OHIO COAL DEVELOPMENT OFFICE
ANNUAL PROJECT ABSTRACT
AS OF DECEMBER 2004

1. PROJECT SPONSOR:

McDermott Technology Inc.
1562 Beeson Street
Alliance, Ohio 44601

2. PROJECT MANAGER/TITLE:

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3. OCDO GRANT NO. CDO/D-97-2 **4. PHONE:** (330) 860-6175
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5. PROJECT TITLE: Coal Ash Corrosion Resistant Boiler Materials Test Program

6. PROJECT TERM FROM: October 26, 1998 **TO:** October 31, 2005

7. PROJECT UPDATE ____X___ --OR-- **FINAL REPORT** _____

8. BUDGET:

CO-SPONSOR'S NAME	**COST-SHARE**
OCDO	$ 620,953
The Babcock & Wilcox Co.	$ 295,000
U.S. DOE	$ 700,000
Ohio Edison	$ 223,650
Tube Vendors	$ 25,000
TOTAL PROJECT COST	$1,864,603

ABSTRACT

9. OVERVIEW OF PROJECT & OBJECTIVES:

McDermott Technology, Inc. (MTI), through Babcock & Wilcox (B&W), is conducting a five-year project to permit testing of several advanced tube materials at temperatures typical of advanced supercritical boilers (1100°F and higher steam temperature) in a boiler exhibiting coal ash corrosive conditions.

The objective of this program is to test and evaluate promising advanced materials to determine their resistance to fire-side coal-ash corrosion in an operating boiler at steam conditions representative of the superheater in an advanced supercritical boiler. To accomplish this, ten primary and two secondary advanced materials are incorporated into three identical test sections, cooled with reheat steam, which are installed in the Unit #1 boiler at Reliant Energy's (formerly Orion Power, formerly Duquesne, formerly Ohio Edison) Niles plant located in Niles, Ohio. To assess corrosion over time, the first

section was intended to be removed and evaluated after one (1) year of operation, the second after three (3) years of operation and the last after five (5) years of operation. The final section may be permitted to operate up to two years longer depending on previous experience and plant operations.

The benefits of having new reliable boiler tube alloys, which promote advanced supercritical boilers are that they allow for greater usage of high sulfur Ohio coal with greater boiler efficiency. The improved efficiency also reduces SO_2, NO_x and CO_2 emissions that make for a cleaner environment at a lower generating cost. In addition, these materials can be applied in numerous existing plants experiencing coal-ash corrosion, such as the Niles unit.

10. WORK TO DATE & CONCLUSIONS:

1998-1999: Design of the test system began in November of 1998 and was completed in 1999. During 1999 the test section materials were obtained, the sections fabricated and equipment installed in the Niles Unit #1 boiler. During the summer startup tuning of the controls was completed with the sections operating at an outlet steam temperature of 1050F. No significant difficulties were experienced with the system or data acquisition system and in November 1999 the outlet steam temperature was increased to 1075F.

2000: In January 2000 some corrections were made to the program that calculates daily averages and all previous data was re-averaged. In March a detailed inspection and measurements were taken and a project status meeting was held to review the results with Orion Power, OCDO and DOE personnel. Corrosion was measurable but not advanced far enough to provide good results. As a result it was decided to wait until the fall of 2001 (next maintenance outage) to remove the first section.

2001: The electronic controllers for two valves failed in late December 2000 (due to overheating) causing the valves to open and the sections to run cool. In mid-January the third valve failed. This does no harm to the unit or the sections but it does delay corrosion.
A brief inspection was made during a forced boiler outage on March 12, 2001. The sections were examined for evidence of impending failures that could terminate the test before Section “A” can to be removed for metallography. On each section, maximum wastage occurred on the outlet end of the top (outlet) row. There was no evidence of coal ash corrosion of the lower (inlet) leg.

On September 25, 2001 Reliant Resources Inc. announced their acquisition of Orion Power Holdings Inc. which will include the Niles Plant. According to the plant management, since they purchased the company and its obligations, no impact is expected.

During a brief outage for boiler tube leak repairs on October 15, a small hole was discovered in Section “C” (closest to the center of the boiler). The same samples in the other two sections showed major corrosion loss and were in jeopardy of breaking through as well. Consequently the three 3 ft. sections of tubing (dutchmen) one was installed in Section “C”, the completed replacement loop (top two rows) for Section “A” was installed and a dutchman in Section “B”. In addition, a dutchman was installed in the middle of the top row of Section “B”.

2002: Evaluation of the samples from the top two rows of Section A was initiated in January. A draft of the Topical Report for Section A was completed and released to DOE and OCDO on October 31, 2002.

In July B&W was advised that Niles' current outage plans will postpone removal of Section B until the fall of 2003. The intermediate inspections were adjusted accordingly and the schedule was updated.

On October 8, the superheater test sections were briefly inspected (visually). All six return bends were dislodged from their support lugs. All three sections were carefully inspected for evidence of steam leakage, and there were no leaks. The system ran as intended during November and December.

2003: The system ran as intended January through June with no incidents. A visit was made to the plant on May 27 to inspect the existing tubes while the boiler was down. One tube sample in both B & C Sections was found to be severely corroded.

Due to the ash on the tubes and the access and lighting conditions during the inspection, some confusion exists as to which alloy is corroded. It was decided that these samples would be replaced at the next opportunity and the corroded specimens returned for examination. Meanwhile the control valves were locked open to keep the sections cool and minimize further corrosion. Another visit was made to the plant on June 19 to inspect the existing tubes in more detail (boiler was down again). The supports on the baffle wall of both Sections had moved off the support lugs. The lower test row of Section C is bowed downward and was touching the adjacent 3rd row (from the top). The upper row of Section C had significant wastage in two of the samples (310Ta and 310HCbN). Most of the unclad samples in Section B showed significant wastage as well. Since the samples from Section A were removed in November 2001, it has been running cool since with valves open. There was concern that the thinning walls of Sections B and C would not last until the September outage so two bends were weld prepped and sent to the site in preparation for removal of the top two rows of both Sections.

The system ran through July with the control valves locked open to keep the sections cool and minimize further corrosion. The bends were installed connecting the top two rows in August and the valves were left open (run cool) until the September outage. The removed top two rows of both Sections were transported to B&W's Research Center and metal loss was preliminarily assessed using calipers. Based on these measurements the remaining life of each specimen was considered in regard to operating an additional 18 months. Since the Section taken from the C position (farthest from the boiler sidewall) was badly distorted but the one from the B (middle) location is in good condition, it was decided to replace the specimens in Section B whose remaining life would not be expected to achieve 18 more months and reinstall it in the boiler in the C location during the upcoming fall outage to obtain additional operating time. The Niles unit came down for its outage on September 24th. Plans for evaluation of the specimens in Section C were initiated and the unacceptable specimens in Section B were removed and the remaining portions weld prepped. After further review of the corrosion, one additional sample was marked for removal leaving 15 of the original 33 specimens for further exposure.

Segments of leftover IncoClad and some HR3C material to replace the removed specimens were installed in the two-row portion of Section B in early October, the welds were x-rayed and the Section was returned to the plant and re-installed in location C. Fifteen (15) of the original thirty-three (33) specimens remain for exposure for an additional period of 12-18 months. Work to prepare the specimens from Section C for metallurgical evaluation began and some testing was initiated. In November the repaired Section B was re-installed in the C location. Section C segments were disassembled and measurements and sample preparations continued at BWRC. Note that removal of the last Section is currently planned for October (fall) of 2004 but the actual removal date will depend on the outage dates set by Reliant Energy and may extend to the spring of 2004. This would be positive in that additional operating time would be incurred on the samples but the Final Report will be delayed accordingly. All (34) thirty-four of the tube samples from Section C were sectioned to yield dimension rings, and specimens for metallography and composition verification. This included the specimens that were part of the original installation, and those that were added later to replace samples that had evidenced excessive wall losses. The dimension rings were lightly grit-blasted to remove scale and oxide, then the wall thickness was measured at eight different o'clock positions. These values were compared with the original wall thickness at these locations in order to determine the amount of wall thickness lost. An additional wall thickness measurement was made, based on visual assessment, the minimum wall thickness did not coincide with one of the predetermined positions. In this case, the change in wall thickness was determined based on the average initial wall thickness rather than the actual at that location. The appearance of dimension ring cross sections was documented using contact prints. The appearance of the grit-blast surface of dimension rings was documented at the 12, 3, and 6 o'clock locations. (Note: to be consistent with the report for Section A, the 12 o'clock orientation faced downward into the gas flow direction, the 6 o'clock orientation faced upward and away from the gas flow direction, and the 3 o'clock orientation was half-way between the two.) In Section A, it was noted in some cases that the weld heat affected zones may have been more aggressively attached than the remainder of the tube sample. To evaluate this, weld cross sections were prepared to evaluate the weld heat affected zone for each of the candidate materials. It is anticipated that the report for Section C will have the same format as that of Section A. In December, the insulation damaged when accessing some instrumentation was repaired and the unit restarted on December 22 and controls verification planned for early January 2004 after which Section B (in the C location) will be operated at full temperature. Full cross section rings from Section C were polished and are prepared for evaluation using the scanning electron microscope at the First Energy Beta Labs. First Energy Beta Labs have been contracted to perform an analysis of the deposit for comparison with the analysis for Section A. It is also planned to use the energy dispersive (semi-quantitative) analysis capabilities of the scanning electron microscope at First Energy Beta Labs to verify that the correct alloys were in their proper locations.

2004: After a protracted restart between January and May, the system ran as intended May through December with no incidents. A visit was made to the plant on May 27 to inspect the existing tubes while the boiler was down. One tube sample in both B & C Sections was found to be severely corroded.

After startup of Section B (in the C location) in late December, checkout began in January and it was discovered that the position transmitter for the flow control valve was malfunctioning so a new one was ordered. Without a proper valve position reading it is

possible for the valves to completely close and damage the sections if it occurs for any significant length of time. This was discovered when it very briefly occurred during checkout (no damage is expected but it will be inspected at the next opportunity). The inlet valve was locked open until the transmitter could be reinstalled (required a brief outage due to the temperature in the equipment location). Though there was a brief outage on February 22, the new position transmitter for the flow control valve arrived on site a couple days later. The next unit outage occurred on May 19 for a tube failure and the failed transmitter was replaced. The unit was restarted but had to shut down again on May 25 before the controls could be tuned (not related to this project). On June 2 the unit restarted and shortly thereafter the section controls were released and the section operated at intended temperature for the remainder of the year with the exception of a boiler shut down on September 28 for a two-week outage (unrelated to the project). During that outage Section B (in the C location) was inspected and found to be in good condition.

Metallurgical analyses of all twelve candidate alloys from Section C were completed including a characterization of the external scale/metal interface and chemical analysis of selected regions. Analysis and characterization of the coal ash deposit on the surface of the tubes and assessment of metal loss across weld regions were also completed. Of particular concern was that the heat-affected zone of the tube-to-tube welds might be less resistant to corrosion, which proved not to be the case. It was also noted that although the IN 72 samples appeared very resistant to hot corrosion, they seemed to be experiencing a grain boundary cracking that increases as a function of time. This was further investigated. The draft Topical Report for Section C was released for final internal review in early March. In April, all comments on the draft report were returned to the author. The Introduction and operating history for 2002 and 2003 was written and sent to the writer as well. The draft Topical Report was sent to OCDO and DOE in late June, comments were received in August and the report was revised to address DOE's comments and was resubmitted to DOE on September 3.

11. PLANS FOR COMING YEAR:

During 2005, the system will continue to be operated and data obtained until the outage, currently scheduled for March, when the final Section B (in the C location) will be removed. Following removal, the specimens from Section B will be evaluated and the Final Report written and released by the end of the calendar year. If possible, a paper will be presented in the fall of 2005 discussing the results.

12. HIGHLIGHTS/ACCOMPLISHMENTS:

In 1998-1999 design, fabrication and installation of the test sections and system were completed. During 2000, the system operated as desired for a cumulative total of nineteen months. Several minor control and hardware problems were corrected and the system now runs reliably with little or no human attention. Both visual and detailed inspections were made which verified corrosion is occurring at an appreciable rate but removal of the first section was postponed until the fall of 2001 to provide better results. During 2001, another 12 months of operation were added to the total now at 31 months. Control valve problems continued to fail periodically so the positioners were converted to a mechanical type rather than electronic to eliminate this nuisance. Two inspections were made, in March and September, which showed major corrosion in some samples, particularly SAVE25. As a result, the top two rows of Section A were removed and

transported to the lab for evaluation and a 3 ft. section of the top row of the other two sections was replaced to extend the operating life. During 2002, the samples from Section A were evaluated and a lengthy Topical Report written. The electronic positioners were replaced with mechanical versions to withstand the heat better and the control logics were adjusted to accommodate their slower response time. The position indicator on Section B became unreliable early in the year but after some tinkering, it has since been operating properly. The intermediate thermocouple on Section A (which no longer contains any test samples) began to read high so it was ignored until it was replaced. A visual inspection of Sections B and C was accomplished on October 8, 2002. During 2003, the top two rows (containing all of the specimens) of Sections B and C were removed. Section B was repaired by replacing badly corroded specimens with new pieces and was reinstalled in the boiler but in the C location to obtain an additional 12-18 months of operation. The specimens from Section C were cut apart, specimens for dimensioning were measured, metallurgical evaluations and reporting were initiated. During 2004, the Topical Report on Section C was completed and released in late June of 2004 and two papers and a poster were presented on the results of Sections A and C. The unit restarted in late December 2003 and controls checkout was performed in early January 2004. However, due to a valve transmitter problem, Section B had to be operated with the control vale open (running cool) until May when it was replaced. Since then it has operated at intended temperature except for a planned two-week outage in September.

13. ARTICLES/PRESENTATIONS:

In 1999 a paper, Titled “Status of Coal Ash Corrosion Resistant Materials Test Program” by Dennis McDonald and Dave Meisenhelter from Babcock & Wilcox and Dr. Vinod Sikka of the Oak Ridge National Laboratory was presented at the 16th Annual International Pittsburgh Coal Conference held in October in Pittsburgh, Pa.

In 2000, 2001 and 2002 no publications were made.

In 2003 a paper titled “Coal Ash Corrosion Resistant Materials Testing: Evaluation of the First Section Removed in November 2001” was prepared and presented in March at the 28th International Coal Utilization & Fuel Systems Conference in Clearwater Florida and at the 17th Fossil Energy Materials Conference in Baltimore, MD in April.

In 2004 a paper titled “Coal Ash Corrosion Resistant Materials Testing Program; Evaluation of the Second Section Removed in August 2003” by Dennis McDonald and Ed Robitz from Babcock & Wilcox was presented at the 29th International Coal Utilization & Fuel Systems Conference in Clearwater Florida held April 19-22, 2004. A poster was prepared for and presented at DOE’s 18th Fossil Energy Materials Conference in Knoxville Tenn. June 2-4. An update of that same paper was presented at EPRI’s “4th International Conference on Advances in Materials Technology for Fossil Power Plants” in Hilton Head SC, October 25-26, 2004.