Mining data to identify problems, improve performance takes perseverance, know-how

The editors corralled Bob Anderson, principal, Competitive Power Resources, Palmetto, Fla, shortly after he concluded a planning meeting for the first "HRSG Forum with Bob Anderson," Feb 28-Mar 1 and 2, 2017, to ask how he approaches problem diagnosis using data from the plant historian.

Anderson, a former plant manager and HRSG troubleshooter for a large utility's F-class fleet, said the value of captured data for performance and problem assessments can't be overstated. He shows by example, below, that one data plot can tell several stories and suggest multiple corrective actions.

Anderson stressed that while the conclusions derived from the exercise described may look simple to identify, the process of getting there requires the ability to combine a high level of plant/process operating experience with a high level of knowledge on the reaction of plant components, materials, and systems to various stimuli.

Furthermore, he continued, correct conclusions require the willingness and ability to always question your findings objectively. This requires the time to think about what data might "shoot down" your preliminary conclusion, then collect, re-plot, and review those data as many times as it takes to accept your findings without question.

Anderson added, "The experience, discipline, and time required to conduct such self-questioning is critical to a quality result. Mike Pearson, an Ontario-based consultant and master of this analytical approach, was my demanding mentor."

HRSG FORUM WITH BOB ANDERSON
Feb 28 - Mar 2, 2017
EPRI Campus, Charlotte, NC

Case history

The gas turbine (GT) at a 1 × 1 single-shaft combined-cycle plant designed for flexible operation has a staged combustion system that permits emissions compliance and a relatively good heat rate down to low loads. The HRSG is a three-pressure, reheat, horizontal-gas-flow unit equipped with only HP (high pressure, main steam) and RH (reheat steam) terminal attemperators. There is no duct burner or SCR.

The facility is designed to operate in the following modes:

1. High GT and high steam-turbine (ST) load in combined cycle (Fig 1).
2. Low GT load and low ST load (sliding pressure) in combined cycle.
3. Low GT load and *zero* ST load in open cycle (Fig 2).

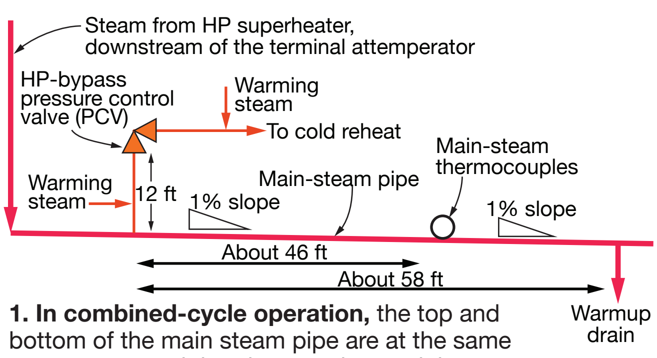
The problem: Repeated severe water erosion damage to the HP bypass pressure control valve (PCV). This caused the PVC to leak in combined-cycle service, requiring multiple repairs at significant unbudgeted costs and involving long forced outages.

The HP-bypass PCV installation arrangement is compliant with the OEM's guidelines. It is located at the top of a 12-ft vertical pipe run directly above the main-steam pipe branch tee and is provided with warming steam both before and after the PCV, as shown in Figs 1 and 2.

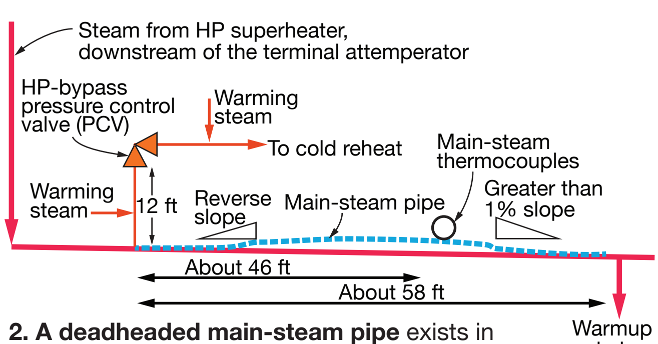
Anderson was hired to conduct a root-cause analysis (RCA) of the valve as a subcontractor to Structural Integrity Associates Inc. In addition, he and Dr R Barry Dooley of SIA conducted one of their respected Level I assessments of cycle chemistry, FAC, and undesirable thermal transients (access "HRSG assessments" using the search function at www.ccj-online.com).

Anderson said he and Dooley have conducted these surveys at over 50 combined-cycle plants worldwide and have *always* identified significant previously undetected problems during each survey.

The historical data plot



1. In combined-cycle operation, the top and bottom of the main steam pipe are at the same temperature and the pipe remains straight



2. A deadheaded main-steam pipe exists in open-cycle service when the gas turbine is operating at low load and the steam turbine is offline. This mode of operation allows condensate to pool along the bottom of the pipe, shrinking it relative to the top of the pipe. Result: the pipe humps upward

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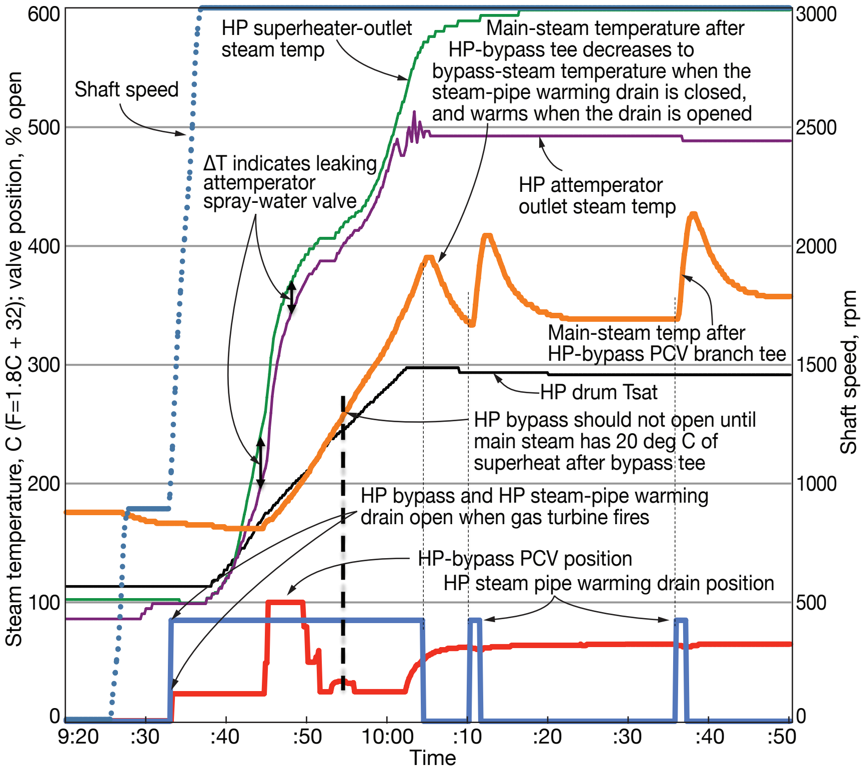

3. Data plots of critical operating data over time are for a cold start followed by open-cycle service

in Fig 3 identifies three potential contributors to the PCV water-erosion issue repeatedly experienced. While this one plot simplifies presentation of the three problems, selecting the data points to be plotted during the various modes of plant operation, reviewing the plots, rearranging the plots to facilitate analysis, and scaling and annotating the plots require significant experience and practice, Anderson stressed.

Fig 3 presents key historian data for a cold start followed by open-cycle operation. This unit has no GT bypass stack, so open cycle here means the HRSG is producing steam that is routed to the condenser via the HP and IP steam-turbine bypass systems. Below are thumbnails for each of the three operating conditions and system/equipment line-ups considered by Anderson as contributors to HP-bypass PCV erosion.

Note: To accurately determine the relative importance of the contributors to PCV erosion, review of additional data, beyond that provided by the plant's control system, was considered prudent by Anderson. He suggested the installation of additional monitoring instruments for better decision-making, enabling the owner to apply only those corrective actions necessary to solve the problem.

No. 1. The HP-bypass PCV (red line) and main-steam-pipe warming drain (bright blue) open immediately when the GT fires at 9:33. Main-steam temperature (orange) measured 46 ft downstream of the PCV branch tee tracks Tsat (black) until 9:53. As the main-steam pipe warms it forms condensate. When the PCV is open during the warm-up period, some or all of this condensate may pass through the PCV.

No. 2. During early startup (9:41 to 10:03), the HP attemperator block and control valves are closed (not shown in Fig 3), but the HP superheater outlet (attemperator inlet) steam temperature (green) is consistently higher than the attemperator outlet steam temperature (purple). This is characteristic of spray water leaking into the main-steam pipe.

There is a small-bore drain located on the main-steam pipe after the attemperator that is open during startup; but once steam flow begins pushing the leaking spray water along the pipe it likely will bypass the drain and some may be ingested by the PCV.

No. 3. The main-steam pipe, from the HP-bypass branch tee to the ST inlet valves has a 1% downward slope, as shown in Fig 1. A drain pot is located 58 ft downstream of the bypass branch tee; it has a 3-in. automatic drain valve (bright blue) and serves as the main-steam-pipe warming drain.

When open-cycle operation begins at 10:04 this valve closes, and the main-steam temperature measured about 46 ft downstream of the bypass tee (orange) begins to cool to the steam temperature measured after the HP-bypass PCV and its desuperheater.

At 10:11 and 10:36 the warming drain valve automatically opens for a couple of minutes. This indicates that sufficient condensate has formed in the section of deadheaded pipe between the HP-bypass tee and the ST inlet valves to trigger the warming drain-pot level switch. Each time the warming drain valve opens, main-steam temperature measured 46 ft downstream of the bypass tee quickly heats up to more than 400C.

The main-steam pipe thermocouples installed 46 ft downstream of the bypass tee are located on top of the steam pipe. Data suggest condensate forming and pooling in the bottom of the deadheaded main-steam pipe causes a top-to-bottom temperature difference that bows the pipe upwards, overcoming the 1% downward slope and causing condensate to run back towards the bypass branch tee where it is ingested by the PCV.

Corrective actions:

- Delay opening the HP-bypass PCV until the main-steam temperature measured downstream of the bypass tee increases to 20-deg-C above Tsat.
- Repair the leaking HP attemperator spray and block valves.
- Leave the main-steam-pipe warming drain open during open-cycle operation. This may require modulating the drain valve's position to limit steam flow while avoiding condensation in the deadheaded section of pipe.

Additional short stories that could come from this case history:

- The main-steam warming drain has an orifice installed; it is not on the drawings and is of unknown size. This slows warming of the main-steam pipe and increases the time before the HP-bypass PCV achieves 20-deg-C of superheat and can be opened safely.
- The attemperator valves leak because the control logic treats the block valve as "martyr" and the control valve as "master." This is backwards and ensures both valves will begin to leak.

Wrap-up. Pearl Street President Jason Makansi, a consultant who specializes in controls/diagnostics/prognostics, concurred with Anderson's decision to request instrumentation beyond that provided with the plant. "The importance of the foregoing analysis to me," he said, "is that the models used by the DCS to control/automate the plant, especially starts, normally don't factor in the level of data analysis required for sophisticated troubleshooting. Anderson's work uncovered some interesting flaws in the original design." CCJ