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Westinghouse Electric Company Experiences in Chemistry On-line Monitoring In Eastern European Nuclear Power Plants

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INTRODUCTION

Westinghouse Electric Company has provided a number of Chemistry On-Line Monitoring (OLM) Systems to Nuclear Power Plants in Eastern Europe. Eleven systems were provided to the Temelin Nuclear Power Plant (NPP) located near the village of Temelin in the south of the Czech Republic. Four systems were provided to the Russian NPP at Novovoronezh. In addition, a system design was developed for primary side chemistry monitoring for units 5 and 6 of another eastern European VVER. This paper will discuss the status of the Temelin OLM systems, including updates to the Temelin designs, and briefly describe the other Eastern European installations and designs mentioned above. Some of the problems encountered and lessons learned from these projects will also be discussed.

On-line chemistry analysis systems allows plant chemistry personnel to accurately monitor chemistry throughout the major systems of each unit and provides the chemistry conditions to the reactor operators and chemistry staff in real time. The importance and advantages of carefully and continuously monitoring chemistry on-line in operation of the plant are well known and were discussed in previous papers.

TEMELIN

The Temelin Nuclear Power Plant (NPP) is located near the village of Temelin in the south of the Czech Republic. Systems were provided by Westinghouse along with CEZ, S.A., Jaderná Elektrárna Temelín and SKODA as part of a state-of-the-art instrumentation and control system for the Temelín Nuclear Power Plant. The Temelín Plant is a two unit plant with a 1000 nominal megawatt pressurized water VVER reactors in each unit.

Papers were presented at the 2nd and 3rd PAKS conferences describing the design of the Temelin Chemistry OLM systems. A brief history of the panels is shown in table 1 below:

Table 1 Temelin Chemistry On-line Monitoring Systems History

Date	Action
1993	Chemistry OLM Contract for Temelin as part of Overall I&C Contract
1994-1996	Design, Construct, Test, and Ship Systems
1995	PAKS Conference Paper (Tom Wright)
1996-2000	Training for Operational Personnel
1997	PAKS Conference Papers (John Balavage, et. al.)
1998-2000	System Upgrades
1999-2000	Installation, Testing, and Startup Unit 1 Chemistry OLM Panels
2001	Installation, Testing, and Startup Unit 2 Chemistry OLM Panels

Chemistry on-line monitoring systems provided to Temelin are listed in table 2. Each system consists of several panels, typically, a power distribution panel, a main analyzer panel, a sample conditioning or chiller panel, and additional panels as necessary. The systems were described in previous conference papers and will only be described herein to the extent needed to discuss the upgrades.

Table 2, Temelin Chemistry On-Line Monitoring Systems

System	Number of Panels	Number of Samples	Number of Analyzes
Unit 1 Secondary Side (SSOLM)	3	25	41
Unit 2 Secondary Side (SSOLM)	3	25	41
Unit 1 Steam Generator Blowdown (SGBD)	3	4	14
Unit 2 Steam Generator Blowdown (SGBD)	3	4	14
Steam Generator Blowdown Treatment (SGBDT)	2	9	12
Unit 1 Boron Concentration Monitoring System (BCMS)	7	7	7
Unit 2 Boron Concentration Monitoring System (BCMS)	7	7	7
Unit 1 Reactor Building Waste Gas (RBWG)	8	8	10
Unit 2 Reactor Building Waste Gas (RBWG)	8	8	10
Unit 1 Reactor Coolant System (RCS)	4	5	9
Unit 2 Reactor Coolant System (RCS)	4	5	9

Temelin Status

Installation, upgrading, and testing of the unit 1 systems was mostly completed by late 2000. Since that time they have been operated and maintained on a day-to-day basis by plant personnel, including lay-up of the panels for an extended period of time while unit 1 was shut down to solve other plant problems. Westinghouse continues to have some involvement is seeing that the systems are operating properly through the Provisional System Acceptance (PSA) and warranty period.

Westinghouse involvement has been in troubleshooting problems that required additional assistance and in hardware problems.

For unit 2, the systems have been mounted in place and most internal modifications and upgrades have been performed. Some modifications, such as Y2K upgrades and software/configuration modifications require electrical power to the panels to be available before they can be made. External connections to the panels including wiring, tubing, piping, and ductworks are presently being made. Testing of the unit 2 chemistry OLM panels is expected to start in the second half of 2001.

Training for plant personnel responsible for operation and maintaining the chemistry OLM systems was provided. Classroom sessions (in 1997) and hands-on training by participation in factory acceptance testing at the panel fabricator (1996) was conducted in the U.S for several key individuals to provide an early start on familiarization with the panels. After the panels were installed training was provide at the Temelin site by lectures and hands-on training by participation in the testing. This provided a controlled environment for the trainees to become familiar with the panels and provided the opportunity to train more people than was provided by the earlier training. Participation in solving problems encountered during testing allowed the trainees to get a deeper understanding of the systems.

Temelin System Upgrades

All 11 systems were shipped to the site by late 1996. Many upgrades were made to the systems during the installation/startup/testing phase of the project. Three of the major upgrades will be discussed in the following paragraphs.

Boron Concentration Monitoring System (BCMS)

The Temelin BCMS analyzes seven sample streams by titration using sodium hydroxide after complextion of the boric acid with mannitol. All seven sample streams were sequenced through a single Applikon on-line titrator in the original design. The computers in the data acquisition system controlled sequencing and operation of the Applikon analyzer. All seven samples were sequenced through a single analyzer because the on-line analyzers are expensive.

Major concerns with analysis times were identified with the BCMS system after installation of the unit 1 BCMS system was underway. The first concern was long sample times. Because the samples were sequenced, the sequencer had to go through all the other samples to be analyzed before repeating an analysis. The long time between repeated analysis on a single sample, was not acceptable during start ups (and going critical), when repeated frequent analysis of a few samples are necessary. Even if only the three samples were monitored during startups (it is possible to skip individual samples in the sequencer), the combined time for all three samples was still to long.

The second concern was that the titration for an individual sample in the Applikon analyzer was taking too long. Complete analysis of a single sample were desired in less than 15 minutes and originally were taking as much as 20 minutes or slightly more.

A third concern identified was the transit time to get the sample to the analyzers. Transit time adds to the overall delay of the sample analysis because the sample has already aged by the time it has taken to transit the sample through the sample lines before it can be analyzed. Also, if the samples are being sequenced and no bypass of the samples close to the analyzer exists, then the sequencer must allow sufficient time to thoroughly flush the sample line before sampling for another analysis. This adds even more time to the analysis.

Solution for the first concern is obvious; simply add additional analyzers to reduce or eliminate the sequencing delays. However, this is a very expensive solution. Fortunately, CEZ happened to have three (3) AnaChem on-line analyzers that they originally planned to install for this purpose. This concern was solved by upgrading the three existing AnaChem analyzers to the most current version (they were purchased several years earlier), buying one additional AnaChem analyzer, and installing two AnaChem analyzers in each of the BCMS systems for unit 1 and unit 2. The AnaChem analyzers were each devoted to a single sample that was not sequenced. During startups, only one of the five (5) samples remaining in the Applikon analyzer is put into service so that only that sample cycles continuously in the sequencer. Therefore, during startups, each of the three streams monitored, has an exclusive analyzer and the long delays times caused by sequencing are not a problem.

Second concern related to the length of time that was required to perform the analysis with the Applikon analyzer. Several improvements were made to speed up the total time to do the titration. These steps included:

1. Upgrade the CPU board in the computer used to monitor and control the Applikon analyzer from a 486 processor to a 150 MHz Pentium.
2. Change the software configuration to read the Applikon program from the hard disk rather than the Applikon itself.
3. Add an option to do a "fast titration".

Testing of these changes showed that time to perform the titration could be reduced to less than ten minutes, which was approximately the same as for the AnaChem analyzer.

Increasing sample flow to about three (3) liters per minute with most of the flow being recycled reduced transit time in the sample lines.

Combining all of these upgrades results in a sampling analysis time being less than 15 minutes from the time the sample entered the sample line. Which was the desired result.

Figure 1 shows a schematic of the changes that were made to the BCMS to accommodate these changes. With these changes, Westinghouse can configure the Boron Concentration Monitoring System to exactly meet the customers needs ranging from a single sample stream analyzed continuously and quickly to multiple streams with some .having individual analyzers for more rapid analysis and sequencing of those sample streams that do not require as rapid analysis.

Reactor Building Waste Gas System

Concerns with delays in sample analysis time also arose with the RBWG system due to the sequencing and low flow rate in the sample lines. This was an important concern in this system because some of the results are used to control the burning of hydrogen in the waste gas system. An analysis time of less three minutes was desired for these samples. In the original design eight (8) samples were sequenced through a single analyzer that measured oxygen and hydrogen. Adding four sub-panels to the system a separate sample being analyzed by each sub-panel alleviated the sample delay times caused by the sequencing. Significantly increasing the flow rate through the system bypass significantly reduced the sample transit time. Table 3 lists the samples analyses performed and whether the sample is sequenced.

Table 3, Temelin RBWG Samples

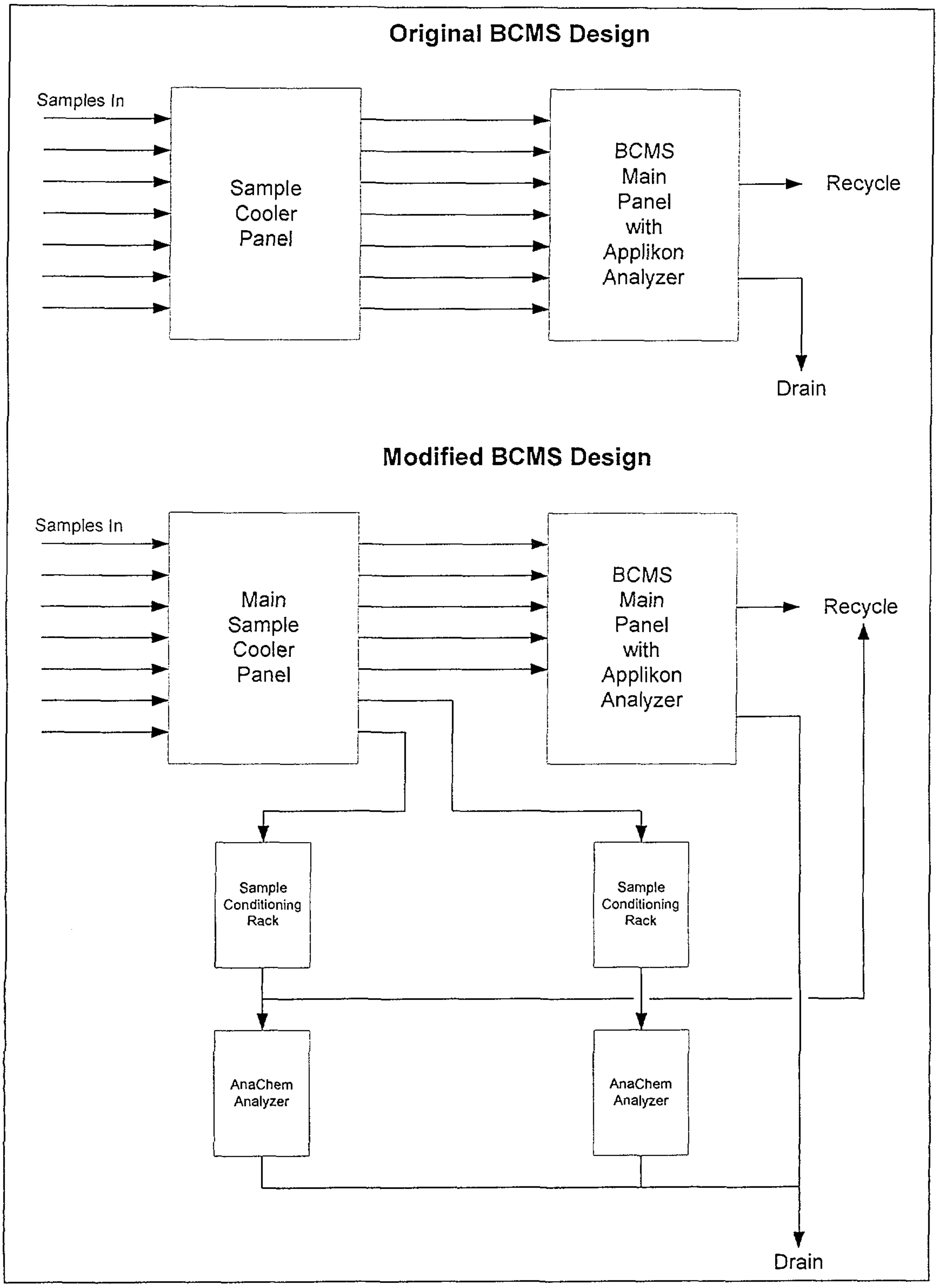
Sample	Sequenced	Analyses
TB30Q01	Yes	H_2
TB30Q02	Yes	H_2
TP15Q01	Yes	H_2
TP60Q04	Yes	H_2
TS14Q01	No	H_2,O_2
TS10Q02	No	H_2
TS10Q04	No	O_2
TS15Q01	No	H_2,O_2

Alarms

Local alarms are generated by the data acquisition system and displayed at an alarm annunciator panel in each of the systems. Analytical measurements from the panels are passed on to the plant computer system, where plant alarms based on those analyses are generated. In addition to alarms related to analyzed values, the local alarm panel also displays information about the state of the systems. These include information such as sample temperature alarms, analyzer in-service/out-of-service state and others.

Many of the on-line monitoring systems are located in rooms with restricted access and are normally locked. Local alarms that are displayed solely on the local annunciator panel will be observed

Figure 1, Temelin BCMS Upgrades to Minimize Sample Analysis Delay Times



only when a person enters the room. In order to provide some information on the state of the systems on a plant wide basis, it was decided to provide information on the state of the local sample temperature alarms and low sample flow alarms.

Since temperature alarms already existed locally in the systems, incorporation of these alarms on a wider basis meant incorporating them in the Temelin plant database and generating the appropriate displays. This work is outside of the OLM scope; we simply provide the information used to build the database and displays.

Low flow alarms did not exist locally because they were not part of the original design. To implement low flow alarms, a flowmeter (rotameter) in each of the sample lines was replaced with a new one containing a low flow sensor. The low flow sensors were wire to new flow alarm relays and then to the data acquisition system. From that point implementation was similar to the temperature alarms.

Because the data acquisition system was not designed accommodate the inputs from the flow alarms and additional inputs could not easily be added, in some cases, similar samples were grouped into a common flow alarm. Also because the low flow alarms were not originally designed into the system, the required number of annunciator windows were not available or the number of discrete outputs to poser the annunciators were not available (without making unreasonable changes) in all systems. In those cases a single common low flow alarm was generated on the annunciator panel. In all cases a local alarm was created by generating an alarm warning on the data acquisition systems display screen in addition to the common alarms in the annunciator panel

Temelin Challenges

The Temelin chemistry on-line monitoring project has presented many challenges to be overcome. Some of the more interesting ones were:

- Obvious Challenges
  - ♦ Language barriers
  - ♦ Long distance communications
  - ♦ Time-Zone differences
  - ♦ Metric/English measurements and sizes
  - ♦ Vendor support in a foreign country
- Long time between shipment and installation/startup.
  - ♦ The first systems were shipped to Temelin in 1994 and all shipments (based on the original design) were completed by the end of 1996.
  - ♦ Between the time of purchase of the original components and the installation some of the vendors have been bought or merged with other vendors
  - ♦ Vendor part numbers for many of the components have changed.
  - ♦ Some of the components have been replaced by newer models or become obsolete.
  - ♦ Plant design changes resulting in information used to design OLM panels being out-of-date.
- Continuity of personnel
  - ♦ Loss of personnel through job changes/transitions/retirement.
  - ♦ New people have had to be trained on-the-job.
- Vendor Documentation
  - ♦ Documentation from some of the component vendors has been difficult to obtain, often it seems

as if they are doing the design when they install the hardware, or they don't really have the documentation.

- ♦ This has resulted in delays in Westinghouse providing design information to the customer and in changes to the Westinghouse documentation when vendors have made changes in the field to make their systems work.

- Quality Assurance requirements, imposed by the customer, mandated treatment of all components as though they are safety related. These requirements have caused delays with inspection and shipment of replacement parts. Combined with the changing part numbers this has been a particularly vexing challenge.

NOVOVORONESH EHMS

In early 1998 Westinghouse was awarded a contract to supply Emergency Hydrogen Monitoring Systems (EHMS) for the primary circuit in unit 4 at the Novovoronezh Nuclear Power plant at Novovoronezh, Russia. Westinghouse designed, constructed (actually hired a sub-contractor to construct), tested, shipped, and provided testing, training, and startup assistance. These panels were constructed in 1998, the first was tested at the panel fabrication facility in December of 1998, and the others in early 1999. The systems were installed by the utility and started up in mid 1999.

Although measurement of hydrogen is a relatively simple, the design constraints for these systems were unique. Some of the constraints were:

- The sample could not be sent to a low pressure drain. It needed to be returned to the primary circuit at high pressure.
- Amount of gasses sent to the vent system was severely limited.
- The original design called for the system to be capable of operating while submerged in water.

Each system consisted of a mechanical panel, an air-conditioned electrical panel, and a data acquisition system. A strip chart recorder, for the control room was also provided.

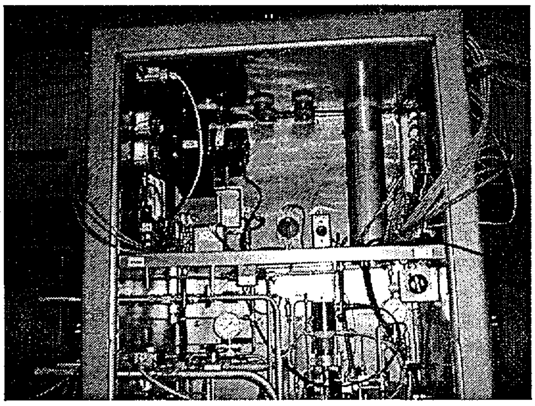
All of the mechanical hardware, including sample conditioning, the hydrogen sensor, supporting hardware for the hydrogen sensor, and the sample recycle equipment were located in the mechanical panel. Since some electrical equipment needed to be located in the mechanical cabinet, the section containing the electrical equipment was isolated from the rest of the cabinet tom minimize the chance of the electrical equipment being exposed to water. Figure 2 is a photograph of the dry part and part of the wet part of the mechanical cabinet.

The electrical cabinet contained the power conditioning and power, distribution equipment for the system. A data acquisition system and the hydrogen analyzer were also located in the electrical cabinet. One IBM compatible PC running data management/process control software was remotely connected to each of the data acquisition systems.

Westinghouse fabricated the electrical panel in house and a panel fabricator fabricated the mechanical panel. The electrical panel was shipped to the panel fabrication shop and for testing, including EMC testing. Personnel from Novovoronezh traveled to the US for training, testing, and approval of the systems before they were shipped.

The plant was totally responsible for the installation with Westinghouse providing information and documentation as required for interfacing and licensing. After the systems were installed, one Westinghouse engineer traveled to the site to perform further training, and assist in the site testing and initial start-up.

Figure 2, Novovoronezh EHMS Mechanical Panel



OTHER PLANTS

Primary chemistry on-line monitoring systems were designed for two 1000 MW units of a VVER in southeastern Europe. The design started with the Temelin Reactor Coolant On-Line Monitoring System but was changed extensively based to some extent on experiences with the Temelin and Novovoronezh systems but more based on input experienced plant chemistry personnel from that plant. The design has yet to be implemented and may require extensive scaling back to fit with budgetary constraints. Hopefully, further details of this can be presented at future conferences.

CONCLUSIONS

Westinghouse Electric Company successfully implemented chemistry on-line monitoring systems at the Temelin NPP and Novovoronezh NPP and provided a design for another VVER plant. Close cooperation with the customers overcame the challenges in the design, installation and startup of the systems to provide systems needed and wanted by the customers. Primary and secondary circuit parameters have been monitored with the systems provided.