Water Treatment Comparison for Two Boilers

Techniques for Supercritical and Subcritical Units

By Bryan D. Hansen, P.E.

In a modern, coal-fired power plant, a boiler is used to generate steam for a steam turbine-generator, which in turn creates electricity. It is important that the water used in this process be the proper quality to maintain a high plant efficiency and reduce maintenance expenditures.

The heat released during combustion is absorbed in the heat transfer surfaces of the furnace. Using the correct treatment for the boiler feedwater is important to ensure that contaminants and corrosion products do not deposit in the boiler tubes or carry over to the steam turbine. Deposits in the boiler will result in the loss of boiler efficiency and could lead to overheating and failure of boiler tubes, resulting in unscheduled outages and expensive repairs. Deposits resulting from carryover to the steam turbine will decrease turbine efficiency and result in expensive turbine repairs.

Two Different Designs

There are two basic boiler technologies: subcritical and supercritical. Subcritical boilers operate below the supercritical pressure of water, approximately 3,200 psi. For a subcritical boiler, water is heated in the boiler to generate steam. The steam is separated from boiler water in a steam drum and sent to the steam turbine. The remaining water in the drum re-enters the boiler for further conversion to steam.

For the once-through supercritical design, feedwater enters the boiler, is converted to steam, and is passed directly to the steam turbine. The supercritical pressure for water is the thermodynamic condition, where there is no clear distinction between liquid and gas phases. Supercritical boilers operate above the supercritical pressure for water. They can only be of a once-through design because there is no difference between liquid and gas phases, and it would be impossible to separate steam from water in a steam drum for a supercritical unit. The steam in the boiler is fed to the turbine-generator, generating electricity. After expansion in the turbine, the steam is condensed and is pumped back to the boiler where the process is repeated again.

Operation of both types of units requires attention to feedwater chemistry. Any condenser cooling-water in-leakage or an upset in the makeup water quality will result in contaminants entering the feedwater cycle. These contaminants, as well as corrosion products from the condensate and feedwater piping, will be transported to the boiler. In the case of a subcritical boiler, these contaminants may be removed by boiler blowdown. However, in the case of a once-through (supercritical) unit, the contamination cannot be removed by blowdown, and contaminants will deposit in the boiler tubes or on the turbine. Condensate polishing is often provided to remove these contaminants from the feedwater cycle.
condensate feedwater before they enter the boiler.

**Condensate Polishing**
While full-flow condensate polishing is required for a supercritical unit, it is optional for a subcritical unit. Subcritical units can use either a partial-flow or full-flow condensate polishing system. Since the subcritical unit gets phase separation in the drum, it is not essential for all subcritical units to have condensate polishers. Drum separation will provide a relatively pure steam output while retaining most of the dissolved solids and particulate matter in the liquid phase to be removed by boiler blowdown. Supercritical units do not have a drum unit for separation because the water phase and steam phase have the same density. Therefore, any solids transported into the boiler will carry over with the steam. These units must have condensate polishers to remove contaminants from the cycle. Because the subcritical unit has two distinct phases in the boiler drum, it has less stringent feedwater chemistry than a supercritical unit. Subcritical units can use sodium phosphate solutions to buffer the boiler water in the steam separation drum while maintaining a small amount of phosphate to react and condition any small amount of hardness that may enter the boiler through condenser tube leaks. Boiler conditioning chemicals such as sodium phosphate must not be fed to supercritical boilers. All chemicals fed to a supercritical unit must be volatile.

The cycle makeup water quality and condensate quality must be very high when using the OT method. Poor condensate quality will result in accelerated corrosion rates and excessive transport of corrosion products to the boiler. Also, copper alloys cannot be used in the condensate and feedwater systems, especially with an OT program. Since the water quality demand for OT is so pure, the unit generally must have a condensate polisher when using an OT program.

**Conclusion**
As Table 1 demonstrates, a mix of techniques is required for supercritical and subcritical units to achieve the desired level of treatment to keep your boilers functioning efficiently.

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**Table 1: Water Treatment Comparison**

<table>
<thead>
<tr>
<th></th>
<th><strong>Supercritical Units</strong></th>
<th><strong>Subcritical Units</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Condensate Polisher</strong></td>
<td>Required</td>
<td>Recommended</td>
</tr>
<tr>
<td><strong>All Volatile Treatment (AVT)</strong></td>
<td>Allowed</td>
<td>Allowed</td>
</tr>
<tr>
<td><strong>Oxygenated Treatment (OT)</strong></td>
<td>Recommended</td>
<td>Allowed with Condensate Polishing</td>
</tr>
<tr>
<td><strong>Phosphate Boiler Conditioning</strong></td>
<td>None</td>
<td>Acceptable</td>
</tr>
<tr>
<td><strong>Boiler Blowdown</strong></td>
<td>None</td>
<td>To Control Boiler Solids</td>
</tr>
</tbody>
</table>

Bryan Hansen is a senior chemical engineer in the Energy Group. He has a bachelor’s degree in chemical engineering from the University of Missouri-Columbia.
Reliability: Beyond the Numbers
Using Key Performance Measures

By Bill Strongman, P.E.

In today’s electric utility environment, managers are expected to spend less money on maintenance and system upgrades without sacrificing reliability. At the same time, utility boards and commissions are becoming more concerned about reliability and asking tough questions.

Boards and commissions are becoming acquainted with reliability indices and are beginning to use them as key performance measures to evaluate how utilities run their businesses. But do they understand what the numbers mean?

The Numbers

The indices measure duration and frequency of customer outages on an industrywide basis. One organization, the American Public Power Association (APPA) has taken the initiative to provide its members with software and training for reporting and recording the indices. The universally recognized indices used by the APPA are shown in Figure 1. They are:

**ASAI** – Average system availability index. ASAI is a measure of the overall reliability of the system. It represents the percent of time during the year that the average customer has power.

**SAIDI** – System average interruption duration index. SAIDI is a measure of duration. It measures the number of minutes over the year that the average customer is without power.

**SAIFI** – System average interruption frequency index. SAIFI is a measure of the number of times the average customer experiences an interruption in supply. For SAIFI, an interruption is a loss of supply for longer than one minute.

### Reliability Indices

**Figure 1:**

\[\text{ASAI} = \frac{\text{(customer minutes on)}}{\text{(total number of customer minutes per year)}}\]

- average number of customers per year = 28,365
- total number of minutes per year = 527,040
- total no. of customer min. per year = 28,365 x 527,040 = 14,949,840,960
- customer minutes on = 14,949,840,960 - 3,278,973
- ASAI = 14,946,561,987 / 14,949,840,960 = 0.999780668
- Average customer has power 99.98% of the time

\[\text{SAIDI} = \frac{\text{(customer minutes out)}}{\text{(number of customers)}}\]

- Customer minutes out = \(\sum\) outages (customer x minutes)
- number of customers = average no. connected for period
- Customer minutes out = 3,246,153
- number of customers = 28,365
- SAIDI = 3,246,153 / 28,365 = 114.44
- Average customer is without power for 114.44 min. per year

\[\text{SAIFI} = \frac{\text{(customer interruptions)}}{\text{(number of customers)}}\]

- Customer interruptions = \(\sum\) outages (customers out)
- number of customers = average no. connected for period
- Customer interruptions = 43,603
- number of customers = 28,365
- SAIFI = 43,603 / 28,365 = 1.54
- Average customer is interrupted 1.54 times per year

\[\text{CAIDI} = \frac{\text{(customer minutes out)}}{\text{(customer interruptions)}}\]

- Customer minutes out = \(\sum\) all outages (customers x min.)
- Customer interruptions = \(\sum\) outages (customers out)
- Customer minutes out = 3,246,153
- Customer interruptions = 43,603
- CAIDI = 3,246,153 / 43,603 ≈ 74.45
- Average customer that is interrupted is off for 74.45 minutes per interruption

\[\text{SAIFI (short)} = \frac{\text{(customer interruptions < 1 min)}}{\text{(number of customers)}}\]

- Customer interruptions momentary = \(\sum\) all outages (customers out)
- momentary = less than 1 minute
- Customer interruptions momentary = 171,700
- number of customers = 28,365
- SAIFI (short) = 171,700 / 28,365 ≈ 6.05
- Average customer is interrupted 6.05 times per year for less than 1 minute
CAIDI – Customer average interruption duration index. CAIDI is a measure of duration that provides the average amount of time a customer is without power per interruption.

An additional reliability index, SAIFI (Short), is the number of times the average customer experiences an interruption of less than one minute.

Interpreting the Numbers
Although these numbers in isolation have little meaning, they become significant when comparing a utility’s performance against industry averages, or when identifying trends. There are organizations that report outage statistics on behalf of member utilities so utilities can see how they perform against counterparts, but only a few utilities currently participate in these types of surveys. The APPA, as mentioned previously, is working toward providing this type of report for its member municipal utilities.

Even if a utility does not participate in a comparative survey, it can use the indices to identify trends in reliability, as shown in Figure 2.

The utility from which the data in Figure 2 was taken has experienced an improvement in reliability over the year shown. This type of information can be used to demonstrate to boards and commissions that the reliability initiatives undertaken by the utility are having a positive impact.

One must be cautious when using CAIDI. CAIDI, as mentioned previously, is a measure of the length of time the average customer can expect to be without power during an interruption. Some might think improved CAIDI means that the utility is doing a better job of restoring power; however, it’s more likely that improved CAIDI simply means that the utility was experiencing more short duration outages.

One might also interpret a reduction in CAIDI to be an improvement in reliability. Figure 3 demonstrates that this is not always the case. As can be seen, examining CAIDI would suggest an improvement in reliability from February to April, when in fact SAIDI and SAIFI show clearly that reliability is worsening. Both average frequency and average duration have increased. This reverses course from June to August, where SAIDI and SAIFI improved but CAIDI became worse. Why? Because CAIDI, by definition is SAIDI divided by SAIFI. Thus, if the change in SAIFI is proportionately greater than the change in SAIDI, then CAIDI will move in the opposite direction of the other two indicators.
Behind the Numbers
The real value for the manager trying to meet reliability expectations while being pressured to reduce costs is the data behind the statistics. Once the data has been captured, managers can look back and see why their reliability might be moving in the wrong direction. Figure 4 shows outages by cause. This information can help direct resources to the causes that need to be dealt with first. Figure 4 would suggest that the utility allocate more resources to upgrades and maintenance of underground equipment.

The data will also include the locations of outages. By cross-referencing location and cause, the utility can prioritize where it needs to spend its limited capital and operating dollars to improve reliability.

The utility manager can also look for trends by cause, as shown in Figure 5. This utility has experienced a significant reduction in outages caused by overhead equipment failure, but an increase in outages caused by underground equipment failure. This would suggest a trend toward more underground equipment failures.

Drawing a conclusion strictly on these numbers would be imprudent. The utility manager should look into possible causes for the change. It may be that a single anomaly such as improperly installed elbows is causing the increase in underground equipment failure. What is truly important is to know what is driving the number rather than the numbers themselves.

Although the reliability indices are important in demonstrating to boards and commissions that reliability initiatives are paying off, the real hidden gem is in the data itself. The data provides information that will help the utility manager prioritize capital and operating spending so that reliability can be improved without increasing costs.

For more information on this subject please send an email to the following address: Bill Strongman <techbriefs@burnsmcd.com>
Design Data
Making It Work for You

By Bryan Claxton

Any time a new facility is designed or an existing facility is altered, data is created that describes that facility. The data created includes design drawings, equipment schedules, specifications, catalog cuts, photographs, and operations and maintenance manuals. This information is valuable during the design process, but it may have even greater value once the design process is complete. Conserving this data and making it readily available once the facility is operational creates a powerful data foundation by which day-to-day efficiencies are accrued.

DataConservation™ and Data Retrieval Options
Burns & McDonnell applied its DataConservation™ strategy to a new water treatment facility in a fast-growing Colorado city. The goal was to come up with a digitally designed data management structure that could be used by the city once the water treatment facility was completed. The solution had to provide access to all the necessary design information — and fit within the city’s current information management structure.

A variety of solutions for making design data available to city staff were analyzed. The simplest solution was to scan all the operations and maintenance manuals, design drawings, photos, and similar documents, then transfer this information to a CD. The next intermediate step was to utilize a viewing package that allowed the viewing of scanned files. Adobe Acrobat was considered as an option that would allow the city to view all the data in a static PDF format. This option allowed for better dissemination of the information than the CD option because the information could be placed on city servers and extracted by anyone on the network.

The CD and PDF options had a major flaw: each provided a static snapshot of the facility data, and neither could be easily updated. In order to fully leverage the design data, the system housing the data had to be able to grow and evolve with the life cycle of the facility. To meet this goal, a third option was developed that utilized a Microsoft SQL Server 2000 database foundation and ESRI ArcIMS as a user interface to the design information.

Ease of Operation Using Client’s Staff
The ability to easily update and expand the data management system as the facility evolved was the key issue in the selection of the third option. The data management system is a tool by which city personnel can find and interact with facility information. The application, called the Electronic Operations and Maintenance Application (EOMA), was built to seamlessly integrate with the city’s existing information management strategies and disseminate the facility design information throughout the city’s
The software and programming languages were chosen based on the client’s existing assets and skills, to make the EOMA a facility data foundation that the city could modify and adjust with in-house staff.

**Microsoft SQL Server 2000 Geodatabase**
The EOMA’s foundation is the Microsoft SQL Server 2000 geodatabase. The geodatabase can be easily updated whenever the facility changes. Update procedures and techniques were also tailored to the skills and assets of the city and detailed documentation was provided as a reference guide for updating the system. The geodatabase foundation enables the city to integrate new information whenever necessary using in-house staff capabilities. For example, there is no need for new custom code in the application just because a pump was changed out and new pump information needs to be included in the system.

The design drawings from the facility were loaded into the geodatabase using ESRI Arc Toolbox. The Arc Toolbox provides tools to easily translate a variety of different drawing and vector data types into a geodatabase. Design drawing standards related to the layering scheme make it possible to extract different features such as walls or pumps and import them into the database as separate feature types. Once the design drawings are loaded into the geodatabase, a user interface can be used to view and interact with the data.

**User Interface and Information Retrieval**
The user interface for EOMA is a website that runs on the city’s Intranet server. The centerpiece of the website is an ESRI ArcIMS application that allows a user to look at facility drawings and zoom in or "drill down" to any part of the facility. Figure 1 shows the interior design drawing for the facility. The ArcIMS module of the system retrieves the spatial or mapping data from the geodatabase and renders it on screen. That spatial data is the design drawings for the facility. The floor plan of the facility is the starting point by which a user can zoom, pan, and "drill down" into details about different sections of the facility. A user can retrieve operations and maintenance manuals, photos, original design drawings and links to other sections of the website by simply pointing at a feature and clicking on it, or by using the links that are located on the left side of the window. Figure 2 shows a photo and O&M Manual.

The operations and maintenance information is
stored in an Adobe Acrobat PDF format and is opened in a separate window, where bookmarks within the document make it easy to jump to the particular section of interest. Additionally, the full functionality of the Adobe Acrobat viewer is available to users allowing them to pan, zoom, and print any of the documents.

Other sections of the EOMA allow users to carry out daily calculations, such as process and feed calculations, or search the database of design drawings or operations and maintenance manuals by vendor or keyword. Figure 3 shows the powder activated carbon functional calculator. In order to accommodate a variety of different users, numerous methods are available to navigate to the design information. As an example, users could choose to use the mapping module and visually zoom to a certain pump and retrieve the operations and maintenance manual, or they can use the search module and type in the keyword pump and find the manual. Each user may have a different methodology for finding the information, but the foundational information will be the same regardless of the methodology to extract it. The EOMA puts design information at the user’s fingertips.

Summary
The EOMA’s geodatabase foundation allows flexibility to expand the system in any direction. In the future, real-time connection to the water treatment facility’s SCADA system, connection to a Maximo work order management system, and the inclusion of all city facilities are options that may be pursued. The original goal of the project was to create a way for the city to easily get to the operations and maintenance information for the new treatment facility. The result is a foundation of design data built through DataConservation™ strategies that will not only provide the design data to the city, but will be able to grow as the city’s needs change.

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