Performance monitoring & troubleshooting with a new individual condenser tube circulating water flow and fouling (CWFF) meter – A case study

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Introduction

Midwest Generation Joliet Station in Illinois has two coal-fired units, Unit 7 and Unit 8. Both 550 MW units are located on the Des Plaines River and have been in operation since 1963-1964. The circulating water system is a once-through system comprised of a bar rack, traveling screens, circulating water pumps and reversible condensers. The original condenser tubes on Unit 8 were replaced with similar material in 2005. In 2006, after less than a year of operation, significant microbiological influenced corrosion, or MIC, damage was identified during routine eddy current testing of the tubes.

Later that year, the station decided to test and evaluate new Circulating Water Flow and Fouling (CWFF) instrumentation to determine the cooling water velocities [1] [2]. MIC most likely occurs under stagnant conditions or in operations with low or intermittent flow [3]. The objective was multifold, to measure cooling water velocities and to examine the effect of other variables in the ongoing MIC attack of the SS condenser tubes. In addition to providing useful information regarding the root cause for MIC, the study unveiled a number of other condenser performance-related issues presented in this article.

Units 7 and 8 share a total of four circulating water pumps. All four pumps are identical in model and rated pumping capacity. The condenser configuration is presented in Figure 1. As mentioned previously, the condenser is equipped with circulating water flow reversing valves, which remove the macrofouling from the tube sheet. Joliet Station experiences rapid debris (macro) fouling and so, as a standard operation, the condenser circulating water is generally reversed on a daily cycle. The primary method for microfouling control is chlorination. Additionally, the station utilizes air drying to remove silt and biofouling by periodically taking a water box out of service, opening the doors and installing hoses connected to an air moving system that circulates warm air through the tubes and dries the fouled material to a point where it is flushed away when the water box is placed back in service. The drying method also is used for a long- and short-term lay-up of the condensers.

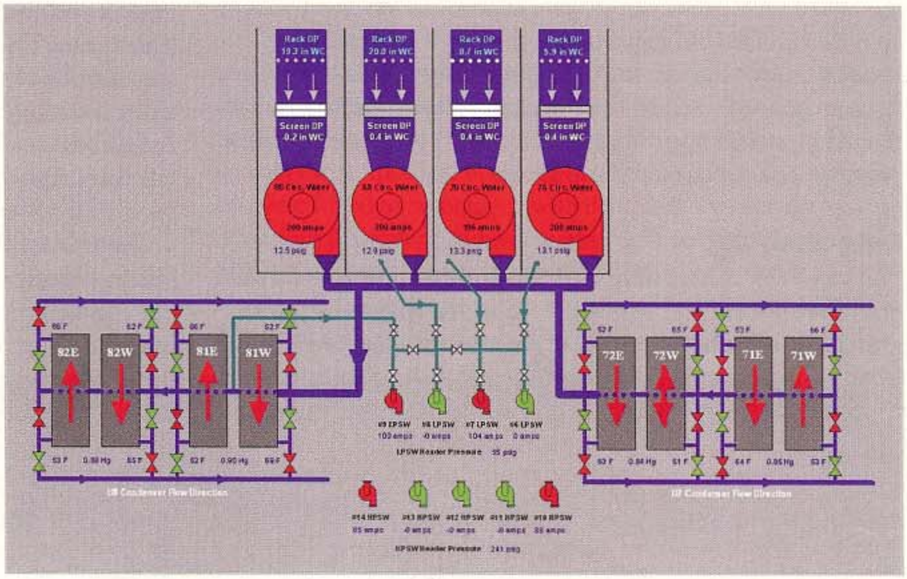

Figure 1. Joliet condenser configuration

Intek's circulating water flow and fouling (CWFF) meter utilizes thermal sensing technology to measure the circulating water flow through an unobstructed flow tube. This technology also enables quantification of heat transfer coefficient. The flow data is single or bi-directional and routed to a process computer for data logging and a range of computations [4]. Important features of the CWFF are that it is accurate, reliable and non-invasive to the flow measurement. For most steam surface condensers used in the power industry, any flow and fouling instrument must be capable of surviving long term submersion, exposure to unfiltered circulating water and allow ease of on-line or off-line tube cleaning methods; the CWFF is well suited to these conditions.

The flow meters were installed in the upper bundle of one of the four outlet water boxes (82East) of the Unit 8 condenser. A photograph of two of the four installed meters is shown in Figure 2. Brackets anchored at two adjacent tubes were used to provide a mechanical brace from the meter to the tubesheet to overcome a concern that violent flow conditions during reverse

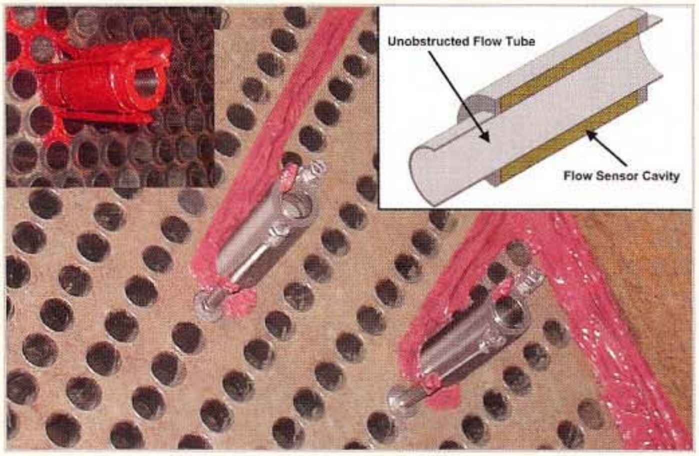

Figure 2. Typical flow meter installation

flow could stress the adhesive used to attach the meters to the monitored tube. Meter cables were attached to tubesheet with epoxy and routed through a port in the outlet waterbox. The installation locations for the CWFF sensors were carefully selected based on a critical examination of the condenser configuration, so that a very small number of key measuring points provided data for meaningful analysis.

Data analysis

The CWFF meters were built and calibrated for both forward flow and reverse flow, so that flow direction change can be recognized and flow rates in both directions can be measured. Upon first inspection, the data indicated that the circulating water pumps were switched at seemingly random intervals. In reality, pumps are taken off to perform system maintenance at low loads when fewer pumps are needed, at lower circulating water inlet temperatures, for bar rack cleaning and waterbox drying.

Figure 3 shows two graphs of operating data (plant measured waterbox temperatures, CWFF temperatures, load, thermocouple (TC) temperatures, CWFF flow rates and CW pump amps) with four CW pumps in operation in July 2007 for a 1-week period. Note the temperature differentials from inlet to outlet increase for increased loads and velocity is ~7 ft/sec during the forward and reverse flow conditions. This data represents measurements that are consistent with the expected operation of the unit and validates the credibility of the meters. Also note that on July 24th, the 7A CW pump was taken out of service for a short period and there is a noted decrease from ~7 ft/sec to ~5.5 ft/sec in all four of the CWFF monitored tubes.

The following sections present data that has been logged and reviewed during the past year of testing in more detail. Topics that are covered include:

- Multiple incidences of macro fouling detection and effectiveness of reverse flushing.
- Pump capacity comparisons.
- Flow stratification.

Multiple incidences of macro fouling detection and effectiveness of reverse flushing

The Joliet Station experienced significant grass and debris accumulation at the bar rack, plugging up the racks. Some debris made it past the traveling screens and ended up in the condenser waterboxes. This type of fouling can become frequent during spring and summer months and was evident from the CWFF meter data. The circulating water flow through the condenser is reversed on a daily basis to remove the macro fouling of the tubesheet. The CWFF meter data illustrates how reverse flushing effectively clears the tubesheets of macro fouling debris.

As an example of one of the numerous recorded incidents, Figure 4 shows data from Sept. 15-25, which captures a persistent fouling event. The condenser begins to experience macro fouling on Sept 18. All of the meters have an abrupt increase in flow rate shown at "Event 'A'". The -1 flow increase is most likely due to a large amount of fouling (not in the monitored tubes) that decreased the number of tubes with clear passage, causing a flow increase in the remaining unfouled tubes. The flow is switched from reverse to forward flow (at 9/18/07, 10:00) and immediately the -1 meter-tube becomes increasingly plugged by debris until flow is finally reduced to zero. Notice that during this time the -2, -3 and -4 meter flow rates steadily increase, thereby indicating a continued decrease of overall flow cross sectional area by additional unmonitored tubes being reduced in flow. The circulating water is again switched from forward flow to reverse flow (at 9/20/07, 8:00), the -1 meter is immediately recovered and measures flow through its tube. The meters continue to indicate tube macro fouling until the condenser flow is switched from reverse to forward flow, whereby all the debris is cleared and the measured flow rates return to reasonably steady conditions. Note that the -1 and -2 flow rates are higher than the -3 and -4 flow rates preceding and following these events. This flow stratification will be discussed in the next section. Random macro fouling of this nature is typical where river water supply can be tainted with debris.

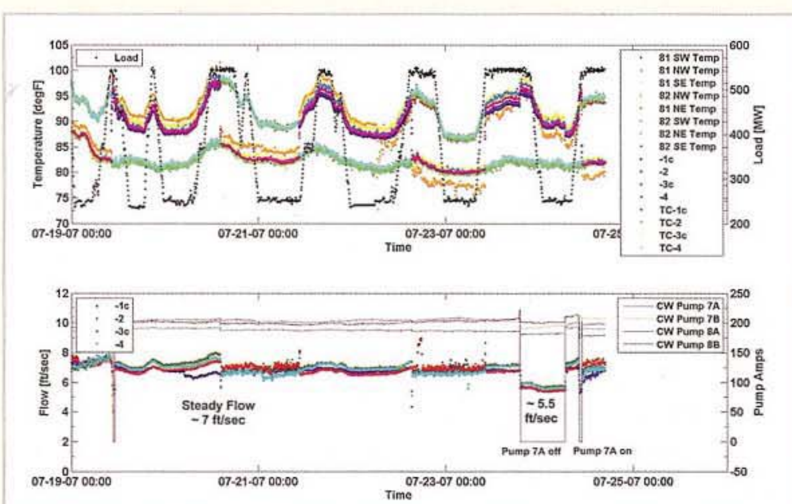

Figure 3. CWFF meter flow velocity and temperature and other plant data [5]

Circulating pump capacity comparison, flow stratification and eductor issues

It has been noted in Figure 4, and observed in other data not shown here, that the -3 and -4 CWFF meters located in the upper portion of the 82SE waterbox were often measuring lower flow rates than the -1 and -2 meters in the lower portion of the same waterbox from June-December 2007 and this flow stratification does not appear to be a result of fouling. This condition does not exist when 1) all pumps are on in both forward and reverse flow, or 2) either pump 7A or 7B are separately off and in the forward flow direction. Additionally, this condition does not develop when pump 7A is off and in the reverse direction; furthermore, this condition appears to correct itself (meaning -3 and -4 increase with time) with Pump7A off and during reverse flow. Figure 5 shows plots used to evaluate pump capacity. Note the X-axis is consecutive chronological data points and not a time scale, in order to more easily assess the configuration effect on tube flow rate. To put the data into a more manageable format, the data is separated into four categories and plotted. These categories are forward flow, each having three pumps running with either Pump7A off, Pump7B off, Pump8A off or Pump8B off.

The plots indicate that the CWFF sensors 3 and 4 see lower velocities than CWFF sensors 1 and 2. This might have been due to the water boxes not being totally full. The station uses service

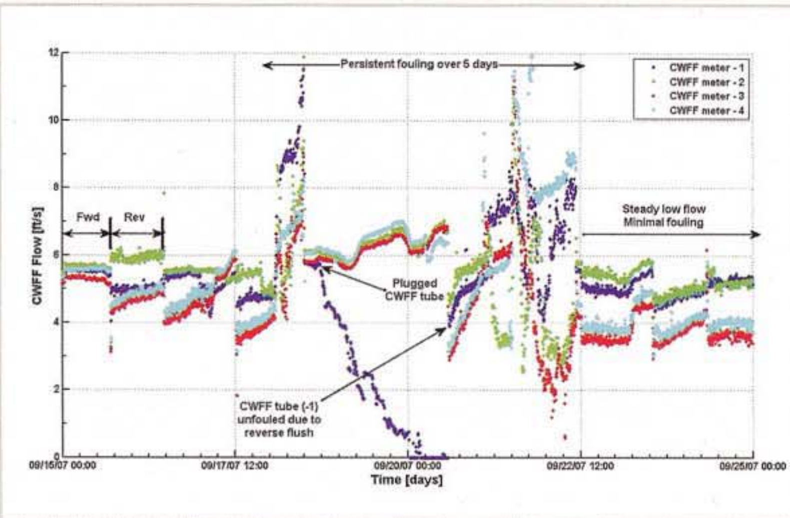

Figure 4. Example of meter responses to macro fouling and effectiveness of reverse flushing [5]

water for the waterbox priming eductors. The priming eductors remove the trapped air from the top of the waterbox and thereby help maintain a full waterbox. To remove larger debris, the strainers were installed in the service water piping. The strainers were found to be plugged with debris and Asiatic clams. Therefore the water box level might not have been drawn up as high as designed, causing lower flows through the top tubes.

The plots also indicate that the velocities are much lower with either 8A or 8B circulating water pump off. This explains

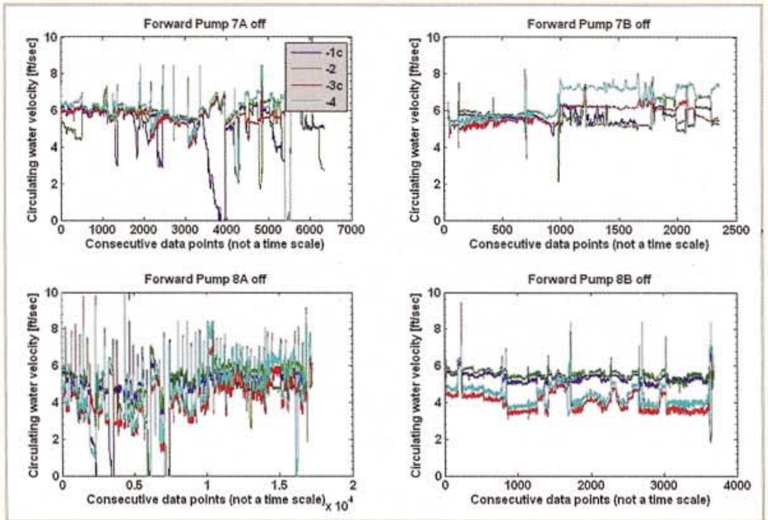

Figure 5. Forward flow rate data for combinations of three different pumps running – sequential data point plot – steady state filtered – ~7months of data [5]

why the station needs two circulating water pumps running on the unit when one of the waterboxes is being isolated. It is a common practice to operate 8A and 8B pumps on Unit 8 and one of the pumps on Unit 7, prior to isolating a waterbox on the Unit 8 side. The same is true for Unit 7. The increase in back pressure is very pronounced and often restrictive if there is only one pump operating on the unit when one of the waterboxes is being isolated. The likely reason for this is a restriction or imbalance in the circulating water piping system design.

One additional point to be made is that the flow monitors detected issues before they resulted in a significant back pressure increase. In all of these cases, the back pressure increased no more than 0.30″ above design pressure. Therefore, the meters might be used as a proactive tool to help determine a back pressure issue before it becomes significant.

Conclusion

This case study has shown that the CWFF technology is accurate and reliable, having performed well for more than a year. The meters have provided information that identified new performance impacting issues and traced down root causes for chronic maintenance problems. Real-time frequent macrofouling of the tubesheet, water box level issues, circulating water pump capacity performance and associated flow configuration impacts, and reversal flow for the purposes of debris flushing, are among the practical issues that were studied. The data history from the flow meters provided the following benefits:

- Helped determine when macrofouling was becoming significant and helped evaluate the effectiveness of reversing the flow to flush away the debris.
- Indicated a flow discrepancy as various circulating water pumps were operated, which led to the diagnosis of the root cause of MIC.
- Indicated significant flow stratification that was due to water box eductor plugging.

Acknowledgement

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