Development of a Coal Combustion Product (CCP) Database System

Final Report
September 1997

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Work Performed Under Contract No.: DE-FC21-93MC30098

For
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Office of Fossil Energy
Federal Energy Technology Center
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ACKNOWLEDGMENT

This report was prepared with the support of the U.S. Department of Energy (DOE) Federal Energy Technology Center Cooperative Agreement No. DE-FC21-93MC30098. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors(s) and do not necessarily reflect the views of DOE.

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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, SO_2 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

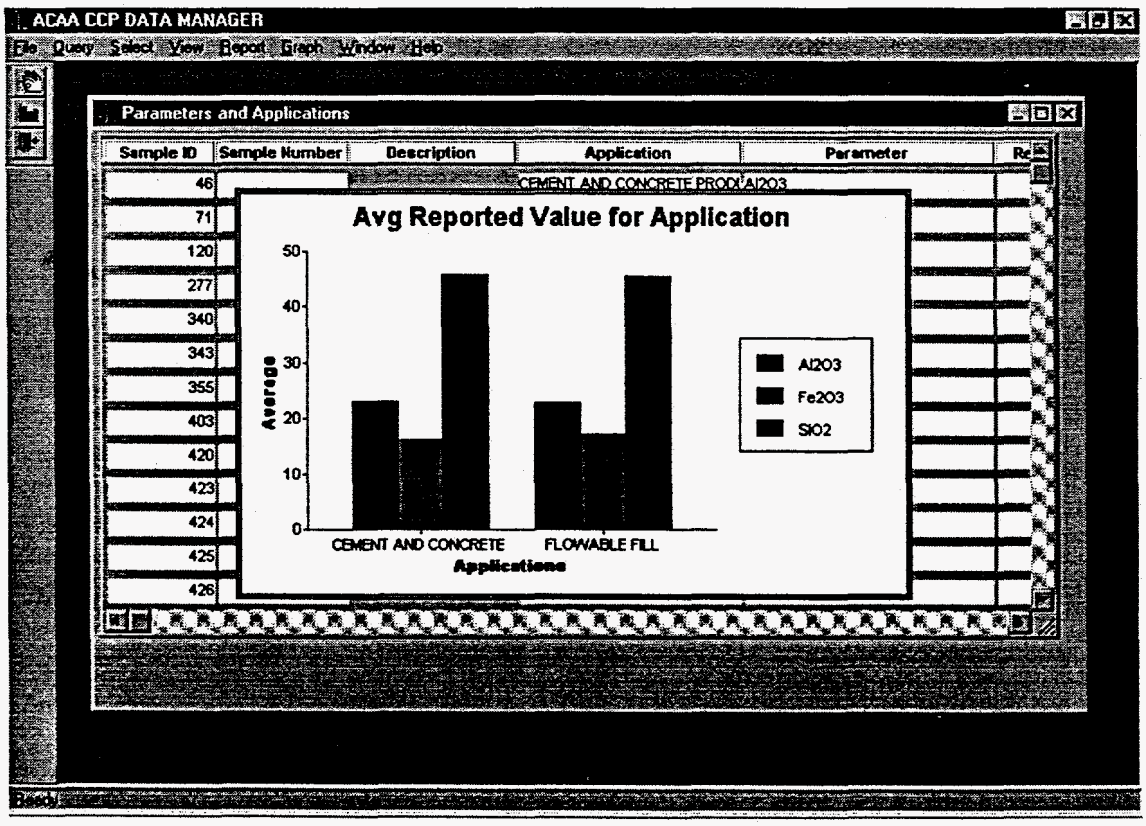
"*Application*" refers to the actual or potential utilization options that have been identified by the submitter of the sample as appropriate for the specific sample. The identified applications are not governed by the standards required for the utilization option or the characterization results of the 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_2O_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		
Fe_2O_3	813	Merwinite	382	Cement Pozzolanic Activity-7D	135
K_2O	313	Mullite	410		
Loss on Ignition	797	Periclase	391	Lime Pozzolanic Activity	601
MgO	384	Quartz	410	Specific Gravity	766
MnO_2	58	Sodalite	189	Water Requirement	649
Moisture Content	788	Spinel	407	Total	4210
Na_2O	313	Tricalcium Aluminate	379		
P_2O_5	146	Total	4129		
SiO_2	813				
SO_3	812				
SrO	57				
TiO_2	57				
Total	7526				

Continued. . .

(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:

- ☐ Coal
- ☐ Pet Coke
- ☐ RDF
- ☐ Fly Ash
- ☐ C
- ☐ F
- ☐ Bottom Ash
- ☐ Deposit
- ☐ Slag
- ☐ Hopper Ash
- ☐ Bed Material
- ☐ Sorbent
- ☐ 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_2 Sorbent & Supplier:

Other Significant Operating Conditions Affecting Sample Formation or Results:

Potential Applications (check all that apply):

- ☐ Cement and Concrete Products
- ☐ Flowable Fill
- ☐ Structural Fill / Embankments
- ☐ Roadbase / Subbase
- ☐ Mineral Filler in Asphalt
- ☐ Snow and Ice Control
- ☐ Blasting Gut / Roofing Granules
- ☐ Grouting
- ☐ Mining Applications
- ☐ Wallboard
- ☐ Waste Stabilization / Solidification
- ☐ Mineral Wool
- ☐ Filler in Plastics
- ☐ Filler in Paint
- ☐ Filler in Metals
- ☐ Synthetic Aggregate
- ☐ Agricultural Soil Amendment
- ☐ pH Control
- ☐ Backfill
- ☐ Filler in Coatings
- ☐ 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: ☐ Pulverized Coal ☐ Cyclone ☐ Fluidized Bed ☐ Stoker	Unit Size (MWe):
Region (see attached map): ☐ Region 1 - Northeast ☐ Region 4 - Northern Plains ☐ Region 7 - Canada ☐ Region 2 - Southeast ☐ Region 5 - Southern Plains ☐ Region 8 - Other ☐ Region 3 - Great Lakes ☐ Region 6 - West ☐ Region 9 - Unknown		

Fuel

Design Fuel Name:	Design Rank: ☐ Bituminous ☐ Subbituminous ☐ Lignite ☐ 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_2 Control? Method: Manufacturer:	SO_2 Control? Method: Manufacturer:	SO2 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: Fly Ash:	Waste Disposal System (dry-landfill, wet-pond): Emission Limits - under what emission limits is the unit regulated?:	

Chemical Analysis

Sample Number:

Parameter	Technique	Method	Date Analyzed	Result	Units	QA/QC Notes
SiO_2					wt%	
Al_2O_3					wt%	
Fe_2O_3					wt%	
Sum of SiO_2, Al_2O_3, Fe_2O_3					wt%	
CaO					wt%	
SO_3					wt%	
Na_2O					wt%	
K_2O					wt%	
P_2O_5					wt%	
TiO_2					wt%	
BaO					wt%	
MnO_2					wt%	
SrO					wt%	
MgO					wt%	
pH						
Moisture Content					wt%	
Loss on Ignition					wt%	
Available Alkalies					wt% as Na_2O	

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	QA/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	
D10					mm	
D50					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 #325 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%	
					wt%	
					wt%	
Iron Oxides						
					wt%	
					wt%	
Calcium Aluminates						
					wt%	
					wt%	
					wt%	
Spinels						
					wt%	
					wt%	
Sodalites						
					wt%	
Calcium Oxides/Hydroxides						
					wt%	
Melilites						
					wt%	
Quartz					wt%	
Mullite					wt%	
Merwinite					wt%	
Periclase					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

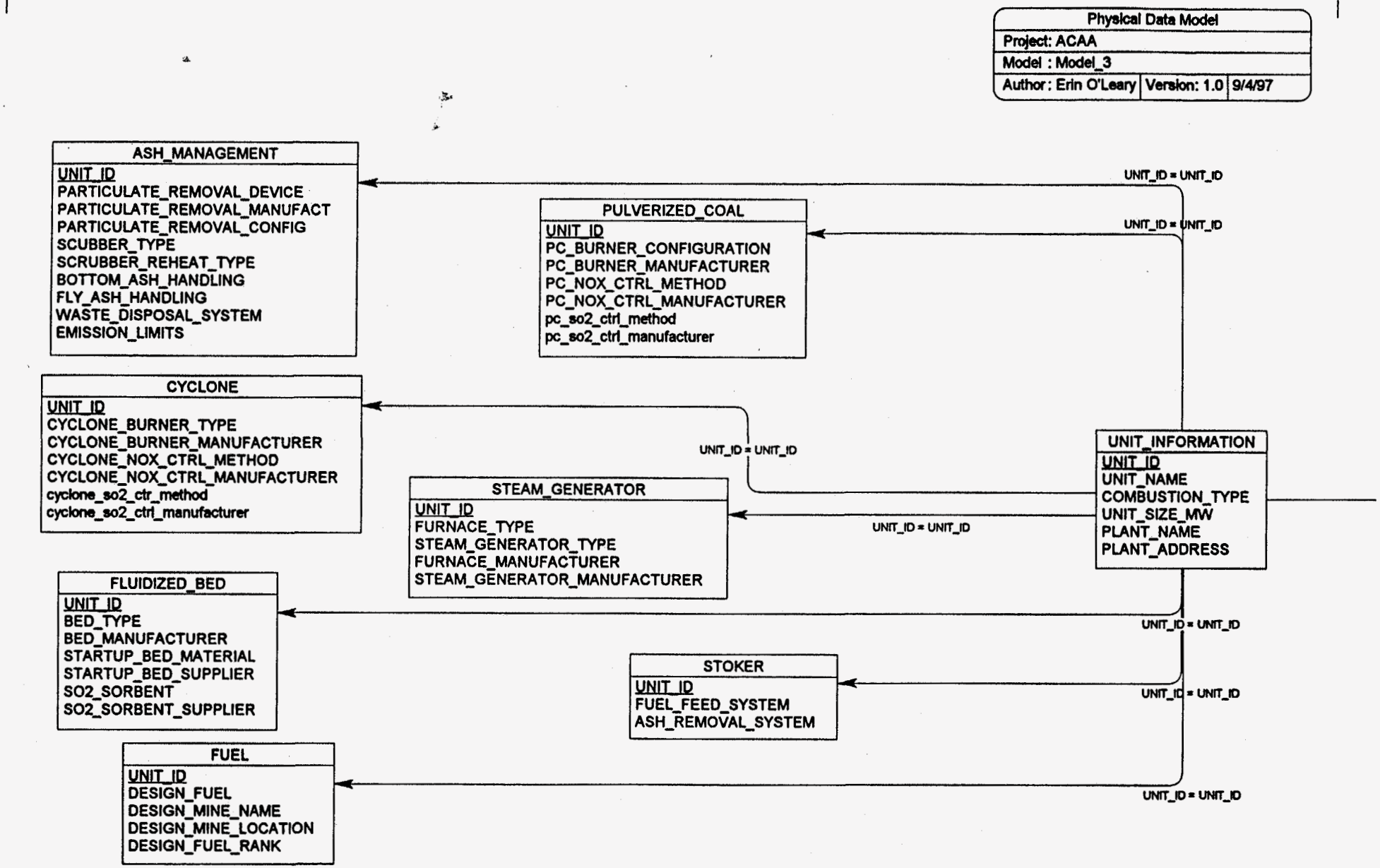
Region 7 – Canada

Region 8 – Other

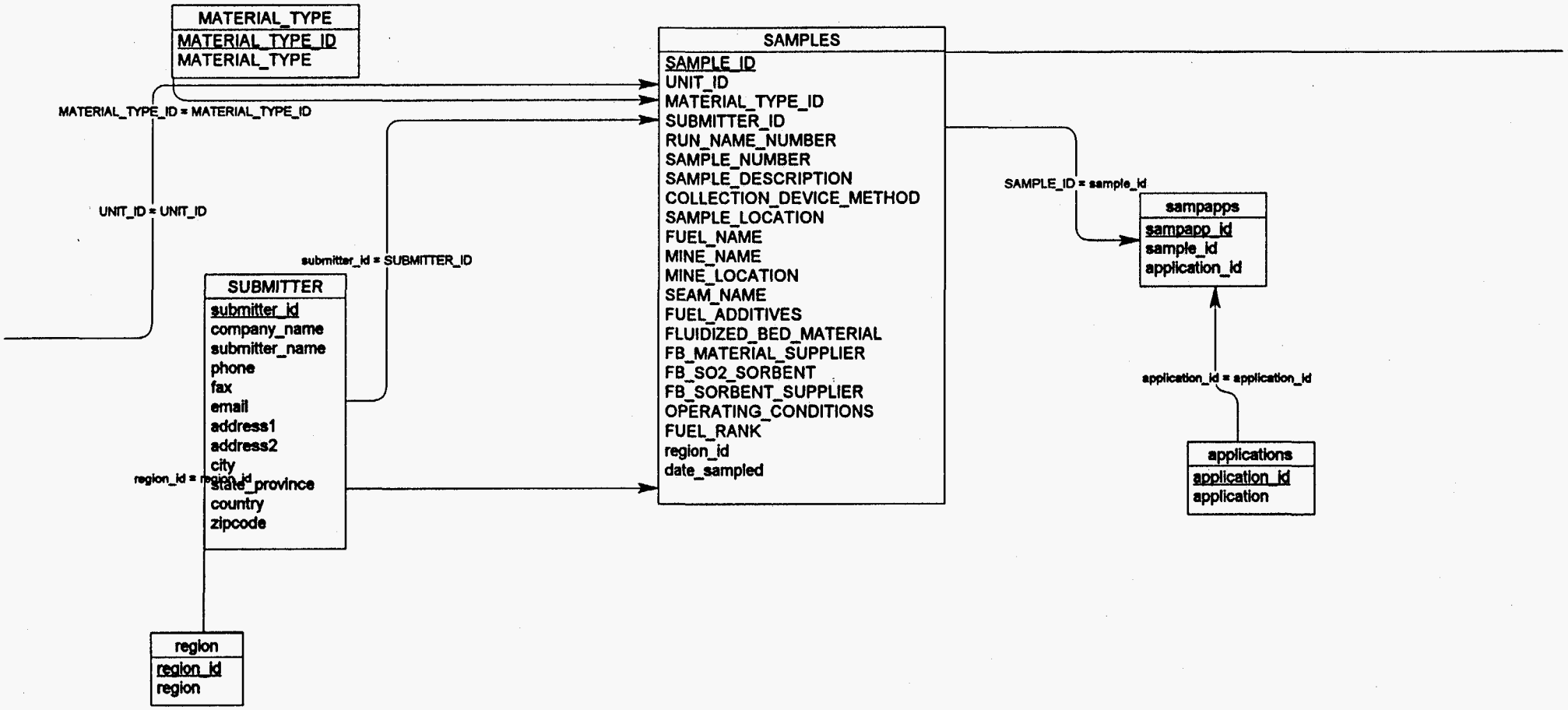
Region 9 – Unknown

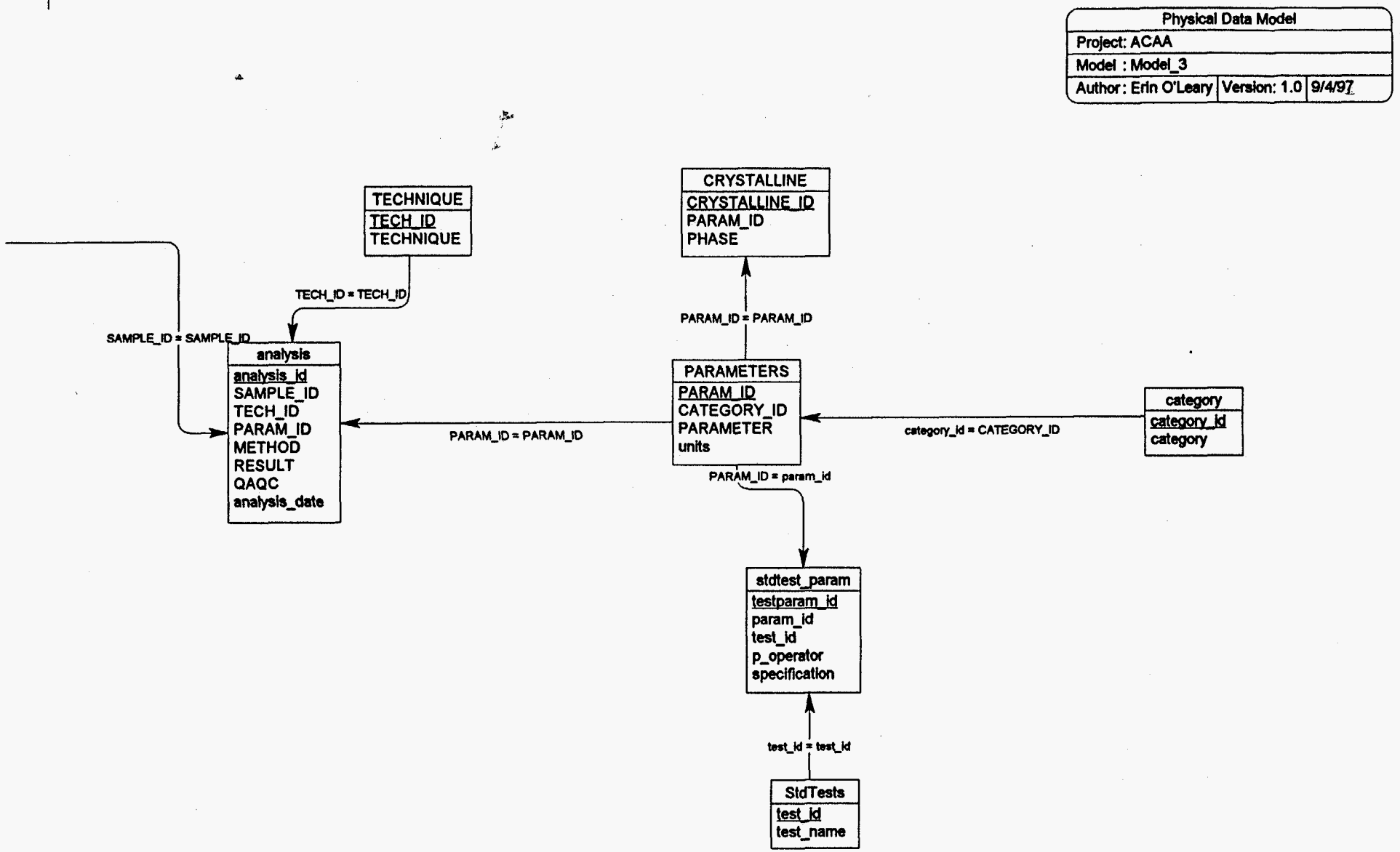
APPENDIX B

DATABASE SCHEMATIC


Physical Data Model
Project: ACAA
Model : Model_3
Author: Erin O'Leary
Version: 1.0
9/4/97
ASH_MANAGEMENT
UNIT_ID
PARTICULATE_REMOVAL_DEVICE
PARTICULATE_REMOVAL_MANUFACT
PARTICULATE_REMOVAL_CONFIG
SCUBBER_TYPE
SCRUBBER_REHEAT_TYPE
BOTTOM_ASH_HANDLING
FLY_ASH_HANDLING
WASTE_DISPOSAL_SYSTEM
EMISSION_LIMITS
PULVERIZED_COAL
UNIT_ID
PC_BURNER_CONFIGURATION
PC_BURNER_MANUFACTURER
PC_NOX_CTRL_METHOD
PC_NOX_CTRL_MANUFACTURER
pc_so2_ctrl_method
pc_so2_ctrl_manufacturer
CYCLONE
UNIT_ID
CYCLONE_BURNER_TYPE
CYCLONE_BURNER_MANUFACTURER
CYCLONE_NOX_CTRL_METHOD
CYCLONE_NOX_CTRL_MANUFACTURER
cyclone_so2_ctr_method
cyclone_so2_ctrl_manufacturer
STEAM_GENERATOR
UNIT_ID
FURNACE_TYPE
STEAM_GENERATOR_TYPE
FURNACE_MANUFACTURER
STEAM_GENERATOR_MANUFACTURER
UNIT_INFORMATION
UNIT_ID
UNIT_NAME
COMBUSTION_TYPE
UNIT_SIZE_MW
PLANT_NAME
PLANT_ADDRESS
FLUIDIZED_BED
UNIT_ID
BED_TYPE
BED_MANUFACTURER
STARTUP_BED_MATERIAL
STARTUP_BED_SUPPLIER
SO2_SORBENT
SO2_SORBENT_SUPPLIER
STOKER
UNIT_ID
FUEL_FEED_SYSTEM
ASH_REMOVAL_SYSTEM
FUEL
UNIT_ID
DESIGN_FUEL
DESIGN_MINE_NAME
DESIGN_MINE_LOCATION
DESIGN_FUEL_RANK
UNIT_ID = UNIT_ID
UNIT_ID = UNIT_ID
UNIT_ID = UNIT_ID
UNIT_ID = UNIT_ID
UNIT_ID = UNIT_ID
UNIT_ID = UNIT_ID
UNIT_ID = UNIT_ID

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




Physical Data Model
Project: ACAA
Model : Model_3
Author: Erin O'Leary
Version: 1.0
9/4/97
TECHNIQUE
TECH_ID
TECHNIQUE
CRYSTALLINE
CRYSTALLINE_ID
PARAM_ID
PHASE
TECH_ID = TECH_ID
PARAM_ID = PARAM_ID
SAMPLE_ID = SAMPLE_ID
analysis
analysis_id
SAMPLE_ID
TECH_ID
PARAM_ID
METHOD
RESULT
QAQC
analysis_date
PARAMETERS
PARAM_ID
CATEGORY_ID
PARAMETER
units
category
category_id
category
PARAM_ID = PARAM_ID
category_id = CATEGORY_ID
PARAM_ID = param_id
stdtest_param
testparam_id
param_id
test_id
p_operator
specification
test_id = test_id
StdTests
test_id
test_name