WHITE PAPER

Heat Exchanger Tube Wear By Mechanical Cleaners

ALAN W. HOVLAND, P.E.
Consultant
Momson, Colorado 80465

DREW A. RANKIN
Cincinnati Gas & Electric Company
W.C. Beckjord Station
New Richmond, Ohio 45157

EDWARD G. SAXON
Conco Systems, Inc
135 Sylvan Street
Verona, Pennsylvania 15147

ABSTRACT

Maintenance of power plant heat exchanger tubes often uses the mechanical cleaner method. This cleaning technique, using steel cleaners, was tested to determine possible tube wall reduction, or we ar, on copper-nickel heat exchanger tubes. Results indicate insignificant tube wear by this cleaning method.

PURPOSE OF TEST

The test was performed to determine the amount of tube wear using mechanical tube cleaners. These cleaners, or scrapers, are used in numerous power plant heat exchangers other than the main condenser. The cleaners tested were manufactured by Conco Systems, and were the C4S model number, which indicates a Conco 4-blade cutting surface, steel construction. See Figure 1 for typical C4S cleaner styles, Figure 2 for water gun, and Figure 3 for cross-sectional view of cleaning action.

Figure 1. Mechanical Tube Cleaners (Conco C4S)

TEST PROCEDURE

The test was performed on three new heat exchanger tubes at the Cincinnati Gas and Electric's W.C. Beckjord Station, New Richmond, Ohio. The procedure used was as follows:

Three new heat exchanger tubes approximately 30 feet long, were secured, each in an angle support spanning the length of the tube.

On Tube A, a new cleaner was used on every shot. Tube B used a new cleaner every ten shots. Tube C used the same cleaner for every shot. The Tube B method represents the most comparative simulation to actual cleaning because the tube cleaners are commonly used several times and are then discarded.

The cleaners were propelled through the tubes using 200 to 400 PSIG water pressure provided by a Conco water gun and pump. A bucket and tarp were used to catch the cleaner and water as they exited the tube. See Figure 4 for typical test set-up. A high speed cutoff wheel was used to remove six-inch samples from each tube.

Each tube received 100 shots, or passes, with the cleaners as described above. The method used to check wall thickness consisted of carefully measuring the tube wall of the three test tubes & after various intervals (1st, 2nd, 10th, 25th, 50th and 100th pass). The primary measuring device was Brown & Sharpe digital vernier caliper accurate to four decimal places or 0.0005 inch. All measurements were double checked using a second dial-type calipers accurate to three decimal places, or 0.001 inch.

The tube wall thickness was initially measured at four end (exit) locations, one in each quadrant, and then averaged to attain the average tube wall thickness. Thereafter, the tube wall was measured at comparable quadrants after removal of six-inch inspection samples and after the 1st, 2nd, 10th, 25th, 50th and 100th shot with the cleaners. The tube wall thinning was measured in each quadrant as shown in Figure 4.

The four measured thickness were taken approximately 0.1 inch inside each cutoff end. This was to ensure that any cutoff burrs or metal slivers did not affect the measurement.

CONCO

Figure 2. Conco Water Gun, 200-400 PSIG

TUBE MATERIAL

The tube material was 90/10 copper nickel, one inch diameter, 18 BWG. The nominal wall thickness for 18 BWG is 0.049 inch, +/- 0.0045 (minimum thickness 0.0445 inch). The copper-nickel tube was alloy 706, which is a cold worked material produced by roll forming and seam-welding at high frequency current (450 kilohertz). Forging rollers at the exit of the welding process pressures the heated tube walls into each other to form a seamed tube. Finishing rolls then follow to assure tube straightness and uniform diameter.

The copper-nickel 706 alloy tubes conform to ASTM B543 with minimum tensile strength of 45 kPSI and a minimum yield strength of 30 kPSI.

TEST RESULTS

The results were plotted using the four quadrant data and the average wall thickness as a function of a number of shots.

The original measured wall thickness (average)for each tube was 0.0456, 0.0460 and 0.0464 inch. The minimum specification thickness is 0.0445 inch. All tubes had a minimum initial thickness above this minimum value.

Tube A: New Cleaner Each Shot

On Tube A , the original wall thickness measured 0.0456 inch. Over the span of 100 cleaner shots, the sample measured 0.0451 inch; only 0.0005 inch less than the original tube wall. See Figure 5 for average wall thickness vs. number of cleaning shots.

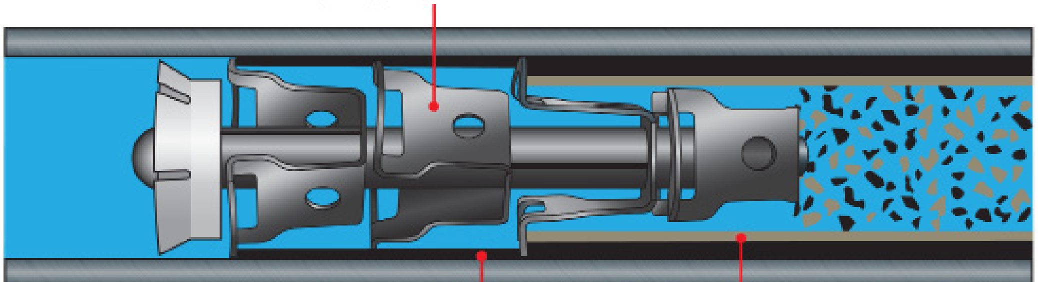


Figure 3. Cross-section showing mechanical tube cleaning action.

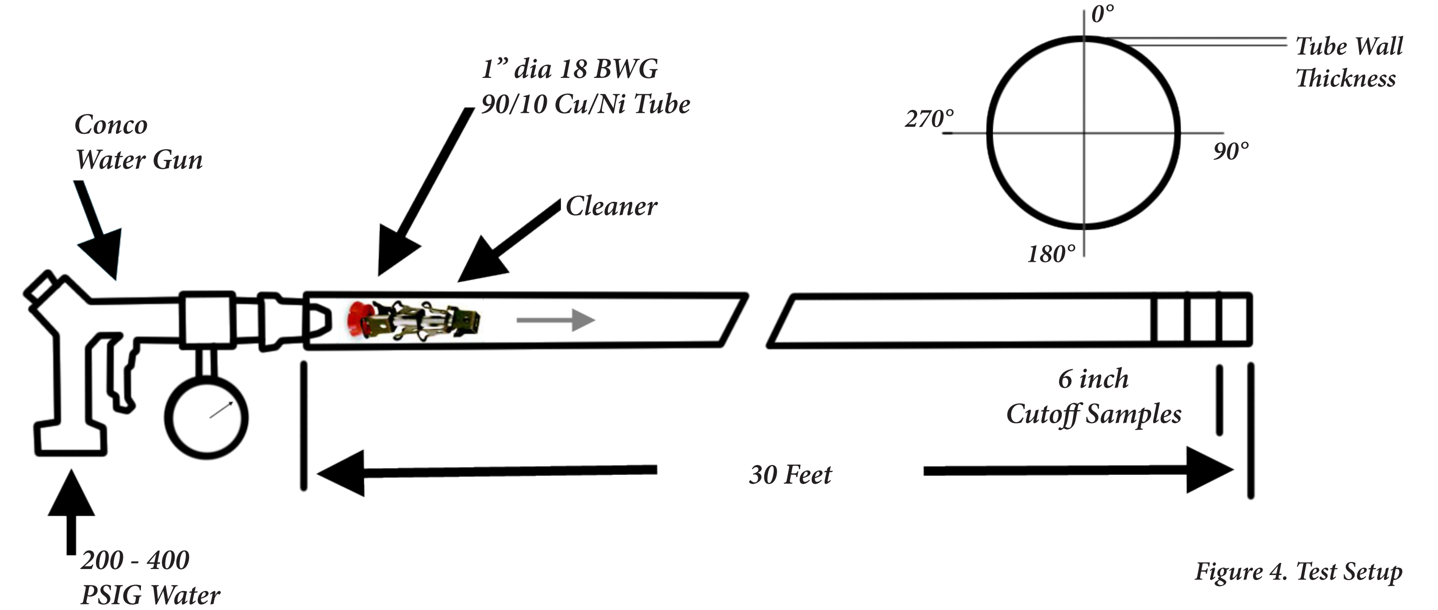


Figure 4. Test Setup

Tube B: New Cleaner Each Ten Shots

Tube B's original wall thickness measured 0.0460 inch. The maximum difference in wall thickness occurred at pass #10, 0.0451 inch. This measurement represents a wall thickness reduction of 0.0009 inch less than the original. After 100 shots, the tube wall measured 0.0452 inch; 0.0008 inch less than the original. See Figure 6 for average wall thickness vs. number of cleaning shots.

Tube C: Same Cleaner for 100 Shots

Tube C's original wall thickness measured 0.0464 inch. The maximum difference in wall thickness occurred at pass #25, 0.0442 inch. This represents a 0.0022 inch reduction in wall thickness from the original. From 25 shots to 100 shots there was an apparent increase of wall thickness. This is most likely due to the measurement being taken after the six inch cutoff sample was removed. This apparent increase may be attributable to longitudinal variation in the tube thickness which can occur during the manufacturing roll forming process.

At 100 shots of the cleaner, the tube wall measured 0.0455 inch, or 0.0009 inch less than the original. See Figure 7 for average wall thickness vs. number of cleaning shots.

ANALYSIS OF RESULTS

The test wear after 100 shots is summarized as follows:

--- Wall Reduction ---

	100 Shots	Average/Shot
Tube A	0.0005"	0.000005"
Tube B	0.0008"	0.000008"
Tube C	0.0009"	0.000009"

This data indicates that more times the same cleaner is used, an increase in tube wear is noted. This would indicate that more frequent cleaner replacement is desirable.

Mechanical cleaners are usually replaced due to corrosion, wear or loss. The typical use is ten shots per cleaner before discard.

The data also indicates that the total reduction after 100 shots for Tube B (typical cleaner replacement at ten shots) is only 0.0008 inch. At this rate, it would take over 2800 passes per tube to reduce the wall thickness to a 50% level.[1] Thus, at the normal power plant heat exchanger cleaning frequency of one cleaning per year, it would (theoretically) take 2800 years to reduce the wall thickness to a critical level.

[1] *Average initial thickness x 0.50/wear x 100*

- *(0.056 + 0.0460 + 0.0464)/3 x 0.50/0.0008 x 100*
- *2875 passes*

In contrast to this prediction, if severe fouling is allowed to build up in plant heat exchangers, the tube life expectancy would only be five to ten years. The use of mechanical cleaners, which can normally remove 90% of the fouling, will increase the life of plant heat exchanger tubes, and also provide an increase in operating efficiency.

Another observation from this test data is that the majority of the tube wall reduction occurs within the first <u>two</u> cleaner shots. The reason for this could be that the first two passes on the new tubes used in this test, function as cleanout passes - removing foreign material, smoothing out tube irregularities, removing some "exfoliation" of the base metal. Thereafter, the reduction in the tube wall is almost insignificant and within the accuracy of the test measuring devices.

Figure 5. Tube A - New Cleaner Each Time

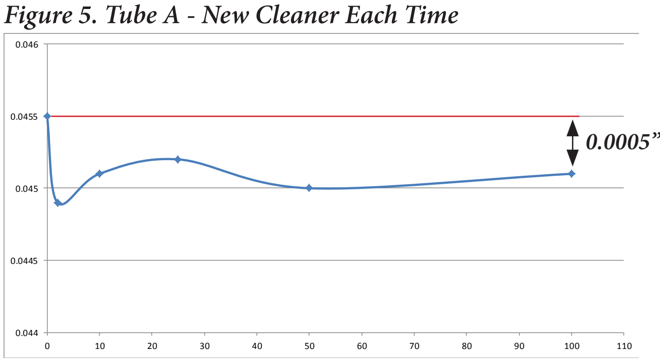


Figure 6. Tube B - New Cleaner Every 10 Shots

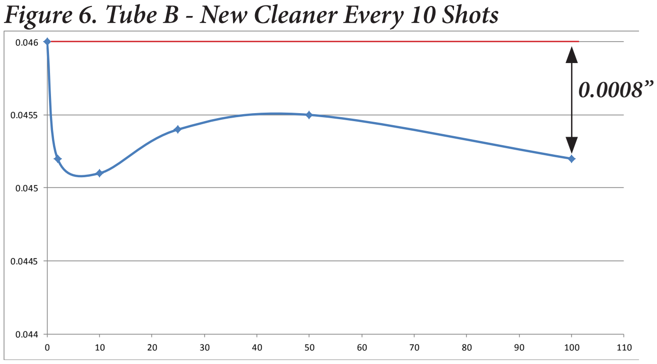
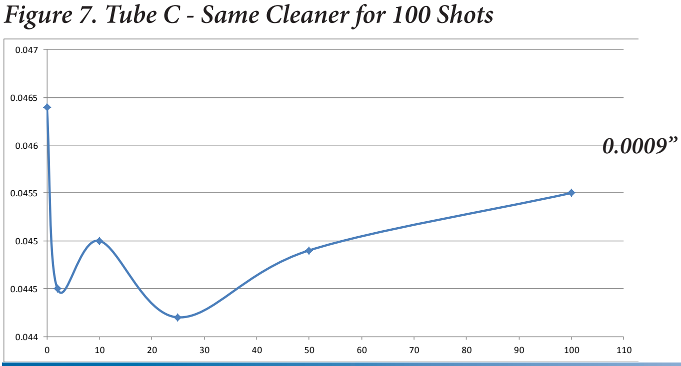


Figure 7. Tube C - Same Cleaner for 100 Shots



CONCLUSION

The tube wear by the mechanical, steel constructed cleaners was found to be from 0.0005 inch to 0.00009 inch after 100 shots for the three different procedures used in the test. The variation in procedure was the amount of shots (or passes) the cleaners were used before they were replaced.

Since the tube material for this test was 90/10 copper-nickel, it is reasonable to assume that tube wear on the harder tubes, such as stainless steel or titanium, would be on this order of magnitude or less.

In summary, the overall test results indicate a very small or insignificant amount of tube wear by this tube cleaning technique.

Table 1. Tube Wall Thickness in Inches (Averaged Data Shown in Figures 5, 6 and 7.)

		Number of Shots					
	x°	0	2	10	25	50	100
Tube A	0°	.0455	0.445	.0450	.0450	.0450	.0455
	90°	.0455	.0450	.0450	.0450	.0445	.0450
	180°	.0460	.0450	.0455	.0455	.0450	.0445
	270°	.0455	.0450	.0450	.0455	.0455	.0455
	AVG	.0455	.0449	.0451	.0452	.0450	.0451
Tube B	0°	.0465	.0455	.0455	.0450	.0455	.0450
	90°	.0460	.0445	.0455	.0455	.0455	.0450
	180°	.0455	.0455	.0450	.0455	.0455	.0455
	270°	.0460	.0455	.0445	.0455	.0455	.0455
	AVG	.0460	.0452	.0451	.0454	.0455	.0452
Tube C	0°	.0450	.0435	.0445	.0445	.0450	.0455
	90°	.0465	.0445	.0455	.0455	.0450	.0460
	180°	.0455	.0450	.0450	.0440	.0450	.0455
	270°	.0465	.0450	.0450	.0440	.0445	.0450
	AVG	.0454	.0455	.0450	.0442	.0449	.0455

CONCO