JV TASK 19 – COAL-FIRED UTILITY BOILERS: SOLVING ASH DEPOSITION PROBLEMS

Final Report

Prepared for:

AAD Document Control
National Energy Technology Laboratory
U.S. Department of Energy
PO Box 10940, MS 921-143
Pittsburgh, PA 15236-0940

Cooperative Agreement No. DE-FC26-98FT40321; Fund 4725
Performance Monitor: Robert Patton

Prepared by:

Christopher J. Zygarlicke
Donald P. McCollor
Steven A. Benson
Jay R. Gunderson

Energy & Environmental Research Center
University of North Dakota
PO Box 9018
Grand Forks, ND 58202-9018

April 2001

DISCLAIMERS

EERC DISCLAIMER

LEGAL NOTICE THIS RESEARCH REPORT WAS PREPARED BY THE ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC), AN AGENCY OF THE UNIVERSITY OF NORTH DAKOTA, AS AN ACCOUNT OF WORK SPONSORED BY DOE AND EPRI. BECAUSE OF THE RESEARCH NATURE OF THE WORK PERFORMED, NEITHER THE EERC NOR ANY OF ITS EMPLOYEES MAKES ANY WARRANTY, EXPRESS OR IMPLIED, OR ASSUMES ANY LEGAL LIABILITY OR RESPONSIBILITY FOR THE ACCURACY, COMPLETENESS, OR USEFULNESS OF ANY INFORMATION, APPARATUS, PRODUCT, OR PROCESS DISCLOSED, OR REPRESENTS THAT ITS USE WOULD NOT INFRINGE PRIVATELY OWNED RIGHTS. REFERENCE HEREIN TO ANY SPECIFIC COMMERCIAL PRODUCT, PROCESS, OR SERVICE BY TRADE NAME, TRADEMARK, MANUFACTURER, OR OTHERWISE DOES NOT NECESSARILY CONSTITUTE OR IMPLY ITS ENDORSEMENT OR RECOMMENDATION BY THE EERC.

DOE DISCLAIMER

THIS REPORT WAS PREPARED AS AN ACCOUNT OF WORK SPONSORED BY AN AGENCY OF THE UNITED STATES GOVERNMENT. NEITHER THE UNITED STATES GOVERNMENT, NOR ANY AGENCY THEREOF, NOR ANY OF THEIR EMPLOYEES MAKES ANY WARRANTY, EXPRESS OR IMPLIED, OR ASSUMES ANY LEGAL LIABILITY OR RESPONSIBILITY FOR THE ACCURACY, COMPLETENESS, OR USEFULNESS OF ANY INFORMATION, APPARATUS, PRODUCT, OR PROCESS DISCLOSED OR REPRESENTS THAT ITS USE WOULD NOT INFRINGE PRIVATELY OWNED RIGHTS. REFERENCE HEREIN TO ANY SPECIFIC COMMERCIAL PRODUCT, PROCESS, OR SERVICE BY TRADE NAME, TRADEMARK, MANUFACTURER, OR OTHERWISE DOES NOT NECESSARILY CONSTITUTE OR IMPLY ITS ENDORSEMENT, RECOMMENDATION, OR FAVORING BY THE UNITED STATES GOVERNMENT OR ANY AGENCY THEREOF. THE VIEWS AND OPINIONS OF AUTHORS EXPRESSED HEREIN DO NOT NECESSARILY STATE OR REFLECT THOSE OF THE UNITED STATES GOVERNMENT OR ANY AGENCY THEREOF.

THIS REPORT IS AVAILABLE TO THE PUBLIC FROM THE NATIONAL TECHNICAL INFORMATION SERVICE, U.S. DEPARTMENT OF COMMERCE, 5285 PORT ROYAL ROAD, SPRINGFIELD, VA 22161; PHONE ORDERS ACCEPTED AT (703) 487-4650.

EPRI DISCLAIMER

THIS DOCUMENT WAS PREPARED BY THE ORGANIZATION(S) NAMED ABOVE AS AN ACCOUNT OF WORK SPONSORED OR COSPONSORED BY THE ELECTRIC POWER RESEARCH INSTITUTE, INC. (EPRI). NEITHER EPRI, ANY MEMBER OF EPRI, ANY COSPONSOR, THE ORGANIZATION(S) ABOVE, NOR ANY PERSON ACTING ON BEHALF OF ANY OF THEM:

(A) MAKES ANY WARRANTY OR REPRESENTATION WHATSOEVER, EXPRESS OR IMPLIED, (I) WITH RESPECT TO THE USE OF ANY INFORMATION, APPARATUS, METHOD, PROCESS, OR SIMILAR ITEM DISCLOSED IN THIS DOCUMENT, INCLUDING MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, OR (II) THAT SUCH USE DOES NOT INFRINGE ON OR INTERFERE WITH PRIVATELY OWNED RIGHTS, INCLUDING ANY PARTY'S INTELLECTUAL PROPERTY, OR (III) THAT THIS DOCUMENT IS SUITABLE TO ANY PARTICULAR USER'S CIRCUMSTANCE; OR

(B) ASSUMES RESPONSIBILITY FOR ANY DAMAGES OR OTHER LIABILITY WHATSOEVER (INCLUDING ANY CONSEQUENTIAL DAMAGES, EVEN IF EPRI OR ANY EPRI REPRESENTATIVE HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES) RESULTING FROM YOUR SELECTION OR USE OF THIS DOCUMENT OR ANY INFORMATION, APPARATUS, METHOD, PROCESS, OR SIMILAR ITEM DISCLOSED IN THIS DOCUMENT.

ACKNOWLEDGMENTS

This report was prepared with the support of the U.S. Department of Energy (DOE) National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-98FT40321. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors(s) and do not necessarily reflect the views of DOE.

The Energy & Environmental Research Center's (EERC's) Principal Investigator wishes to acknowledge the following organizations and people for their support, advice, and help in completing the project and this final report.

The authors acknowledge the efforts of Lucinda Hamre (EERC), for her dedication in putting this document together.

Special thanks also go to Warren McNaughton, Cornice Engineering, Inc., for his detailed editing and organizational work on the document.

EPRI was a commercial sponsor of this joint venture project (under Contract No. EP-P3116/C1471), and David O'Connor and Arun Mehta from EPRI were instrumental in preparation and review of this guide.

Finally, gratitude is expressed to the following individuals from various utilities, who either critiqued the document or provided photographs and other information: Ken Stuckmeyer, AmerenUE; Gary Walling, Alliant Energy; Charlie Bullinger, Great River Energy; Gerry Goblirsch, Xcel Energy; and Fran Mara, Alliant Energy.

EXECUTIVE SUMMARY

Considerable research efforts conducted by academic and private institutions have created several different pathways that a coal-fired utility can take to mitigate ash deposition for a specific boiler and fuel. However, most utilities still find themselves struggling to determine what resources are available, what analyses and tests should be performed, and what approach should be taken to successfully overcome ash deposition problems. This project had the goal of producing a concise, comprehensive “guidebook” for utilities facing ash-related problems. This guidebook is meant to be used as a guideline for solving ash deposition problems associated primarily with coal-fired utility boilers and is an interim document, which means it will be updated as knowledge progresses.

In general, a utility operator or engineer notices an alleged ash deposition problem, either by visual observation of ash deposition types or by boiler-monitoring devices or controls. Sometimes, an ash deposition problem may be suspected but not verified until the boiler is shut down and inspected off-line. Once an ash deposition problem is detected or suspected, a series of logical steps must be taken to alleviate or solve the problem. A general procedure is prescribed which consists of identification of the ash deposition problem, characterizing the boiler or ash deposit symptoms which point to a problem, diagnosing the root cause of the problem, and prescribing mitigation measures to alleviate or solve the problem.

Eight chapters make up the confidential “guidelines” report in Appendix A (the confidential report is available from EPRI by contacting EPRI Distribution Center, PO Box 23205, Pleasant Hill, California 94523, phone [800] 313-3774 or phone [650] 855-2121, press 2). Chapter 1 gives an introduction to the report and guidance on its use. Chapter 2 provides logic charts and summary tables that guide a utility operator or engineer step-by-step through the ash deposition solving process, complete with thumbnail photos of deposit types and descriptions of boiler symptoms. The user of the manual is guided through a process of determining the location of the ash deposition problem, gathering samples, and procuring any historical information or recorded boiler operating data. With this information and following the logic charts, the user can proceed to Chapters 3 and 4 for more descriptive information on deposit types and boiler symptoms. Chapter 3 lists ash deposit types starting with the lower radiant furnace and proceeding through the upper radiant furnace, high-temperature convective pass, and low-temperature convective pass and ending with the air heater or selective catalytic reduction region of the boiler. All of these areas can develop characteristic ash deposits that are thoroughly explained and exemplified using pictures. Chapter 4 lists only boiler operating symptoms that may signify that an ash deposition problem is occurring, such as uncharacteristically high furnace exit gas temperatures or depressed reheater steam temperatures. Both Chapters 3 and 4 not only describe ash deposit types and symptoms but they prescribe diagnostic tests for determining root causes of ash deposition, and they give prioritized remedial measures for potentially solving the ash deposition problem.

Chapter 5 provides descriptions of diagnostic tests that could be used for determining ash deposition root causes, such as methods for analyzing ash deposits to learn why ash deposition is occurring. Chapter 6 is a compilation of nine actual case studies where utilities or other

institutions were attempting to solve ash deposition problems. Each case study begins with a short summary showing how the guidelines would be used to solve the ash deposition problem. Chapter 7 is a scientific background section that describes the “whys” concerning ash deposition. It describes coal mineral and ash properties and provides discussions on fly ash formation, transport, ash deposition, and deposit sintering and methods for understanding ash deposition in general. Finally, Chapter 8 is a “clearinghouse” of resources and references that may aid a utility person in finding proper help for solving ash deposition problems. Some of the resources include 1) a listing of laboratories that perform specialized coal and deposit analyses, plus a description of analytical techniques; 2) annotated bibliographies of books and papers related to coal and deposit analysis, ash deposition, and ash deposit remediating additives; 3) a listing of companies and other institutions that have capabilities for bench- and pilot-scale combustion testing or can perform equipment modifications and installations; and 4) a listing and description of universities, institutions, and companies that perform ash deposition modeling, computational fluid dynamics modeling, and engineering design.

TABLE OF CONTENTS

ACKNOWLEDGMENTS	i
EXECUTIVE SUMMARY	iii
LIST OF FIGURES	vi
LIST OF TABLES	vii
CHAPTER 1 – INTRODUCTION	1
Background	1
Objectives	2
Results	2
Interest Categories	4
CHAPTER 2 – ROADMAP FOR ADDRESSING AND ANTICIPATING ASH DEPOSITION PROBLEMS.....	5
Introduction	5
Ash-Related Problems	7
Boiler-Related Problems	7
Ash Deposit Found.....	9
Action A-1: Define the Ash Deposition Problem and Gather Initial Information Pertaining to the Deposit, Unit, and Coals Burned	9
Action A-1(a). Determine the Locations and Extent of the Deposition Problem	11
Action A-1(b). Determine the History of the Problem	13
Action A-1(c). Gather Necessary Unit Information.....	15
Action A-1(d). Determine Whether Ash Deposit Samples Are Available or Can Be Obtained.....	19
Action A-1(e). Determine Whether Coal Samples Can Be Obtained.....	19
Action A-2: Preliminary Identification of Deposition Type.....	21
Action A-3: Match Description of Ash Deposition Type	23
Action A-4: Root-Cause Determination.....	25
Action A-4(a). Check for Boiler Causes	25
Action A-4(b). Lay Out a Diagnostic Plan	27
Action A-4(c). Obtain Ash Samples as Required.....	27

Action A-4(d). Obtain Coal Samples as Required	27
Action A-4(e). Sequentially Perform Diagnostic Tests, Modeling, and Analysis as Required	29
Action A-5: Develop and Apply Remedial Measures Specific to the Underlying Cause(s)	31
Action A-6: Establish a Long-Term Monitoring Program for Effectiveness	33
Boiler-Specific Condition Found – Follow Flowchart Actions B-1 Through B-6	35
Action B-1: Document Control Room or Plant Observation and Gather Initial Information Pertaining to the Deposit, Unit, and Coals Burned	35
Action B-1(a). Document the Details of the Boiler-Specific Problem	37
Action B-1(b). Determine the History of the Problem	37
Action B-1(c). Determine Whether a Deposition Problem Is Occurring	37
Action B-1(d). Gather Necessary Unit Information	39
Action B-1(e). Determine Whether Ash Deposit Samples Can Be Obtained (if appropriate)	39
Action B-1(f). Determine Whether Coal Samples Can Be Obtained (if appropriate)	39
Action B-2: Find the Boiler-Specific Problem in Table 4-1	41
Action B-3: Match Description Using Details Provided in Chapter 4	43
Action B-4: Root-Cause Determination	43
Action B-5: Develop and Apply Remedial Measures Specific to Underlying Cause(s)	45
Action B-6: Establish a Long-Term Monitoring Program for Effectiveness	45
CHAPTER 3 – ASH DEPOSITION SYMPTOMS, DEPOSIT TYPES, AND REMEDIAL MEASURES	46
Introduction	46
Symptoms and Remedial Measures by Boiler Location	47
CHAPTER 4 – BOILER-SPECIFIC SYMPTOMS AND REMEDIAL MEASURES	53
Introduction	53
Symptoms and Remedial Measures by Boiler Operating Condition	53
CHAPTER 5 – CONCLUSIONS	58
CONFIDENTIAL REPORT	APPENDIX A

LIST OF FIGURES

Figure 2-1 Overall Roadmap for Diagnosing Ash Deposition Problems	6
Figure 2-2 Following Flowchart A for Known Ash Deposition Problem, Beginning with Action A-1	8
Figure 2-3 Action A-1(a): Determine Locations and Extent of Problem.....	10
Figure 2-4 Action A-1(b): Determine the History of the Problem	12
Figure 2-5 Action A-1(c): Gather Necessary Unit Information	14
Figure 2-6 Actions A-1(d, e): Determine Whether Ash Deposit and Coal Samples Can Be Obtained.....	18
Figure 2-7 Action A-2: Tentative Identification of Deposition Type.....	20
Figure 2-8 Action A-3: Match Description of Ash Deposition Type.....	22
Figure 2-9 Action A-4(a): Check for Boiler Causes	24
Figure 2-10 Actions A-4(b, c, d): Lay Out a Diagnostic Plan; Obtain Ash and Coal Samples	26
Figure 2-11 Action A-4(e): Sequentially Perform Diagnostic Tests, Modeling, and Analysis as Required	28
Figure 2-12 Action A-5 and Action A/B-5: Develop and Apply Remedial Measures Specific to Underlying Causes.....	30
Figure 2-13 Action A-6: Establish Long-Term Monitoring	32
Figure 2-14 Follow Flowchart B for Boiler-Specific Observation, Beginning with Action B-1	34
Figure 2-15 Actions B-1(a, b, c): Documenting the Problem, Its History and Whether a Deposit Problem Is Occurring.....	36
Figure 2-16 Actions B-1(d, e, f): Gathering Unit Information and Determining Whether Ash and Coal Samples Are Available.....	38
Figure 2-17 Action B-2: Find Boiler-Specific Problem in Table 4-1	40
Figure 2-18 Action B-3: Match Description Using Details Provided in Chapter 4 and Action B-4: Root-Cause Determination	42
Figure 2-19 Action B-5: Develop and Apply Remedial Measures and Action B-6: Long- Term Monitoring	44

LIST OF TABLES

Table 2-1 Useful General Boiler Information	16
Table 2-2 Useful General Boiler Parameter Information.....	17
Table 3-1 Boiler Zones or Regions and Associated Ash Deposit Characteristics That Indicate a Potential Ash Deposition Problem	48
Table 4-1 Boiler Zones or Regions and Associated Boiler Conditions or Observations	55

CHAPTER 1 – INTRODUCTION

This document is primarily intended to aid utilities in solving ash deposition problems. The following decision-making model and the subsequent steps will enable the reader to evaluate the problems they are having, determine whether they are related to ash deposition or boiler problems, and then begin the steps necessary to solve the problem.

Background

Considerable research efforts conducted by academic and private institutions have created several different pathways which a coal-fired utility can take to mitigate ash deposition for a specific boiler and fuel. However, most utilities still find themselves struggling to determine what resources are available, what analyses and tests should be performed, and what approach should be taken to successfully overcome ash deposition problems. This project had the goal of producing a concise, comprehensive “guidebook” for utilities facing ash-related problems. This guidebook is meant to be used as a guideline for solving ash deposition problems associated primarily with coal-fired utility boilers and is an interim document, which means it will be updated as knowledge progresses.

This report is meant to be used as a guideline for solving ash deposition problems associated primarily with coal-fired utility boilers. It is an interim guideline, and as knowledge increases in the area of remediating ash deposition, this document will be updated. Some of the fundamental principles described herein may apply to stoker-fired or fluidized-bed combustors, but the primary application is intended for pulverized coal (pc) or cyclone-fired coal boilers. In general, a utility operator or engineer notices an ash deposition-related problem either by visual observation or by boiler monitoring devices or controls. Sometimes, an ash deposition problem may be suspected but not verified until the boiler is shut down and inspected off-line.

Once an ash deposition problem is detected or suspected, a series of logical steps must be taken to define and characterize the ash deposition problem, diagnose the root cause for the ash deposition problem, and then prescribe mitigation steps to alleviate or solve the ash deposition problem. In this document, a general procedure is prescribed that consists of identifying the ash deposition problem, characterizing the boiler or ash deposit symptoms which point to a problem, diagnosing the root cause of the problem, and prescribing mitigation measures to alleviate or solve the ash deposition problem.

Other fuels such as biomass or opportunity fuels may create similar ash deposition phenomenon, but the primary application herein is for coal. Chapter 2 gives the basic roadmap logic structure for solving an ash deposition problem. More specific details about deposit types, boiler symptoms, resources, and places to go for help are part of the confidential section of this report in Appendix A. This report can be obtained from EPRI by contacting EPRI Distribution Center, PO Box 23205, Pleasant Hill, California 94523, phone (800) 313-3774 or phone (650) 855-2121, press 2.

Objectives

The objective of project was to compile a concise, comprehensive report to serve as a “guidebook” for utilities facing current or potential problems related to ash deposition from coal combustion. The guidelines were assembled in a report format that is relatively easy for a boiler operator or engineer to use. Clearly understandable case studies are presented in Appendix A and referenced from which the user can derive comparisons. Direction, advice, and critical reviews to the report were rendered by EPRI staff and other utility experts. Specific objectives were to:

- 1) Generate a functional report outline.
- 2) Write a draft report.
- 3) Subject the report to a thorough review by utility experts.
- 4) Finalize the report in a logical format that is easy to follow.

Results

The confidential guideline report (Appendix A to this report) is structured in such a way that utility personnel can identify ash deposition types and implement appropriate mitigation strategies. By combining coal and ash deposit analysis strategies and full-scale field experience with invaluable comments and input from utility personnel, a step-by-step guideline for identifying ash deposit types and attempting to alleviate ash deposition was generated, as applied primarily to pulverized- and cyclone-fired coal boilers.

The guideline in Appendix A is divided into eight chapters. Chapter 1 serves as an introduction to the remainder of the guideline report, and it gives some explanation of how to use the report.

Chapter 2 focuses on the first step in solving an ash deposition problem, which involves defining the problem and gathering historical information related to the ash deposition problem. This chapter also uses logic charts to guide the user through the important stage of attempting to recognize what type of ash deposit problem is being encountered and in what part of the boiler. Chronology of the ash deposition event is important at this stage as well, determining how it was recognized and how often it occurs. Problems addressed here are those that cannot be addressed immediately using sootblowers or other means. A team of plant staff may need to be assembled and the exact location and periodicity of the ash deposition problem determined. It should then be determined if ash deposits can be collected, and if so, then pertinent information such as boiler location, position on walls or tubes, and any deposit physical characteristics such as texture, size, color, and density are all helpful. Recorded boiler information is essential. In addition, any other changes that may have been made before ash deposition occurred, such as coal switches, changes in boiler operation, boiler tuning, recent heavy rains, etc., should be noted and documented.

Chapter 2 also provides logic charts and summary tables that guide a utility operator or engineer step-by-step through the ash deposition solving process. Two main paths are open to access the detailed information about a specific problem: either visual appearance of an ash deposition

problem or observation of a boiler condition. Thumbnail photos of deposit types and descriptions of boiler symptoms are provided. Ash deposit characteristics and boiler symptoms are grouped according to region or zone in a typical coal-fired boiler. If an operator is noticing unusually high reheat steam temperatures or visual inspections show ash deposit bridging in the reheat section of the convective pass, then the user can go to the high-temperature convective pass zone of this manual to look for symptoms or ash deposit descriptions. With this information and following the logic charts, the user proceeds to Chapters 3 and 4 for more descriptive information on deposit types and boiler symptoms.

Chapters 3 and 4 are the heart of the guidelines. Chapter 3 provides detail about several ash deposit types at various locations in the boiler and suggests diagnostic tests that can be done to verify the root cause of the ash deposition. Oftentimes, operators know they have a particular ash deposition problem occurring, but they do not know where to go next or how to attack the problem because the root cause is not understood. For this reason, a diagnostic step is performed to determine the root causes of the ash deposition problem, if possible, so that wise solutions of deposit mitigation strategies can be implemented. Once a preliminary identification of an ash deposition problem or boiler condition has been made, more specific chemical, engineering, or modeling information may be necessary to clearly identify the source of the ash deposition problem. This step is critical, but is often left out by utilities, with the end result that ash deposition problems are not dealt with properly. Chapter 3 provides detailed information about how to perform this vital step. Chapter 3 also gives remedial measures for alleviating the ash deposition problem. Oftentimes, visual inspections of the boiler during on-line operation or the collection of ash deposits during off-line servicing reveal certain characteristics of ash deposition that intimate an ongoing or impending problem.

In addition to recognizing ash deposit types in the boiler, often there will be certain boiler symptoms that are noticed in the control room or through boiler inspections which indicate an ash deposition problem. Chapter 4 focuses on these boiler operation symptoms that are indicative of an ongoing or approaching ash deposition problem, and it also lists ash deposition mitigation measures that may be implemented for remediating the problem.

Chapter 5 provides a brief description of over 20 different diagnostic tests delineated in Chapters 3 and 4. The list of diagnostic analyses or testing procedures that are listed here are labeled so that they can be referenced in other sections of this report. Coal, fly ash, and ash deposit chemical and mineral analyses make up the bulk of these diagnostic tests. Other diagnostic tests may involve bench-, pilot-, or even full-scale combustion testing. Utilities are encouraged to budget yearly resources for training and maintaining an expertise in utilizing the types of diagnostic exercises detailed in this section.

Chapter 6 documents several case studies on a variety of ash deposition problems encountered by utilities. The case studies are intended to give utility personnel examples of how to implement diagnostic testing, identify ash deposition symptoms and root causes, and implement remedial measures for reducing or solving ash deposition problems.

Chapter 7 provides a scientific and fundamental explanation of how ash deposits form and the impacts of boiler design, operation, and fuel type. This chapter, in essence, answers some of the

“whys” of ash deposition phenomena in utility boilers and is extremely helpful for utility personnel in that it may facilitate the utility to find and develop mitigation strategies that are not covered in this guide.

The final chapter of the guidelines document, Chapter 8, lists several resources that will aid utility personnel in their efforts to alleviate ash deposition. Chapter 8 includes 1) a listing of laboratories that perform specialized coal and deposit analyses, plus a description of analytical techniques; 2) annotated bibliographies of books and papers related to coal and deposit analysis, ash deposition, and ash deposit remediating additives; 3) a listing of companies and other institutions that have capabilities for bench- and pilot-scale combustion testing or can perform equipment modifications and installations; and 4) a listing and description of universities, institutions, and companies that perform ash deposition modeling, CFD (computational fluid dynamics) modeling, and engineering design.

Interest Categories

- Ash deposition
- Utility boiler operation
- Convective pass fouling
- Radiant zone slagging
- Coal quality impacts on ash deposition
- Coal analysis
- Prediction of ash behavior
- Ash deposition mitigation strategies

CHAPTER 2 – ROADMAP FOR ADDRESSING AND ANTICIPATING ASH DEPOSITION PROBLEMS

Introduction

When an ash deposition problem or event is occurring at a coal-fired utility boiler, two parallel roadmaps can be used to begin solving the ash deposition problem as shown in Figure 2-1 and described here:

- a) The observation of an ash deposition condition during a plant inspection (Actions A-1 through A-6).
- b) The observation of a boiler-specific condition in the control room or elsewhere in the plant (Actions B-1 through B-6).

These roadmaps are shown on the following page. Each step within the roadmap is explained in detail here. The chapter is generally organized with a portion of the flowchart highlighted by shading on the left-hand pages and the corresponding discussion about that step on the right-hand page.

Any references to remedial measures or diagnostic tests are found in the confidential section of this report in Appendix A. Chapters 3 and 4, included in this nonconfidential report, only describe the ash deposition types and boiler symptoms, respectively.

Figure 2-1
Overall Roadmap for Diagnosing Ash Deposition Problems

Ash-Related Problems

If an ash deposit has been found during a plant inspection, the utility should follow the left-hand sequence of actions designated Actions A-1 through A-6. These actions will lead eventually to Chapter 3, which contains a key organizing table (Table 3-1) and where deposit-specific information about deposition problems has been compiled. The table gives about 20 ash deposit types with written descriptions and pictures of each deposit.

Boiler-Related Problems

If a boiler-specific condition has been identified, then the right-hand path, designated Actions B-1 through B-6, should be followed. Boiler-specific conditions are sorted into two sources of information: control room observations and unit (field) observations. Examples of boiler-specific conditions that might trigger an investigation into potential effects on ash deposits include poor burner performance, high furnace exit gas temperatures (FEGTs), diminished main steam temperature readings, or high amperage draws on induced-draft fans. Following these steps will lead eventually to Table 4-1 and more detailed information in Chapter 4, which describes about 15 boiler control room or boiler proper symptoms that indicate a potential ash deposition problem.

It should be noted that these two paths are not truly separate in practice. Many ash deposit problems will have, at their root, a boiler-related cause. That cause must be addressed in order to mitigate the deposition problem. Similarly, many boiler-specific conditions, if not addressed, may eventually lead to significant ash deposition problems.

Figure 2-2
Follow Flowchart A for Known Ash Deposition Problem, Beginning with Action A-1

Ash Deposit Found

Follow Flowchart Actions A-1 through A-6.

Action A-1: Define the Ash Deposition Problem and Gather Initial Information Pertaining to the Deposit, Unit, and Coals Burned

The first action consists of five substeps which, when completed, will result in a full definition of the problem and aid in gathering background information that will be used in later stages of the investigation.

Figure 2-3
Action A-1a. Determine Locations and Extent of Problem

Action A-1a. Determine the Locations and Extent of the Deposition Problem

Typically, the solution of an ash deposition problem begins with the observation, made during a unit inspection, of a developing problem. The process, however, may start with the suspicion of a problem, which is later confirmed by a targeted visual examination of the suspect areas. If the concern is triggered by a suspect boiler characteristic or control room reading, see Flowchart B (Figure 2-14), and begin following Flowchart Actions B-1 through B-6.

If the ash deposition problem is verified visually, then agreement on location(s) of interest is optimally done in a team effort including operators, plant managers, and plant engineers. Review of past inspection records may indicate changes in dominant locations or an acceleration in the extent of the problem.

At a minimum, the following information should be documented:

- Location in the boiler where the deposition problem is occurring (secondary superheater pendants, wall slag, reheater, economizer, etc.).
- Specific location on tube banks or waterwalls where the deposit is occurring. It is especially important to note whether the deposit is forming on the front (upstream) or back (downstream) side of tubes, at the top or bottom of the tube bank, etc. If a deposit sample is picked off of a convective pass floor, then the location on the tube bank should be estimated from where it fell.
- Describe the amount of deposit coverage in the boiler, if possible, such as “half of the front-side of the reheater has 6-inch (15-cm)-thick ash deposits.” If the deposit is a piece of a larger subset, this should be noted.
 - Notes should be made of the physical characteristics of the deposit such as texture (sandstonelike, glassy, etc.)
 - Size (measured thicknesses or description, such as massive)
 - Color (brown, grey, etc.)
 - Density (light, heavy, dense, or massive)

Figure 2-4
Action A-1b. Determine the History of the Problem

Action A-1b. Determine the History of the Problem

Chronology is of utmost importance, including when the ash deposition event occurred and what coals were being burned at the time of the event. Review of past inspection records may be indicated to provide as complete a history of the problem as possible. Seek the answer to questions such as:

- Is this problem a chronic problem or a first-time event?
- How often does the ash deposition problem occur?
- Is the problem seasonal, periodic with fuel changes, obviously related to specific operating conditions, or otherwise tied to specific triggering events?
- How severe is the problem? Has the magnitude or extent of the problem varied over time?
- How was the problem recognized?

Figure 2-5
Action A-1c. Gather Necessary Unit Information

Action A-1c. Gather Necessary Unit Information

Often, the ash deposition problem is caused by, or can be directly related to, unit operating conditions. Although it can be time-consuming, it is important early in the process to obtain at least a minimum of unit information that can be analyzed to help determine the root cause of the problem.

A list of general boiler information and of general operating information that will be useful in the analysis of the ash deposition problem can be found in Tables 2-1 and 2-2. Note that operating information should be obtained, where possible, to match with the occurrence of the problem. For example, if the problem has just recently developed, then a selection of historical operating information can be compared to a detailed examination of recent operating conditions to highlight potentially important differences. In such a case, applicable unit information should be downloaded for up to a month before the ash deposition event occurred.

Any other changes that may have been made before ash deposition occurred, such as coal switches, changes in boiler operation, boiler tuning, recent heavy rains, etc., should be noted and documented.

Table 2-1
Useful General Boiler Information

Boiler Manufacturer
Date Installed
Type <ul style="list-style-type: none">Pulverized Coal Tangentially FiredPulverized Coal Wall-FiredPulverized Coal Low-NO_xCyclone
Rating
Dimensions of Furnace Box <ul style="list-style-type: none">WidthLengthHeightVolume
Heating Surface Area <ul style="list-style-type: none">TotalSuperheaterReheaterEconomizer
Steam <ul style="list-style-type: none">Flow RatePressureTemperature
Characteristics of Design Fuel <ul style="list-style-type: none">MoistureVolatile MatterAshGrindabilityFusion TemperatureHeating Value
Fuel Feed Rate
Number of Mills
Number of Burners
Ash Collection Devices Used

Table 2-2
Useful General Boiler Parameter Information

Unit Load
Main Steam Flow
Throttle Pressure
Feedwater Flow
Economizer Feedwater Temperature
Superheater Outlet Temperature
Superheater Inlet Temperature
Superheater Spray Flow
Reheater Spray Flow
Reheater Outlet Temperature
Reheater Inlet Temperature
Air Heater Air Inlet Temperature
Air Heater Air Outlet Temperature
Air Heater Gas Outlet Temperature
Coal Feed Rate
Pulverizer Exit Temperature
Furnace O ₂
Stack CO ₂
Stack CO
Stack SO ₂
Stack Opacity
Ambient Air Temperature
Furnace Pressure
Burner Tilt (for pulverized coal-fired furnaces)
Number of Sootblowers Out-of-Service (dates of service termination, location, etc.)

Figure 2-6
Actions A-1d, e. Determine Whether Ash Deposit and Coal Samples Can Be Obtained

Action A-1d. Determine Whether Ash Deposit Samples Are Available or Can Be Obtained

Determine whether ash deposits can be collected (or have already been collected) for later use in diagnostic tests.

If samples are not currently available, a schedule for collecting samples should be established. Alternatively, depending on location, it may be possible to scoop samples off of tubes using some sort of sampling apparatus.

Action A-1e. Determine Whether Coal Samples Can Be Obtained

Determine whether coal samples or coal analyses can be obtained for the time during which the event occurred. Sometimes, plants archive coal samples and analyses for a period of weeks or months.

Figure 2-7
Action A-2: Tentative Identification of Deposition Type

Action A-2: Preliminary Identification of Deposition Type

The primary objective of this step in the process is to complete the preliminary identification of the deposition type. This task should be accomplished by consulting Table 3-1.

Table 3-1 is used in the following manner. First, using the location information gathered in Step A-1, the boiler zone or region in which the primary deposition problem is found should be determined and then linked to one of the five primary zones in Table 3-1:

- Lower furnace radiant zone
- Upper furnace radiant zone
- High-temperature convective zone
- Low-temperature convective zone
- Air heater and SCR regions

Much of the classification of deposition types can be done through the visual appearance of the deposit. The second column contains a generic description of the deposition type, and a photograph showing typical features is included as the final column of the table. Using these two visual clues, it should be possible to form a preliminary identification of the deposition type. Further confirmation may be obtained from additional information about “Location” and “Boiler Types,” also provided in the table. From the table, the utility user is directed to specific pages in Chapter 3 (in confidential Appendix A), which contain the details of how to proceed for each ash deposition type. This chapter simply gives the user both quick and detailed references to many different ash deposit types.

Although every effort has been made to provide a list of all known deposition types in this guideline, it may be possible that a specific deposition problem does not exactly match one of those listed. In that case, the generic roadmap of steps to be followed (this chapter) is still the same; however, the user will have to develop the specific details of diagnosis and remedial action similar to those provided. Furthermore, in this case, the user should review several of the write-ups in Chapter 3 (Appendix A), such as for Ash Type 3-9 – Massive Ash Deposition on Overhang Superheat Pendants or 3-12 – Sandstonelike Feathered Deposits Forming on Backside of Tubes to stimulate ideas for a logical flowchart of diagnostic tests and remedial actions. The case studies provided in Chapter 6 (Appendix A) may also provide ideas to help develop an appropriate investigative strategy. If all else fails, the theoretical descriptions of how ash deposits form, in Chapter 2, may give the users fundamental information by which they can at least “get close” to one of the ash deposit types in Table 3-1.

Figure 2-8
Action A-3: Match Description of Ash Deposition Type

Action A-3: Match Description of Ash Deposition Type

After an ash deposit type has been identified from the summary information in Chapter 3 (Appendix A), the user can proceed to the detailed descriptions in the remainder of Chapter 3 (Appendix A).

The detailed descriptions for each ash deposition type in Chapter 3 (Appendix A) consist of three major sections:

- A brief introductory section that contains additional information about the nature of the deposit, its development, appearance, or other factors that can help confirm the preliminary identification performed in Action A-2 (“Description of Deposit”).
- A discussion of the diagnostic tools to be used to determine root cause.
- A detailed list of remedial measures.

The purpose of Action A-3 is to review the “Description of Deposit” to confirm that the deposition type chosen seems to be appropriate.

Figure 2-9
Action A-4a. Check for Boiler Causes

Action A-4: Root-Cause Determination

Once a type of ash deposition problem is identified, more specific chemical, engineering, or modeling information may be necessary to clearly identify the source of the problem. This step is critical, but is often left out by utilities because of the lack of money or time that may be needed. The end result is that the ash deposition problems are not dealt with properly. Proper choice of remedial action will depend on understanding the underlying root cause of the deposition problem, similar to a doctor knowing exactly what disease is being treated before prescribing a particular medicine.

Each deposition type in Chapter 3 (Appendix A) contains sections on diagnosis and remedial measures. These sections provide detailed guidance that can be used to complete Actions A-4 and A-5.

Action A-4a. Check for Boiler Causes

As shown on the roadmap, before diagnostic tests are begun, it is appropriate to determine whether the root cause is obvious and related to boiler operation or conditions. Here “obvious” means evident by reviewing unit and operating information obtained in Action A-1 and other sources, without the production of additional data from testing, modeling, or other diagnostics. For example, a quick check of boiler operation may reveal that the previous shift’s operator had left burner tilts in an unusual upward or positive position which was causing higher-than-normal gas temperatures at the front entrance to the reheater, resulting in hotter-than-normal sticky and sintering ash. These ash deposits could be quickly eliminated by readjusting the burner tilts and sootblower or manual on-line deposit removal methods, with no further deposit growth.

If the answer is yes and boiler operation is the cause, then the user can go directly to applying the remedial measures for this deposition type. The user should access Chapter 4 (Appendix A) for any appropriate boiler-specific issue and specifically review the appropriate remedial measures suggested for specific boiler operation-caused deposition.

If the root cause is either not evident from review of operating data, nor does it appear to be simply related to boiler operation, then Actions 4(b-e) should be undertaken using the detailed information of Chapter 3 (Appendix A) to develop the detail for identifying root causes of the ash deposit type and remedial measures.

Figure 2-10
Actions A-4b, c, d. Lay Out a Diagnostic Plan; Obtain Ash and Coal Samples

Action A-4b. Lay Out a Diagnostic Plan

For many ash deposition problems, numerous analytical methods, tests, and modeling studies can be performed to determine the root cause of ash deposition. Before a time-consuming and potentially expensive root-cause analysis program is begun, a specific plan of attack should be developed. Such a plan will include items such as:

- A specific list of open questions, prepared using the guidelines to help determine the sequence of diagnosis.
- An estimated budget and schedule for the diagnosis methods chosen. Although costs will be job-specific, the ranges of costs provided with the descriptions of diagnostic tests in Chapter 5 (Appendix A) of these guidelines can help provide budgetary estimates of cost.
- Responsible party. It may be necessary to seek outside assistance if equipment or skills needed to complete a particular diagnostic are not available in-house. A list of potential suppliers of services, current through mid-2000, can be found in Chapter 8 (Appendix A) of these guidelines.

Action A-4c. Obtain Ash Samples as Required

Action A-4d. Obtain Coal Samples as Required

Once the necessary tests, analysis methods, and modeling studies have been specified, it should be possible to determine what ash and coal samples will be required. If coal samples are collected, it is generally a good rule to obtain at least a 1-gallon or 4-liter sample by volume and document when it was sampled and what mine it supposedly came from.

Figure 2-11
Action A-4e. Sequentially Perform Diagnostic Tests, Modeling, and Analysis as Required

Action A-4e. Sequentially Perform Diagnostic Tests, Modeling, and Analysis as Required

The descriptions in Table 3-1 for each ash deposition type provide guidance about which specific diagnostic methods are indicated. A list and discussion of each diagnostic technique and an estimate of cost by year 2000 standards is provided in Chapter 5 (Appendix A). Coal, fly ash, and ash deposit chemical and mineral analyses make up the bulk of these diagnostic tests. Other diagnostics may involve bench-, pilot-, or full-scale combustion testing and various types of modeling.

Table 5-1 (of the confidential report) lists analyses and tests appropriate to the majority of cases and gives the page number to go to for review of a particular diagnostic. Additional details of analytical techniques and laboratories that perform them are given in Chapter 8 (of the confidential report).

Figure 2-12
Action A-5 and Action A/B-5: Develop and Apply Remedial Measures Specific to Underlying Causes

Action A-5: Develop and Apply Remedial Measures Specific to the Underlying Cause(s)

For most ash deposition problems, specific remedial measures can be devised to mitigate the problem. Each description in Chapter 3 (Appendix A) provides an extensive list of remedial measures for specific problems. The remedial measures are, for the most part, listed in the order that they should be considered for use. In some cases, a fully satisfactory solution is not available, given the current state-of-knowledge about the deposition type. In these cases, some general guidance, the best that can currently be done, is provided.

Figure 2-13
Action A-6: Establish Long-Term Monitoring

Action A-6: Establish a Long-Term Monitoring Program for Effectiveness

The final step in the roadmap is to put in place a program to monitor the effectiveness of the remedial measures chosen.

If long-term monitoring indicates that the problem has not been sufficiently addressed, it will be necessary to apply additional remedial measures. The list of remedial measures provided in Chapter 3 (Appendix A) for the specific deposition type should be reviewed and additional steps taken to deal with the condition.

Figure 2-14
Follow Flowchart B for Boiler-Specific Observation, Beginning with Action B-1

Boiler-Specific Condition Found – Follow Flowchart Actions B-1 Through B-6

This flowchart describes the steps to be followed if a boiler-specific condition is found. That condition may either be a control room observation or found through plant observation of the boiler. For example, a boiler operator may detect sudden or slowly decreasing steam temperatures, reheater duct pressure drops, or rising FEGTs, all of which may indicate a growing ash deposition problem on the reheater steam tubes. The steps roughly parallel those for ash deposition found in Flowchart A.

Action B-1: Document Control Room or Plant Observation and Gather Initial Information Pertaining to the Deposit, Unit, and Coals Burned

The first action consists of six substeps which, when completed, will result in a full definition of the problem and aid in gathering background information that will be used in later stages of the investigation. Those steps are described in detail on the next several pages.

EERC GZ18023.CDR

Figure 2-15
Actions B-1a, b, c. Documenting the Problem, Its History, and Whether a Deposit Problem Is Occurring

Action B-1a. Document the Details of the Boiler-Specific Problem

Two categories of boiler-specific problems will typically trigger the use of Flowchart B by the utility: control room observations or observations of plant conditions. A control room problem may be a reheat temperature reading, and a plant condition may be an observation that a particular sootblower is physically malfunctioning. In this substep, the condition should be fully specified, including such parameters as out-of-range readings, fluctuations, design levels, recent changes in physical settings, results of plant inspections showing equipment condition, etc.

Action B-1b. Determine the History of the Problem

Historical information about changes in condition should be obtained where possible.

Action B-1c. Determine Whether a Deposition Problem Is Occurring

It is possible that the boiler-specific condition is a precursor to a deposition problem. At this stage of the flowchart, it is appropriate to schedule a visual inspection of those zones or regions of the boiler where deposition may be present as a result of the boiler-specific condition(s) identified. Typical locations can be found by reviewing the material in Chapter 4 (Appendix A), corresponding to the boiler condition.

If deposition has occurred, the locations and extent of the problem should be determined and documented as outlined in Action A-1(a). It is prudent to review material (specifically diagnostics and remedial measures) in Chapter 3 (Appendix A), appropriate to the deposition type found, in addition to continuing through Flowchart B based on boiler condition.

EERC CZ18024.CDR

Figure 2-16
Actions B-1d, e, f. Gathering Unit Information and Determining Whether Ash and Coal Samples Are Available

Action B-1d. Gather Necessary Unit Information

If a clear-cut, boiler-specific problem has been observed, then it may not be necessary to gather any more extensive unit information than that discussed in Action B-1(a) and Action B-1(b) above. However, if the underlying causes of the boiler-specific problem are more complex, not definitely established, or symptomatic of additional problems, then unit information similar to that outlined for Action A-1c and as listed in Tables 2-1 and 2-2 may be required for later analysis.

Action B-1e. Determine Whether Ash Deposit Samples Can Be Obtained (if appropriate)

If, in the process of checking out boiler-related ash deposition problems, ash deposition is identified, then samples of the deposits should be collected and the user can proceed to Chapter 3 (Appendix A).

Action B-1f. Determine Whether Coal Samples Can Be Obtained (if appropriate)

It may be necessary to determine whether ash deposit and coal samples can be obtained. As with Action B-1d above, if the boiler-specific symptom has a direct and readily determined cause or if deposition has not yet become a serious problem, then these substeps can probably be skipped. If there is any indication of deposits forming, it would be advisable to obtain a coal sample and determine if changes have occurred.

Figure 2-17
Action B-2: Find Boiler-Specific Problem in Table 4-1

Action B-2: Find the Boiler-Specific Problem in Table 4-1

Table 4-1 provides a list of common boiler-specific conditions that act as precursors to ash deposition problems. By going through the table, the user will be directed to the appropriate pages in Chapter 4 (Appendix A) for detailed diagnostic and remedial measures.

Conditions are first organized by specific boiler zones or the regions that are typically affected. The boiler-specific condition or observation is presented, as well as the boiler type affected by this problem. Additional information on the potential problem or cause is also shown. The final column provides the appropriate page number where details of diagnostics and remedial measures can be found.

Although every effort has been made to provide a list of the most common boiler-specific conditions that can act as precursors to ash deposition problems, a specific boiler condition may not exactly match one of those listed in Table 4-1. In that case, the generic roadmap of steps to be followed is still the same; however, the user will have to develop the specific details of diagnosis and remedial action similar to those provided in Chapter 4 (Appendix A). In this case, the user should review several of the conditions in Chapter 4 (Appendix A) to stimulate ideas for a logical flowchart of diagnostic tests and remedial actions. The Case Studies provided in Chapter 6 (Appendix A) may also help to develop an appropriate investigative strategy.

Figure 2-18
Action B-3: Match Description Using Details Provided in Chapter 4 and Action B-4: Root-Cause Determination

Action B-3: Match Description Using Details Provided in Chapter 4

The brief introductory section provided for each boiler-specific condition or observation in Chapter 4 (Appendix A) (“Description”) can be used to confirm that the user has found the appropriate diagnostic and remedial measures.

Action B-4: Root-Cause Determination

The application of diagnostics appropriate to root-cause determination for boiler-specific causes is somewhat more straightforward than for ash deposition. As a result, it is not as important that a plan of testing be established, although it is still important to understand:

- 1) What specific open questions are to be answered.
- 2) What the estimated budget and schedule are to complete any required testing.
- 3) Who the responsible party is for completing the testing.

The required tests are outlined in the descriptions specific to each boiler condition in Chapter 4 (Appendix A). If needed by the specific diagnostic test, ash and coal samples should be gathered during this phase of the project.

Figure 2-19
Action B-5: Develop and Apply Remedial Measures and Action B-6: Long-Term Monitoring

Action B-5: Develop and Apply Remedial Measures Specific to Underlying Cause(s)

For most boiler-specific conditions, specific remedial measures can be devised to mitigate the problem. Each write-up in Chapter 4 (Appendix A) provides an extensive list of remedial measures for specific problems. The remedial measures are, for the most part, listed in the order that they should be considered for use. If a fully satisfactory solution is not available given the current state-of-knowledge, some general guidance reflecting the best that can currently be done is provided.

Action B-6: Establish a Long-Term Monitoring Program for Effectiveness

The final step in the roadmap is to put in place a program to monitor the effectiveness of the remedial measures chosen. This may be as simple as checking control room readings or may involve periodic field inspection to ensure that both the boiler condition and any resultant deposition problem have been remedied. Thorough monitoring may, in some cases, require installing new or repairing existing monitoring equipment or sensors such as FEGT measuring devices.

If long-term monitoring indicates that the problem has not been sufficiently addressed, it will be necessary to apply additional remedial measures. The list of remedial measures provided in Chapter 4 (Appendix A) for the specific boiler condition should be reviewed and additional steps taken to deal with the condition.

CHAPTER 3 – ASH DEPOSITION SYMPTOMS, DEPOSIT TYPES, AND REMEDIAL MEASURES

Introduction

Oftentimes, visual inspections of the boiler during on-line operation or the collection of ash deposits during off-line servicing reveal certain characteristics of ash deposition that intimates an ongoing or impending problem. Ash deposit characteristics that are indicative of an ongoing or approaching ash deposition problem are described in this section, with indexed mitigation measures that may be implemented for remediating the problem.

Ash deposit characteristics are grouped according to region or zone in a typical coal-fired boiler. If visual inspections show ash deposit bridging in the reheat section of the convective pass, then the user of this manual can go to the high-temperature convective pass section and look for symptoms and the index to diagnostic tests and remedial measures that can be taken for the particular deposition type being encountered. The boiler zones or regions that are used for the purpose of guiding the user to understand the particular ash deposition problem are summarized as follows:

Lower Furnace Radiant Zone

Upper Furnace Radiant Zone

High-Temperature Convective Zone

Low-Temperature Convective Zone

Air Heater and SCR Regions

Symptoms and Remedial Measures by Boiler Location

In order to match the type of ash deposition problem being encountered and begin the process to prescribe or implement remedial measures, a list of ash deposit characteristics are listed in Table 3-1, grouped according to boiler locations. The ash deposit characteristics are followed by the description, location, and boiler type. One should match the type of ash deposition characteristic noted and refer to the detailed description in the specific write-ups in subsequent sections of the chapter for specific diagnostic and remedial measures. Each of the ash deposition types has prescribed remedial measures listed below it and potential additional cross-referencing to remedial measures for similar ash deposit problems. The diagnostic steps are prioritized in order of ease of implementation, effectiveness, and cost. Cross references are also included for diagnostic analyses or tests found in Chapter 5 (Appendix A). Further scientific background on ash deposition in general and many mechanistic aspects of these ash deposit types can be found in Chapter 7 (Appendix A).

It is noted that some of the remedial measures proposed for one particular ash type may work successfully for another. The reader is encouraged to look at several “similar” ash types when searching for remedial measures in this document. The remedial measures proposed for a particular deposit type are by no means the only remedial measures, and each plant may prioritize remedial measures differently.

Table 3-1

Boiler Zones or Regions and Associated Ash Deposit Characteristics That Indicate a Potential Ash Deposition Problem

Boiler Zone or Region	Ash Deposit Characteristics	Brief Description	Specific Location Within Boiler Zone	Boiler Type(s) Affected	Page Number (in Appendix A)	Example
3-1 – Light Reflective Ash Deposits	Fine, light-colored “reflective,” weak deposit, thin-layered, finely sized	Waterwalls	All types	3-9

3-2 – Molten Waterwall Slag Deposits	Dense, highly sintered or molten slag deposits covering patches or entire waterwall areas, up to several centimeters or 2 inches thick	Waterwalls, lower, middle radiant boiler regions	pc-fired	3-13

3-3 – Burner Eyebrow Deposits	“Sticky” ash rimming or accumulating on the waterwalls near burners	Rim around burners, called “eyebrows”	pc-fired boilers with low-NO _x burners	3-17

3-4 – Cyclone Slag Tap Freezing	Molten ash (cyclone slag tap freezing)	Barrel of the cyclone, barrel walls, cyclone and furnace slag taps	Cyclone-fired	3-19

3-5 – Inadequate Cyclone Slag Cover	Lack of captive slag or inadequate slag cover on refractory surface of cyclone barrel	Barrel of the cyclone and barrel walls	Cyclone-fired	3-23

Boiler Zone or Region	Ash Deposit Characteristics	Brief Description	Specific Location Within Boiler Zone	Boiler Type(s) Affected	Page Number (in Appendix A)	Example
3-6 – Metallic Highly Fused Molten Slag	Highly-fused, metallic-looking and often several centimeters or up to 2 inches thick	Lower furnace radiant zone	All types	3-25

3-7 – Porous or Vesicular Slag on Waterwalls	Highly-fused, very porous slag typically with a “bubbly” appearance; termed “vesicular” slag	Waterwalls directly or at 2–3 m (4–9 ft) above burners	All types	3-29

3-8 – Ash, Slag, and Sludge Buildup on Slope Walls or in Hoppers	Excessive accumulations or piles of slag which may be sticky or plasticlike	Just above ash hoppers	Dry-bottom boilers	3-31

3-9 – Massive Ash Deposition on Overhang Superheat Pendants	Massive ash deposition as in several inches or centimeters up to several feet or a meter in thickness	Overhang superheat pendants	All types	3-33

3-10 – Fine, Light-Colored, Seemingly “Reflective Ash” on Waterwalls	Fine, light-colored, “reflective” weak deposit, thin-layered and finely sized	Waterwalls	All types	3-37

3-11 – Sandstonelike Feathered Fouling Deposits on Front Edge of Tubes	Feathered deposits, light brown to grey in color and usually several inches or centimeters in thickness	Front edge of tubes pointing into the gas stream, convective pass reheater	All types	3-39

Boiler Zone or Region	Ash Deposit Characteristics	Brief Description	Specific Location Within Boiler Zone	Boiler Type(s) Affected	Page Number (in Appendix A)	Example
3-12 – Sandstonelike Feathered Deposits Forming on Backside of Tubes	Feathered deposits, light brown to grey in color and up to several inches or centimeters thick, sometimes bridging to adjacent tubes	Backside of steam tubes	All types	3-43

3-13 – Massive and Very Dense Deposits on Leading Edge and Bridging Areas of Tubes	Massive, dense, nearly slaglike deposits, dark green-grey color; may also have running slag or dripping slag appearance	Convective pass regions beyond furnace exit; may be localized, not necessarily affecting entire bank; may form on leading edges of tubes and bridge to backside of tubes	All types	3-47

3-14 – Alternating Light and Dark Bands of Hard Sandstone- or Enamel-Like Deposits	Alternating light grey and brown or red deposits that are fairly dense and smooth in appearance. Moderately hard.	Usually second or third bank of the reheater or primary superheater	All types	3-51

3-15 – Residual Ash Layers on Steam Tubes after Sootblowing	Residual layers may appear as a thicker, oxidized scale or a 1–5 cm jagged and sintered ash deposit with some bare tube spots	Steam tubes	All types	3-53

Boiler Zone or Region	Ash Deposit Characteristics	Brief Description	Specific Location Within Boiler Zone	Boiler Type(s) Affected	Page Number (in Appendix A)	Example
3-16 – Higher Deposition Rates on One Side of Convective Pass Versus Other	Asymmetric deposit rates on one side versus the other	Convective pass	All types	3-57

3-17 – Densely Sintered Enamel-Like Sulfate-Rich Deposits	Often white to reddish-brown; can range from thin (1–3 mm) enamel-like layers on upstream side of tubes to dense deposits (1–8 mm thick) growing on either side of the tube. Deposits often conform to round tube shape and are, therefore, hard to spot.	Lower-temperature primary superheater or economizer regions.	All types	3-61

3-18 – Light Grey–Light Brown Deposits Covering a Major Portion of Convective Surface	Very light (1–3 mm), even thickness typically covering 50% or more of the convective surface. Can quickly change from fluffy, loosely bound to sintered.	Convective surface	All types	3-65

3-19 – Piles of Light Brown to Red-Grey Deposits on Top of Economizer	Calcium sulfate-rich deposits, light brown to grey in color will fall off primary superheater tubes and support structures and accumulate on top of the economizer	Front or on top of the economizer	All types	3-67

3-20 – Air Heater Ash Deposits or Corrosion	Very fine, light brown or grey ash will accumulate in the air heater primarily as a condensate	Air heater, SCR, ID fan, and regions beyond	All types	3-69

Boiler Zone or Region	Ash Deposit Characteristics	Brief Description	Specific Location Within Boiler Zone	Boiler Type(s) Affected	Page Number (in Appendix A)	Example
3-21 – High Porous Popcornlike Deposits Accumulating on Air Heaters/Economizers	Also described as low-density or porous “egg-shell-like” ash particles	Air heater, SCR, ID fan, and regions beyond	All types	3-71

3-22 – SCR Blinding	Very fine, light grey or brown calcium sulfate- or phosphate-rich particulate or dust on SCR catalyst surfaces	Air heater, SCR, ID fan, and regions beyond	All types	3-73

CHAPTER 4 – BOILER-SPECIFIC SYMPTOMS AND REMEDIAL MEASURES

Introduction

Boiler symptoms noticed in the control room or observed through boiler inspections are indicative of a developing or ongoing ash deposition problem. Changes in boiler operating characteristics thus may provide a warning of developing problematic ash deposition. Boiler-operating symptoms that can be related to ash deposition problems are described in this section, with indexing to ash deposition measures that may be implemented to remediate the problem.

Boiler symptoms are grouped according to region or zone in a typical coal-fired boiler. For example, if an operator is noticing increased attenuation sprays in the superheaters, then the operator can go to Table 4-1 to find where that topic is covered in Chapter 4 (Appendix A) and look for descriptions of ash deposition-related causes and indexing to diagnostic tests and remedial measures that can be taken for the particular ash deposition type being encountered.

Symptoms and Remedial Measures by Boiler Operating Condition

In order to determine the type of ash deposition problem being encountered and begin the process to implement remedial measures, boiler operation-related symptoms are listed here, grouped according to boiler location as described in Table 4-1. In the table, the boiler symptoms are listed in column two, followed by boiler types affected, possible deposition-related causes, and the page for the subsequent sections containing individual detailed descriptions, diagnostics, and remedial measures. In the chapter, each of the boiler symptoms has prescribed diagnostic and remedial measures listed with it, along with cross references to diagnostic tests and to ash deposit types more fully described in Chapter 3 (Appendix A).

Lower Furnace Radiant Zone

Upper Furnace Radiant Zone

High-Temperature Convective Zone

Low-Temperature Convective Zone

Air Heater and SCR Regions

Table 4-1
Boiler Zones or Regions and Associated Boiler Conditions or Observations

Boiler Zone or Region	Boiler-Specific Condition or Observation	Boiler Type	Potential Problem/Cause	Page Number (in Appendix A)
4-1 – Furnace Tilts Frequently Showing an Independence from Load	Tangentially fired boilers only	Excessive wall deposition or slagging and higher-than-normal FEGT, resulting in convective pass fouling.	4-7
4-2 – Pierced or Dented Lower Slope Tubes or Floors	All boilers with overhang pendants	Results in leaking tubes; symptom of large ash deposits on overhang pendants which fall onto lower slopes.	4-11
4-3 – Poor Burner Performance	pc-fired boilers	Carryover of sparklers that impact the surface of convective deposits, fusing ash particles.	4-13
4-4 – High Furnace Exit Gas Temperature (above design)	All boilers	Radiant boiler slagging; sticky or molten deposits leading to fouling of superheat pendants or high-temperature convective pass.	4-15
4-5 – Significantly Diminished Main Steam Temperature Readings	All boilers	Indication of ash fouling or slagging on convective pass heat-transfer surfaces.	4-19
4-6 – Increased Attemperation Sprays in Superheaters	All boilers	Could be a sign of increased wall slagging.	4-21
4-7 – Changes in Heat Absorption Rate in Various Sections of the Boiler	All boilers	Increased wall slagging or convective pass fouling.	4-23

Boiler Zone or Region	Boiler-Specific Condition or Observation	Boiler Type	Potential Problem/Cause	Page Number (in Appendix A)
4-8 – Sparklers Entering the Convective Pass	All boilers	Sparklers impact the surface of convective deposits, burn, and fuse surrounding ash particles.	4-25
4-9 – High Differential Pressure Across Tube Bundles	All boilers	May be the result of ash deposition; however, by the time this pressure drop is noticed, ash deposition is usually very severe.	4-27
4-10 – Uncleaned Surface Between Retractable Blower Paths	All boilers	Residual ash layers, up to an inch or 2–3 cm thick, remain after sootblowing.	4-29
4-11 – Higher-than-Design Temperatures In Convective Pass (from performance monitor or temperature monitor)	All boilers	Radiant boiler slagging; sticky or molten deposits leading to fouling of superheat pendants or high-temperature convective pass.	4-33
4-12 – Changes in Location of Problematic Deposition	All boilers	If locations of heavy ash deposition change rapidly such as from waterwalls to the reheater, then fuel quality or obvious boiler operation may be suspected.	4-37
4-13 – Higher Deposition Rates on One Side of Convective Pass Versus Other	All boilers	Uneven, asymmetrical deposits. If consistent ash deposition occurs asymmetrically in one particular location of the boiler, then there may be burner, pluggage, or air distribution problems.	4-39
4-14 – High Differential Pressure Across Economizer Tube Bundles	All boilers	Ash deposition or ash buildup on economizer surfaces.	4-41

Boiler Zone or Region	Boiler-Specific Condition or Observation	Boiler Type	Potential Problem/Cause	Page Number (in Appendix A)
4-15 – High Amperage Draw on Induced-Draft Fan	All boilers	Ash deposition in convective pass heat-transfer tube sections.	4-43
4-16 – Low O ₂ Readings	All boilers	Potentially severe slagging and possibly fouling caused by localized reducing condition.	4-45
4-17 – Increased Stack Temperature	All boilers	Sign of slagging or fouling causing inefficient heat absorption.	4-47
4-18 – High Carbon Content In Fly Ash	All boilers	Detrimental to the disposal or resale of the ash and potential indicator of wall slagging from carbon particle impact.	4-49

CHAPTER 5 – CONCLUSIONS

The accumulation of slagging and fouling ash deposits in utility boilers has been a source of aggravation for coal-fired boiler operators for over a century. Many new developments in analytical, modeling, and combustion testing methods in the past 20 years have made it possible to identify root causes of ash deposition. A concise and comprehensive guidelines document has been assembled for solving ash deposition as related to coal-fired utility boilers.

While this report accurately captures the current state of knowledge in ash deposition, note that substantial research and development is under way to more completely understand and mitigate slagging and fouling. Thus, while comprehensive, this document carries the title “interim,” with the idea that future work will provide additional insight.

Primary target audiences include utility operators and engineers who face plant inefficiencies and significant operational and maintenance costs that are associated with ash deposition problems. Pulverized and cyclone-fired coal boilers are addressed specifically, although many of the diagnostics and solutions apply to other boiler types.

Logic diagrams, ash deposit types, and boiler symptoms of ash deposition are used to aid the user in identifying an ash deposition problem, diagnosing and verifying root causes, determining remedial measures to alleviate or eliminate the problem, and then monitoring the situation to verify that the problem has been solved. In addition to a step-by-step method for identifying and remediating ash deposition problems, this guideline document (Appendix A) provides descriptions of analytical techniques for diagnostic testing and gives extensive fundamental and practical literature references and addresses of organizations that can provide help in alleviating ash deposition problems.