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# Gear tooth cavitation erosion

# Condenser monitoring instrumentation identifies abnormal condition

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Upset operating conditions that degrade condenser performance have a negative impact on cycle efficiency, causing increases in fuel consumption to meet power demands. These inefficient abnormal operating conditions can occur rapidly and often go undetected and/or require extensive time and resources to investigate and resolve. Standard condenser instrumentation typically provides little to no early detection or guidance for troubleshooting and determination of the root-cause for the abnormal operating condition.

The following case study shows how an investment in condenser instrumentation can economically result in improved early detection, trouble shooting, and correction of upset conditions. This increased visibility in condenser performance and operation will help to maintain plant efficiency.

## Unit description and background

A condenser monitoring system, using test-grade instrumentation, was installed on a 340 MW coal-fired unit at East Kentucky Power Cooperative's Spurlock Station, with the goal of continuously monitoring condenser performance. The condenser is a Westinghouse single pass single shell design, with divided waterboxes supplying circulating cooling water to two tube bundles from a mechanical draft cooling tower. The east side tube bundle is fed from a branch tee, off the main circulating cooling water supply line, that tees upward into the east inlet waterbox. The straight-through side of the tee continues further and elbows upward into the west inlet waterbox. [This tee and elbow configuration plays an important role in the findings]

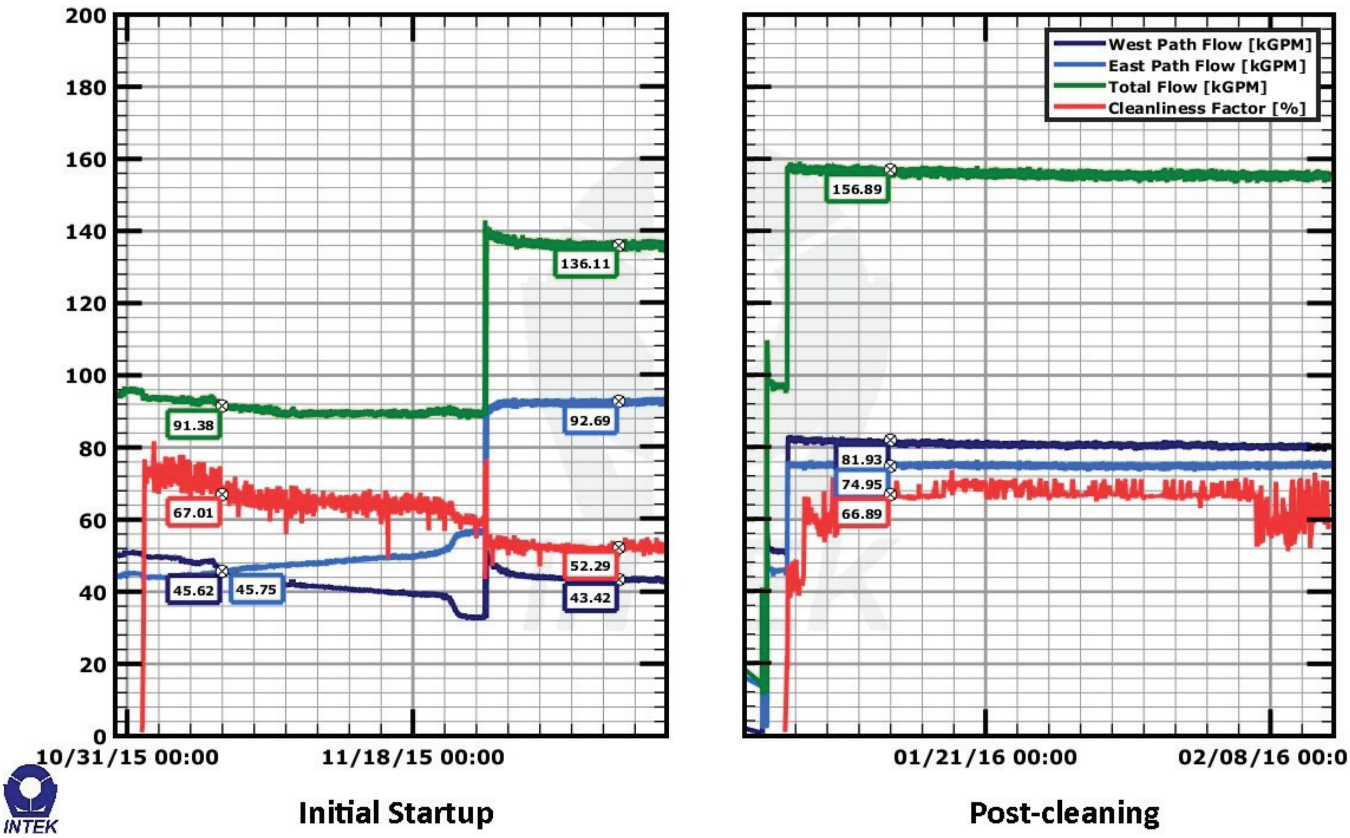


*Figure 1.*

Previous analysis of the existing plant instrumentation had revealed uncertainties in the condenser pressure, inlet circulating water temperature, and outlet circulating water temperature values. There was no existing instrumentation to directly measure circulating water flow rates nor means to continuously measure condenser air in-leakage. To address these issues new instrumentation was installed, in the form of a condenser monitoring system, which comprised the following instrumentation:

- RTDs (Qty. 2): Measure circulating water temperature into each inlet waterbox.
- RTDs (Qty. 8): Measure circulating water temperature out of each outlet waterbox. Four RTDs in each outlet circulating water pipe to account for thermal stratification.
- Combination Pressure-Temperature probes (Qty. 2): Measure condenser shell side steam pressure and temperature. One P-T probe located at the circulating cooling water inlet end of the condenser, and the other probe located at the circulating cooling water outlet end of the condenser, on the adjacent tube bundle. Both probes are located 2 ft. above the top of the tube bundle.
- Differential Pressure (DP) meters (Qty. 2): Measure circulating water flow through each flow path (A flow path is defined as the flow from an inlet waterbox to an outlet waterbox). Each DP meter is installed across the respective outlet waterbox and the circulating cooling water pipe transition.
- RheoVac Air In-Leak Monitors (Qty. 2): Located at air off-take for each bundle, and on the common air off-take line. RheoVac probes can be moved to different locations as needed.

The DP meters were field calibrated using a pitot traverse method, at the cooling tower risers, for three flow rates; two circulating water pumps running, one circulating water pump running, and a mid-flow rate with both circulating water pumps running with discharge valves throttled. The cooling

*Figure 2.*

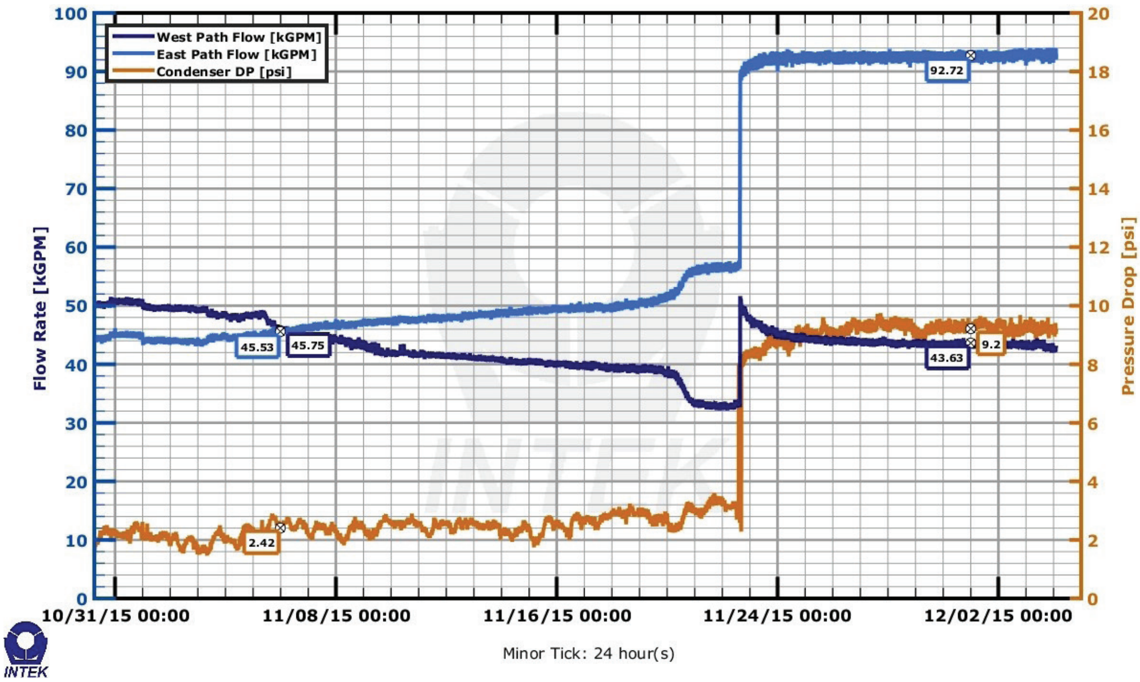


*Figure 3.*

tower blowdown and cooling water supply to plant equipment were isolated prior to DP meter calibration.

Data from all of the instrumentation is logged in a main processing unit that calculates and graphically displays the desired information. For this particular installation steam pressure, steam temperature, circulating water flow inlet and outlet temperature, air in-leakage, and circulating water flow rate are measured and condenser duty and cleanliness factor are calculated in the main processing unit. The displayed graphics can be suited to the owner's particular needs.

## Event details

The event described in this report occurred as the unit was coming out of an outage. The condenser monitoring system installation and calibration was completed shortly after the unit went online; however, due to maintenance work, only one circulating water pump was initially available for service. The second circulating water pump went online 11/22/15.

Figure 1 shows that the unit started up with ≈95 kGPM total flow [Green] then decreased for the next 3 weeks to a level of ≈88 kGPM. When the second pump was put into service the total flow of ≈135 kGPM was well below the expected 2 pump flow rate of ≈155 kGPM measured during the DP meter field calibration. Divergence between the east path flow [Light Blue] and west path flow [Dark Blue] suggested macrofouling of the west path was the root-cause for the reduced flow rate and the condenser performance degradation. The impact of the decreased flow rate resulted in a Cleanliness Factor [Red] decrease of 15% over a one-month period.

## Actions taken

At a later date, while the unit was offline, the inlet waterboxes were inspected for debris. A significant amount of foreign debris was found lodged in the tubes and lying in the bottom of the west inlet waterbox. Further inspection revealed that additional debris had accumulated in the circulating cooling water supply line (downstream of the previously described tee) that feeds the west inlet waterbox. Approximately ten cubic feet of debris was removed from the water box, circulating cooling water supply line, and circulating water pump suction basin. Pictures from the waterbox and piping inspection are shown in figure 2. Efforts to remove the debris were time constrained by operational requirements, so not all debris was removed from the tubes in the west tube bundle at that time. The services of a condenser cleaning contractor will be required to fully remove the debris from the condenser tubes at the next opportunity.

## Results

The startup of the unit following the macrofouling event is shown in the right half of figure 1. The total flow rate increased to ≈157 kGPM. The condenser cleanliness factor increased to 70% even though some debris remained embedded in the west bundle's tubes.

## Conclusions

Upon further investigation, the source of the debris was found to be the repair of an underground cooling tower makeup water line that occurred adjacent to the online circulating water pump basin between 11/03/15 and 11/05/15, shortly after the initial unit startup. The fouling occurred in the west inlet waterbox due to the tee and elbow configuration of the circulating water supply line; the trajectory of the entrained debris carried it past the branch tee of the east waterbox to the end of the line at the west waterbox. This fouling event occurred shortly after the initial startup of the condenser monitoring system and rapidly caused a significant decrease in condenser performance. This type of abnormal operating condition was not obvious on the less sensitive plant instrumentation that simply measured DP across circulating cooling water supply and return lines. While the plant's DP measurement has a slight upward trend, it would have been difficult for operators to detect an abnormal operating condition. As shown in Figure 3, the individual path flow rates [**light blue** and **dark blue**] indicate an abnormal condition much more clearly than the plant instrument does [**orange**].

If Spurlock Station had not installed the condenser monitoring system, it is likely the unit would have run for an extended period of time with higher than necessary turbine backpressure at the expense of increased fuel consumption. While it is not possible to estimate the potential cost of this macrofouling event, it is easy to state that early detection of macrofouling will help Spurlock Station achieve East Kentucky Power Cooperative's goal of generating electricity at the lowest possible cost for its member owners. This specific example demonstrates how an initial investment in a condenser monitoring system could provide an immediate pay back for plant operators and owners. ■

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