Update on Coal Ash Corrosion-Resistant Materials Testing Program

Dennis K. McDonald
Babcock & Wilcox, 20 S. Van Buren Ave., P.O. Box 351, Barberton, Ohio 44203-0351
Email: dkmcdonald@babcock.com; Telephone (330) 860-6175; Fax (330) 860-2348

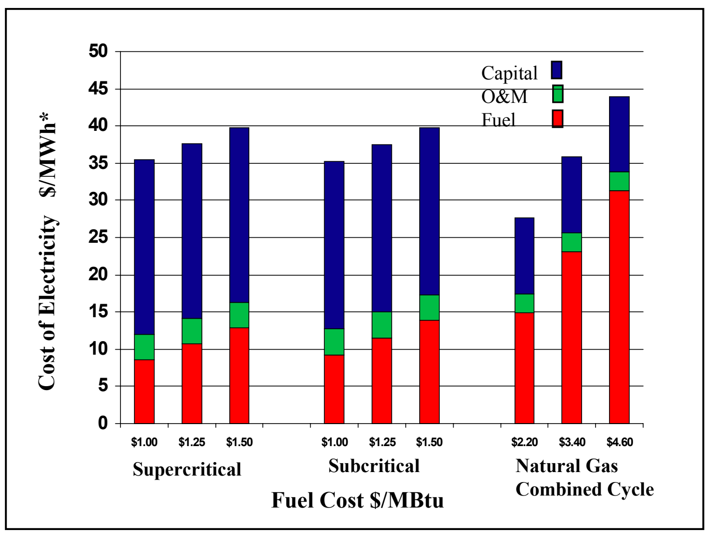
The "Coal Ash Corrosion Resistant Materials Testing Program" is being conducted by B&W at Reliant Energy's Niles plant in Niles, Ohio. The total estimated cost of $1,864,603 is co-funded by DOE contributing 37.5%, OCDO providing 33.3% and B&W providing 17%. The remaining 12% is in-kind contributions by Reliant Energy and tubing suppliers.

Materials development is important to the power industry, and to the use of coal. Figure 1 compares the cost of electricity for subcritical and supercritical coal-fired plants with a natural gas combined cycle (NGCC) plant based on an 85% capacity factor. This shows that at $1.20/MBtu for fuel, coal is competitive with NGCC when gas is at $3.40/MBtu or higher. An 85% capacity factor is realistic for a coal-fired plant, but NGCC plants are currently only achieving about 60%. This gives coal an advantage if compared on the basis of cost per kW generated per year. When subcritical and supercritical plants are compared,

Subcritical Coal Plant
- $1100 / kW EPC
- O&M (non-Fuel) $3.50 / MWh
- Avg. Heat Rate 9220 Btu/kWh

Supercritical Coal Plant
- $1150 / kW EPC
- O&M (non-Fuel) $3.50 / MWh
- Avg. Heat Rate 8550 Btu/kWh

Natural Gas Combined Cycle
- $500 / kW EPC Cost
- O&M (non-fuel) $2.50 / MWh
- Avg. Heat Rate 6800 Btu/kWh



(Assumptions: 85% capacity factor, Tax life 20 years, Book life 30 year, All heat rates HHV, Levelized Capital Charge - EPRI Tag)

Figure 1: Comparison of Cost of Electricity

supercritical is only slightly more costly than subcritical because the higher capital cost is nearly offset by the fuel savings resulting from the higher efficiency. Consequently, subcritical coal-fired plants would dominate the market were it not for environmental concerns, especially CO_2.

Efficiency

Steam cycle efficiency is a function of the turbine cycle and boiler efficiencies and parasitic power requirements. Typically, about 11% of the cycle losses are from boiler efficiency, about

50% are from the condenser and only about 2% are from parasitic power needs. This means that significant improvement will come primarily from the turbine cycle and improving inlet steam conditions is the most effective approach.

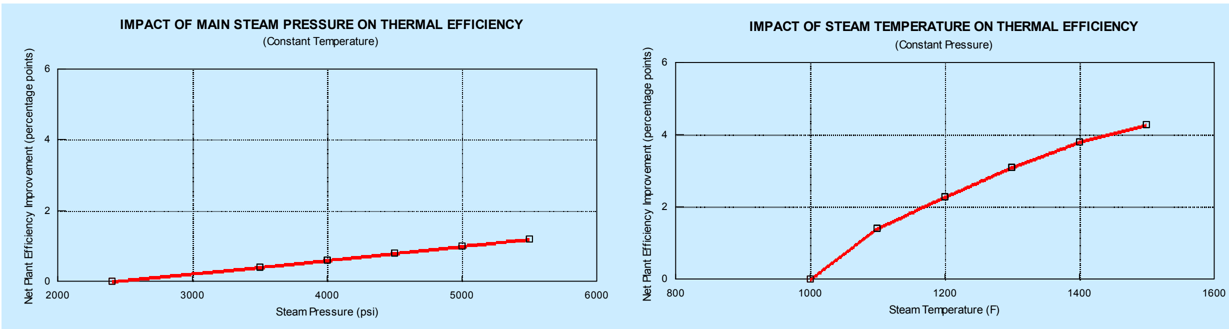


Figure 2: Impact of Steam Pressure and Temperature on Efficiency

As Figure 2 demonstrates, studies have shown that large increases in pressure have only a modest impact on efficiency but the improvement is significant for just a 50F increase in steam temperature. Increasing pressure also means that all pressure parts get proportionately thicker. This results in higher metal temperatures in the boiler requiring higher-grade alloys. Thus significant environmental value would be needed to economically justify increasing cycle pressure to gain a small amount of efficiency.

Materials with good creep strength at 1200F are available and though fabricability is an issue, they could be used for components external to the boiler. But the high temperature leading rows of the superheater and reheater within the boiler operate 100F to 150F higher at their surface and are exposed to corrosive combustion gases. Long-term data on the corrosion resistance of these alloys is non-existent.

The Program

The objectives of the program are to 1) evaluate the corrosion performance of newly developed superheater/ reheater materials for coal-fired boilers at surface temperatures equivalent to 1100ºF (593ºC) steam, 2) select materials resistant to fireside corrosion, and 3) generate long-term corrosion field data.

The corrosion rate for most austenitic materials used for high temperature tubing increases exponentially with temperature to a peak between 1300F and 1400F and then decreases rapidly beyond the peak. To accelerate corrosion the system was designed to achieve surface metal temperatures in this peak range.

Design began in November of 1998 and the sections were installed in April. The Sections are cooled by 600F, 315 psi reheat steam but located within the superheater bank of the B&W 120 MWe cyclone-fired Niles boiler which is a 1950’s vintage subcritical unit burning a 3-3.5% sulfur Ohio coal. Figure 3 shows the location.

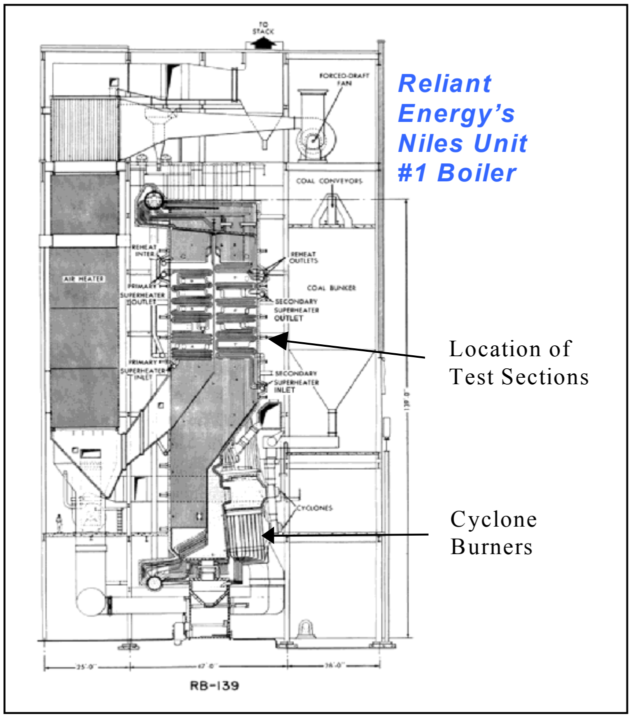


Figure 3: The Niles Boiler

Three identical four-row sections contain specimens of the 12 alloys tested; most are included three times within the top two rows to expose them to three temperature regimes. The only difference between sections is that the first section was scheduled for removal and evaluation after 1 year of operation, the second after 3 years and the third after 5 years.

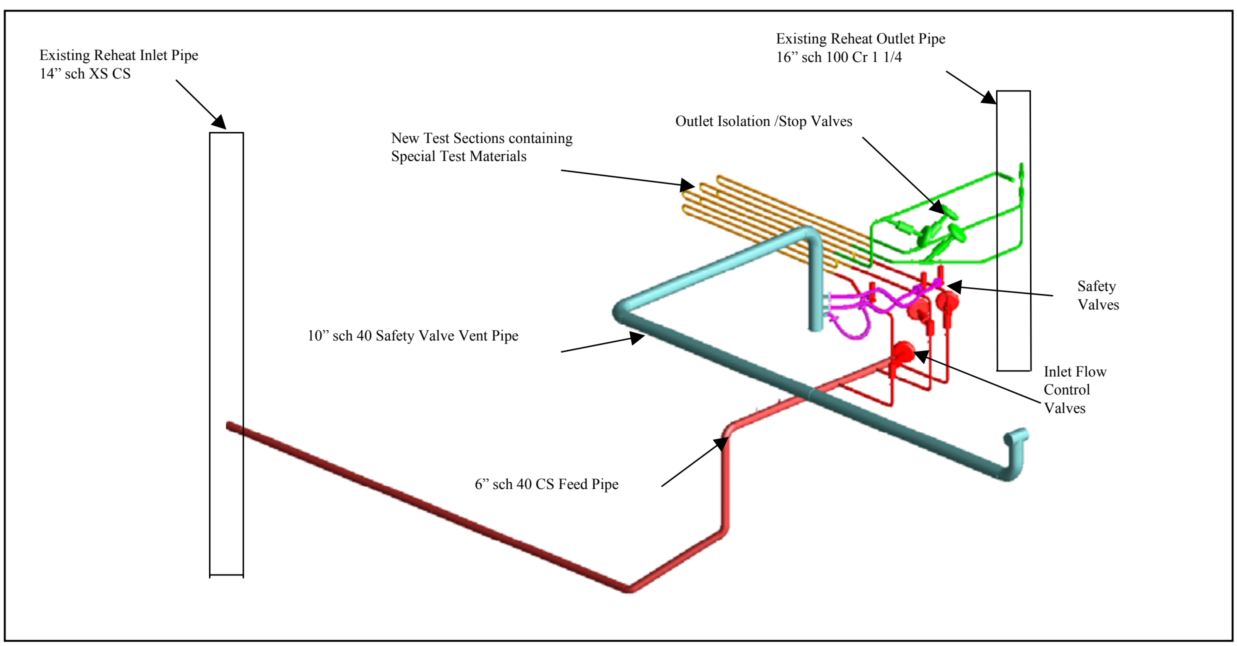


Figure 4: The System Arrangement

The surface metal temperatures are continuously calculated by the data acquisition system and correlated to the internal steam temperature, measured by thermocouples at the inlet, intermediate bend and outlet, which is controlled by varying the steam flow by inlet valves.

Each of the three (3) identical test sections contains ten (10) primary and two (2) secondary advanced material samples. The primary samples are placed in three different locations within the section (see Figure 5 and Table 1). The three sections extend through the furnace front wall for the full depth of the furnace up-pass. The sections are supported from the baffle wall at their rear and the furnace front wall at their front and the wall penetration is sealed with an insulated casing box.

Table 1: Advanced Materials

#	MATERIAL	SUPPLIER	ASME RECOGNIZED	SIMILAR MATERIAL
1	Incoclad – Core is Incoloy 800H	INCO	Yes - Code Case 1325	SB407-UNS N08800
2	Thermie	ORNL	No	Inconel 617
3	HR3C – SA213TP310HCbN	Sumitomo	Yes	
4	Ta Modified 310	ORNL	No	SA213TP310H or SA213TP310HCbN
5	800 Modified	ORNL	No	Incoloy 800H
6	Save25	Sumitomo	No	SA213TP310H or SA213TP310HCbN
7	HR120	Haynes	No	SA213TP310H
8	NF709	Nippon Steel	No	SA213TP310H or SA213TP310HCbN
9	Fe3Al-2Cr/304H	ORNL	Yes	Core is SA213TP304H
10	TP347HFG – SA213TP347HFG	Sumitomo	Yes	
11	Transition Piece	SA312TP304H	Yes	
12	690 clad 800HT weld metal INCO 52	INCO	Yes	Incoloy 800H
13	671 clad 800HT weld metal INCO 72	INCO	Yes	Incoloy 800H
14	SA213TP310H	NA	Yes	

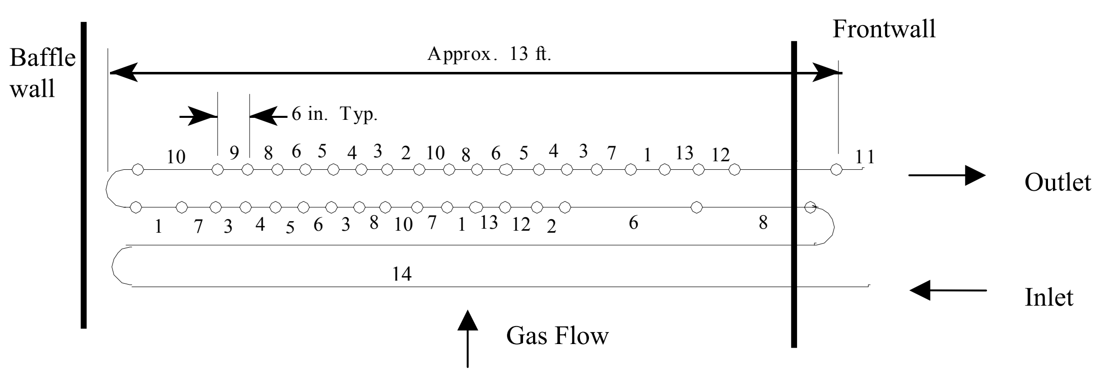


Figure 5: Location of Specimens within the Section

As shown in Table 1, some of the materials are ASME code approved and some are not. This fact required us to get a Code Variance from the State of Ohio to operate the system.

The Sections were fabricated at McDermott Technologies Inc., B&W's research facility in Alliance, Ohio. All but one of the 6 in. long specimens are 2.5 in. diameter by 0.400 wall. They were joined using alloy 625 filler metal by rotating the tube in a tungsten-arc orbital welder; every one of the 116 welds was x-ray clear.

Figure 6: Tungsten-arc Orbital Welder

Figure 7: Installation into Niles Boiler

Installation was completed in May of 1999, followed by shakedown and controls tuning. During this period the steam temperature was controlled first to 1000F and then to 1050F before being raised to the current temperature of 1075F which produces a predicted surface metal temperatures in the top row between 1300F and 1350F.

Since startup, the system has been plagued with valve controller overheat failures, resulting from unexpectedly high ambient temperatures, causing the inlet valve to open which cools the section around 800F at the outlet. This condition has seldom lasted more than a day or two, thanks to the rapid response of the operators at the Niles plant. But to eliminate this problem a cooling fan and ductwork were installed to blow cool air across each of the valves. This resulted in significant improvement but occasional problems continued so the electronic controllers were recently replaced with mechanical devices hoping to eliminate the nuisance altogether.

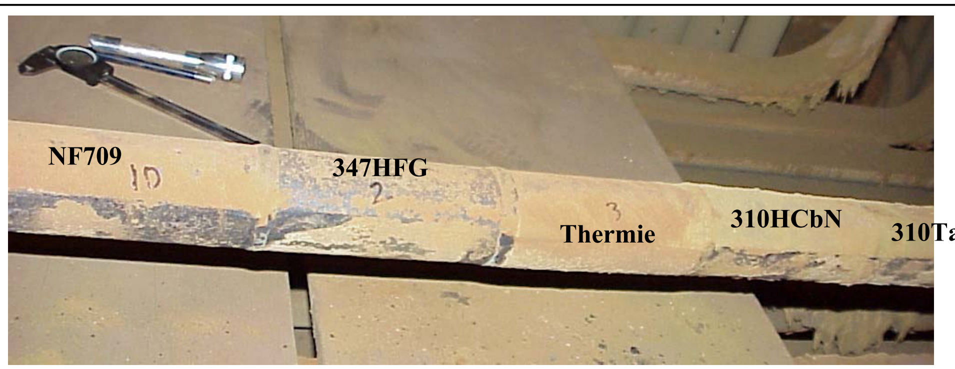


Figure 8: March 12, 2001 In-situ Inspection

Between startup and removal, inspections were made on about 6-month intervals. In March of 2001, in-situ measurements were made using calipers. Figure 8 shows the in-situ condition. Varying corrosion was exhibited among the specimens with extreme corrosion experienced in the SAVE25 piece. As a result, when the first Section was removed in December 2001, a short piece of the top row, which included the SAVE25 specimens, was removed from the two remaining sections and replaced with Incoclad tubing.

Evaluation of the first Section is underway at McDermott Technologies Inc. Figure 9 shows the best and worst specimens from the top (hottest) row. After 22 months of operation, the SAVE25 specimen actually developed a pinhole leak just prior to removal.

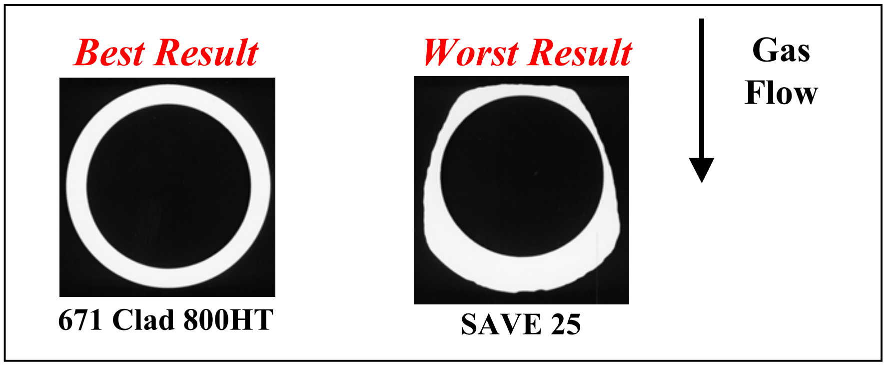


Figure 9: Best and Worst Specimens from First Section

The as-received condition of the specimens from the first Section has been documented; ring segments have been cut, de-scaled and measured. Metallographic rings have been mounted and ground and the chemistry has been determined for all specimens. These rings are now being polished, etched and documented and additional specimens through welds will be taken. The chemical analysis of each specimen will be compared to the original material specifications, the dimensional data will be evaluated relative to as-received measurements and time-temperature data, and SEM evaluation of the deposit and scale will be completed. These results will be recorded in a Topical Report scheduled for completion in June 2002.

REFERENCES:

"Status Of Coal Ash Corrosion Resistant Materials Test Program", by Dennis K. McDonald and David K. Meisenhelter, The Babcock & Wilcox Company and Vinod K. Sikka, Oak Ridge National Laboratory, presented at the 1999 Pittsburgh Coal Conference.