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THE USE OF AN EDDY CURRENT INSPECTION OF BRASS TUBES IN A SURFACE CONDENSER TO PROVIDE A CONDITION ASSESSMENT

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ABSTRACT

A Borelex, Inc. Power Plant in Ashland, Maine had a need to evaluate their Surface Condenser. The unit had 27 tubes that were previously plugged. The unit had steam impingement troubles in the past and the plant wanted to focus the inspection in this area. The condenser contains 6,084 tubes that are 7/8" OD, 0.049" wall, 303" long, admiralty brass. The plant decided to use the Eddy Current Technique (ECT) to inspect 600 tubes. The condenser uses local river water.

TesTex told the plant the unit could be inspected and a color-coded tube sheet map showing the results could be completed in one shift. The contractor arrived at the plant at 7 am. The crew went through the usual plant indoctrination and safety training. Testing on the condenser using an Air-Assist System, the contractor was able to inspect the 600 tubes, perform analysis, and present a color-coded tube sheet map by 5 pm. A total of nine tubes showed wall thinning greater than 60%, which were recommended for plugging. The preliminary report provided listed the flaw locations and whether the defects were located on the I.D. or O.D. of the tube.

In addition to this inspection, the plant also performed a hydro-pressure test to find any additional tube leaks. A few more tube leaks were found in areas that were not inspected with eddy current. These leaks along with the 9 tubes recommended for plugging were plugged.

Prior to this inspection the plant felt the issues with the condenser were leaks in the joint between the tube and the tubesheet, where the tube has been rolled. The inspection showed the most severe wall losses found were on the O.D. of the tubes at various locations along the length of the tube. The tubes with wall losses less than 60% showed I.D. thinning at various places along the length of the tube. The effects of the tube plugging were that the water chemistry is better than ever and the vacuum pressure is higher than before.

INTRODUCTION

Boralex, Inc. in Ashland, ME suspected their condenser to be leaking due to poor water chemistry and low vacuum pressure. The plant was looking for a cost-effective way to inspect 600 of the tubes in one shift.

NOMENCLATURE

ECT – Eddy Current Technique
I.D. – Inside Diameter
KHz - kilohertz
MW - megawatt
NDT – Non-Destructive Testing
O.D. – Outside Diameter

The Ashland Boralex Power Plant is a Wood Residue Thermal Power Station. The plant was constructed in 1993 and has an output of 40MW.

The Surface Condenser is a single pass unit consisting of one water box containing 6,084 admiralty brass tubes. The tube dimensions are 7/8" O.D., 0.049" wall thickness, and 25'-3" in length. Prior to the October 2007 outage, the unit had 27 tubes mechanically plugged. Please note that a plugged tube is when a round metal insert is placed into the tube at both tubesheets and sealed. The plugs used in this condenser are expansion seal plugs. A surface condenser is used in power plants to condense the steam after it has gone through the tube. Water obtained from a reservoir or nearby river goes through the I.D. of the tubes and the condensing steam is on the shell side of the tubes. This condenser uses the local river water. The unit had steam impingement troubles in the past and the plant wanted to focus the inspection in this area. The condenser tubes are cleaned twice per year. The condenser tubes are cleaned using a high-pressure washer with nozzles that blasts the silt and mud out of the tubes.

The plant suspected the condenser was leaking. An eddy current inspection performed on an identical condenser at a sister plant in Livermore Falls, ME showed issues at tube support plates. Using this information, the plant decided to perform an eddy current inspection on the tubes. The initial goal was to inspect 10% of the tubes.

A brief explanation of the theory of Eddy Current Testing (ECT) is explained in the next few lines. Wall losses and pitting can be detected by injecting a high frequency magnetic field (1-1280KHz) into a tube and measuring the distortions in the resulting magnetic field that occur in a flawed region. A probe with circumferential coils is inserted into the I.D. of the tube. The probe is then excited to create the high frequency magnetic field. Flaws are detected by measuring the magnetic field directly under the flaw area with the coil. A flaw or defect causes the magnetic flux lines in that area to be distorted or different than expected. This distortion can be measured as a change in the horizontal and vertical components of the signal. With suitable calibration tables, flaws can be analyzed and a determination of the flaw depth can be made.

Calibration standards are used to provide accurate sizing of the defects found. The calibration standard needs to match the actual tubes in the unit that are being tested. The tube specifications include O.D., wall thickness, and metallurgy. ASME has set guidelines of the defects that should be on the calibration standard. The defects consist of an O.D. ring and an I.D. ring along with several O.D. pits of different depths. In addition to these defects, many companies also include general wall losses on their standard for accurate sizing of erosion. A properly set up calibration allows the technician to size the defects found and also report whether the defects are on the I.D. or O. D. of the tube. The technician sets the calibration up at four different frequencies that are used simultaneously during an inspection. The use of four frequencies eliminates false positives that may be detected in one or two frequencies but not all four frequencies. The multiple frequencies also aid in mixing out support and baffle plates.

High frequencies (>1 KHz.) are used in non-magnetic metal tubes because the low magnetic permeability of these materials presents little resistance to the penetration of the metal. By using high frequencies, the magnetic field produced has a very good signal to noise ratio while still penetrating the metal.

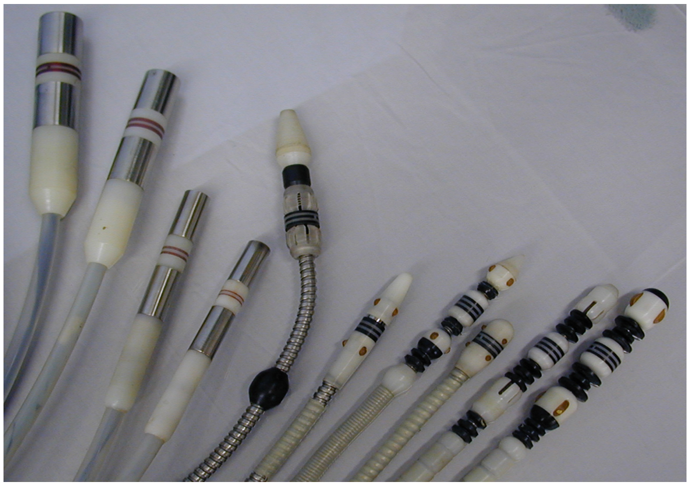
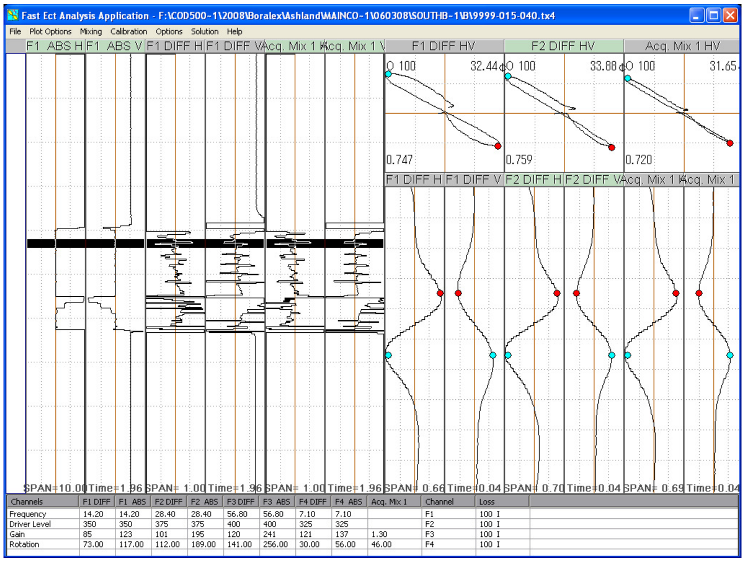


Figure 1 shows different sizes of Eddy Current Probes

The calibration data collected during the 2008 inspection is shown in Figure 2. There are several windows of data. The first two windows on the left side F1 ABS H and F1 ABS V are the horizontal and vertical components plotted on the x-axis vs. time on the y-axis. The absolute signal is used to detect and size general wall losses such as erosion in the tube. The next two windows F1 DIFF H and F1 DIFF V are the horizontal and vertical components of the differential plotted on the x-axis vs. time on the y-axis. The differential signal is the subtraction of two oppositely wound coils. The differential signal is used to detect small defects such as pitting and cracking. The next two windows Acq. Mix1H and Acq.Mix1V are the horizontal and vertical components of the mix channel plotted on the x-axis vs. time on the y-axis. The mix channel is a combination of different frequencies that is used to cancel out support/baffle plates that are in contact with the tube. The mix channel allows defects under a support or baffle plate to be detected and sized. The top three windows on the right hand side show a zoomed view of an area of the data. The F1DIFFHV is the differential horizontal and vertical components inspected at the first frequency. The F2DIFFHV is the differential horizontal and vertical components inspected at the second frequency. The Acq.Mix1HV window is the differential horizontal and vertical components inspected at the mixed channel. All three of these windows plot the horizontal signal on the x-axis and the vertical component on the y-axis. The angles generated by these plots are used to determine the percentage of wall loss for the defect. The number in the top left of these windows shows the percentage of wall loss. These wall loss values in the three windows along with the third and fourth frequency not shown need to be within 10% to be considered a defect for most situations. While the third and fourth frequencies are not shown on the captured screen, the waveforms are viewed during analysis. The values from all four frequencies are shown in the table below the waveform. The six windows located at the bottom right are the zoomed view but plotted with either the horizontal or vertical component on the x-axis vs. time on the y-axis at the three different frequencies. The technician uses all the data to determine the condition of the tube.



Channels	F1 DIFF	F1 ABS	F2 DIFF	F2 ABS	F3 DIFF	F3 ABS	F4 DIFF	F4 ABS	Acq. Mix 1	Channel	Loss
Frequency	14.20	14.20	28.40	28.40	56.80	56.80	7.10	7.10		F1	100 I
Driver Level	350	350	375	375	400	400	325	325		F2	100 I
Gain	85	123	101	195	120	241	121	137	1.30	F3	100 I
Rotation	73.00	117.00	112.00	189.00	141.00	256.00	30.00	56.00	46.00	F4	100 I

Figure 2 shows the calibration waveform that was collected during the 2008 inspection.

Traditionally, a technician manually pushes the probe through the entire length of the tube to perform an eddy current inspection. The probe is inserted into the I.D. of the tube at the near tubesheet and is pushed through the tube to the far tubesheet. Data is collected as the probe is manually withdrawn from the tube. Plant personnel looked at two proposals from companies to manually perform the ECT inspection of the condenser tubes. These companies predicted they could inspect a maximum of 400 tubes in a shift.

To save time and cost the "Air Assist System" was utilized. This system utilizes plant air as a motive force to push the probe through the tube quickly. With this system, the probe is still retrieved manually as data is collected. The Air Assist System can inspect approximately 2000 – 30' long tubes per shift. This system can be used to inspect condensers, feedwater heaters, and other heat exchangers. The equipment is lightweight and easily transportable. This system allows for 100% inspections to be completed in a short amount of time during an outage. A preliminary report that includes a color-coded tubesheet map is provided within hours of the completed testing.

Figure 3 shows the air assist gun as a probe is ready to shoot through the condenser tube.

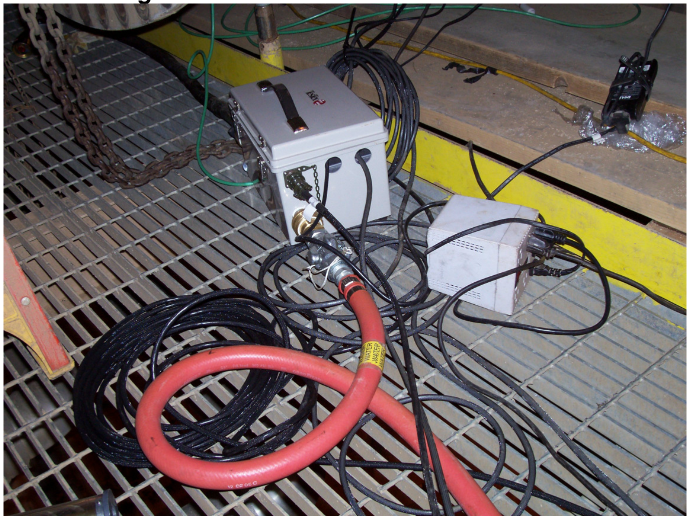


Figure 4 shows the air assist box with air lines and cables.

The original contract was established to inspect 10% of the condenser tubes. The pattern chosen by the plant focused on the area that had the most plugs. The failing mechanism for the tubes were 1) vibration of the tubes in the area of the tube support plates and 2) the areas closest to the turbine exhaust where erosion existed from wet steam at the turbine exhaust. The previous Livermore inspection also influenced the selected inspection area.

The condenser tubes were cleaned prior to the inspection. The technicians arrived at the plant at 7am, and the crew went through the usual plant indoctrination and safety training. Upon completion of training, the crew set up the equipment, calibrated the system, and marked up the tubesheet for numbering identification. The technicians proceeded to inspect 600 tubes using their Air Assist System. The inspection crew was able to complete the testing and submit a color-coded tubesheet identifying the tubes with wall loss and also showing the location of plugged tubes.

The inspection identified 9 tubes with greater than 60% wall loss. The preliminary report identified the location of the defects and indicated if they were I.D. or O.D. defects. The worst nine tubes showed defects on the O.D. side of the tube. However, many other tubes showed I.D. pitting at wall losses in the range of 20-40%.

After the completion of the Eddy Current Inspection, the plant performed a hydro-pressure test. A total of 4 tubes were easily identified as leaking. These were located on the outside row of tubes. An additional tube was leaking, but it could not be identified due to being located deep into the bank of the tubes.

The plant plugged the four failed tubes plus the nine tubes identified as having greater than 60% wall loss. The water chemistry has greatly improved after plugging these tubes. The cost for water treatment chemicals dropped dramatically. The vacuum pressure has also improved.

The plant had a shutdown starting in May 2008. The condenser was cleaned, and TesTex returned to inspect 1560 tubes using their Pusher/Puller System. The inspection focused on the bottom half of the unit. Every other row of tubes was inspected in this section. Once the Pusher/Puller ECT System was set-up, it took approximately seven hour to test the tubes, analyze the data, and present a preliminary report that included the color-coded tubesheet map shown in Figure 5.

The color-coded tubesheet map is shown in Figure 5. Each circle represents a tube. The view is as one is looking at the South Tubesheet. The tubes colored in white were not tested. The black tubes are plugged. The light blue tubes showed less than 20% wall loss, dark blue showed 20-39% wall loss, green tubes showed 40-59% wall loss, yellow tubes showed 60-79% wall loss, and the red tubes showed greater than 80% wall loss. The map illustrates the location in the condenser where the most thinning is occurring.

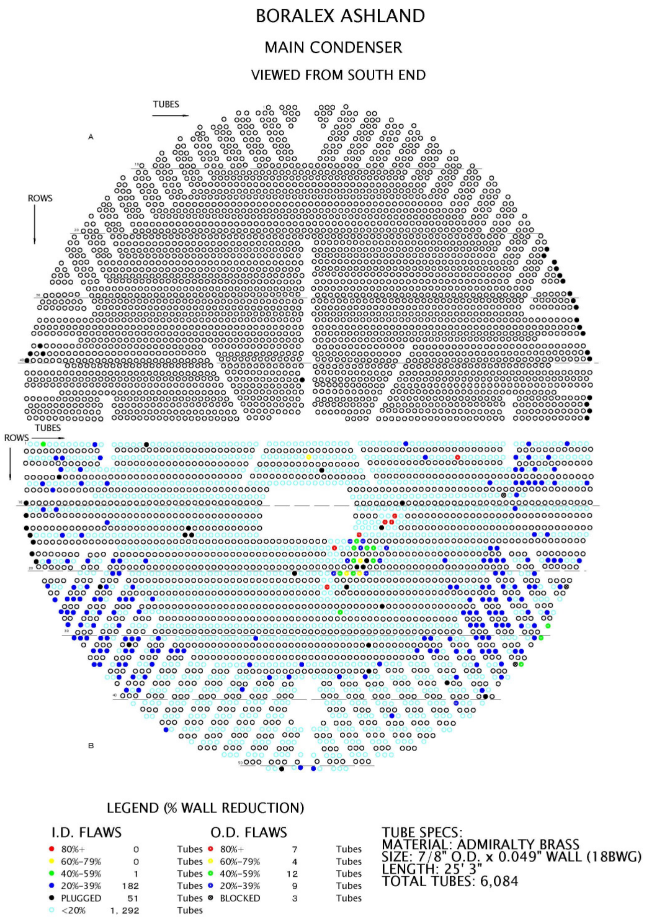
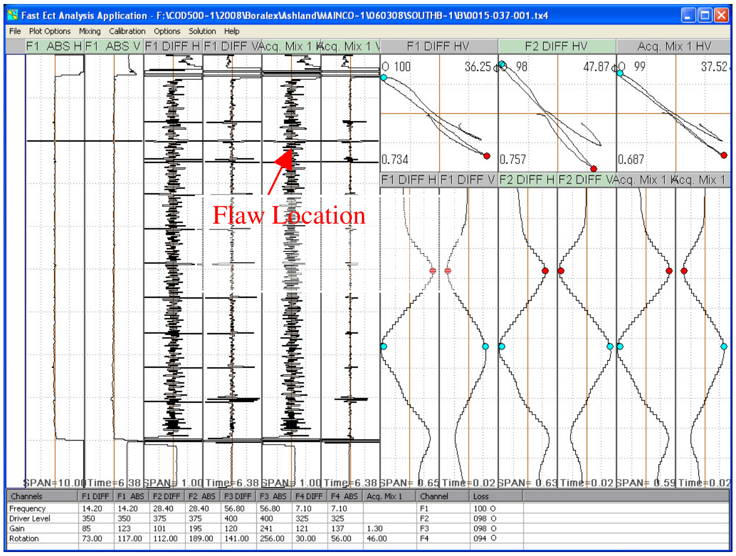


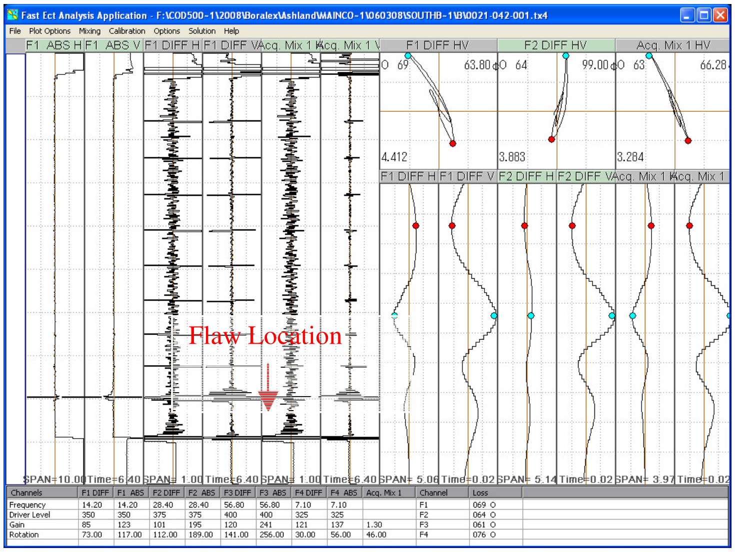
Figure 5 shows the color coded Tubesheet Map detailing the condition of the tubes.

Sample waveforms collected from the Surface Condenser during the 2008 inspection are shown in Figures 6 – 8. During the inspection, the probe was inserted into the south end of the tube and pushed through to the north end of the tube. Data was collected as the probe was being extracted from the tube. Therefore the top of the waveform corresponds to the north end of the tube and the bottom of the waveform corresponds to the south end of the tube. The horizontal lines in the F1DIFFH and F1DIFFV are where the support plates come in contact with the tube.



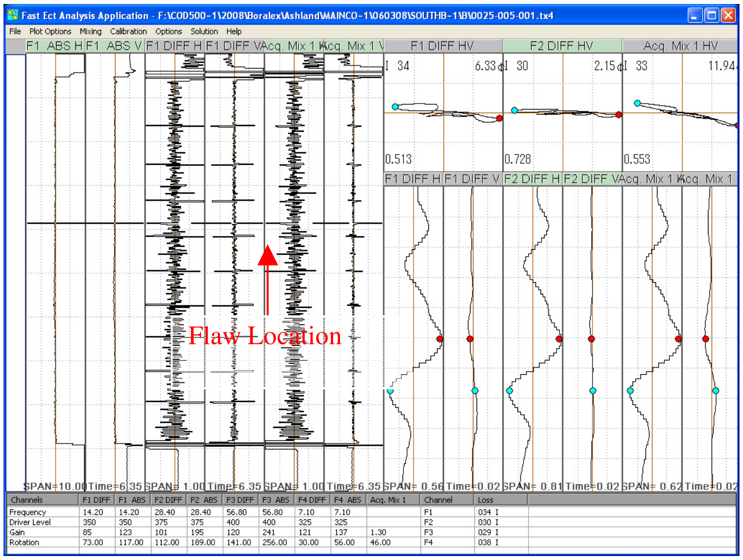
Channels	F1 DIFF	F1 ABS	F2 DIFF	F2 ABS	F3 DIFF	F3 ABS	F4 DIFF	F4 ABS	Acq. Mix 1	Channel	Loss
Frequency	14.20	14.20	28.40	28.40	56.80	56.80	7.10	7.10		F1	100 O
Driver Level	350	350	375	375	400	400	325	325		F2	098 O
Gain	85	123	101	195	120	241	121	137	1.30	F3	098 O
Rotation	73.00	117.00	112.00	189.00	141.00	256.00	30.00	56.00	46.00	F4	094 O

Figure 6 is a sample waveform collected from the main condenser at Boralex-Ashland. This particular tube, tube 15 -37 (Bottom) indicated greater than 95% OD Wall Loss. The flaw is located at space 9 of the tube (between baffles 8 and 9).



Channels	F1 DIFF	F1 ABS	F2 DIFF	F2 ABS	F3 DIFF	F3 ABS	F4 DIFF	F4 ABS	Acq. Mix 1	Channel	Loss
Frequency	14.20	14.20	28.40	28.40	56.80	56.80	7.10	7.10		F1	069 O
Driver Level	350	350	375	375	400	400	325	325		F2	064 O
Gain	85	123	101	195	120	241	121	137	1.30	F3	061 O
Rotation	73.00	117.00	112.00	189.00	141.00	256.00	30.00	56.00	46.00	F4	076 O

Figure 7 is a sample waveform collected from the main condenser at Boralex-Ashland. This particular tube, tube 21 -42 (Bottom) indicated a 65% OD Wall Loss. The flaw is located at space 2 of the tube (between baffles 1 and 2).



Channels	F1 DIFF	F1 ABS	F2 DIFF	F2 ABS	F3 DIFF	F3 ABS	F4 DIFF	F4 ABS	Acq. Mix 1	Channel	Loss
Frequency	14.20	14.20	28.40	28.40	56.80	56.80	7.10	7.10		F1	034 I
Driver Level	350	350	375	375	400	400	325	325		F2	030 I
Gain	85	123	101	195	120	241	121	137	1.30	F3	029 I
Rotation	73.00	117.00	112.00	189.00	141.00	256.00	30.00	56.00	46.00	F4	038 I

Figure 8 is a sample waveform collected from the main condenser at Boralex-Ashland. This particular tube, tube 25 -5 (Bottom) indicated a 35% ID Wall Loss. The flaw is located at space 7 of the tube (between baffles 6 and 7).

During the 2008 inspection of the surface condenser, the contractor found 7 tubes with greater than 80% wall loss and 4 tubes with 60-80% wall loss. The thinning found was on the OD of the tubes. The plant also performed a pressure test on the tubes and found four leaking tubes that were not part of the inspection scope. These four tubes along with the seven tubes with greater than 80% wall loss were mechanically plugged.

Through the use of eddy current the plant knows the condition their condenser is in. The plant's water chemistry has improved. The vacuum pressure has also increased. Boralex-Ashland plans to continue inspecting 25% of the tubes each outage until all the tubes are inspected. At that time, they will evaluate the condition of the unit and will perform inspections in areas of concern.