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Addendum to
Long-Term Testing Report

FULL-SCALE DEMONSTRATION OF LOW-NO_X CELL™ BURNER RETROFIT

September 1994 Outage:
Examination of Corrosion Test Panel
and UT Survey in DP&L Unit #4

Prepared for
The U. S. Department of Energy
Under Cooperative Agreement DE-FC22-90PC90545
(B&W CRD-1250)

Submitted by
Babcock & Wilcox
A McDermott Company

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to
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Prepared By

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Sponsored By

The U. S. Department of Energy

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DP&L agreed to be the host utility for the full-scale demonstration of the LNCB, offering the use of J.M. Stuart Station Unit No. 4 (JMSS4) as the host site. JMSS4 is a B&W 605 MW_e Universal Pressure (UP) boiler, a once-through design, originally equipped with 24, two-nozzle cell burners arranged in an opposed wall configuration .

"Legal Notice"

Addendum to Long-Term Testing Report

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1.0 INTRODUCTION

As part of the DOE "Full-Scale Demonstration of Low NO_X Cell Burner Retrofit" program, a corrosion test panel was installed on the west sidewall of Dayton Power & Light Unit #4 at the J. M. Stuart Station (JMSS4) during the burner retrofit outage in November 1991. The test panel, with an original dimension of 12 feet long by 80 tube wide, consisted of four sections of commercial coatings separated by bare SA213-T2 tubing. Details of the test panel layout and location of installation were discussed in the Long-Term Testing Report[1] issued by B&W in March 1994. During the retrofit outage, a UT survey was performed to document the baseline wall thicknesses of the test panel, as well as several furnace wall areas outside the test panel. The purpose of the UT survey was to generate the baseline data so that the corrosion wastage associated with the operation of Low NO_X Cell Burners (LNCB® burner) could be quantitatively determined.

The corrosion test panel in JMSS4 was examined in April 1993 after the first 15-month operation of the LNCB® burners. Wall segments approximately 6 inches in height were cut out from the top and bottom portions of the test panel and sent to B&W for destructive metallurgical analysis. The corrosion wastage on the bare T2 tubes across the test panel was determined statistically, and the corrosion resistance of the four coatings was evaluated metellographically. The results revealed that the bare T2 tubing on the test panel located in areas near the front wall did not suffer any meaningful wastage; however, bare T2 positioned in areas near the center line of the west side wall showed relatively high metal losses. A maximum metal wastage of 21 mils was measured on the bare T2 tubes after the first 15 months operation, which was equivalent to a corrosion rate of approximately 17 mils per year (mpy). The aluminum-spray coating suffered localized corrosion attack underneath the coating layer due to high coating porosity introduced from the coating process. However, the chromized and the two weld-overlay coatings exhibited excellent corrosion resistance to the low-NO_X combustion environment in JMSS4. UT survey was also performed during the Spring 1993 outage; however, determination of the tube wastage based on the UT data was inconclusive. Details of the corrosion analysis and UT data were documented in the Long-Term Testing Report.[1]

The second JMSS4 outage following the LNCB® burner retrofit took place in September 1994. Up to this point, the test panel in JMSS4 had been exposed to the corrosive combustion environment for approximately 31 months under normal boiler operation of JMSS4. This test period excluded the down time for the April 1993 outage. During the September 1994 outage, 70 tube samples of approximately one-foot length were cut from the bottom of the test panel. No samples were retrieved from the top portion of the panel due to funding constraints. These samples were evaluated by the Alliance Research Center of B&W using the same metallurgical techniques as those employed for the previous outage. In addition, UT measurements were taken on the same locations of the lower furnace walls in JMSS4 as those during the prior outages. Results of the metallurgical analyses and UT surveys from different exposure times were compared, and the long-term performance of waterwall materials was analyzed. The corrosion data obtained from the long-term field study at JMSS4 after 31 months of LNCB® burner operation are summarized in this stand-alone addendum report.

2.0 METALLURGICAL EXAMINATION OF CORROSION TEST PANEL

2.1 Sampling Location on Corrosion Test Panel

Because of funding constraints during the second outage, only one cross cut could be made to retrieve samples from the corrosion test panel for metallurgical examinations. It was therefore decided to select the tube samples from either the top or bottom portion of the test panel, depending upon which location had suffered more corrosion wastage. The sample analyses from the April 1993 outage after the first 15 months operation revealed that the bare T2 tubes at the bottom location of the test panel had suffered more metal losses than those at the top. With the burner operating parameters unchanged, the bottom portion of the test panel should have continued to suffer more corrosion attack during the next 16-month operation. However, to ensure the worst area being investigated, the final decision regarding the sampling location was postponed until the September 1994 outage, during which the surfaces of the test panel were visually examined.

Inspection of the corrosion test panel indeed revealed that the wastage was more severe toward the bottom location. Two major observations were noted to support this generalization. First, the color of the coal ash deposit existing on the test panel was darker at the bottom elevation, suggesting that a higher amount of unburned carbon was present in this region. The higher unburned carbon content indicates that the combustion gas in this region was more reducing. Secondly, the lower surfaces of the test panel contained a number of spots where the ash deposit and perhaps corrosion products (scale) had exfoliated before the inspection. Exfoliation is indicative of a thicker deposit/scale formation on the tube surfaces, which is more susceptible to thermal cycling and other types of physical damage associated with boiler operations. Corrosion rates can be significantly enhanced if fresh metal is constantly exposed to the combustion gases. Consequently, it was decided to remove the panel samples from the bottom location for corrosion analyses.

Figure 1 is a drawing of the corrosion test panel installed on the west sidewall of JMSS4. The panel layout is viewed from outside of the furnace wall facing east. Therefore, the assigned tube numbers increase as the tube location approaching the center line of the west sidewall. The initial length of the corrosion test panel installed in JMSS4 was 12 feet. About six inches of materials were removed from both the top and bottom portions of the test panel during the April 1993 outage. As a result, the remaining panel length during the last 16-month operation was approximately 11 feet. The shaded areas at the panel bottom represents the one-foot long tube samples that were retrieved from the September 1994 outage. Figure 1 also indicates the approximate locations of four gas sampling ports. The bare T2 tubes immediately adjacent to the sampling ports were not removed so that these ports can be used for future in-furnace gas analysis.

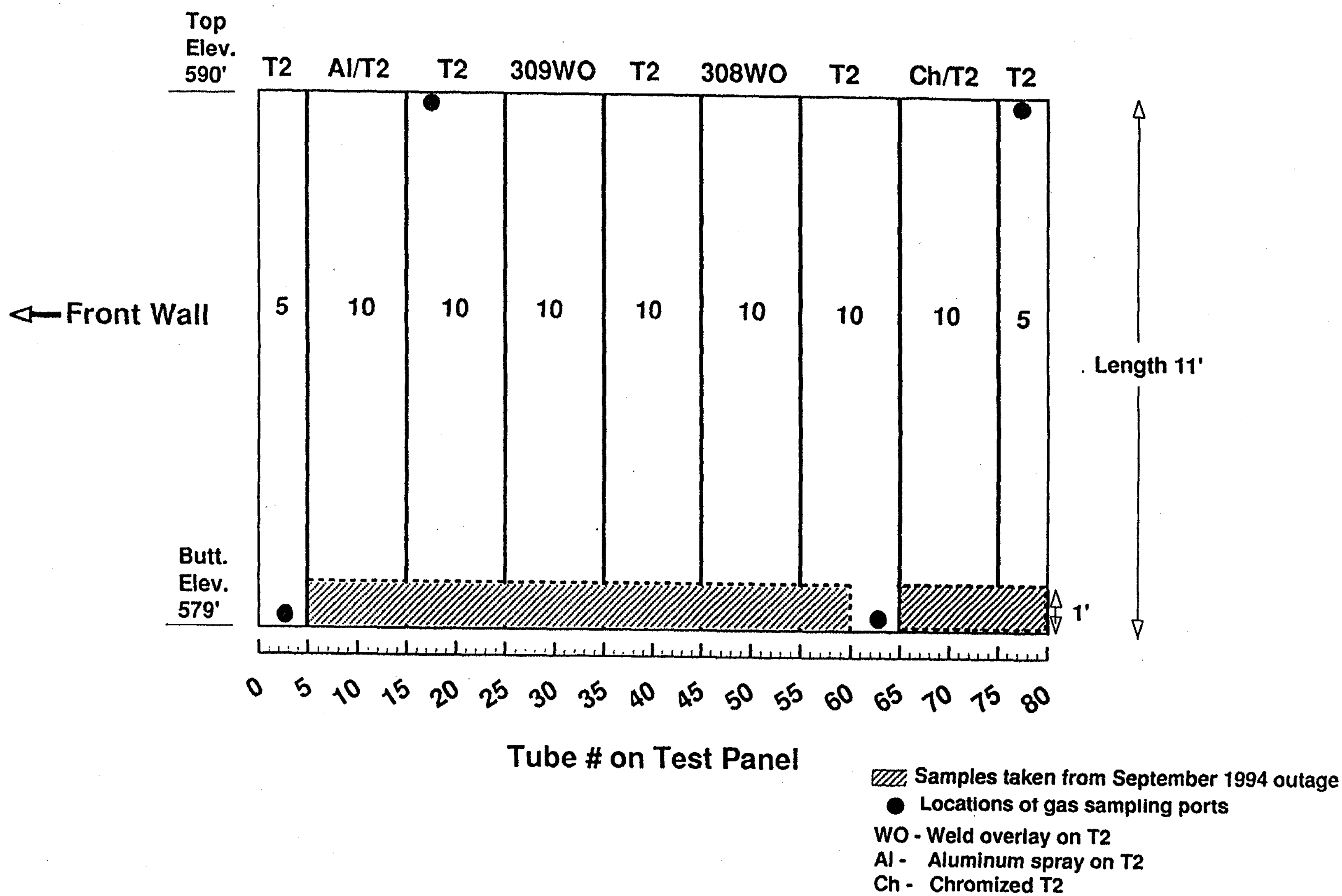


Figure 1 - Drawing of the corrosion test panel remained on the west sidewall of JMSS4 prior to the Fall 1994 Outage.

2.2 Determination of Tube Wastage on Corrosion Test Panel

Corrosion wastage of the sample tubes was determined statistically based on the measured changes of outer diameters (ODs) before and after the overall 31-month operation at JMSS4. The original ODs were measured from the archived tube samples cut off from the ends of the corrosion test panel prior to the panel installation. The final ODs were measured from the exposed samples retrieved from the September 1994 outage. The OD measurements were performed by first grit-blasting the tube surfaces to remove all coal ash deposit and corrosion products (scale), followed by measuring the ODs with a certified micrometer at several locations of each tube sample (without hitting the membranes). Efforts were made to achieving an identical grit-blast finish on all tube surfaces.

As demonstrated in the Long-Term Testing Report,[1] determination of the corrosion wastage based on the tube OD losses, followed by statistical analysis, is a viable approach. Variation in the tube ODs is generally much smaller than that of other types of dimensions, such as tube wall thickness and surface scale thickness. Consequently, corrosion-rate calculations based on the "mean" OD changes can generate much reliable corrosion data.

The OD measurements were performed on the same bare T2 and chromized tubes as those examined previously during the April 1993 outage, i.e., the first outage after the burner retrofit. Therefore, a direct comparison of the metal wastage as a function of exposure time at the completion of 15 months (April 1994) and 31 months (September 1994) is possible. The locations of the bottom samples retrieved from each tube during these two outages were only ~8 inches apart vertically. Therefore, due to the short distance, the bottom samples of the same tube retrieved from two different times can be assumed to have subjected to similar combustion environments. Consequently, the corrosion information obtained from these two outages can provide a trend of long-term corrosion behavior for the waterwalls of JMSS4 at the bottom elevation of the test panel.

3.0 RESULTS AND DISCUSSION - CORROSION TEST PANEL

3.1 Tube Wastage of Corrosion Test Panel

Figure 2 summarizes the "mean" OD thicknesses of bare and chromized T2 tubes from the bottom test panel after the field exposure for 31 months in JMSS4. The original mean ODs of the bare and chromized T2 tubing were 1.249 and 1.252 inches, respectively, as indicated by the horizontal lines. Cross-sectional metallographic examinations revealed that the maximum metal loss on the bare T2 outside the furnace (facing the windbox) was approximately 1 mil. This small loss was attributed primarily to oxidation of the metal with the heated air in the windbox. Therefore, the corrosion wastage of the bare T2 on the furnace fireside is equivalent to the total OD losses shown in Figure 2 minus 1 mil. Negligible wastage was found on the windbox side of the chromized tubes. Therefore, all wastage on the chromized T2 was attributed to fireside corrosion.

Figure 3 displays the mean wall losses (in mils) of the test panel on the fireside. The measurements indicate that the corrosion wastage of bare T2 increases with increasing tube number, with the highest tube loss being ~26 mils on Tube #79. This trend is consistent with the previous results from the April 1993 outage documented in the Long-Term Testing Report.[1] That is, higher corrosion wastage on the bare T2 was found near the center line of the west sidewall at the bottom elevation of the test panel.

It is also noted that the wall losses of each adjacent pair of bare T2 tubes are noticeably different, with one being higher than the other. Such a variation is again consistent with the corrosion results obtained from the April 1993 outage. It has been interpreted in the Long-Term Test Report that such variations were caused by an appreciable difference in the metal temperatures between each pair of tubing, as JMSS4 consists of two-pass furnace walls. Consequently, the metal

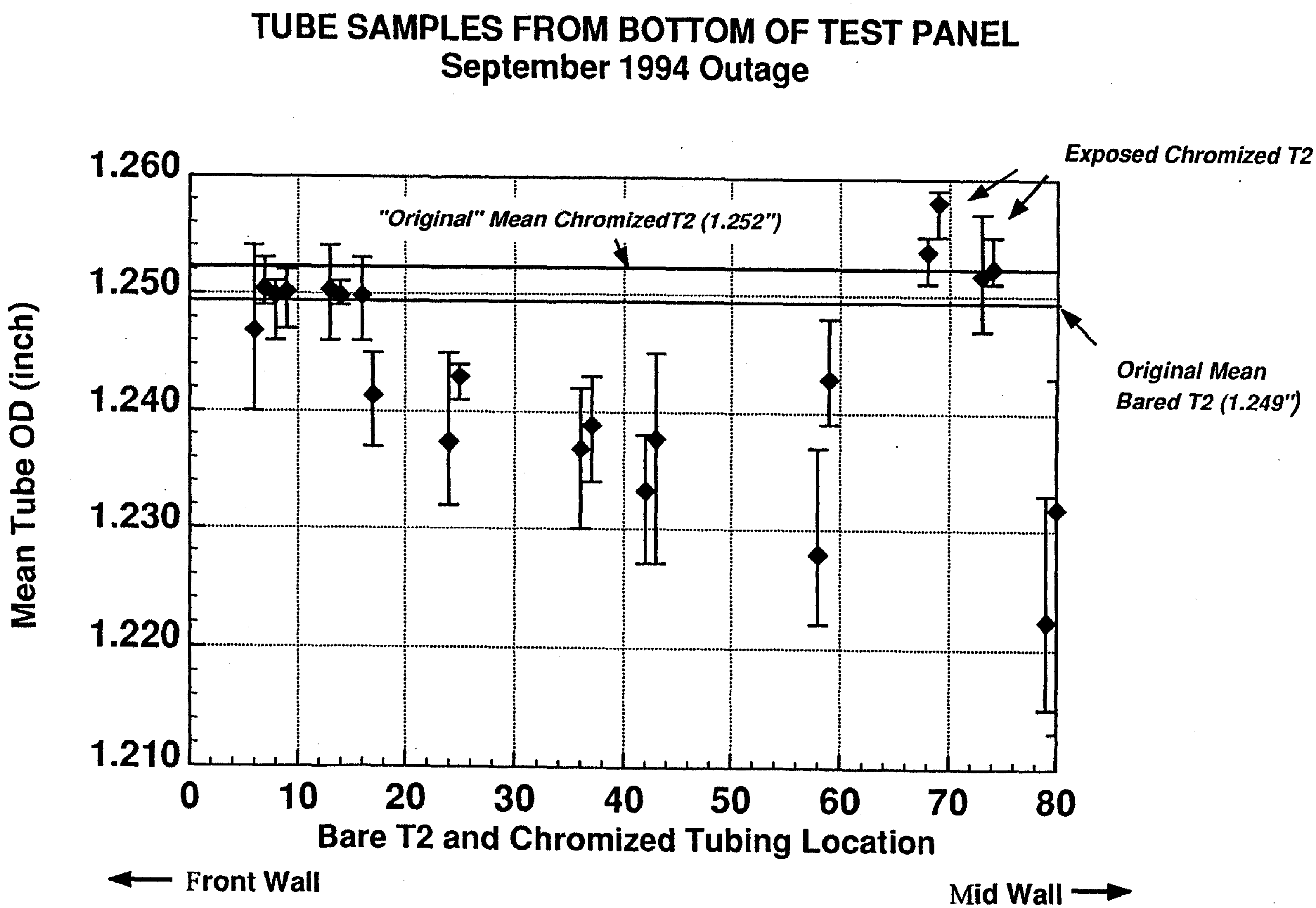


Figure 2 - Measured "mean" OD thicknesses of the bare and chromized T2 tubes at the bottom elevation of the corrosion test panel.

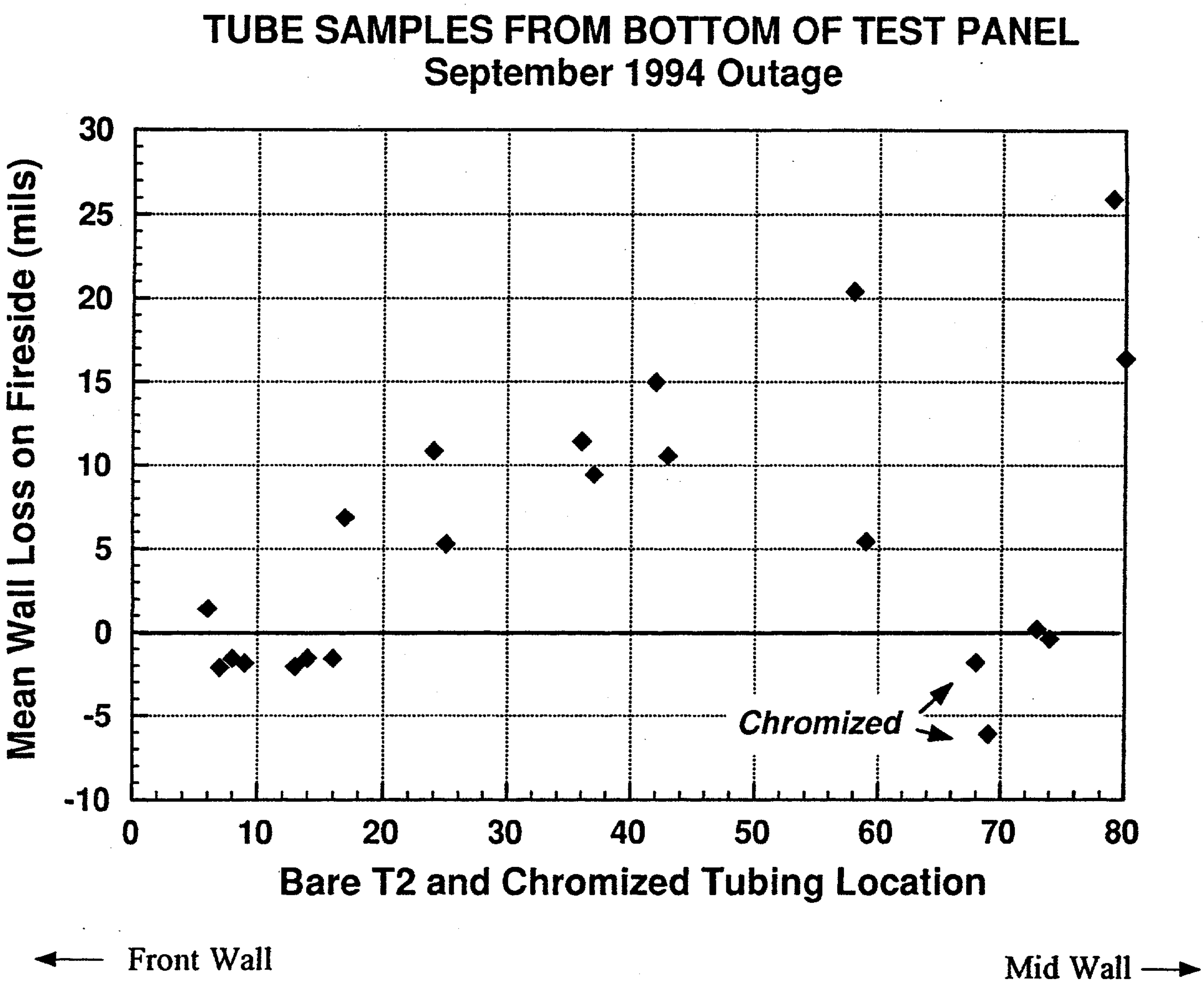


Figure 3 - Measured "mean" wall losses of the bare and chromized T2 tubes at the bottom elevation of the corrosion test panel.

temperatures of the second-pass tubes would have been higher than those of adjacent first-pass, which led to higher corrosion wastage. Using the JMSS4 unit design data, the first and second passes of the waterwall tubes on the corrosion test panel were identified, which are summarized in Table 1.

Table 1 - Identification of First and Second Passes on the Corrosion Test Panel

Tube Numbers from Front Wall	Odd/Even Number	Pass
Tubes #1 - 19	Odd	2nd
Tubes #2 - 20	Even	1st
Tubes #21 - 61	Odd	1st
Tubes #22 - 60	Even	2nd
Tubes #63 - 79	Odd	2nd
Tubes #62 - 80	Even	1st

Relating the wall-loss data in Figure 3 to the tube pass identifications in Table 1, the second-pass tubes indeed show higher corrosion wastage than their neighboring first-pass tubes. Therefore, this correlation agrees well with the previous interpretation, i.e., differences in the corrosion wastage of two adjacent tubes were primarily caused by their tube metal temperatures.

The measured metal wastage in Figure 3 for the bare T2 with tube numbers less than 15 scatters along the original OD thickness. Again, a similar observation was found on these tubes from the results of April 1993 outage (i.e., after the first 15-month exposure in JMSS4). Considering the standard deviation of the measurements, the scattering of wastage data signifies that negligible fireside corrosion has occurred on these bare T2 tubes at the bottom elevation of the test panel close to the front wall. The range of data scattering suggests that the standard deviation is approximately ±2 mils.

Data of the chromized T2 tubes in Figure 3 also show no sign of wall losses at the bottom elevation of the test panel, even though they were located near the center line of the west sidewall where the corrosion attack on bare T2 was more severe. In fact, these coated tubes show "negative" wall losses compared to the archived samples. As discussed in the Long-Term Testing Report, the negative tube losses were primarily caused by non-uniformity of the initial coating thickness on the as-chromized product. The coating thickness produced on the ends of an as-chromized tube panel, from which the archived samples were taken, was usually the thinnest. As a result, the OD thicknesses of the exposed chromized tubes which suffered negligible metal losses may appear to have increased when compared to the archived tube-end samples.

The wall thickness losses of some bare T2 tubes retrieved from both April 1993 and September 1994 outages are compared in Figure 4. Only those tubes showing meaningful amounts of corrosion wastage are plotted. As mentioned previously, the vertical distance of the bottom samples retrieved from each tube of the test panel during the two outages was only ~8 inches apart. Because no major changes in the operation of JMSS4 were incurred, the corrosive environment can be assumed to be identical on the test panel within this short vertical distance. Therefore, except for the difference in exposure time, the bottom samples from each tube would have been exposed to the same corrosive condition. Consequently, the corrosion data generated from these two outages may define the trend of metal loss with time and give a good indication of the materials long-term performance at the bottom elevation of the test panel on the west sidewall.

Two types of variations in the wall losses of bare T2 as a function of time can be deduced from Figure 4. If the standard deviation of the wall losses is taken as ±2 mils as discussed previously, the trend of corrosion wastage on Tubes #36, 37, 43, and 80 may be considered linear with time. On the other hand, the trend for Tubes #42, 58, and 79, on which higher corrosion wastage was found, first increases sharply with time but levels off after longer exposure.

As discovered previously in the program, the primary mode of corrosion attack in the lower furnace of JMSS4 was sulfidation. The data in Figure 4 suggest that the metal wastage on bare T2 followed a linear trend when the sulfide scale formed on the tube surfaces was thin. The formation of a thin scale could have been attributed to either the combustion environment being less severe (e.g., in areas near the front wall) and/or the exposure time being insufficient (e.g., in the early stage of the sulfidation process). After the sulfide scale has grown thicker, some corrosion resistance may

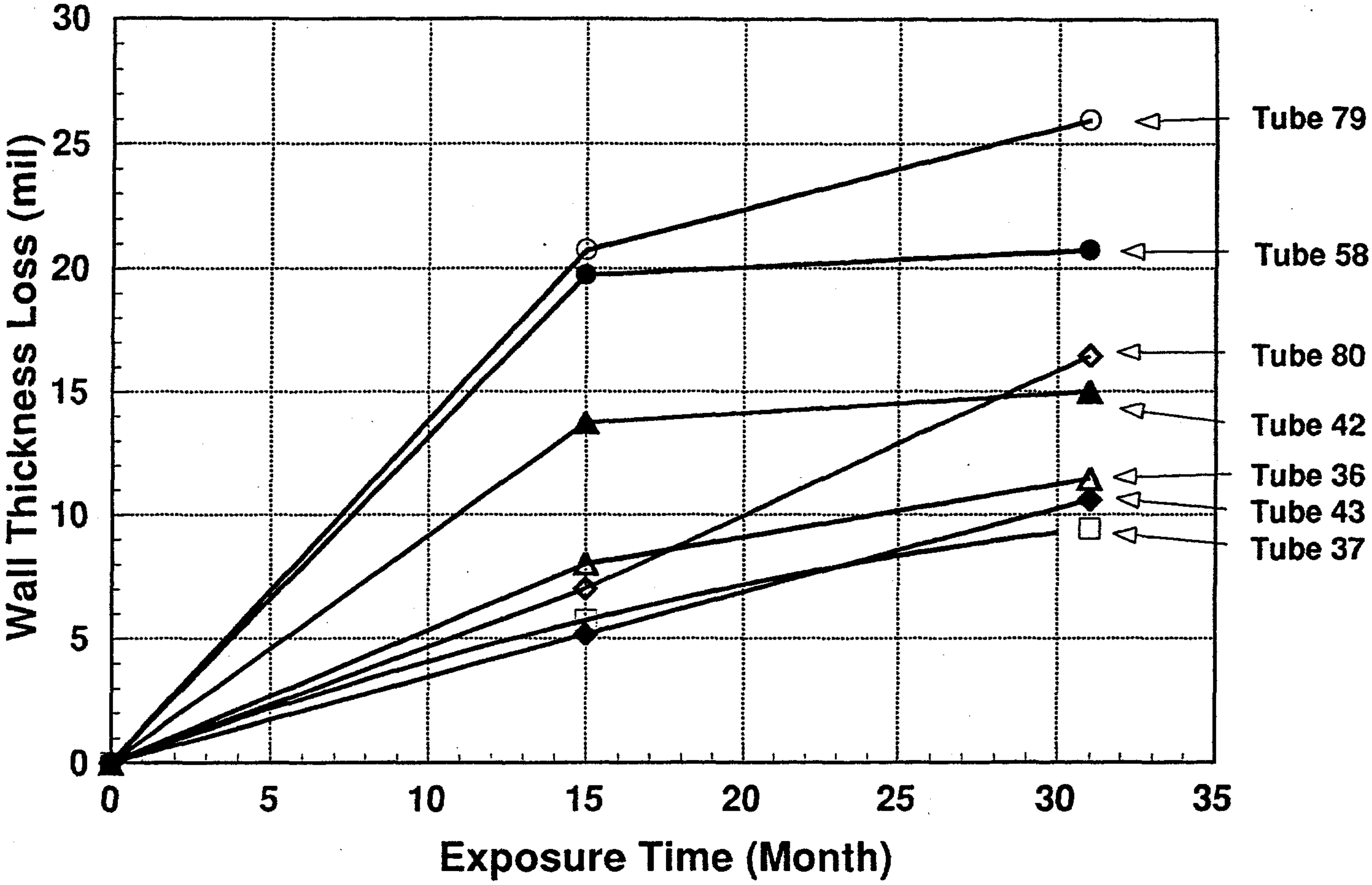


Figure 4 - Comparison of wall thickness losses on bare T2 tubes from two outages at the bottom elevation of the corrosion test panel.

have eventually been established by the scale. Subsequently, the wall thickness loss deviated from the undesired linear trend.

The results presented above indicate that a thick sulfide-base scale might have caused deviation of the corrosion kinetics from linear behavior. Cross-sectional examinations of the bare T2 samples during both outages after the burner retrofit revealed that the sulfide scale on T2 was indeed dense and adherent to the metal. Such a thick sulfide scale would have acted as a diffusion barrier to impede the kinetics of the corrosion process, which in turn reduced the corrosion attack. Nevertheless, the sulfide scale formed on T2 under the reducing combustion environments of investigation should not be regarded as protective, as the corrosion rate of T2 from sulfidation is still much higher than that from oxidation when exposed to an oxygen-rich combustion gas.

Figure 5 illustrates the variation of corrosion rates in mil per year (mpy) with tube location for the bare T2 and chromized tubing. The corrosion rates were derived by linearly extrapolating the 31-month corrosion data (in Figure 3) to one year. As expected, the highest corrosion rate, ~10 mpy, occurs on the bare T2 tube of #79 at the bottom elevation of the test panel. The corrosion rate on the chromized T2 is negligible (the negative data points were caused by reasons discussed previously).

Figure 6 compares the linear corrosion rates of bare T2 tubes at the bottom location of the test panel after the 15 and 31-month exposures in JMSS4. The corrosion rates of Tubes #36, 37, 43, and 80 remain essentially constant with time. On the other hand, Tubes #42, 58, and 79 exhibit a trend of decreasing corrosion rate with exposure time. Again, the decrease is likely to have been attributed to the formation of a dense and adherent sulfide scale on T2. The highest corrosion rate observed on Tube #79 at the bottom elevation of the test panel has been reduced from 17 to 10 mpy during the total field exposure of 31 months.

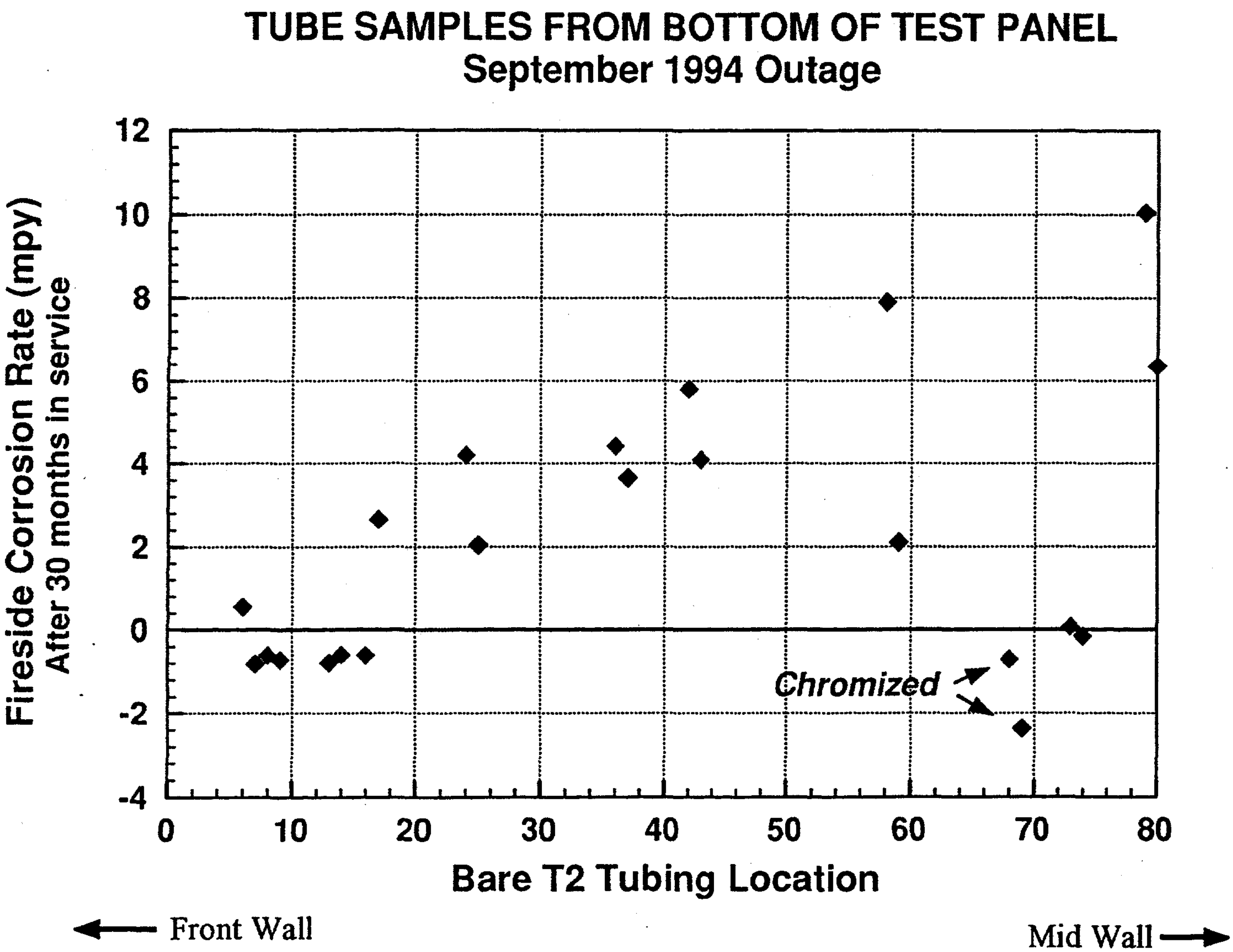


Figure 5 - Variation of corrosion rates of bare T2 and chromized tubes with the tube location at the bottom elevation of the corrosion test panel.

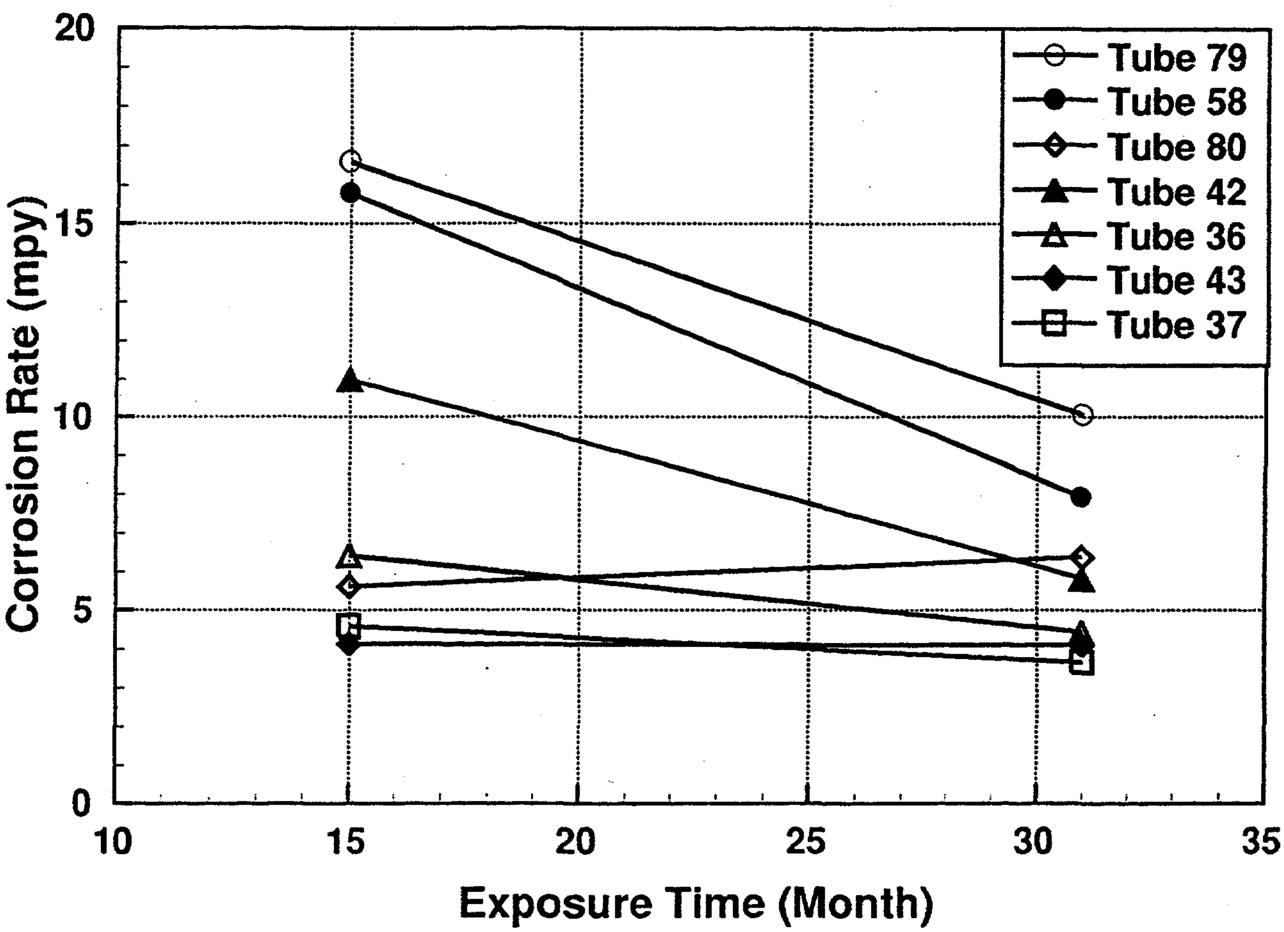


Figure 6 - Comparison of the linear corrosion rates of bare T2 tubing with time at the bottom elevation of the corrosion test panel.

A corrosion rate of 10 mpy is approaching a wastage level that was experienced on the furnace walls before the burner retrofit. At this level, performance of the unit would not be significantly affected if regular inspection and wall replacement are carried out during outages. If the beneficial characteristics of the sulfide scale continue to prevail, i.e., the scale being dense and adherent, the corrosion rate of bare T2 may be further decreased with time. On the other hand, if defects such as cracking and spallation are developed later on in the scale, the corrosion kinetics may change. Based on the available corrosion data, it is not possible to accurately predict longer term performance of the furnace walls beyond the current exposure period investigated. Therefore, continuing monitoring of the corrosion test panel in JMSS4 is recommended.

3.2 Metallographic Examinations on Corrosion Test Panel

Cross-sectional metallographic examinations were performed on some of the tube samples obtained from the September 1994 outage. The standard metallographic procedures were employed for cross-sectional sample preparation. The deposit and scale morphologies present on the sample surfaces, as well as their chemical compositions, were analyzed using an optical microscope and a secondary electron microscope (SEM) equipped with energy dispersive X-ray (EDS) analytical capabilities.

Similar to the metallographic analysis results from the April 1993 outage (after the first 15-month operation), the primary mode of corrosion attack on the test panel in JMSS4 was sulfidation. Sulfidation refers to the corrosion products formed on the metal surfaces being predominately sulfides. The growth rates of sulfides are generally much faster than those of corresponding oxides when formed on metals under an oxidizing environment. Therefore, the metal wastage is expected to be higher in the reducing combustion environments.

Figure 7 is an SEM micrograph of a bare T2 sample retrieved from the bottom of Tube #78. The EDX analysis indicated that the scale on the sample surface consisted of mixed corrosion products, mostly iron sulfide (presumably FeS) and some iron oxide (presumably Fe_3O_4). The scale

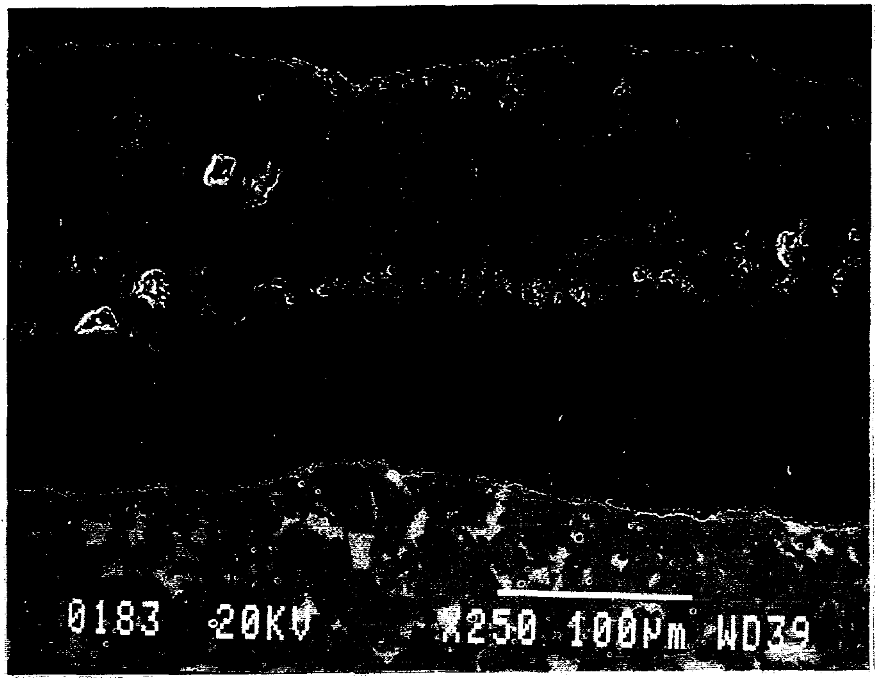


Figure 7 - Cross-sectional SEM micrograph of bare T2 from Tube 79 at the bottom elevation of the corrosion test panel.

exhibited a double-layered morphology, with the outer layer containing some embedded ash particles and the inner layer being essentially ash-particle free. Such a morphology implies that the growth mechanism of this corrosion product on bare T2 involved both inward and outward diffusion. The inward scale growth would have been dominated by the diffusion of sulfur from the gas/scale interface to the scale/metal interface of the sulfide layer, and the outward growth involved the diffusion of iron in the opposite direction.

A similar scale morphology was found on all bare T2 tubes across the test panel; however, thicknesses of the scales formed on the tube surfaces increased with increasing tube number. This trend is consistent with the wall-loss data in Figure 3, of which more corrosion wastage took place in areas near the center line of the west sidewall. The sulfide scale in Figure 7 is dense and adherent to the underlying metal. As discussed earlier, such a scale morphology is desirable, which has resulted in improved corrosion resistance of T2 tubing by serving as a diffusion barrier to impede the corrosion kinetics.

The cross-sectional SEM micrograph of an aluminum (Al)-spray coating on T2 is shown in Figure 8. It is noted that the Al-sprayed T2 tubes on the test panel were situated close to the front wall of JMSS4. Therefore, as illustrated by the wall-loss data, severity of the corrosion attack in this wall area was relatively mild. However, EDX analysis still revealed a large amount of sulfur existing at the coating/substrate interface. The presence of sulfur in this region suggests that sulfur has penetrated into the coating layer and consequently reacted with the surface of T2. This mode of sulfidation attack indicates that the coating was porous and unable to prevent the corrosive gases from reaching the T2 substrate. Such findings are again consistent with the results of previous laboratory studies in this program as well as the first examinations of the corrosion test panel during the April 1993 outage. The results of these previous studies were documented in the Long-Term Testing Report.[1]

Figure 8 - Cross-sectional SEM micrograph of Al-sprayed T2 at the bottom elevation of the corrosion test panel.

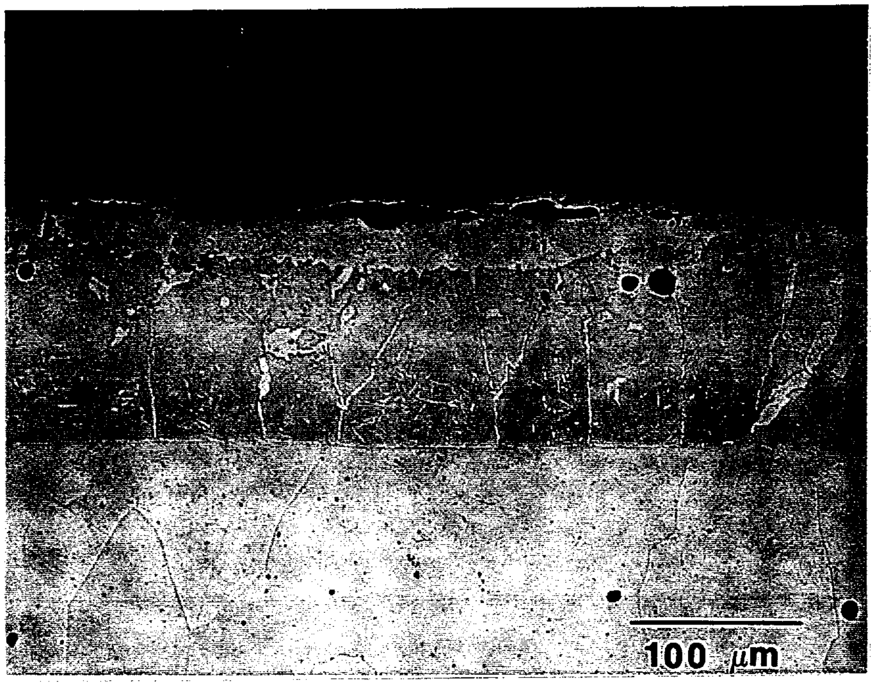
Figures 9 and 10 are the cross-sectional SEM micrographs of 309 and 308 weld-overlay coatings on T2 tubes, respectively. The surface composition of 309 weld overlay is equivalent to that of 309SS (Fe-22Cr-12Ni), and the surface chemistry of 308 weld overlay is comparable to that of 304SS (Fe-18Cr-8Ni). After the 31-month field exposure, both coatings demonstrated excellent corrosion resistance to the sulfidation attack in JMSS4. The surfaces of these weld overlays have formed a thin corrosion scale underneath the coal ash layer. EDS analyses revealed that the scale was rich in Cr and O, and also contained some Fe, Ni, and S. These compositions suggest that the scales consist of primarily Cr-rich spinel oxide and a small amount of spinel sulfide. As mention previously, the formation of an oxide-base scale on metal can provide much better corrosion protection than the corresponding metal sulfide. Consequently, the good performance of these weld overlaid T2 in JMSS4 was attributed to the ability of oxide formation on these coated surfaces upon exposure to the reducing combustion gases. These findings are again in agreement with the previous field study during the April 1993 outage after the corrosion test panel had been exposed for 15 months.

On the chromized tubing, a protective scale also formed over much of the sample surfaces. EDX analysis showed that the chemical composition of this scale was rich in Fe, Cr, and O, and contained very little S. Therefore, similar to the weld overlays, the surface scale was consisted primarily of spinel oxide. Figure 11(a) is a cross-sectional optical micrograph showing the typical chromized T2 surface after the 31-month exposure in JMSS4. The bright phase existing on the surface as well as along the columnar grain boundaries of the coating layer is chromium carbide formed during the chromizing treatment. The ash layer and scale were apparently lost during the cross-section preparation. The micrograph in Figure 11(a) reveals that the microstructure of the chromized tubing after the exposure remains essentially identical to that of as-coated, and no meaningful corrosion attack has occurred. Therefore, sulfidation in the lower furnace of JMSS4 has been significantly retarded by the use of chromizing coating.

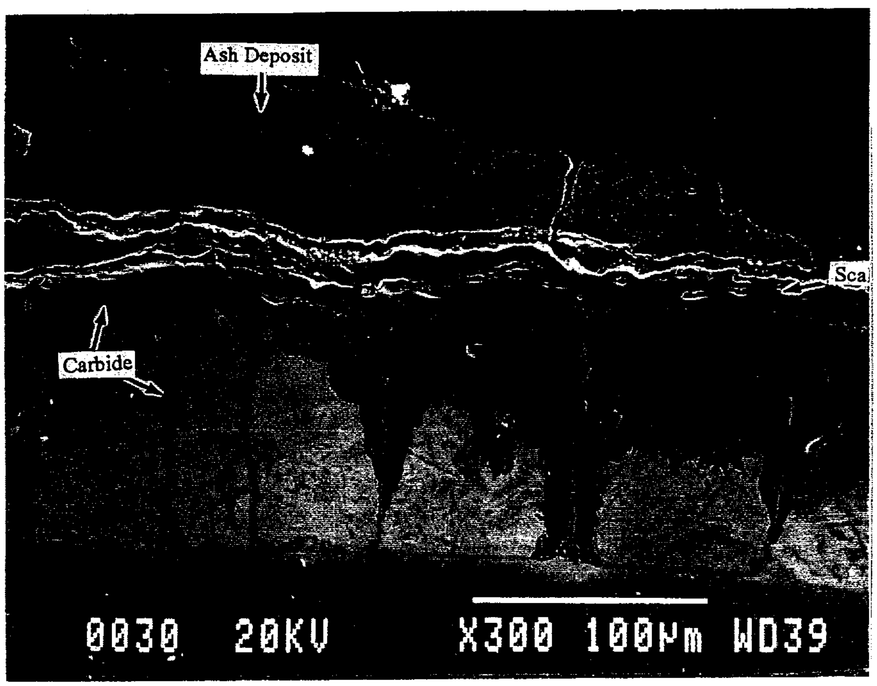
Close examinations of the chromized T2 sample disclosed a few areas where the corrosion attack has penetrated into the coating layer, as shown on the right portion of the coating layer in

Figure 9 - Cross-sectional SEM micrograph of 309 weld-overlaid T2 at the bottom elevation of the corrosion test panel.

Figure 10 - Cross-sectional SEM micrograph of 308 weld-overlaid T2 at the bottom elevation of the corrosion test panel.



(a)



(b)

Figure 11 - Cross-sectional micrographs of chromized T2 from Tube 75 at the bottom elevation of the corrosion test panel.

Figure 11(b). The finger-like corrosion front apparently proceeded along the columnar grain boundaries of the coating layer. It is believed that this localized attack was initiated by the residual halide salt remained on the surfaces from the chromizing treatment, and the attack had occurred during the storage period before the test panel went into service. Removal of the halide salt from the finished surfaces would have eliminated this problem. It is noted that the chromium carbide layer on the outer surface as well as the chromium carbide precipitates within the grain boundaries were virtually unaffected by the field exposure. Therefore, without the residual halide salt, chromizing should have performed equally well as those weld-overlay coatings in the reducing combustion gases.

Furthermore, even the deepest corrosion penetration in the chromized coating terminated at the coating/substrate interface. Beyond this point, the corrosion attack proceeded laterally. The change of the attack path was probably attributed to the presence of a very thin corrosion-resistant carbide layer at the coating/substrate interface. Apparently, this interfacial carbide was very corrosion resistant and has prevented the corrosion front from penetrating into the T2 substrate

It should be mentioned that several modified chromizing processes have been recently developed by B&W, which can optimize the microstructure of the carbide precipitates in the coating layer. In addition, the chromizing/siliconizing co-diffusion coating under B&W's near-term development may eliminate the decarburized zone underneath the coating layer. Therefore, the performance of these next-generation diffusion coatings is expected to be further improved when exposed to the reducing combustion gases.

4.0 ULTRASONIC THICKNESS MEASUREMENT OF FURNACE WALLS

4.1 History of UT Survey

B&W and DP&L have performed a series of UT measurements on the lower furnace walls of JMSS4 during the last four scheduled outages that took place in April 1990, November 1991, April 1993, and September 1994. The UT survey in Spring 1990 was performed prior to the LNCB® burner retrofit, the Fall 1991 outage was during the burner retrofit, and the other two were after the retrofit.

The UT data obtained from the April 1990 outage revealed that some areas of the JMSS4 furnace walls had already suffered high corrosion wastage resulting from the standard cell burner operation. The lowest remaining wall thickness from this survey was 160 mils (0.160 inch), approaching the flag point for furnace wall replacement. Consequently, some areas of the furnace walls were replaced. DP&L attributed the severe tube wastage to the existence of reducing combustion gases in the lower furnace due to improper mixing of coal and air. Because of the replacement of some furnace walls, most of the UT data obtained from the 1990 outage could no longer be used as the baseline. Nevertheless, this UT survey was imperative to selection of the location for installation of the corrosion test panel.

During the LNCB® burner retrofit outage in November 1991, a number of UT measurements were again taken. The survey included eight horizontal bands along the furnace walls and 12 points around each burner cell. In addition, the UT measurements were obtained from the corrosion test panel at 6 elevations ranging from 578 feet-6¾ inches to 590 feet-5¾ inches at a 2-foot interval. Figure 12 illustrates the furnace wall areas where the surfaces were grit-blasted and UT surveyed. When possible, a total of five UT readings were obtained from each sampling point, a half inch apart vertically between two adjacent points, so that an averaged wall thickness at that location could be derived. These UT results were then considered as the new baseline for calculations of the furnace wall wastage.

In the April 1993 outage, after approximately 15-month operation of the LNCB® burners in JMSS4, a UT survey was again performed on the lower furnace walls. Whenever accessible, the survey repeated the five UT measurements at each sampling location as those performed in November 1991. Details of all previous UT surveys and averaged readings were summarized in the Long-Term Testing Report.[1]

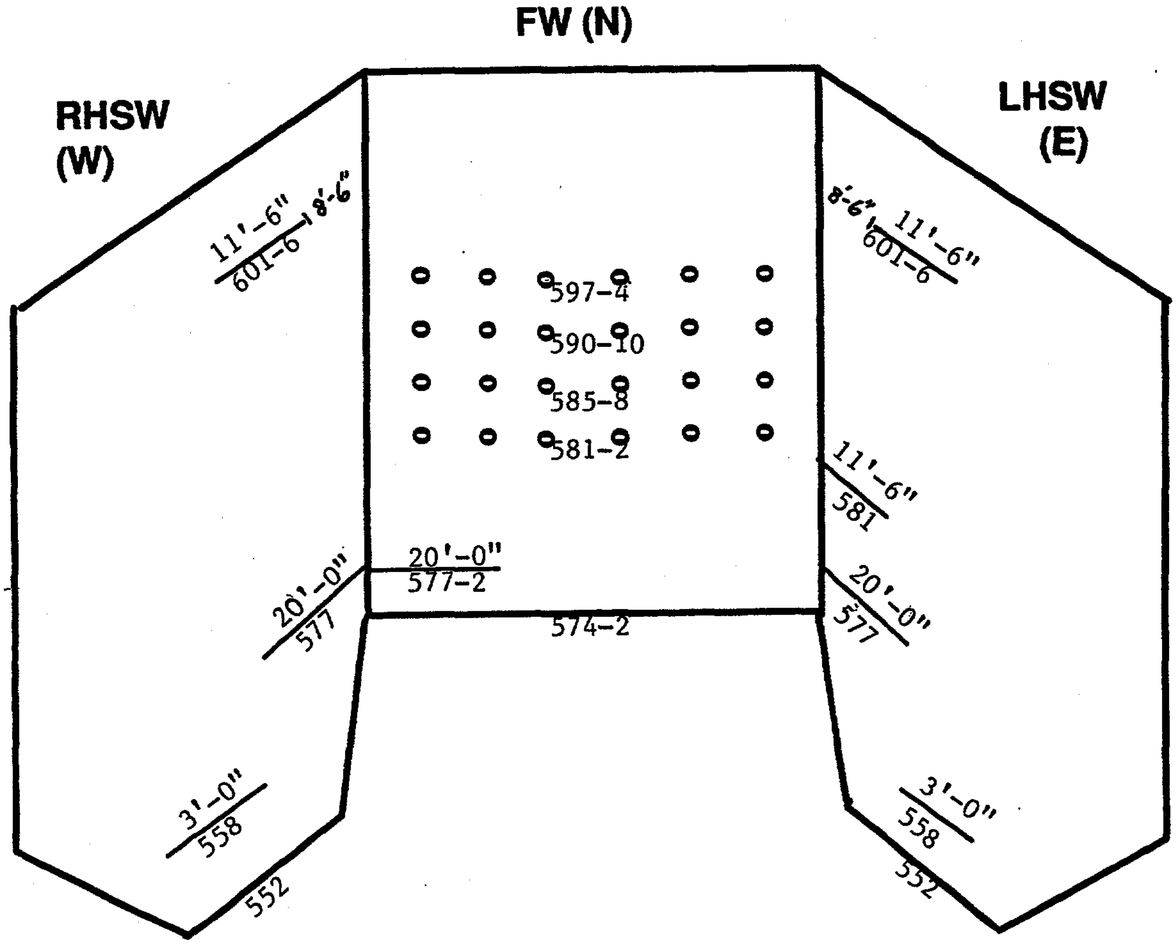


Figure 12 - Locations of Furnace Walls Where the Surfaces were Grit-Blasted and UT Measured for Remaining Tube Thicknesses.

Because of inconsistency in the measuring techniques encountered, the UT data from the previous outages could not clearly indicate the trend of corrosion wastage with time on the furnace walls. Therefore, expansion of the UT data was needed. It was decided that the UT survey be carried out again in JMSS4 during the Fall 1994 outage.

4.2 Sampling Locations of UT Survey

The locations where the UT survey was performed on the furnace walls of JMSS4 in Fall 1994 were identical to those shown in Figure 12. However, the UT survey was carried out after several burner panels had already been replaced. In addition, some new replacement panels were hung on the furnace walls adjacent to the burners. These replacement panels hindered the accessibility of UT measurements to the areas underneath. Consequently, the UT measurements at a number of sampling points adjacent to the burners had to be omitted. These areas, either already replaced or inaccessible, include:

1. Burner Panel for 4B4L and 4B4U,
2. Burner Panel for 4D5L and 4A5U,
3. Burner panel for 4E4L and 4E4U, and
4. Burner panels for 4C1L and 4F1U.

Furthermore, the surfaces of two furnace wall areas in JMSS4 had not been grit-blasted prior to the UT measurements. As a result, a significant degree of error must have been introduced to the measured data by the presence of a coal ash layer on the tube surfaces. These non-blasted areas are:

1. Elevation 601 feet-6 inches on the RHSW, and
2. Elevation 588 feet-4 inches on the RHSW within the corrosion test panel.

4.3 Procedures of UT Survey

Personnel from B&W and DP&L collaborated in the Fall 1994 UT measurements. The equipment used for the Fall 1994 survey consisted of Sonic Mark I flow detectors and Harisonic 15 MHz transducers with a 0.25 inch contact diameter. Like the previous UT measurements, five readings were taken at each sampling point. The averaged value from each sampling location was calculated and then carefully compared to those of adjacent locations to eliminate any obvious discrepancy caused by equipment and human errors.

It should be pointed out that the data generated from UT measurement usually involve a fairly large standard deviation. There are three primary sources for this deviation:

1. Tube ID scale/deposit - The scale buildup on the ID surfaces can cause as much as ±5 mils (0.005 inch) to the UT readings.
2. Equipment reproducibility - The flaw detector has a reproducibility limit of ±3 mils (0.003 inch).
3. Operator inconsistency - Operator's interpretation on the UT signals introduces additional uncertainty.

As a result, the overall standard deviation associated with UT measurement can be as large as ±15 mils. When evaluating the UT data and making comparison, the range of standard deviation must be considered.

5.0 RESULTS AND DISCUSSION ON UT SURVEY

The averaged readings of remaining wall thicknesses at various sampling locations from the last three UT surveys are summarized in Appendix A. When possible, the replacement history on these wall areas is also documented. In comparison, the readings obtained from the Spring 1993 outage appear to be high; therefore, these data are less reliable and are not used for the wastage comparison.

Based on the UT data generated from the 1991 and 1994 outrages, the trend of furnace wall wastage is still difficult to be clearly defined. The difficulty is encountered by the fact that some of the UT data show tube wall "growth" from 1991 to 1994, and the others exhibit small losses compared to the range of standard deviation. The worst case of tube wastage on the left-hand sidewall is ~12 mils (0.012 inch), and the worst case on the right-hand sidewall is ~20 mils (0.020 inch) occurring on the bare T2 of the corrosion test panel. Again, due to a relatively large standard deviation involved in the UT measurement (±15 mils), the uncertainty associated with these maximum metal losses would also be significant.

6.0 CONCLUSIONS

1. Results of the metallurgical examinations from the bottom portion of the corrosion test panel indicate that the corrosion wastage increased with increasing tube number from the front wall to the center line of right-hand sidewall. This trend is in agreement with that found in the previous analysis.

2. The sulfide scale formed on the bare T2 tubing of the corrosion panel was relatively dense and adherent, thus preventing the underlying metal from uncontrollable sulfidation attack. The maximum corrosion rate on T2 after a total exposure of 31 months in JMSS4 was ~10 mpy. This corrosion rate could be further reduced if the sulfide scale continues to remain dense and adherent to the tube surfaces.

3. The two weld-overlay coatings and chromized coating provided satisfactory protection to the T2 tubes from the corrosion attack in JMSS4. On the other hand, the aluminum-spray coating was relatively porous and unable to prevent sulfur from penetrating into the coating layer.

4. Results of the UT survey performed during the last three outages have started to show the corrosion wastage on some areas of the lower furnace walls in JMSS4. However, due to a large standard deviation associated with UT measurement, the trend of wall wastage still can not be clearly defined based on the available UT data.

7.0 RECOMMENDATIONS

It is recommended that destructive metallurgical examination of the corrosion test panel in JMSS4 be continued. Additional wastage data can be used to better define the long-term corrosion trend in JMSS4.

8.0 REFERENCES

1. C. F. Eckhart, R. F. DeVault, and S. C. Kung, "Full-Scale Demonstration of Low-NO_X Cell™ Burner Retort, Long-Term Testing," Program under DOE Cooperative Agreement DE-FC22-90PC90545, Task Report No. DOE/PC/90545-1, March 1994.

APPENDIX A

SUMMARY OF UT DATA

			FW UT READINGS			
			TEST POINT AVERAGES			
	TUBE #	TEST POINT	FALL '94	SPRING '93	FALL '91	COMMENTS
	FROM LHSW					
EL. 580'-3"	424	1	244		236	
	423	2	247		228	
	417	3	233		230	
	416	4	234		227	
	410	5	237		229	
	409	6	233		243	
	403	7	238	240	236	REPLACED FALL '91
	402	8	238	239	230	REPLACED FALL '91
	396	9	227	237	235	REPLACED FALL '91
	395	10	237	244	238	REPLACED FALL '91
	389	11	239	239	232	REPLACED FALL '91
	388	12	237	239	241	REPLACED FALL '91
	384	13	242	243	248	
	383	14	240	247	232	
	364	15	235		230	
	363	16	237		239	
	354	17	231	238	236	
	353	18	236	237	234	
	321	19	N/A	251		REPLACED SPRING '93
	320	20	N/A	242		REPLACED SPRING '93
	293	21	N/A			REPLACED SPRING '93
	292	22	N/A			REPLACED SPRING '93

			RHSW UT READINGS			
			TEST POINT AVERAGES			
	TUBE #	**TEST POINT**	**FALL '94**	**SPRING '93**	**FALL '91**	**COMMENTS**
	FROM FW					
EL. 601'-6"		NOT AVAILABLE				
EL. 577'-2"	8	1	242	241	240	
	9	2	237	241	241	
	14	3	233	242	230	
	15	4	234	251	235	
	20	5	238	249	242	
	21	6	235	251	237	
	28	7	227	251	231	
	29	8	228	251	229	
	91	9	260		250	REPLACED SPRING '89
	92	10	253		244	REPLACED SPRING '89
	Tube from FW Hopper Nose					
EL. 558'-0"	-2	1	231	240	234	
	-1	2	225	240	236	
	6	3	234	238	228	
	7	4	237	237	225	
	13	5	236	239	229	
	14	6	237	239	232	
	20	7	237	243	235	
	21	8	236	242	236	
	25	9	238		236	
	26	10	244		231	

			LHSW UT READINGS			
			TEST POINT AVERAGES			
	TUBE # FROM FW	TEST POINT	FALL '94	SPRING '93	FALL '91	COMMENTS
EL. 601'-6"	59	1	N/A	248		REPLACED SPRING '88
	60	2	234	239	245	REPLACED SPRING '88
	65	3	239	243	246	REPLACED SPRING '88
	66	4	237	237	238	REPLACED SPRING '88
	72	5	235	241	245	REPLACED SPRING '86
	73	6	240	242	243	REPLACED SPRING '86
	80	7	N/A			
	81	8	N/A			
EL. 581'-2"	34	1*	290	250	251	REPLACED SPRING '90
	35	2*	272	247	247	REPLACED SPRING '90
	41	3	238	248	237	REPLACED SPRING '88
	42	4	236		244	REPLACED SPRING '88
	48	5	N/A		245	REPLACED SPRING '88
	49	6	N/A		248	REPLACED SPRING '88
	55	7	233		243	REPLACED SPRING '88
	56	8	244		238	REPLACED SPRING '88
	62	9	246		231	REPLACED SPRING '87
	63	10	245		240	REPLACED SPRING '87
	69	11*	256	241	241	REPLACED SPRING '87
	70	12*	241	247	249	REPLACED SPRING '87
	76	13	240	245	239	REPLACED SPRING '87
	77	14	241	243	244	REPLACED SPRING '87
	83	15	N/A	248		REPLACED SPRING '87
	84	16	N/A	239		REPLACED SPRING '87
		* - ALUMINIZED				

			LHSW UT READINGS			
			TEST POINT AVERAGES			
		TEST POINT	FALL '94	SPRING '93	FALL '91	COMMENTS
EL. 577'-5"	34	1*	264	249	254	REPLACED SPRING '90
	35	2*	257	252	255	REPLACED SPRING '90
	41	3	240	247	247	REPLACED SPRING '88
	42	4	242	245	249	REPLACED SPRING '88
	48	5	237		249	REPLACED SPRING '88
	49	6	248		253	REPLACED SPRING '88
	55	7	244		252	REPLACED SPRING '88
	56	8	248		246	REPLACED SPRING '88
	62	9	245		240	REPLACED SPRING '87
	63	10	241		240	REPLACED SPRING '87
	69	11*	239	252	250	REPLACED SPRING '87
	70	12*	262	249	249	REPLACED SPRING '87
	76	13	251	249	250	REPLACED SPRING '87
	77	14	260	252	259	REPLACED SPRING '87
	83	15	243	253	245	REPLACED SPRING '87
	84	16	246	241	238	REPLACED SPRING '87
	Tube # from Hopper Nose					
EL. 558'-0"	1	1	238	251	238	
	2	2	230	247	220	
	7	3	232	243	229	
	8	4	230	243	235	
		* - ALUMINIZED				

			RHSW TEST PANEL READINGS			
			TEST POINT AVERAGES			
	TUBE # ON TEST PANEL FROM FW	TEST POINT	FALL '94	SPRING '93	FALL '91	COMMENTS
EL. 590'-2"	1	1	246			Bare T2
	2	2	246			Bare T2
	3	3	237			Bare T2
	4	4	242			Bare T2
	5	5	240			Bare T2
	6	6	282			Aluminum Spray on T2
	7	7	284			Aluminum Spray on T2
	8	8	284			Aluminum Spray on T2
	9	9	254			Aluminum Spray on T2
	10	10	267			Aluminum Spray on T2
	11	11	242			Aluminum Spray on T2
	12	12	259			Aluminum Spray on T2
	13	13	243			Aluminum Spray on T2
	14	14	263			Aluminum Spray on T2
	15	15	260			Aluminum Spray on T2
	16	16	239			Bare T2
	17	17	239			Bare T2
	18	18	247			Bare T2
	19	19	244			Bare T2
	20	20	235			Bare T2
	21	21	226			Bare T2
	22	22	226			Bare T2
	23	23	240			Bare T2
	24	24	235			Bare T2
	25	25	237			Bare T2
	29	26	310			309 Weld Overlay on T2
	32	27	345			309 Weld Overlay on T2
	36	28	227			Bare T2
	37	29	236			Bare T2
	38	30	231			Bare T2
	39	31	236			Bare T2
	40	32	228			Bare T2
	41	33	236			Bare T2
	42	34	229			Bare T2
	43	35	233			Bare T2
	44	36	228			Bare T2
	45	37	239			Bare T2
	49	38	357			308 Weld Overlay on T2
	52	39	322			308 Weld Overlay on T2
	56	40	230			Bare T2
	57	41	237			Bare T2
	58	42	232			Bare T2
	59	43	232			Bare T2
	60	44	223			Bare T2
	61	45	233			Bare T2
	62	46	234			Bare T2
	63	47	229			Bare T2
	64	48	231			Bare T2
	65	49	229			Bare T2
	66	50	239			Chromized T2
	67	51	245			Chromized T2
	68	52	245			Chromized T2
	69	53	243			Chromized T2
	70	54	247			Chromized T2
	71	55	241			Chromized T2
	72	56	242			Chromized T2
	73	57	241			Chromized T2
	74	58	237			Chromized T2
	75	59	240			Chromized T2
	76	60	235			Bare T2
	77	61	229			Bare T2
	78	62	226			Bare T2
	79	63	226			Bare T2
	80	64	233			Bare T2

			RHSW TEST PANEL READINGS			
			TEST POINT AVERAGES			
	TUBE # on TEST PANEL FROM FW	TEST POINT	FALL '94	SPRING '93	FALL '91	COMMENTS
EL. 586'-4"	1	1	225	245		Bare T2
	2	2	229	246		Bare T2
	3	3	225	246		Bare T2
	4	4	232	250		Bare T2
	5	5	238	248		Bare T2
	6	6	239	250		Aluminum Spray on T2
	7	7	245	267		Aluminum Spray on T2
	8	8	246	256		Aluminum Spray on T2
	9	9	248	287		Aluminum Spray on T2
	10	10	244	255		Aluminum Spray on T2
	11	11	250	280		Aluminum Spray on T2
	12	12	245	270		Aluminum Spray on T2
	13	13	241	260		Aluminum Spray on T2
	14	14	238	249		Aluminum Spray on T2
	15	15	244	254		Aluminum Spray on T2
	16	16	240	251		Bare T2
	17	17	222	237		Bare T2
	18	18	231	245		Bare T2
	19	19	217	236		Bare T2
	20	20	224	236		Bare T2
	21	21	238	246		Bare T2
	22	22	222	234	239	Bare T2
	23	23	228	236	235	Bare T2
	24	24	219	230	233	Bare T2
	25	25	227	237	236	Bare T2
	29	26	292	295	292	309 Weld Overlay on T2
	32	27	323	338	322	309 Weld Overlay on T2
	36	28	210	231	242	Bare T2
	37	29	224	235	239	Bare T2
	38	30	217	229	237	Bare T2
	39	31	226	239	238	Bare T2
	40	32	203	230	233	Bare T2
	41	33	220	242	236	Bare T2
	42	34	214	234	232	Bare T2
	43	35	225	243	235	Bare T2
	44	36	212	228	237	Bare T2
	45	37	226	235	230	Bare T2
	49	38	326	336	336	308 Weld Overlay on T2
	52	39	339	354	347	308 Weld Overlay on T2
	56	40	214	238	235	Bare T2
	57	41	228	241	237	Bare T2
	58	42	213	235	232	Bare T2
	59	43	228	244	244	Bare T2
	60	44	213	239		Bare T2
	61	45	229	239		Bare T2
	62	46	232	246		Bare T2
	63	47	215	238	232	Bare T2
	64	48	225	243	238	Bare T2
	65	49	212	226	230	Bare T2
	66	50	242	245	243	Chromized T2
	67	51	237	248	236	Chromized T2
	68	52	238	245	231	Chromized T2
	69	53	242	246	244	Chromized T2
	70	54	244	249	245	Chromized T2
	71	55	242	249	239	Chromized T2
	72	56	243	249	240	Chromized T2
	73	57	252	251	249	Chromized T2
	74	58	240	245	240	Chromized T2
	75	59	241	250	239	Chromized T2
	76	60	228	242	230	Bare T2
	77	61	210	231	230	Bare T2
	78	62	230	244	237	Bare T2
	79	63	222	240	233	Bare T2
	80	64	224	237	250	Bare T2

			RHSW TEST PANEL READINGS			
			TEST POINT AVERAGES			
	TUBE # ON TEST PANEL FROM FW	TEST POINT	FALL '94	SPRING '93	FALL '91	COMMENTS
EL. 584'-4"	1	1	235	240		Bare T2
	2	2	233	235		Bare T2
	3	3	232	250		Bare T2
	4	4	236	245		Bare T2
	5	5	236	240		Bare T2
	6	6	246	265		Aluminum Spray on T2
	7	7	248	275		Aluminum Spray on T2
	8	8	258	265		Aluminum Spray on T2
	9	9	261	270		Aluminum Spray on T2
	10	10	242	270		Aluminum Spray on T2
	11	11	248	280		Aluminum Spray on T2
	12	12	266	275		Aluminum Spray on T2
	13	13	241	265		Aluminum Spray on T2
	14	14	245	270		Aluminum Spray on T2
	15	15	244	260		Aluminum Spray on T2
	16	16	243	245		Bare T2
	17	17	236	230		Bare T2
	18	18	238	240		Bare T2
	19	19	228	222		Bare T2
	20	20	235	240		Bare T2
	21	21	229	237	238	Bare T2
	22	22	224	222	239	Bare T2
	23	23	230	227	232	Bare T2
	24	24	215	228	245	Bare T2
	25	25	225	239	237	Bare T2
	29	26	310	308	311	309 Weld Overlay on T2
	32	27	327	314	328	309 Weld Overlay on T2
	36	28	201	221	241	Bare T2
	37	29	219	231	236	Bare T2
	38	30	205	227	240	Bare T2
	39	31	228	236	237	Bare T2
	40	32	207	221	234	Bare T2
	41	33	231	239	238	Bare T2
	42	34	207	221	239	Bare T2
	43	35	210	232	239	Bare T2
	44	36	209	225	238	Bare T2
	45	37	233	235	243	Bare T2
	49	38	351	365	352	308 Weld Overlay on T2
	52	39	351	345	329	308 Weld Overlay on T2
	56	40	209	226	239	Bare T2
	57	41	226	239	233	Bare T2
	58	42	205	228	237	Bare T2
	59	43	220	237	238	Bare T2
	60	44	220	231	240	Bare T2
	61	45	226	242	246	Bare T2
	62	46	228	237	237	Bare T2
	63	47	218	235	244	Bare T2
	64	48	224	234	235	Bare T2
	65	49	216	232	240	Bare T2
	66	50	240	242	241	Chromized T2
	67	51	236	250	251	Chromized T2
	68	52	241	247	251	Chromized T2
	69	53	240	247	250	Chromized T2
	70	54	240	245	247	Chromized T2
	71	55	241	250	250	Chromized T2
	72	56	234	245	241	Chromized T2
	73	57	245	243	248	Chromized T2
	74	58	240	251	250	Chromized T2
	75	59	237	238	241	Chromized T2
	76	60	232	240	242	Bare T2
	77	61	223	238	240	Bare T2
	78	62	228	242	227	Bare T2
	79	63	219	230	232	Bare T2
	80	64	232	237	240	Bare T2

			RHSW TEST PANEL READINGS			
			TEST POINT AVERAGES			
	TUBE # ON TEST PANEL FROM FW	TEST POINT	FALL '94	SPRING '93	FALL '91	COMMENTS
EL. 582'-4"	1	1	230	246		Bare T2
	2	2	235	243		Bare T2
	3	3	232	248		Bare T2
	4	4	224	242		Bare T2
	5	5	239	242		Bare T2
	6	6	239	284		Aluminum Spray on T2
	7	7	238	289		Aluminum Spray on T2
	8	8	243	288		Aluminum Spray on T2
	9	9	237	287		Aluminum Spray on T2
	10	10	240	286		Aluminum Spray on T2
	11	11	236	280		Aluminum Spray on T2
	12	12	239	289		Aluminum Spray on T2
	13	13	241	286		Aluminum Spray on T2
	14	14	243	280		Aluminum Spray on T2
	15	15	240	287		Aluminum Spray on T2
	16	16	241	291		Bare T2
	17	17	227	278		Bare T2
	18	18	232	245		Bare T2
	19	19	227	249		Bare T2
	20	20	234	244		Bare T2
	21	21	224	244	237	Bare T2
	22	22	221	247	234	Bare T2
	23	23	226	240	234	Bare T2
	24	24	219	239	245	Bare T2
	25	25	233	241	247	Bare T2
	29	26	317	334	302	309 Weld Overlay on T2
	32	27	322	342	315	309 Weld Overlay on T2
	36	28	211	228	235	Bare T2
	37	29	224	238	236	Bare T2
	38	30	222	236	243	Bare T2
	39	31	231	240	247	Bare T2
	40	32	219	232	234	Bare T2
	41	33	234	237	236	Bare T2
	42	34	204	233	230	Bare T2
	43	35	230	241	238	Bare T2
	44	36	208	231	245	Bare T2
	45	37	230	240	236	Bare T2
	49	38	332	346	324	308 Weld Overlay on T2
	52	39	331	339	320	308 Weld Overlay on T2
	56	40	204	237	240	Bare T2
	57	41	233	245	247	Bare T2
	58	42	210	235	240	Bare T2
	59	43	229	237	233	Bare T2
	60	44	215	228	229	Bare T2
	61	45	231	245	237	Bare T2
	62	46	227	242	239	Bare T2
	63	47	215	238	238	Bare T2
	64	48	234	243	240	Bare T2
	65	49	214	239	234	Bare T2
	66	50	232	240	234	Chromized T2
	67	51	245	244	248	Chromized T2
	68	52	242	245	247	Chromized T2
	69	53	235	247	240	Chromized T2
	70	54	236	243	244	Chromized T2
	71	55	234	246	236	Chromized T2
	72	56	238	255	250	Chromized T2
	73	57	238	250	245	Chromized T2
	74	58	234	245	243	Chromized T2
	75	59	233	247	246	Chromized T2
	76	60	223	241	237	Bare T2
	77	61	207	241	245	Bare T2
	78	62	234	245	238	Bare T2
	79	63	212	232	239	Bare T2
	80	64	226	242	244	Bare T2

			RHSW TEST PANEL READINGS			
			TEST POINT AVERAGES			
	TUBE # ON TEST PANEL FROM FW	TEST POINT	FALL '94	SPRING '93	FALL '91	COMMENTS
EL. 580'-7"	1	1	241	242		Bare T2
	2	2	248	248		Bare T2
	3	3	236	242		Bare T2
	4	4	238	238		Bare T2
	5	5	248	250		Bare T2
	6	6	273	273		Aluminum Spray on T2
	7	7	281	286		Aluminum Spray on T2
	8	8	271	275		Aluminum Spray on T2
	9	9	261	276		Aluminum Spray on T2
	10	10	273	281		Aluminum Spray on T2
	11	11	255	288		Aluminum Spray on T2
	12	12	267	271		Aluminum Spray on T2
	13	13	261	278		Aluminum Spray on T2
	14	14	265	272		Aluminum Spray on T2
	15	15	275	289		Aluminum Spray on T2
	16	16	250	243		Bare T2
	17	17	230	245		Bare T2
	18	18	237	241		Bare T2
	19	19	238	241		Bare T2
	20	20	231	245		Bare T2
	21	21	234	239	230	Bare T2
	22	22	239	246	238	Bare T2
	23	23	242	242	241	Bare T2
	24	24	237	238	238	Bare T2
	25	25	229	237	234	Bare T2
	29	26	316	319	309	309 Weld Overlay on T2
	32	27	320	351	326	309 Weld Overlay on T2
	36	28	233	245	242	Bare T2
	37	29	231	242	232	Bare T2
	38	30	231	243	236	Bare T2
	39	31	235	247	234	Bare T2
	40	32	219	238	231	Bare T2
	41	33	236	243	241	Bare T2
	42	34	229	240	239	Bare T2
	43	35	236	241	231	Bare T2
	44	36	229	246	247	Bare T2
	45	37	236	247	237	Bare T2
	49	38	302	339	306	308 Weld Overlay on T2
	52	39	321	342	315	308 Weld Overlay on T2
	56	40	237	241		Bare T2
	57	41	233	241	242	Bare T2
	58	42	225	238	232	Bare T2
	59	43	236	243	236	Bare T2
	60	44	220	225	236	Bare T2
	61	45	234	242	234	Bare T2
	62	46	235	246	231	Bare T2
	63	47	226	249	248	Bare T2
	64	48	231	248	236	Bare T2
	65	49	222	239	230	Bare T2
	66	50	243	245	248	Chromized T2
	67	51	239	243	240	Chromized T2
	68	52	230	241	238	Chromized T2
	69	53	231	251	247	Chromized T2
	70	54	234	252	253	Chromized T2
	71	55	241	252	254	Chromized T2
	72	56	243	242	238	Chromized T2
	73	57	229	245	248	Chromized T2
	74	58	231	247	246	Chromized T2
	75	59	232	245	247	Chromized T2
	76	60	234	249	238	Bare T2
	77	61	213	240	233	Bare T2
	78	62	231	240	238	Bare T2
	79	63	226	247	239	Bare T2
	80	64	234	249	250	Bare T2

			FW BURNER PANEL READINGS			
			TEST POINT AVERAGES			
	TUBE # FROM LHSW	TEST POINT	FALL '94	SPRING '93	FALL '91	COMMENTS
BURNER 4D1L	81	9*	275			REPLACED SPRING '93
	80	10*	273			REPLACED SPRING '93
	48	11*	273			REPLACED SPRING '93
	47	12*	275			REPLACED SPRING '93
BURNER 4D2L	147	9*	266			REPLACED SPRING '88
	146	10*	265			REPLACED SPRING '88
	104	11*	265			REPLACED SPRING '93
	103	12*	269			REPLACED SPRING '93
BURNER 4B3L	186	1*	250			REPLACED SPRING '93
	185	2*	240			REPLACED SPRING '93
	171	3*	285			REPLACED SPRING '93
	170	4*	263			REPLACED SPRING '93
	204	5*	246			REPLACED SPRING '93
	203	6*	269			REPLACED SPRING '93
	202	9*	270			REPLACED SPRING '93
	201	10*	276			REPLACED SPRING '93
	171	11*	280			REPLACED SPRING '93
	170	12*	278			REPLACED SPRING '93
	186	13*	268			REPLACED SPRING '93
	185	14*	269			REPLACED SPRING '93
BURNER 4D6L	369	1	223	235	231	
	368	2	230	239	236	
	354	3	227	228	225	
	353	4	232	230	232	
	384	5	242	245	241	
	383	6	237	236	240	
	384	9	221	231	235	
	383	10	237		237	
	352	11*	263	272	271	REPLACED SPRING '89
	351	12*	268	276	277	REPLACED SPRING '89
	369	13	236	234	229	
	368	14	229	230	232	
		* - ALUMINIZED				

			FW BURNER PANEL READINGS			
			TEST POINT AVERAGES			
	TUBE # FROM LHSW	TEST POINT	FALL '94	SPRING '93	FALL '91	COMMENTS
BURNER 4A1U	48	3*	264			REPLACED SPRING '93
	47	4*	252			REPLACED SPRING '93
	80	5*	269			REPLACED SPRING '93
	79	6*	275			REPLACED SPRING '93
	48	9*	266			REPLACED SPRING '93
	47	10*	248			REPLACED SPRING '93
	80	11*	263			REPLACED SPRING '93
	79	12*	267			REPLACED SPRING '93
	65	13	235	238		
	64	14	229	242		
BURNER 4A2U	102	3*	262			REPLACED SPRING '93
	101	4*	261			REPLACED SPRING '93
	147	5*	277	265	268	REPLACED SPRING '88
	146	6*	268	258	267	REPLACED SPRING '88
BURNER 4B3U	204	5*	270			REPLACED SPRING '93
	203	6*	285			REPLACED SPRING '93
	202	9*	293			REPLACED SPRING '93
	201	10*	279			REPLACED SPRING '93
	171	11*	269			REPLACED SPRING '93
	170	12*	257			REPLACED SPRING '93
	186	13	237	247		
	185	14	237	248		
BURNER 4A6U	354	3	233	243	239	
	353	4*	260	245	242	
	384	5	236	241	239	
	383	6	235	243	237	
	354	9	234	240	235	
	353	10	224	241	238	
	384	11	227	232	232	
	383	12	234	233	230	
	369	13	233	234	237	
	368	14	236	245	250	
		* - ALUMINIZED				

			RW BURNER PANEL READINGS			
			TEST POINT AVERAGES			
	TUBE #	TEST POINT	FALL '94	SPRING '93	FALL '91	COMMENTS
	FROM LHSW					
BURNER 4C2L	124	1	212	229	229	
	125	2	222	233	228	
	140	3	228		230	
	141	4	232		234	
	108	5	238	244	238	
	109	6	240	247	242	
	140	9	235		239	
	141	10	233		232	
	108	11	238	240	250	
	109	12	232	242	240	
	123	13	235	242	241	
	124	14	228	235	231	
BURNER 4E3L	169	3*	266			REPLACED SPRING '93
	170	4*	268			REPLACED SPRING '93
	203	5*	259			REPLACED SPRING '93
	204	6*	265			REPLACED SPRING '93
	203	9*	273			REPLACED SPRING '93
	204	10*	281			REPLACED SPRING '93
	169	11*	268			REPLACED SPRING '93
	170	12*	267			REPLACED SPRING '93
	183	13*	269			REPLACED SPRING '93
	184	14*	265			REPLACED SPRING '93
BURNER 4C5L	324	9*	259			REPLACED SPRING '93
	325	10*	252			REPLACED SPRING '93
BURNER 4C6L	390	3	232			
	391	4	234			
	346	5*	285			REPLACED SPRING '93
	347	6*	289			REPLACED SPRING '93
	390	9	228			
	391	10	235			
	345	11*	269			REPLACED SPRING '93
	346	12*	274			REPLACED SPRING '93
		* - ALUMINIZED				

			RW BURNER PANEL READINGS			
			TEST POINT AVERAGES			
	TUBE #	**TEST POINT**	**FALL '94**	**SPRING '93**	**FALL '91**	**COMMENTS**
	FROM LHSW					
BURNER 4F2U	140	3	233		235	
	141	4	236		243	
	106	5	235	239	236	
	107	6	234	238	241	
	140	9	239		240	
	141	10	238		247	
	106	11	237	235	238	
	107	12	239	235	242	
	124	13	224	235	230	
	125	14	227	236	242	
BURNER 4E3U	203	3*	265			REPLACED SPRING '93
	204	4*	268			REPLACED SPRING '93
	169	5*	262			REPLACED SPRING '93
	170	6*	265			REPLACED SPRING '93
	203	9*	289			REPLACED SPRING '93
	204	10*	285			REPLACED SPRING '93
	169	11*	283			REPLACED SPRING '93
	168	12*	275			REPLACED SPRING '93
	185	13	230	237		
	184	14	227	236		
BURNER 4F5U	324	9*	248			REPLACED SPRING '93
	325	10*	239			REPLACED SPRING '93
	290	11*	261			REPLACED SPRING '93
	291	12*	264			REPLACED SPRING '93
	306	13	235			
	307	14	233			
BURNER 4F6U	390	3	233	233		
	391	4	225	236		
	346	5*	288			REPLACED SPRING '93
	347	6*	282			REPLACED SPRING '93
	390	9	235			
	391	10	234			
	345	11*	275			REPLACED SPRING '93
	346	12*	271			REPLACED SPRING '93
	366	13	237		245	REPLACED FALL '91
	367	14	229		245	REPLACED FALL '91
		* - ALUMINIZED				