Expecting More from the Nuclear Fleet

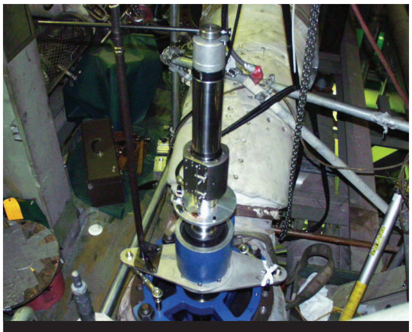
Maintaining balance-of-plant components is crucial.

By Nancy Spring, Senior Editor

From welds to valves to concrete floors, nuclear power plants are beginning to show their age. At the same time, plant owners are hoping to extend their plants' operating lives.

High-profile projects performed during scheduled outages like turbine or steam generator replacements are marvels of engineering and scheduling prowess. But the less glamorous balance-of-plant (BOP) systems also need constant attention.

In April, the Nuclear Regulatory Commission (NRC) approved a 20-year operating license extension for Oyster Creek Generating Station, the oldest nuclear power plant in the U.S. In late August, plant operators removed a 25-foot section of underground pipe that was leaking inside the turbine building, close to where two smaller leaks had been discovered months before.Station operators continue to inspect pipes in the affected area as part of the site's aging management program.



Boring machine repairing the threads on a nuclear high pressure steam bypass valve at Palo Verde power plant. Photo, Climax.

To extend the lives of aging reactors like Oyster Creek and boost efficiency, utilities are instituting innovative maintenance programs and repair procedures. It's no wonder: of the 104 nuclear plants operating in the U.S. today, 52 have been in service for between 30 and 39 years. As of June 2009, the NRC had extended the licenses of 54 reactors and has license renewal applications under consideration for another 16 units.

"Repair and maintenance issues in the industry include lifetime extension projects, where a critical component must be fixed to get an operating license renewed, and uprates to get 5 percent or 6 percent more energy out of the plant," said Andy Becker, vice president of marketing at Climax Portable Machine Tools, a provider of on-site machining solutions.

Uprates and Upgrades

As nuclear power plants in the U.S. fleet reach the end of their licensed operating lives, operators have become masters of the upgrade and the uprate. Upgrades can be performed to support operating license extensions and improve reliability, while uprates also add megawatts to the plant's output.

According to the NRC, uprates to the U.S. nuclear fleet have added generating capacity to existing plants equal to more than five new reactors. And the NRC expects another 24 power uprate applications in the next five years, including 17 extended uprates and seven measurement uncertainty recapture uprates. (See sidebar.)

NRC UPRATES CATEGORIES

Nearly every U.S. commercial nuclear reactor is designed with excess capacity to allow for power uprates. Depending on the increase in power level and original equipment design, major modifications may be necessary—non-nuclear components such as pipes, valves, pumps, heat exchangers, electrical transformers and generators must be able to accommodate the conditions that would exist at the higher power level. The NRC divides power uprates into three categories:

Measurement uncertainty recapture (MUR) power uprates refer to an increase of less than 2 percent of the licensed power level, achieved by implementing enhanced techniques for calculating reactor power.

Stretch power uprates refer to an increase of between 2 percent and 7 percent, with the actual increase in power depending on the design's specific operating margin. Stretch power uprates usually involve changes to instrumentation settings but do not require major plant modifications.

Extended power uprates have been approved for increases as high as 20 percent. Extended power uprates usually require significant modifications to major pieces of non-nuclear equipment such as high-pressure turbines, condensate pumps and motors, main generators, and/or transformers.—NS

If these applications are approved, the resulting uprates would add another 5,254 MWt to the nation's nuclear generating capacity.

A series of plant upgrades and uprates over the past 10 years have already added approximately 1,100 MW to Exelon's nuclear fleet and the company recently embarked on a new uprate program.

Exelon, which operates the largest fleet of commercial nuclear reactors in the U.S.—and the third largest in the world—launched a series of nuclear power uprates that will result in between 1,300 and 1,500 MW of additional generation capacity within eight years. Exelon's uprate projects include measurement uncertainty recapture (MUR) uprates (see sidebar), extended power uprates, generator rewinds and turbine retrofits.

Uprate projects are underway at the Limerick nuclear station in Pennsylvania and the Dresden and LaSalle plants in Illinois. Over the next three years, Peach Bottom in Pennsylvania will replace all six of its main power transformers, an $87 million project.

Equipment upgrades at Exelon's Quad Cities nuclear plant near Cordova, Ill., have already increased the plant's output by 38 MW. In September, Areva completed installing and commissioning two Siemens variable frequency drive (VFD) systems for reactor recirculation pump speed control at Quad Cities Unit 1. The VFD system controls the rotational speed of an AC electric motor by controlling the frequency of the electrical power supplied to the motor.

The new drives are designed to enable more precise reactor recirculation flow control, reduce in-house load due to increased electrical efficiencies and reduce required maintenance—basically, improve plant performance while reducing house load. According to Areva, the NRC projects that more than 2,600 MW of capacity at existing nuclear power plants will have been added through efficiency gains alone by 2013.

Nine more Exelon plants will become involved in uprate projects starting in 2010.

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"When you are talking about an uprate, there's often an increase in fluid flow, so you have to look at the valves and recalculate the feed diameters and the size of the valves," said Frank Gilhooly, global product marketing director, Tyco Flow Control.

As capacity increases, the pressures are increased and the existing valves have to be redesigned, retrofitted or replaced. Tyco is currently working at the Monticello nuclear plant in Minnesota and Nine Mile Point in New York on moisture separator reheater pressure relief valves.

In Situ Is Preferable

Valve repair work is coming up at quite a few older plants. Doing the work on site is preferable to cutting the valve out, transporting it to a machine shop that can handle contaminated materials and then rewelding it back in place.

"Without exception, nuclear plant operators would much prefer not to have to take something out of the plant for repair," said Gilhooly. Tyco has a device that can test the integrity of the set pressure on main steam safety valves in situ, which was used at the Robert E. Ginna and Calvert Cliffs nuclear stations. The company is also working on technologies that could decontaminate isolation valves inline by running special chemicals through the valve to reduce radiation.

Making repairs at nuclear plants requires specialized equipment and techniques. Repairs can be inside the reactor pressure vessel where there is not a lot of space or where radioactivity issues may exist. Robotic machines with computer numerical controlled (CNC) controls are used for these situations.

Climax's Becker said his company's specialty boring machines are used for enlarging steam nozzles or doing turbine housing work and they are becoming more popular as utilities search for ways to produce more power.

"We're seeing more requests for a machine to bore out steam nozzles to make them bigger to generate more steam or bore out the turbine housings themselves to get bigger blades inside," he said.

On the main steam isolation valve (MSIV) on boiling water reactors, routine milling and polishing can be done in place with a tool Climax designed. The project can take two or three hours, not weeks. The MSIV separates the radioactively contaminated part of the plant from the rest of the plant and is heavily regulated. Even after the plant tests the MSIV, it's sometimes remachined to make sure the fit is tight, in case of an emergency. "A lot of customers leave the machine inside the reactor, in case there is a false alarm and they have to remachine it," said Becker. That's what Exelon did at its Peach Bottom Atomic Power Station, he said.

Climax worked on two valve jobs at Palo Verde Nuclear Generating station in Arizona: a steam bypass valve that needed machining in the C-ring gasket area and a feedwater control valve that needed new threads. Modified standard machines were used, which kept expenses down. Palo Verde Unit 2 has been uprated in capacity and is now the nation's largest nuclear plant, according to the NRC.

The Inconel weld 600 issue continues to be a major concern, said Becker. Inconel alloy 600 steam generator tubes and hardware were used in nuclear reactors for electric power generation beginning in the 1950s. But the weld is subject to stress cracking after long exposure to high purity reactor steam and primary water.

"We designed machines to remove the old weld material on site and with our service partners, reweld and then remachine the weld to its proper geometry," Becker said.

Aging and Corrosion

Repair services at aging nuclear power plants appear to be increasing. For example, July 2009 saw the second highest number of orders in Climax's 44-year history, said Becker. What's more, plant maintenance is becoming more sophisticated as companies gain operating experience and technological advancements allow more innovation.

To capitalize on this opportunity, French nuclear company Areva recently teamed up with Day & Zimmermann to offer engineering, construction and maintenance services to U.S. nuclear utilities. The joint venture, Areva DZ, will primarily focus on BOP, implementing major and minor nuclear plant modifications, power uprates, plant upgrades and other complex projects.

FEEDWATER MAINTENANCE GUIDE TACKLES A MAIN CONTRIBUTOR TO NUCLEAR PLANT SCRAMS

Reversing the trend is complicated by power uprates and aging equipment.

A feedwater system maintenance guide from the Electric Power Research Institute's (EPRI) Nuclear Maintenance Application Center (NMAC) provides nuclear plants with detailed guidance and best practices to drive improved reliability and reduce the likelihood of unit trips.

Main feedwater (FW) system events are consistently the largest contributor to automatic and manual scrams at nuclear power plants, directly impacting plant production and availability. NMAC examined FW-related reactor scrams over the past four years and found that while the trend is somewhat cyclical, the number of events is gradually increasing. Based on industry data, between 2006 and 2008 there were 162 feedwater system events, accounting for about 6 million MWh of lost generation, equivalent to a 900 MW unit being off-line for nine months.

Utilities have taken a number of steps to combat this trend, including predictive and preventative maintenance practices, system monitoring, equipment upgrades and improvements and the removal of single-point vulnerabilities when possible. Reversing the trend, however, is complicated by several factors, such as power uprates, which place additional stress on feedwater systems and reduce operating margins; aging of the equipment; and potential concerns regarding supplier quality.

To help nuclear plant owners reverse this trend, NMAC is compiling a report that will identify good maintenance practices contained in existing EPRI products and review technologies that can improve component and FW system reliability. For example, FW heater level control is of great importance to system reliability and efficiency. The NMAC Level Control Guide for Feedwater Heaters (EPRI Report Number 1003472) describes the critical control components and details how to properly set up and maintain these controls to maximize reliability. The Mechanical Seal Maintenance Guide (EPRI Report Number 1000987) guides users in selecting the correct seal design and in troubleshooting problems encountered during operation.

As part of this effort, NMAC is collecting data with the help of its member companies, the Institute of Nuclear Power Operations and the BWR Owners Group. This data provides useful benchmarking information that nuclear plants can use to gauge their FW maintenance practices. For example, the collected data reveals that nuclear power plants are using time-based strategies to determine frequency for major maintenance on components and are also using condition-based monitoring to ensure component reliability. FW pump turbines and FW regulating valves are typically maintained on a time basis, while both time-based and condition-based maintenance practices are used for FW heater level control valves and actuators.

NMAC released the final report, Feedwater System Maintenance Guide, in September (EPRI Report Number 1018699). This report serves as a resource and roadmap to help new and experienced plant personnel make informed decisions regarding maintenance of FW system and components, leading to improved reliability and more cost-effective maintenance. It includes a summary of industry issues, a review of existing EPRI reports related to the FW system and components (including links to the reports), a summary of industry maintenance practices for major FW components and recommendations for monitoring the health of the FW system and components.

The EPRI component reports not only provide maintenance recommendations for important FW equipment, but also provide guidance and assistance for troubleshooting problems that do arise. Additionally, the report identifies specific actions at nuclear plants that have successfully improved overall system performance and reliability.—Michael Pugh, EPRI

Areva has also opened a research facility to analyze corrosion issues at U.S. nuclear power plants. The $6.5 million chemistry and materials center will provide chemistry, corrosion and metallurgical testing and analysis support for operating nuclear power plants.

Corrosion was the cause of problems at Constellation Energy's Calvert Cliffs Nuclear Power Plant. In March 2000, Calvert Cliffs became one of the first plants in the U.S. to earn a 20-year operating license extension from the NRC. Built by Baltimore Gas & Electric in the 1970s on Chesapeake Bay in Maryland and now owned by Constellation Energy, Calvert

TABLE 1 EXPECTED APPLICATIONS FOR POWER UPRATES*

Fiscal Year	Total Power Uprates Expected	Measurement Uncertainty Recapture Power Uprates	Stretch Power Uprates	Extended Power Uprates	Megawatts Thermal	Approximate Megawatts Electric
2009	4	2	0	2	779	260
2010	12	6	0	6	2,116	705
2011	17	13	2	2	1,645	548
2012	7	3	1	3	1,687	562
2013	0	0	0	0	0	0
TOTAL	40	24	3	13	6,227	2,075

*Based on a May 2009 survey of NRC licensees. See sidebar for definitions.
Source, NRC.

Cliffs had replaced the steam generators in the two-unit 1,735 MWe plant. When deterioration of steel on the intake floor, circular water pump bowels (CWB) and salt water pits (SWP) became severe, Calvert Cliffs wanted a repair solution that would help prevent corrosion and last for 20 years, to reduce plant maintenance costs.

Several factors contributed to the deteriorating concrete, according to Structural Preservations Systems, the company that executed the repairs. (See *What Works* on page 18 for more on the project.) First, there was constant exposure to saltwater, which had inundated the system for three decades. Second, several pieces of large electrical equipment grounded to the slab sent stray currents through the concrete. Third was the age of the structure itself.

In 2005, an independent engineering firm performed initial inspections of the CWB, SWP and the main floor. For the $3.25 million project, hydro-demolition was used to remove the majority of the concrete. Hand-chipping was performed under heavily wetted conditions to minimize dust. All work had to be performed while the plant was fully operational, so foreign particles such as dust and debris had to be contained and the debris vacuumed out of the structure.

For the 8,800-square-foot intake floor, an average of 6.5 inches of concrete was removed, a cathodic protection ribbon was installed to prevent continued steel deterioration and a new concrete floor was poured. For the CWBs and SWPs, concrete was removed to one inch under the reinforcing steel, a cathodic protection ribbon was installed and the concrete was replaced. In areas where the concrete was sound, the ribbon still had to be embedded into the concrete, so 1-inch-by-2-inch slots were cut into the concrete.

The team used the impressed current cathodic protection (ICCP) system to help prevent corrosion of the new and existing reinforcing steel in the floor. With ICCP systems, a small, direct current is passed from a permanent anode to the reinforcing steel. An external power supply is connected between the anode and the steel with the appropriate polarity and voltage to prevent the reinforcing steel from giving up electrons. This system repels chloride ions away from the reinforcing steel toward the installed anode and provides flexibility in adjustment since the current or output can be easily adjusted.

The U.S. nuclear fleet is aging, no doubt about it. But with half of the nation's reactors less than 24 years old, diligence on the part of plant operators and advancements in service and repair technology can help ensure that their owners get more power out of them for years to come. pe