REAL TIME WATER CHEMISTRY MONITORING and DIAGNOSTICS

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EPRI has produced a real time water chemistry monitoring and diagnostic system. This system is called SMART ChemWorks and is based on the EPRI ChemWorks codes. System models, chemistry parameter relationships and diagnostic approaches from these codes are integrated with real time data collection, an intelligence engine and Internet technologies to allow for automated analysis of system chemistry. Significant data management capabilities are also included which allow the user to evaluate data and create automated reporting.

Additional features have been added to the system in recent years including tracking and evaluation of primary chemistry as well as the calculation and tracking of primary to secondary leakage in PWRs.

This system performs virtual sensing, identifies normal and upset conditions, and evaluates the consistency of on-line monitor and grab sample readings. The system also makes use of virtual fingerprinting to identify the cause of any chemistry upsets. This technology employs plant-specific data and models to determine the chemical state of the steam cycle..

The SMART ChemWorks (SCW) system is currently being deployed at over 30 US nuclear plants, including PWRs and BWRs. These plants have realized benefits in several areas including:

- Reduced personnel time for reviewing routine chemistry
- Optimization of monitoring program
- Quicker response to chemistry excursions and Primary to Secondary Leakage
- Better control of key parameters such as Primary pH and BWR Hydrogen
- Control of chemistry by virtual parameters
- Real time evaluation of corrosion

SMART ChemWorks is deployed as a centralized, web-based system. Real-time data from the plants arrives at EPRI's dedicated server facility on a secure connection through the Internet at a frequency of up to once per minute. The SCW system monitors the incoming data for abnormal conditions, performs virtual sensing, and can identify bad monitors and the cause of chemistry upsets. The output from SMART ChemWorks is routed to a Web page for review by the EPRI investigative team and plant personnel.

If an incipient problem or upset condition is detected, the system triggers alarms, paging or e-mailing of utility chemistry personnel and EPRI's specialists, so that immediate corrective action can be taken. Since this is a web-based system, they can readily review the plant chemistry data wherever they are as long as an Internet connection is available.

This approach is a departure from traditional chemistry management. It's off-site, out-sourced, Internet-based, and driven by an artificial intelligence engine. These characteristics underlie the system's economic efficiencies. The system's advantages are somewhat counterintuitive: its intelligence reduces sampling and manpower requirements, but chemistry control is actually improved.

System Features

The initial functions of this system have been previously described.[1] In recent years, new functionality has been added to enhance the usefulness of the system.

BWR Crack Growth Rate

For BWRs, the calculation for crack growth rate has been added to the system such that a predicted growth rate[2] is continually calculated based on measured plant data. This can be used as an indicator to plant personnel to determine the degree to which they may be operating under detrimental conditions.

This calculated value is considered a virtual sensor, meaning that there is not an actual measurement of crack growth rate being made, but it is calculated in real time based on other parameters that are being measured. The value of virtual sensors is that they can be used in real time for alarming and decision-making. This approach automates what is sometimes a manual operation by plant engineers and chemists.

Benefit is also obtained from the ability to use chemistry measurements to present an assessment of the impact on corrosion. Several BWR plants have been able to use the output from SCW to assist in reviewing plant chemistry control and optimizing it to minimize crack growth. An example of the BWR Crack Growth tracking is shown in Figure 1.

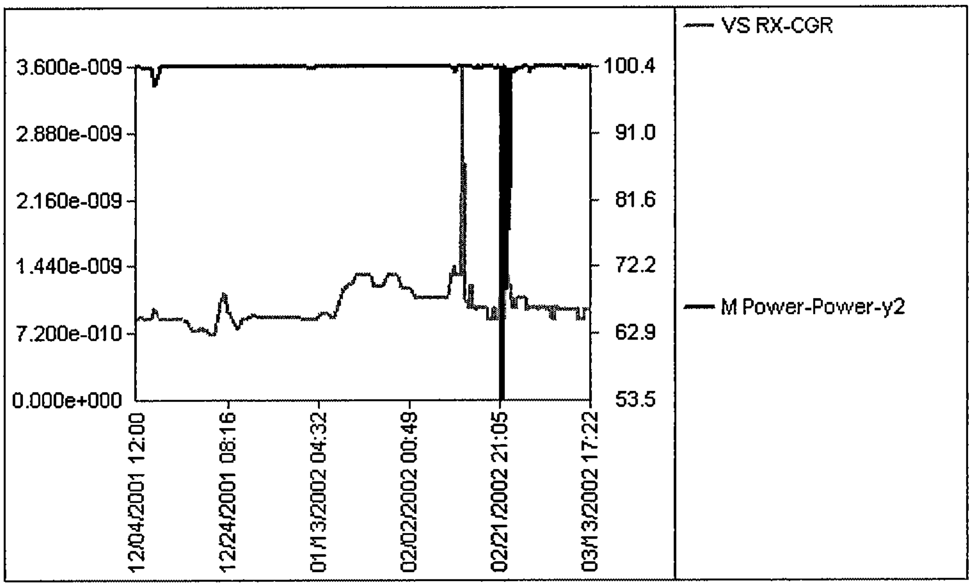

Figure 1 BWR Crack Growth Rate

PWR Primary Chemistry Evaluation

In 2001, a new module was added to the system to assist with planning and tracking the primary pH control program for a plant. The EPRI ChemWorks Primary System pH Calculator was integrated with the SCW system.

On a plant specific basis, the primary pH control program is designed at the beginning of the cycle based on the guidance provided in the EPRI Primary Chemistry Guidelines.[3] This program is the result of a complex set of criteria aimed at optimizing the system to minimize materials corrosion and personnel dose exposure, while providing proper reactivity control. Each plant designs their program such that lithium adjustments are made during the cycle relative to the amount of boron present at each point through the cycle. The combined lithium and boron concentrations, along with the temperature of the system are used to calculate a high temperature pH. The SCW system is then set up with a prescribed pH control scheme for each cycle for each plant. As real time data is collected, the high temperature pH is calculated as a virtual sensor similar to the crack growth rate discussed above. The incoming data is then compared to the planned operating regime and alerts and diagnostic advice can be offered. Figure 2 shows an example of the Primary Chemistry tracking information output by SCW.

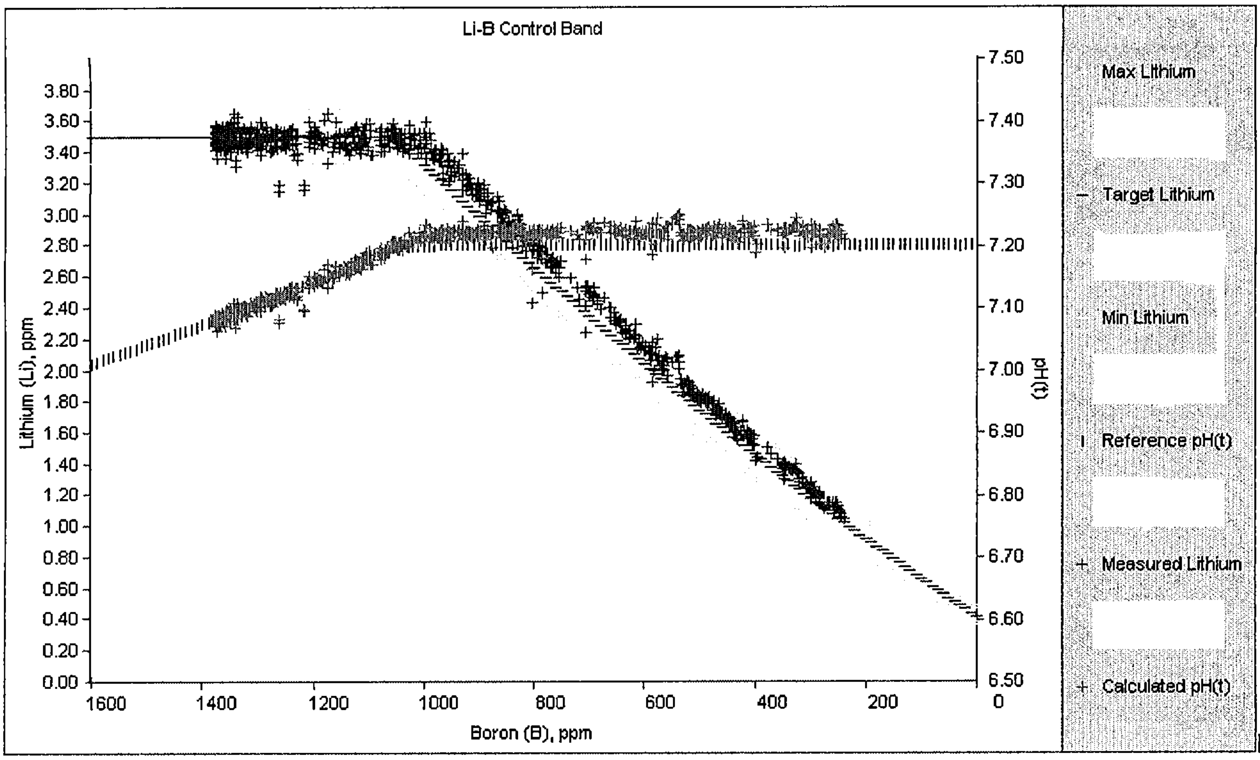

Figure 2 Primary Chemistry Evaluation

Primary to Secondary Leak Tracking

Primary to Secondary Leakage monitoring is an important element of managing steam generator performance at PWR plants. EPRI had previously developed a ChemWorks code called the Primary to Secondary Leak Calculator. This code has built in calculations for various methods to determine the rate of primary to secondary leakage based on isotopic analysis of samples from the primary and secondary systems. In 2000, this functionality was built into the SCW system. SCW is now collecting the raw data for these calculations as well as data from relevant on-line monitors such as N16 monitors and radiation monitors. The output from the system allows the user to view the trend of calculated leak rates along side the trends for on-line monitors. Guidance from the EPRI Primary to Secondary leak Guidelines.[4] When calculated or monitored leakage exceeds action level values as set forth in the guidelines (or a plant specific administrative limit) the system alerts and the appropriate guidance is displayed to the operator. An example of the output for Primary to Secondary Leak monitoring is shown in Figure 3.

Customized Reporting

A recent enhancement to the SCW system is the addition of customized reporting capabilities. Through these new tools, each user of the system can pre-define tables and graphs they would like to view on a regular basis. This information can then be called up with just a few clicks. This feature has been very valuable for plant personnel who regularly review the data, and for those tracking problems in a given plant that stretch out over a period of time. The reporting capability allows the user to create and save a report template that is based on combining any number of charts, tables, and calculated values (i.e., daily averages, maximums, minimums) from the existing databases. These reports allow the user to view any combination of data from across different plants and systems and also to view measured data and calculated data in tandem. Once the report template has been created, the report can quickly be populated with current data and viewed or printed over the web based interface.

Sampling Reduction Program

One of the largest benefits to users of SMART ChemWorks is the ability to reduce the amount of plant sampling that is performed. Since the SCW system has a sophisticated steam cycle simulator built into it, it has the ability to predict many chemistry parameters at locations around the plant with just a few measurements. The power of this feature can be utilized in many cases to reduce the amount of routine chemistry analysis that is performed.

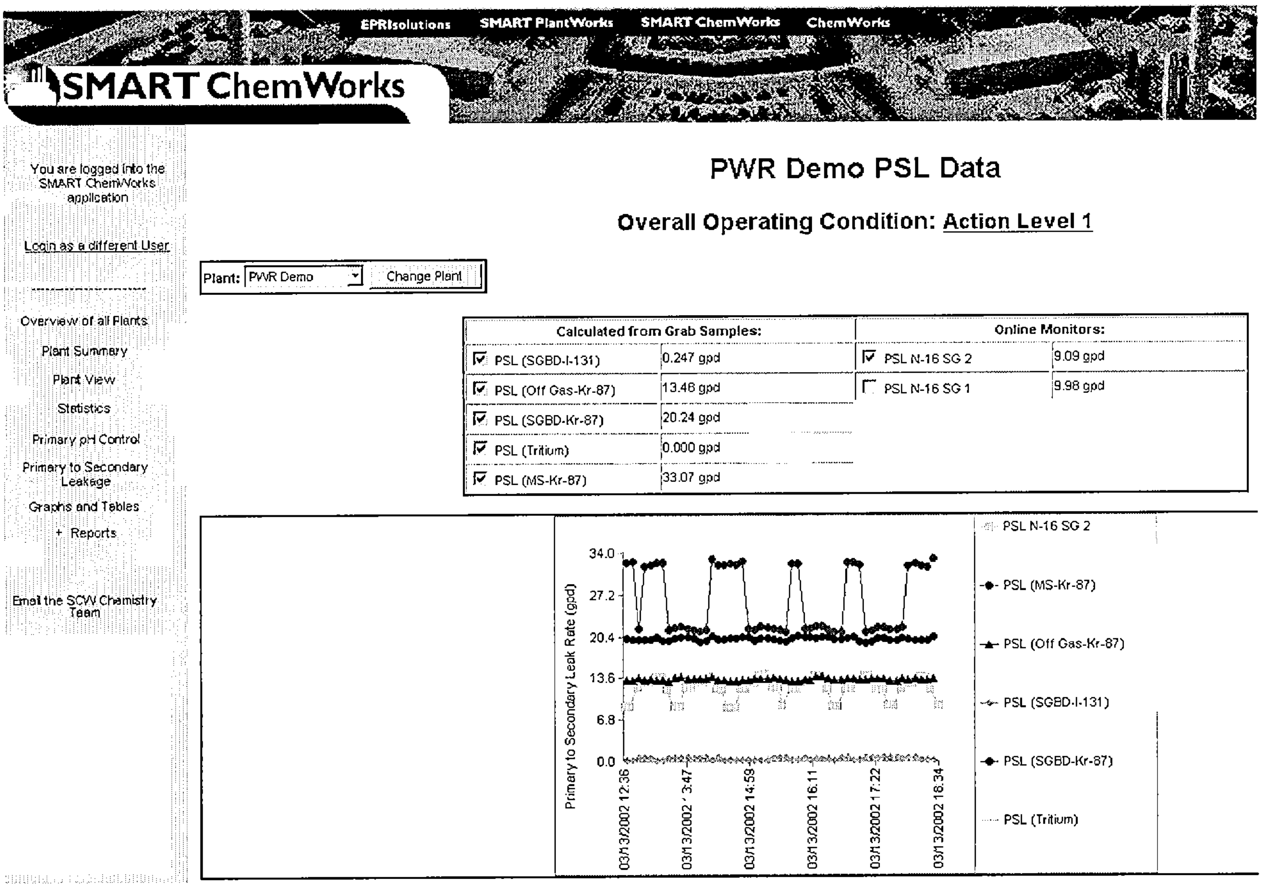

Figure 3 Primary to Secondary Leakage Monitoring

To ensure maintaining an optimum chemistry, it is essential that samples are collected at various locations and data are reviewed routinely. Recently, one plant using SCW changed its sampling philosophy from "lots of samples always" to "increased sampling to identify problems", and initiated a change to its sampling procedure by utilizing SMART ChemWorks. Specifically, the plant initiated a sampling frequency reduction program by using calculated values, or virtual sensors from SCW.

To identify the minimal data required to control operational chemistry, the current plant sampling program was compared with those of EPRI PWR Secondary Water Chemistry Guidelines[5] and vendor recommendations. Possible candidates for the sampling frequency reduction program were considered from non-control/diagnostic parameters with values that can be accurately predicted from SCW. As a first attempt, the parameters shown in Table 1 were selected for evaluation and verification. These are all samples where SCW can predict a value (i.e., Feedwater Na is predicted based on measured SG Na values) and where the station's typical measurements do not have a high degree of certainty because the typical values are below the limits of detection. Additionally, significant changes in these parameters would be reflected in other on-line data that is being continually monitored by the system.

Table 1 Candidates for Sample Reduction

	Feedwater	Main Steam	Heater Drain Tank	Condensate	Condensate Polisher Effluent
Na	x	x	x	x	
Cl	x	x	x	x	x
SO_4	x	x	x	x	x

The verification is performed by comparing the measured values of the parameters with the calculated ones from SCW. Since all the values are below low detection limits, a special sampling analysis using more accurate technique is required. Once the verification processes are completed, sampling frequencies of the parameters are reduced, and calculated values from SCW are used in place.

By adopting the sampling reduction program, the plant expects to significantly reduce the cost for grab samples and analyses. In addition, the plant will have benefits from better utilization of staffs, i.e., increasing plant operation supports, increasing interface with the maintenance shops and operators to keep chemistry issues visible, etc.

Future Work

The use of this real-time monitoring system is becoming more widespread and improvements are being continually made. Recently EPRI completed an upgrade to the Plant Chemistry Simulator that allows for transient analysis of plant chemistry conditions. In this way one can model the predicted change in chemistry conditions over time based on some perturbation to equilibrium conditions, for example the initiation of a condenser leak, or a change in the blowdown flowrate can be modeled to show the expected time to reach an action level value for steam generator chlorides. At some point this functionality will be added to the real-time system to allow not only for diagnosis of current events, but a prediction of the future condition of the system so that counter measures can be quickly implemented and avoid the need for costly shutdowns or power reductions. The expected outcome of several counter measures can be immediately assessed using this tool, to determine the best course of action to keep chemistry in good control.

EPRI has recognized this approach as an ideal way to deliver the EPRI technology in a manner that makes it immediately available and usable for utilities. As such, the platform used within SMART ChemWorks has been dubbed SMART PlantWorks with the intent of expanding the concept to other areas of plant monitoring and diagnostics. Much effort is taking place to incorporate other EPRI codes to provide a more comprehensive plant monitoring package. The WasteLogic family of codes, which assist a plant in evaluating its Low Level Waste processing, is currently being integrated with SCW.

Other work is aimed at providing similar tools for non-nuclear power plants and sub-station monitoring. SMART PlantWorks modules currently exist in the areas of fossil plant chemistry monitoring, electrostatic precipitator monitoring and substation monitoring. More details on these applications can be found at www.smartplantworks.com

Summary

The advanced technology built into SMART ChemWorks and real time access via the Internet allows utilities to make efficient use of on-site chemistry support. With this system, the on-site staff is supplemented with some off site expertise and continual computer based analysis of the data collected.

The use of this system will also allow a utility to optimize their sampling program.

Real time chemistry data, trending tools and SMART ChemWorks diagnostics are available 7 days a week, 24 hours a day to utility staff wherever they have Internet access. The system has been designed to perform the routine monitoring and to provide the critical diagnostic information needed for decision support when a problem does occur in the plant.

References

[1] Gaudreau, T.M., Millett, P.J., Andreani, I., "Implementation of A Real Time Water Chemistry Monitoring and Diagnostic System," presented at Water Chemistry of Nuclear Reactor Systems 8, BNES, 2000.
[2] EPRI TR-103515-R2, BWR Water Chemistry Guidelines –2000 Revision.
[3] EPRI TR-105714-V1R4, PWR Primary Water Chemistry Guidelines, Revision 4, March 1999.
[4] EPRI TR-104788-R2, PWR Primary to Secondary Leak Guidelines, Revision 2, April, 2000.
[5] EPRI TR-102134-R5, PWR Secondary Water Chemistry Guidelines, Revision 5, May 2000.