The program to interact with the database was designed with PowerBuilder, Version 5.0.01®, Sybase, Inc. The program is designed to operate on IBM-compatible personal computers (PCs) with Windows 3.11 or higher (including Windows 95) with the minimum configuration as follows: a 486 processor, 8 MB of RAM, 13 MB of hard drive disk space.

The specific set of features as previously mentioned for the program were discussed by and agreed upon by a subgroup of the ACAA technical committee. The program was designed as a menu-driven program; users control the flow of the program by pointing and clicking on menu items and window prompts. Each window in the program is designed to fit on a monitor running with a resolution of 640 × 480. An example of a typical window in the program is shown below.



A draft version of the program was created and submitted to the ACAA for approval on the design features. Input was also received regarding the program design from attendants at the ACAA 12th International Coal Ash Use Symposium, where a paper was presented on the development of the program. Following approval by the ACAA, the program was finalized, and an installation program and user manual were created. The manual and diskettes for the finished program, "ACAA CCP Data Manager, version 1.0" were compiled and are enclosed with this report.

3.3 Populating the Database

The database was populated with information from another database, the Coal Ash Properties Database (CAPD). This database was developed by the EERC through a consortium of industry, government members, scientists, and engineers called the Coal Ash Resources Research Consortium (CARRC). The consortium members granted a release of this information for this database.

Following is a summary of the data included in the database:

Total Number of Samples in Database	813
-------------------------------------	-----

Sample Characterization					
Chemical		Mineralogical		Physical	
Parameter	Samples	Parameter	Samples	Parameter	Samples
Al ₂ O ₃	813	Anhydrite	379	Autoclave Expansion	648
Available Alkalies	625	Hematite	409	Fineness	774
BaO	57	Lime	398	Cement Pozzolanic Activity-28D	637
CaO	812	Melilite	375	Cement Pozzolanic Activity-7D	135
Fe ₂ O ₃	813	Merwinite	382	Lime Pozzolanic Activity	601
K ₂ O	313	Mullite	410	Specific Gravity	766
Loss on Ignition	797	Periclase	391	Water Requirement	649
MgO	384	Quartz	410	Total	4210
MnO ₂	58	Sodalite	189		
Moisture Content	788	Spinel	407		
Na ₂ O	313	Tricalcium Aluminate	379		
P ₂ O ₅	146	Total	4129		
SiO ₂	813				
SO ₃	812				
SrO	57				
TiO ₂	57				
Total	7526				

(continued)

No. of Samples per Application	
Application	Samples
Agri Soil Amendment	584
Backfill	139
Blasting Gut/Roofing Granules	139
Cement and Concrete Products	594
Coatings Filler	139
Flowable Fill	156
Grain Storage Pads	231
Grouting	149
Metals Filler	139
Mineral Filler in Asphalt	584
Mineral Wool	139
Mining Applications	139
Paint Filler	139
pH Control	361
Plastics Filler	139
Roadbase/Subbase	369
Snow and Ice Control	139
Soil Stabilization	579
Structural Fill/Embankments	139
Synthetic Aggregate	139
Unspecified	219
Wallboard	139
Waste Stabilization/Solidification	139

No. of Samples per Region	
Region	Samples
Northeast	142
Southeast	24
Great Lakes	145
Northern Plains	324
Southern Plains	52
West	60
Canada	20
Other	6
Unknown	40

No. of Samples per Fuel	
Fuel Rank	Samples
Bituminous	275
Subbituminous	355
Blend - Sub.-Bit.	14
Lignite	93
Unknown	75

4.0 RESULTS

Diskettes containing the program are enclosed. The ACAA can copy the diskettes and user manual to distribute at its discretion. The manual has also been submitted on diskette to the ACAA to accommodate future changes and commercial printing.

The program has applications for a variety of users, including CCP producers, marketers, and researchers. CCP producers can compare CCPs produced at their plant(s) with CCPs produced under similar conditions at other plants. Producers can use the program to plan for changes in fuel sources or other physical changes in the plant that will affect the quality of their ash. Marketers will be able to examine product consistency over a period of time. CCP producers and marketers can compare CCP properties and elucidate new ways to utilize a particular CCP. Researchers can use the program to identify CCPs that may be suitable for emerging technologies. Researchers can also use the database to study production condition interactions which produce CCPs with specific properties.

The usefulness of this program cannot be fully realized until it is available to the users. Version 1.0 of the "ACAA CCP Data Manager" is meant to provide ACAA members the opportunity to explore the use of a state-of-the art computer database program for their own specific needs. After users are acquainted with the ease and capabilities of the program, it is anticipated that they will find it advantageous to have their own data stored in the next version of this database; especially as the program is designed so that they will be able to distinguish their own data from the pool of data.

APPENDIX A
COLLECTION FORM

Sample Information

Sample Number:	Unit Name:	Run Name/Number:	Date Sampled:																					
Sample Description:																								
Material Type: <input type="checkbox"/> Coal <input type="checkbox"/> Fly Ash <input type="checkbox"/> C <input type="checkbox"/> Deposit <input type="checkbox"/> Bed Material <input type="checkbox"/> Pet Coke <input type="checkbox"/> F <input type="checkbox"/> Slag <input type="checkbox"/> Sorbent <input type="checkbox"/> RDF <input type="checkbox"/> Bottom Ash <input type="checkbox"/> Hopper Ash <input type="checkbox"/> Other (describe): _____																								
Collection Device / Method:		Location of Sample in Unit:																						
Fuel Name:		Rank:																						
Mine Name:		Mine Location:																						
Seam:		Fuel Additives:																						
FLUIDIZED BED SYSTEMS Bed Material & Supplier: _____ SO, Sorbent & Supplier: _____																								
Other Significant Operating Conditions Affecting Sample Formation or Results: _____																								
Potential Applications (check all that apply): <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 33%;"><input type="checkbox"/> Cement and Concrete Products</td> <td style="width: 33%;"><input type="checkbox"/> Grouting</td> <td style="width: 33%;"><input type="checkbox"/> Filler in Metals</td> </tr> <tr> <td><input type="checkbox"/> Flowable Fill</td> <td><input type="checkbox"/> Mining Applications</td> <td><input type="checkbox"/> Synthetic Aggregate</td> </tr> <tr> <td><input type="checkbox"/> Structural Fill / Embankments</td> <td><input type="checkbox"/> Wallboard</td> <td><input type="checkbox"/> Agricultural Soil Amendment</td> </tr> <tr> <td><input type="checkbox"/> Roadbase / Subbase</td> <td><input type="checkbox"/> Waste Stabilization / Solidification</td> <td><input type="checkbox"/> pH Control</td> </tr> <tr> <td><input type="checkbox"/> Mineral Filler in Asphalt</td> <td><input type="checkbox"/> Mineral Wool</td> <td><input type="checkbox"/> Backfill</td> </tr> <tr> <td><input type="checkbox"/> Snow and Ice Control</td> <td><input type="checkbox"/> Filler in Plastics</td> <td><input type="checkbox"/> Filler in Coatings</td> </tr> <tr> <td><input type="checkbox"/> Blasting Gut / Roofing Granules</td> <td><input type="checkbox"/> Filler in Paint</td> <td><input type="checkbox"/> Soil Stabilization</td> </tr> </table>				<input type="checkbox"/> Cement and Concrete Products	<input type="checkbox"/> Grouting	<input type="checkbox"/> Filler in Metals	<input type="checkbox"/> Flowable Fill	<input type="checkbox"/> Mining Applications	<input type="checkbox"/> Synthetic Aggregate	<input type="checkbox"/> Structural Fill / Embankments	<input type="checkbox"/> Wallboard	<input type="checkbox"/> Agricultural Soil Amendment	<input type="checkbox"/> Roadbase / Subbase	<input type="checkbox"/> Waste Stabilization / Solidification	<input type="checkbox"/> pH Control	<input type="checkbox"/> Mineral Filler in Asphalt	<input type="checkbox"/> Mineral Wool	<input type="checkbox"/> Backfill	<input type="checkbox"/> Snow and Ice Control	<input type="checkbox"/> Filler in Plastics	<input type="checkbox"/> Filler in Coatings	<input type="checkbox"/> Blasting Gut / Roofing Granules	<input type="checkbox"/> Filler in Paint	<input type="checkbox"/> Soil Stabilization
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<input type="checkbox"/> Blasting Gut / Roofing Granules	<input type="checkbox"/> Filler in Paint	<input type="checkbox"/> Soil Stabilization																						

Submitter Information

Submitter Name:	Date:
Company Name:	Phone:
Address:	Fax: E-Mail:

Combustion System Design

Power Company:	Plant Name:	Plant Address (city, state):									
Unit Name:	Combustion Type: <input type="checkbox"/> Pulverized Coal <input type="checkbox"/> Cyclone <input type="checkbox"/> Fluidized Bed <input type="checkbox"/> Stoker	Unit Size (MWe):									
Region (see attached map): <table> <tr> <td><input type="checkbox"/> Region 1 - Northeast</td> <td><input type="checkbox"/> Region 4 - Northern Plains</td> <td><input type="checkbox"/> Region 7 - Canada</td> </tr> <tr> <td><input type="checkbox"/> Region 2 - Southeast</td> <td><input type="checkbox"/> Region 5 - Southern Plains</td> <td><input type="checkbox"/> Region 8 - Other</td> </tr> <tr> <td><input type="checkbox"/> Region 3 - Great Lakes</td> <td><input type="checkbox"/> Region 6 - West</td> <td><input type="checkbox"/> Region 9 - Unknown</td> </tr> </table>			<input type="checkbox"/> Region 1 - Northeast	<input type="checkbox"/> Region 4 - Northern Plains	<input type="checkbox"/> Region 7 - Canada	<input type="checkbox"/> Region 2 - Southeast	<input type="checkbox"/> Region 5 - Southern Plains	<input type="checkbox"/> Region 8 - Other	<input type="checkbox"/> Region 3 - Great Lakes	<input type="checkbox"/> Region 6 - West	<input type="checkbox"/> Region 9 - Unknown
<input type="checkbox"/> Region 1 - Northeast	<input type="checkbox"/> Region 4 - Northern Plains	<input type="checkbox"/> Region 7 - Canada									
<input type="checkbox"/> Region 2 - Southeast	<input type="checkbox"/> Region 5 - Southern Plains	<input type="checkbox"/> Region 8 - Other									
<input type="checkbox"/> Region 3 - Great Lakes	<input type="checkbox"/> Region 6 - West	<input type="checkbox"/> Region 9 - Unknown									

Fuel

Design Fuel Name:	Design Rank: <input type="checkbox"/> Bituminous <input type="checkbox"/> Subbituminous <input type="checkbox"/> Lignite <input type="checkbox"/> Other _____
Design Mine Name:	Design Mine Location:
Design Seam:	

Combustion System Design (cont.)

Steam Generator

Furnace Type (pressurized, balanced draft, etc.):	Furnace Manufacturer:
Steam Generator Type (drum, once-through, etc.):	Steam Generator Manufacturer:

Combustion Type

PC	Cyclone	Fluidized Bed	Stoker
Burner Configuration (one wall, opposed wall, tangential, etc.):	Cyclone Burner Type:	Bed Type (bubbling, circulating, etc.):	Fuel Feed System (spreader, etc.):
Burner Manufacturer:	Cyclone Burner Manufacturer:	Bed Manufacturer:	
NO _x Control? Method: Manufacturer:	NO _x Control? Method: Manufacturer:	Start-up Bed Material & Supplier:	Ash Removal System (traveling grate, etc.):
SO _x Control? Method: Manufacturer:	SO _x Control? Method: Manufacturer:	SO ₂ Sorbent & Supplier:	

Ash Management

Particulate Removal Device (ESP, fabric filters, etc.):	Particulate Removal Manufacturer:	
Particulate Removal Configuration (#, efficiency):	Scrubber Type (wet, dry):	Type of Scrubber Reheat (cool gas, hot gas, etc.):
Type of Ash Handling System: Bottom Ash:	Waste Disposal System (dry-landfill, wet-pond):	
Fly Ash:	Emission Limits - under what emission limits is the unit regulated?:	

Chemical Analysis

Chemical Analysis							
Sample Number:	Parameter	Technique	Method	Date Analyzed	Result	Units	QA/QC Notes
	SiO ₂					wt%	
	Al ₂ O ₃					wt%	
	Fe ₂ O ₃					wt%	
	Sum of SiO ₂ , Al ₂ O ₃ , Fe ₂ O ₃					wt%	
	CaO					wt%	
	SO ₃					wt%	
	Na ₂ O					wt%	
	K ₂ O					wt%	
	P ₂ O ₅					wt%	
	TiO ₂					wt%	
	BaO					wt%	
	MnO ₂					wt%	
	SiO ₂					wt%	
	MgO					wt%	
	pH					wt%	
	Moisture Content					wt%	
	Loss on Ignition					wt%	
	Available Alkalies					wt% as Na ₂ O	

Sample Number:

Chemical Analysis

Parameter	Technique	Method	Date Analyzed	Result	Units	QA/QC Notes
RCRA ELEMENTS						
As				ug/g		
Ag				ug/g		
Ba				ug/g		
Cd				ug/g		
Cr				ug/g		
Hg				ug/g		
Pb				ug/g		
Se				ug/g		
LEACHATE						
As				mg/L		
Ag				mg/L		
Ba				mg/L		
Cd				mg/L		
Cr				mg/L		
Hg				mg/L		
Pb				mg/L		
Se				mg/L		

Sample Number: _____

Physical Analysis

Parameter	Technique	Method	Date Analyzed	Result	Units	G/A/QC Notes
Unit Weight					lbs/ft ³	
Max Dry Density					lbs/ft ³	
Optimum Moisture Content					wt%	
Unconfined Compressive Strength					psi	
Angle of Internal Friction (φ)					degrees (°)	
Coefficient of Permeability (K)					cm/sec	
D ₁₀					mm	
D ₅₀					mm	
Bearing Capacity					psf	
Specific Gravity						
Wet Density					lbs/ft ³	
Dry Density					lbs/ft ³	
Cohesion					psf	
Particle Size/Distribution					% - mm	
Flow Test					%	
Slump Test					in	
Penetration Test					psi	
Bulk Density					lbs/ft ³	
Surface Area					cm ² /g	
Fineness on #225 Sieve					%	
Increase in Drying Shrinkage					%	
Autoclave Expansion					%	
Specific Gravity Variability					%	
Fineness Variability					%	
AEA Demand					oz/yd ³	
Mortar Expansion					%	
Pozzolanic Activity/Cement					%	
Pozzolanic Activity/Lime					psi	
Water Requirement					%	

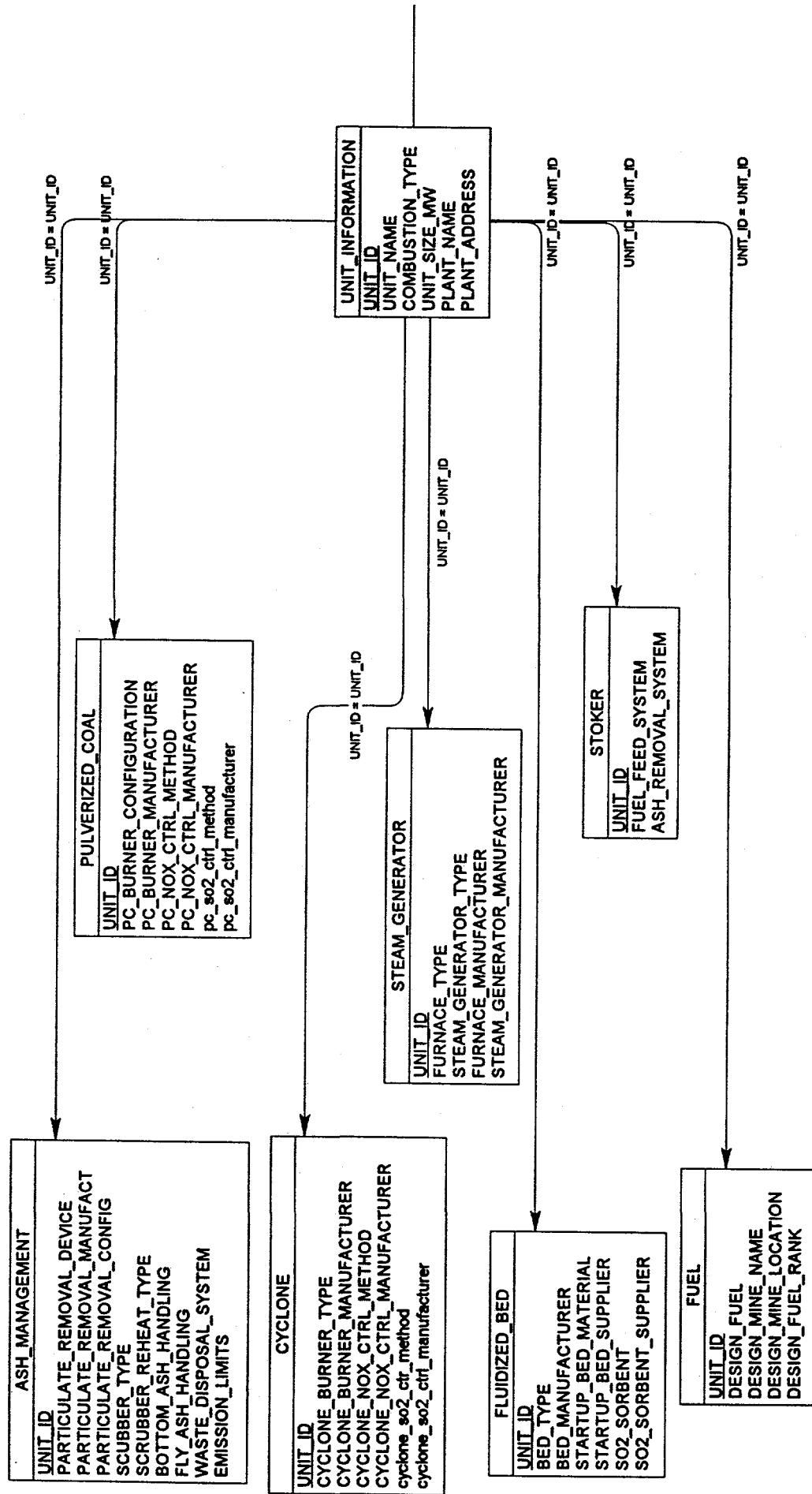
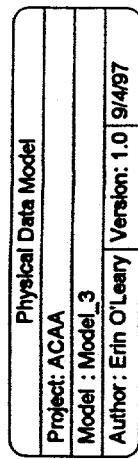
Sample Number: _____

Mineralogical Analysis

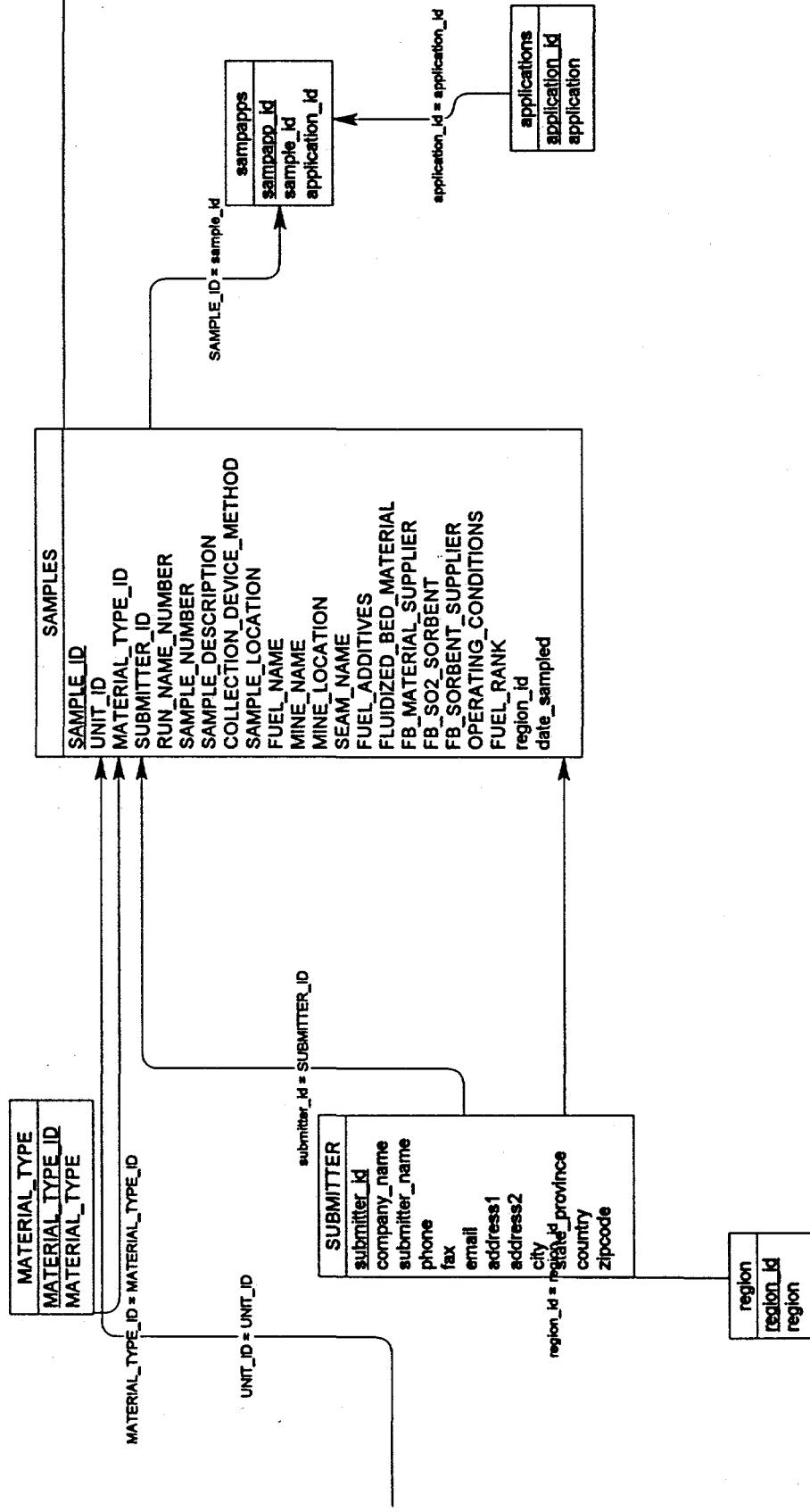
Parameter	Technique	Method	Date Analyzed	Result	Units	QA/QC Notes
% Crystalline					wt%	
% Amorphous					wt%	
CRYSTALLINE PHASES PRESENT						
Calcium Sulfates					wt%	
Iron Oxides					wt%	
Calcium Aluminates					wt%	
Spinel					wt%	
Sodilites					wt%	
Calcium Oxides/Hydroxides						
Mellilites					wt%	
Quartz					wt%	
Mullite					wt%	
Merwinite					wt%	
Periclaste					wt%	

REGIONS	
Region 1 - Northeast	Connecticut Delaware District of Columbia Maine Maryland Massachusetts New Hampshire New Jersey New York Pennsylvania Rhode Island Vermont Virginia West Virginia
Region 2 - Southeast	Alabama Florida Georgia Mississippi North Carolina South Carolina Tennessee
Region 3 - Great Lakes	Illinois Indiana Kentucky Michigan Ohio Wisconsin
Region 4 - Northern Plains	Iowa Minnesota Nebraska North Dakota South Dakota
Region 5 - Southern Plains	Arkansas Kansas Louisiana Missouri Oklahoma Texas
Region 6 - West	Alaska Arizona California Colorado Hawaii Idaho Montana Nevada New Mexico Oregon Utah Washington Wyoming
Region 7 - Canada	
Region 8 - Other	
Region 9 - Unknown	

APPENDIX B
DATABASE SCHEMATIC



Physical Data Model
 Project: ACIAA
 Model : Model_3
 Author: Erin O'Leary Version: 1.0 9/4/97



Physical Data Model	
Project: ACIAA	
Model : Model_3	
Author : Erin O'Leary	Version: 1.0 9/4/97

