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framatome

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33 years of Journal issues are available online through the Journal website **www.NuclearPlantJournal**.com (search box on the right-top) for a nominal fee of $25 per issue. Contact: Anu Agnihotri, email: anu@goinfo.com.

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On The Cover

In 2015, seven debris leakers occurred in GNF fuel at two Entergy plants, which led to a self-assessment of performance at both Entergy and GNF. The new innovative GNF2 bundle, called GNF2.02, was delivered to River Bend in January 2017. See page 48 for more. The cover picture is Entergy Nuclear's River Bend Nuclear Generating Station.

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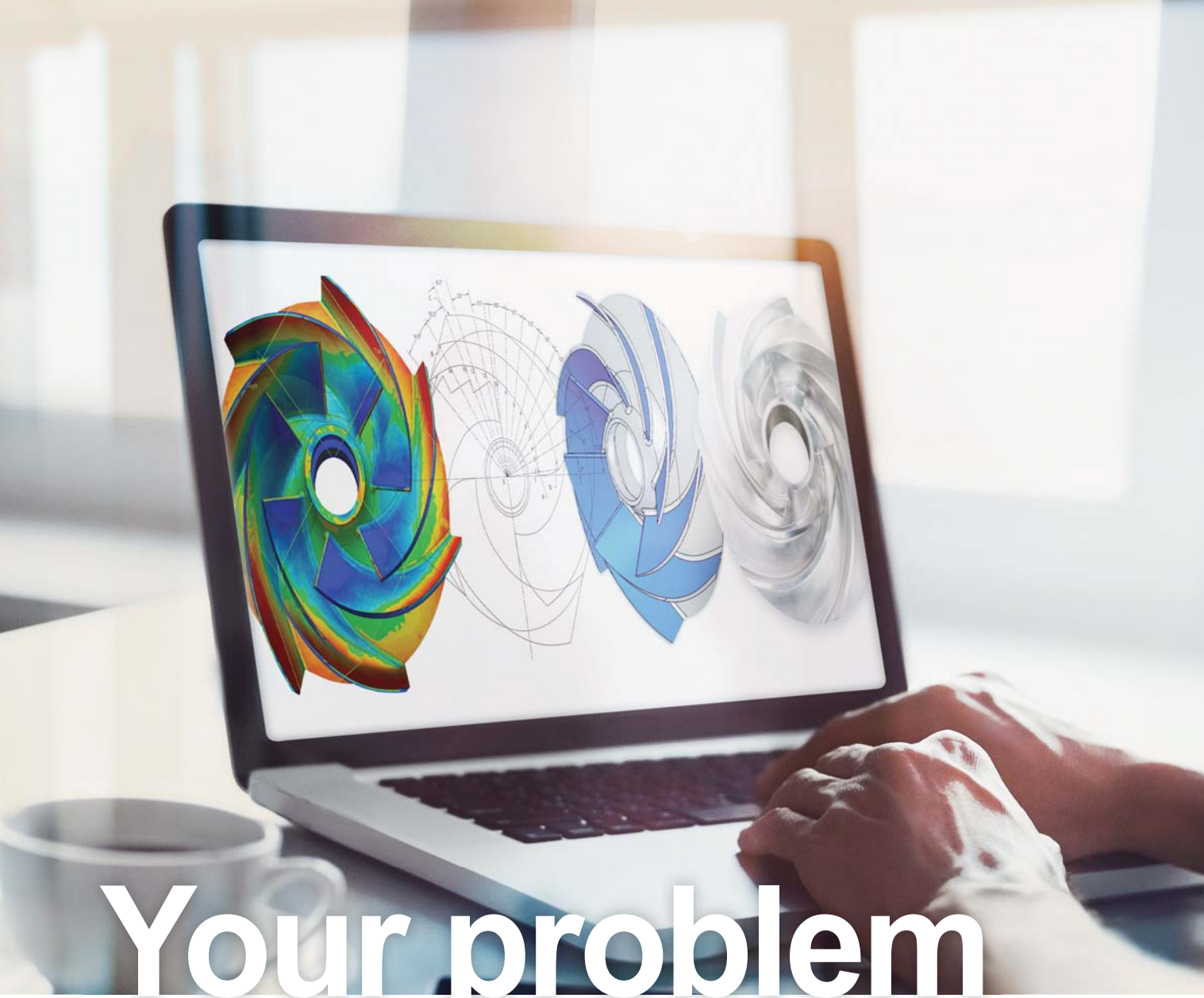

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Hongyanhe Unit 5

The second phase of Liaoning Hongyanhe Nuclear Power Co Ltd entered the installation stage as the first main equipment for the nuclear island of unit 5 -- the reactor pressure vessel (RPV) -- arrived at the plant on Mar 18, 2018.

The RPV, a key piece of equipment at a nuclear power plant, is installed at the center of the nuclear island. It is about 13 meters (42.65 feet) high, with a diameter of four meters (13.12 feet) and a weight of 300 tons. The RPV contains the reactor core, reactor internals and control rods, which can maintain and control nuclear fission reactions. When the unit is in operation the RPV works under pressure of 155 bar at a temperature of over 300° C.

Production of an RPV requires overcoming technological difficulties and complex processes. The RPV for unit 5 was produced by Shanghai Electric Nuclear Power Group.

Construction of unit 5, the first unit of Hongyanhe Nuclear Power's second phase, was started on Mar 29, 2015. The plant will begin installation of the main equipment of the nuclear island for unit 6 by the end of 2018.

Hongyanhe Nuclear Power, partly invested by **China General Nuclear Power Corporation** (CGN), was the first nuclear power plant constructed in Northeast China. The four units of Hongyanhe Nuclear Power's first phase were put into operation in 2016 and the second phase will be completed in 2021.

Contact: CGN, fax: 86 755 83699900, email: news@cgnpc.com.cn.

The first main equipment for the nuclear island of unit five -- the reactor pressure vessel (RPV) -- arrives at Hongyanhe Nuclear Power Co Ltd on Mar 18, 2018.

Fuqing Unit 5

The reactor vessel internals of Fuqing Unit 5, the first HPR1000 demonstration project owned by **China National Nuclear Corporation** (CNNC), completed inspection and acceptance checks on March 15, 2018.

Fuqing Unit 5, developed and designed by CNNC's Nuclear Power Institute of China and manufactured by Shanghai No 1 Machine Tool Co, made its formal debut in the domestic nuclear power sector and in the crucial equipment manufacturing sector.

It will effectively guarantee the construction process of the first HPR1000 reactor, laying a solid foundation for the technology to be exported across the world.

The vessel internals are critical equipment in a nuclear reactor. In the HPR1000, they meet the most stringent nuclear power regulations and standards both at home and abroad, with independent intellectual property rights.

Contact: CNNC, website: en.cnnc.com.cn

Leningrad Unit 1

On March 9, 2018, Leningrad NPP Unit 1's generator was synchronized with the grid and the unit started delivering first kilowatt-hours to the United Energy System of Russia. Innovative Unit 1 with a Generation III+ reactor VVER-1200 is installed at Leningrad Phase II (a branch of Rosenergoatom which is part of the Power Division of **ROSATOM**).

Chief Engineer of Leningrad NPP under Construction Aleksandr Belyaev explained that thermal power of VVER-1200 reactor had been brought up to 35% of rated power and fast-speed turbine K-1200-6,8/50 had successfully achieved 3,000 revolutions per minute. These were done to connect the generator to the grid. The new unit of Leningrad NPP was connected to the grid at the minimum controlled power of 240 MW and has to operate for 4 hours at this level as prescribed by the program. During this time period it will produce some 1 million kWh of electricity.

Contact: ROSATOM, website: http://www.rosatom.ru ■

Utility, Industry & Corporation

Utility

Technology Transfer Award

China Nuclear Power Engineering Co, a subsidiary of **China General Nuclear Power Corp** (CGN), has been honored with the 2017 Technology Transfer Award by the Electric Power Research Institute (EPRI).

It was CGN's first time to win the EPRI award, which is given annually to EPRI members who have made efforts to apply R&D on behalf of their companies and the industry at large. A total of 12 nuclear power technology achievements in advanced nuclear technology (ANT) were presented with the award in 2018.

The only Chinese awardee, CGN was recognized for its breakthrough in technology transfer and application of high-density polyethylene (HDPE), a polyethylene thermoplastic made from petroleum.

HDPE is preferred in nuclear power projects over metal tubes, being more durable, corrosion resistant, easy to install, and with good flow characteristics. HDPE pipes have been applied in overseas nuclear power plants and performed well.

The project team, consisting of technicians from CGN's two subsidiaries, China Nuclear Power Engineering Co and Daya Bay Nuclear Power Operations and Management Co, focused research on the application and localization of nuclear-level HDPE pipes after communicating with EPRI experts and reviewing surveys on the application requirements of anti-corrosion in sea water among domestic nuclear power plants and the domestic production of HDPE pipes.

The two companies worked together on a renovation project in Daya Bay Nuclear Power Plant, replacing metal pipes with HDPE ones to improve corrosion resistance in seawater. Approved by the National Nuclear Safety Administration in April 2017, the project was finished on schedule and now runs well, with the technicians having overcome a number of difficulties.

Meanwhile, during the research, CGN successfully applied for launching an R&D and test platform and an engineering center of non-metal materials for nuclear power plants in Shanghai. It was also approved by the National Energy Administration to work on the application standards of HDPE at level three of nuclear safety classification.

CGN has also partnered with a nuclear new-material company on HDPE products, leading to its being awarded 13 patents. The products have passed the sci-tech evaluation of the China Nuclear Energy Association.

Contact: CGN, website: en.cgnpc.com.cn/encgn

Deactivation Notice

FirstEnergy Solutions (FES) has notified regional transmission organisation PJM Interconnection that it will deactivate the Beaver Valley, Davis-Besse and Perry nuclear power plants during the next three years. The company, which is aiming to leave the competitive market, is seeking legislative policy solutions to keep the plants operating.

Davis-Besse, a single-unit pressurised water reactor, and Perry, a single boiling water reactor, are in Ohio. According to the US Nuclear Energy Institute (NEI), they generate 14.1% of the state's electricity. The two-unit Beaver Valley PWR plant is in Pennsylvania. The four units' total capacity is 4048 MWe and together they provided about 65% of electricity produced by the FES generating fleet last year.

Ohio and Pennsylvania are in a deregulated electricity market, where generators compete against each other to sell power to suppliers through competitive auctions. Nuclear plant operators in such markets have faced competition from low-cost gas, particularly from shale gas developments, and subsidised wind power, leaving well-performing nuclear units at risk of closure for economic reasons.

The state of Ohio is considering legislation that would support the continued operation of nuclear power plants by recognising their contribution to clean energy generation. State governments in New York and Illinois have already adopted such policies. FirstEnergy Corporation has said it will continue to advocate for Ohio to adopt such legislation, although it already announced in November 2016 its intention to withdraw from the competitive electricity market.

FES said the plants will continue to operate normally as the company continues to work towards legislative solutions or the possible sale of the units as an alternative to deactivation. The process to prepare for a potential deactivation, including preparing a detailed decommissioning plan and amending plant licences, can take over two years, FES said. The company has verbally notified the US Nuclear Regulatory Commission of the planned deactivations.

The Beaver Valley and Davis-Besse units have all received renewed operating licences from the NRC. The licence for Beaver Valley unit 1 expires in 2036, unit 2 in 2047 and Davis-Besse in 2037. Perry is currently licensed to operate until 2026.

Contact: ***World Nuclear News****, website: www.world-nuclear-news.org*

Ohi 3

Unit 3 of the Ohi nuclear power plant in Japan's Fukui Prefecture recently reached criticality, operator Kansai Electric Power Company announced. The reactor - the sixth to be restarted after clearing the country's revised safety regulations - is expected to resume commercial operation in April, 2018.

Following the shutdown of all of Japan's reactors after the March 2011 accident at the Fukushima Daiichi plant, Ohi 3 and 4 were given permission to resume operation in August 2012. However, the two 1180 MWe pressurised water reactors (PWRs) were taken offline again for Nuclear Regulation Authority (NRA) inspections in September 2013.

The NRA announced in May 2017 that the two units meet safety standards introduced in July 2013. The NRA approved Kansai's plan for strengthening the units in August 2017. The regulator subsequently conducted pre-operation inspections of the units to confirm that the safety countermeasure equipment complies with the approved construction plan at the plant. The governor of Fukui

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Utility...

(*Continued from page 11)*

Prefecture approved the restart of Ohi units 3 and 4 in November, 2017.

Kansai began loading the 193 fuel assemblies into the core of unit 3 on February 9, 2018, completing the process on February 13, 2018. The reactor was restarted at 5.00pm on March 14, 2018. Kansai said Ohi 3 attained criticality - a sustained chain reaction - at 3.00am on March 15, 2018.

Contact: ***World Nuclear News****, website: www.world-nuclear-news.org*

Industry

Radiological Protection School

With the advent of the many beneficial uses of atomic radiation and nuclear technology over the last century, experts in both national and international fora have worked for the establishment and the evolution of a system of radiological protection (RP). Many RP principles have been agreed and accepted globally and serve as the basis upon which many national regulations and guidance are built. International bodies addressing RP issues within their charters, such as the **Nuclear Energy Agency** (NEA), through its Committee on Radiological Protection and Public Health (CRPPH), have contributed to the evolution of the system of radiological protection by sharing experience and knowledge. This practical feedback continues to refine the underlying principles of the international RP system. These principles also reflect state-of-the-art scientific knowledge, as well as the experience and collective understanding accumulated over many decades. Their application has long benefited from the very experts who helped to establish the global framework of guidance, standards, recommendations and best practices, and who are also involved in applying this framework in their home countries.

A wide variety of guidance and standards documents are available. The technical facts are provided in these documents but how the different elements have evolved, and the full body of understanding that they reflect, are not well documented. Understanding the "spirit" of the RP system is an integral component of its effective application. In order to appropriately apply the RP system to existing and emerging situations, such aspects – the nuances, history and between-the-line meanings – need to be fully understood by tomorrow's leaders in order to progress in the radiological protection field.

The CRPPH has long served as a forum for exchange and co-operation, to establish best practices, contribute to the development of the key recommendations of the International Commission on Radiological Protection (ICRP) and issue innumerable technical and policy documents that capture the state of the art of RP thinking at specific points in time. The NEA decided to develop a learning programme in order to pass on a deep understanding of the spirit of the RP system, along with how it is intended to be applied in diverse and newly emerging circumstances.

As a first step towards the establishment of a long-term programme, the NEA, in co-operation with the Swedish Radiation Safety Authority (SSM) and the Centre for Radiation Protection Research (CRPR) of Stockholm University, has decided to launch a pilot International Radiological Protection School (IRPS).

Contact: Ms Chiara Guido and Dr Ted Lazo, Nuclear Energy Agency, 46, Quai Alphonse Le Gallo, 92100 Boulogne-Billancourt, France; email: irps@oecd-nea.org.

Corporation

Request for Proposals

Canadian Nuclear Laboratories (CNL), Canada's premier nuclear science and technology organization, announced today that it has issued a Request for Proposals (RFP) for the design and construction of its Advanced Nuclear Materials Research Centre (ANMRC), a $370 million modern laboratory research complex that will serve as the backbone of CNL's research and development infrastructure and a major facility in the delivery of its nuclear science and technology programs. The RFP is now available for review on Merx, an online tendering service.

Scheduled to begin construction in 2019, CNL's ANMRC will be one of the largest active research facilities ever to be constructed in Canada, and will enable world-class research in nuclear energy, public health, environmental stewardship and global security.

As the largest single capital investment in the revitalization of the Chalk River campus, the ANMRC will consolidate key capabilities from a number of aging facilities that are scheduled for decommissioning. The ANMRC will feature new shielded facilities that will enable post-irradiation examination of small modular reactor (SMR) and next-generation nuclear fuels, and glovebox facilities to support the development of advanced fuel fabrication concepts. The complex will also include materials storage bays which will simplify the transportation of radioactive material on site, improving work efficiency at the Chalk River campus. Overall, services provided by the ANMRC will be critical to the life extension and long-term reliability of existing reactors, including Canada's fleet of CANDU nuclear power reactors and other designs deployed around the world.

Construction of the ANMRC is part of a 10-year transformation of the Chalk River Laboratories site, funded through a $1.2 billion investment from Atomic Energy of Canada Limited on behalf of the Government of Canada, to modernize the campus. This includes the revitalization of essential site infrastructure, the decommissioning of aging buildings and a significant investment in new, world-class science facilities.

Contact: Philip Kompass, CNL, telephone: (866) 886-2325, email: communications@cnl.ca.

SMR Project

Canadian Nuclear Laboratories (CNL), Canada's premier nuclear science and technology organization, is pleased to announce that it has issued an invitation to small modular reactor (SMR) project proponents who wish to participate in the evaluation process for the construction and operation of an SMR demonstration project at a CNL-managed site. The invitation represents the launch of CNL's SMR review process, including the Pre-Qualification stage, which allows CNL

to evaluate technical and business merits of proposed designs, assess the financial viability of the projects, and review the necessary national security and integrity requirements.

The invitation will remain open, with rounds of intake periods expected to occur semi-annually. Applications received by May 28, 2018 will be assessed in the first round. All projects would be subject to regulatory processes and requirements.

Contact: Patrick Quinn, CNL, telephone: (866) 886-2325.

Alliance

On February 13th, 2018, **Framatome**, Bureau Veritas and Doosan Babcock signed an Agreement creating EQUALLETM, an alliance targeted at supporting the challenge of nuclear Equipment Qualification for the benefit of new build projects and in-service reactors in the United Kingdom.

The qualification of nuclear safety equipment ensures its operability in normal and accidental conditions in compliance with the safety case.

The ambition of EQUALLETM is to contribute to nuclear safety while reducing risks, costs and securing project schedules. Qualifying nuclear equipment involves calculation, analysis and stringent physical testing competencies and technologies and is often underestimated.

Contact: Media Relations, Framatome, telephone: 33 (0) 1 34 96 41 34, email: press@framatome.com.

Fuel Assemblies

Global Nuclear Fuel (GNF) announced that it has manufactured and shipped lead test assemblies of its IronClad and ARMOR accident tolerant fuel solutions to Southern Nuclear Operating Company for plant installation in early 2018.

GNF is working with both Southern Nuclear and Exelon Generation to insert lead test assemblies utilizing an iron-chromium-aluminum fuel cladding material known as IronClad and coated zirconium fuel cladding known as ARMOR into several reactors over the next few years.

The IronClad lead test assemblies will be the first developed through the

(Continued on page 50)

New Products, Services & Contracts

New Products

Tube Testing Tool

Curtiss-Wright EST Group has released its G-160 Tube Testing Tools for leak detection in heat exchangers, condensers and boilers. The new ergonomic design features simple one-handed push-button actuation, patent-pending grippers and durable lightweight cast-aluminum housing. Up to 10 tubes per minute can be tested using less force, which increases operator safety. G-160 Tube Testing Tools are capable of testing tubes ranging from 0.28 inches-1.81 inches (7.1 millimeters-46 millimeters).

Contact: Curtiss-Wright EST Group, telephone: (215) 721-1100, website: www.cw-estgroup.com/g160

G-160 Tube Testing Tools.

Services

Safety Control Solutions

Discrete Logic Solving Systems (DLSS™) provides safety-critical instrumentation and control (I&C) applications-offering numerous nuclear power plant solutions without software-like elements.

Lockheed Martin's is implemented in custom hardware-based logic. No FPGA, microcontroller or microprocessor running software. Familiar PLC-like form, fit, and function, but non-digital.

DLSS offers a hardware-based architecture, solid-state electronics, analog discrete logic circuits; and a simple configuration of common input/output modules and application-specific logic solving modules. Platform configuration is strategically defined to maximize availability (minimize downtime) of the critical functions.

DLSS protects nuclear power plants by monitoring, calculating and actuating protective elements to ensure safety measures are operational when it counts.

When integrated to form a protective system, one or more DLSS system components monitor the status of the nuclear facility through signals received from peripheral input devices or sensors. DLSS samples inputs, solves custom logic, and drives outputs to actuate peripheral protective elements protecting the nuclear facility.

DLSS components can be assembled in separate divisions with application specific discrete voting logic for specific plant safety requirements to implement plant systems.

Contact: Lockheed Martin, telephone: (570) 803-2201.

Contracts

Fuel Manufacturing

BWX Technologies, Inc. announced that its subsidiary BWXT Nuclear Energy Canada Inc. (BWXT NEC) has been awarded a CA$168 million (US $130 million), five-year contract extension to manufacture fuel for Ontario Power Generation's (OPG) Darlington and Pickering nuclear generating stations. The deal extends BWXT NEC's current fuel manufacturing arrangement with OPG to the end of 2023.

Three of BWXT's Canadian-based operations (Peterborough, Arnprior and Toronto) will directly benefit from the positive impacts of the contract extension. The Arnprior operation produces zirconium-alloy tubes, while the Toronto facility produces natural uranium pellets. These components are shipped to the BWXT Peterborough facility where they are assembled into fuel bundles.

Contact: Jud Simmons, BWX Technologies, Inc., telephone: (434) 522-3800, email: hjsimmons@bwxt.com.

Software Services

Studsvik, through its subsidiary Studsvik Scandpower, has signed a second contract with the Russian nuclear fuel producer JSC TVEL increasing the scope of delivery of software and related services from SEK 25 million ($2.9 million) to SEK 38 million ($4.4 million). The initial contract was signed in February of 2018. These contracts need no additional export approvals.

Under these contracts, Studsvik will deliver software licenses and fuel licensing methodology for SEK 25 million ($2.9 million) during the first half of 2018 with software maintenance, consultancy and training services for SEK 13 million ($1.5 million) delivered during 2018 and into 2019.

The orders build on significant investment in software and licensing methodology by Studsvik Scandpower in prior years. The delivery of software

licenses and fuel licensing methodology will render a profit of approx. SEK 17 million ($1.9 million).

Contact: Pal Jarness, Studsvik, telephone: 46 155 22 10 09.

Fuel Testing

Terrestrial Energy has entered into contract for technical services with the European Commission's Joint Research Centre (JRC) in Karlsruhe, Germany. This is part of Terrestrial Energy's validation and verification program for the IMSR® power plant design now underway. The JRC will perform confirmatory studies of the IMSR® fuel and primary coolant salt-mixture. The facility will undertake the tests under conditions compliant with quality assurance protocols of nuclear codes and standards, as is required to advance a nuclear power plant design through the regulatory process.

The JRC is a Directorate-General of the European Commission and is spread across six sites in five different countries within the EU, including Karlsruhe. The JRC employs over 3,000 people, from EU countries and candidate countries to EU membership, who bring their skills, talents, passion and rigour into the scientific activities meant to underpin EU policies.

Contact: Jarret Adams, Terrestrial Energy, telephone: (202) 815-9234, email: jadams@fulloncom.com.

Nuclear Fuel

TVEL JSC and Fortum Power and Heat Oy (Finland) have signed an addendum to the existing fuel supply contract, which is aimed at development of improved second-generation fuel assemblies for VVER-440 reactors at two power units of Loviisa NPP.

Within the project Russian engineers will develop a new modification of fuel assemblies with increased uranium capacity and optimized water uranium balance compared to assemblies currently used at Loviisa NPP. This would enhance the economic efficiency of the power units.

The contract between TVEL JSC and Fortum Power and Heat Oy embraces the supply of nuclear fuel to both power units of Loviisa NPP throughout their lifetime. Modern second-generation uranium-gadolinium fuel for VVER-440 reactors is produced by Machinery plant JSC (a fabrication enterprise of TVEL Fuel Company in Elektrostal, Moscow region).

Contact: Alexander E. Uzhanov, TVEL, telephone: (495) 988-82-82 extension 6290, email: uzhanov@tvel.ru.

Advanced Nuclear Fuel

Centrus Energy Corp. an experienced nuclear fuel technology company, has signed a services contract with **X Energy, LLC** to support the design of a facility to produce advanced nuclear fuel. The contract builds upon a memorandum of understanding the companies signed in September 2017 to collaborate toward production of fuel for advanced nuclear reactors.

Under the agreement, Centrus will provide X-energy, a pioneering reactor technology and fuel company, with technical expertise and resources to support conceptual design of a facility to produce X-energy's uranium oxycarbide (UCO) tristructural isotropic (TRISO) fuel forms. This effort includes nuclear criticality safety analysis, manufacturing equipment layout and infrastructure design, and conceptual development of fuel form transport packages. Centrus will also provide facility space to X-energy at Centrus' Technology and Manufacturing Center in Oak Ridge, Tenn. TRISO fuel forms can meet the requirements for the X-energy Xe-100 high temperature gas cooled reactor, as well as for other advanced nuclear reactor technologies being developed around the world.

The services contract supports the companies' previously announced joint effort to prepare a deployment plan for X-energy's TRISO fuel technology; design a cost-effective, highly automated fuel manufacturing process line; and seek funding for a future commercial fuel production facility.

Contact: Melanie White Lyons, X Energy, telephone: (301) 363-2839, email: mlyons@x-energy.com. ■

New Documents

EPRI

1. *External Hazards: Information Compilation and Analysis—2017 Catalog of Relevant Information Sources*. Product ID: 3002010670. Published October, 2017.

This report contains a catalog of relevant, credible information sources (referred to hereafter as "the Catalog") related to external hazards that are potentially important to the safe operation of nuclear power plants in the United States. The Catalog sources are used to support identification of new information about external hazards. This process supports U.S. nuclear utilities in addressing Recommendation 2 of the Institute of Nuclear Power Operations (INPO) Event Report Level 1-13-10, "Nuclear Accident at the Fukushima Daiichi Nuclear Power Station," which calls for the evaluation of credible new information that challenges the conservatism of current design assumptions for external events.

The Catalog contains information sources related to the following external hazards:

- Seismic events
- External flooding
- Storms and storm-induced high wind events
- Extreme snow, ice, and cold
- Extreme heat

The wide variety of external hazard information sources can make it challenging to understand when relevant new information becomes available. The Catalog serves as a tool to support identification of relevant, credible information sources.

The information source updates presented in this first revision of the Catalog were primarily identified through the following:

- Results of potential new information evaluations conducted in 2016
- Input from subject matter experts and utility representatives

Routine tracking and monitoring of the Catalog sources yields new information about external hazards that is reported by the Electric Power Research Institute (EPRI), typically on an annual basis.

2. *Hot Cell Demonstration of Eddy Current Technology for Nondestructive Measurement of BWR Fuel Rods*. Product ID: 3002010717. Published October, 2017.

Corrosion and hydrogen pickup in zirconium alloys can cause distortion, embrittlement, and the formation of localized hydrogen blisters that can lead to fuel failures and/or enhanced corrosion. Fuel reliability performance margins combined with pending modifications to current regulations and industry expectations are driving the need for poolside inspection techniques that can measure corrosion properties and hydrogen content of zirconium alloy fuel assembly components.

EPRI has been developing improved nondestructive techniques for poolside (on-site) inspection of nuclear fuel components. One method, the frequency-scanning eddy current technique (F-SECT), is used to nondestructively measure corrosion characteristics in fuel assembly materials. Nondestructive characterization techniques that can be deployed poolside at nuclear power plants to inspect fuel assembly materials decrease risk, dose, time, and cost compared to transporting these materials to be destructively analyzed in a hot cell.

F-SECT has successfully measured corrosion performance in zirconium alloy materials in simulated poolside and hot cell environments. This report compares F-SECT measurements of an irradiated fuel rod within a hot cell with measurements obtained using other nondestructive examination methods and destructive examinations. The destructive examinations of the fuel rod identified crud, oxide, and remaining wall thicknesses along with hydrogen concentrations at specific axial locations.

This project evaluates F-SECT's ability to provide accurate measurements of lift-off (crud plus oxide) and remaining wall thickness of the cladding. Nondestructive hydrogen estimates are compromised by the presence of magnetic crud on the fuel rod.

3. *Single Source Cast Austenitic Stainless Steel Research: Summary of EPRI Research and Relevant Sources*. Product ID: 3002010315. Published December, 2017.

This document provides information for utilities on technical documents available to develop an aging management program for concrete structures subjected to corrosion.

In the past several years, there have been numerous EPRI projects which were completed (for example, NDE, MRP, WRTC) involving cast austenitic stainless steel (CASS) research. The results of these projects are scattered throughout many published reports and it can be difficult and time-consuming to collect the various reports relating to specific CASS research. Enough members expressed interest in a summary of CASS research that a project was initiated to collect, summarize, and organize the material currently published in a single document that can be used to direct users to the source documents available through EPRI. Project staff collected all available EPRI published documents related to CASS material, generated summaries of CASS-related content and assembled it into a well-organized report that members can use to quickly find the relevant material along with the report identification number for easy access through epri.com. In addition to EPRI-published material, the report also includes an extensive bibliography of CASS research material published outside of EPRI.

4. EPRI Guidance on Seismic Evaluations in US Focuses on Safety, Reliability, and Economic Performance. Product ID: 3002012351. Published January, 2018.

EPRI research has allowed the US nuclear industry to make extensive progress in re-confirming and enhancing seismic safety following the accident at Japan's Fukushima Daiichi nuclear power plant. Furthermore, EPRI's guidance, which has averted significant costs across the industry, is of value for seismic risk assessments worldwide.

The above EPRI documents may be ordered by contacting the Order and Conference Center at (800) 313-3774, Option 2, or email at orders@epri.com. ■

Meeting & Training Calendar

1. Used Fuel Management Conference, May 1-3, 2018, Savannah International Trade and Convention Center, Savannah, Georgia. Contact: Denise Bell, **Nuclear Energy Institute**, telephone: (202) 739-8039, email: registrar@nei.org.

2. 65th Annual Industry Conference and Supplier Expo: Nuclear Energy Assembly, May 21-23, 2018, Atlanta Marriott Marquis, Atlanta, Georgia. Contact: Denise Bell, **Nuclear Energy Institute**, telephone: (202) 739-8039, email: registrar@nei.org.

3. **ASME** 2018 Annual Meeting, June 2-6, 2018, JW Marriott parq Vancouver, Vancouver British Columbia, Canada. Contact: Kim Williams, ASME, telephone: (212) 591-7037, email: willaimsk@asme.org.

4. 35th Nuclear Air Cleaning Conference, June 3-5, 2018, Charleston Marriott, Charleston, South Carolina. Contact: Dr. Ronald Bellamy**, International Society of Nuclear Air Treatment Technologies** (ISNATT), telephone: (484) 888-2456, email: rrb1rrb1@verizon.net, website: www.isnatt.org/registration

5. 38th Annual Conference of the **Canadian Nuclear Society** and 42nd Annual CNS/CNA Student Conference, June 3-6, 2018, Sheraton Cavalier Saskatoon Hotel, Saskatoon, Canada. Contact: Benjamin Rouben, Canadian Nuclear Society, telephone: (416) 977-7620, email: annualconference@cns-snc.ca.

6. **American Nuclear Society Annual Meeting**, June 17-21, 2018, Marriott Philadelphia Downtown, Philadelphia, Pennsylvania. Contact: Registration Coordinator, American Nuclear Society, email: registrar@ans.org.

7. International Nuclear Digital Experience, June 25-26, 2018, Paris, France. Contact: Michele Le Goff, **French Nuclear Energy Society**, email: inscriptions@sfen.org.

8. National Security and Emergency Preparedness Summit, June 25-29, 2018, Orlando, Florida. Contact: Denise Bell, **Nuclear Energy Institute**, telephone: (202) 739-8039, email: registrar@nei.org.

9. **World Nuclear Exhibition**, June 26-28, 2018, Paris Nord Villepinte- Hall 7, Paris, France. Contact: Severine Gobert, Reed Expo, telephone: 33 (0) 1 47 56 65 36, email: severine.gobert@reedexpo.fr.

10. **Utilities Service Alliance** Executive Summit, July 18-20, 2018, Seattle, Washington. Contact: Jim Kitchens, Utilities Service Alliance, email: jkitchens@usainc.org.

11. 26th ICONE – International Conference on Nuclear Engineering, June 22-26, 2018, Novotel London West, London, England. Contact: Laura Herrera, **ASME**, email: Herreral@asme.org.

12. **Institute of Nuclear Materials Management (INMM)**, 59th Annual Meeting, July 22-26, 2018, Baltimore Marriott Waterfront, Baltimore, Maryland. Contact: INMM, website: www.inmm.org/Events/Annual-Meeting

13. Nuclear Fuel Supply Forum, July 24, 2018, The Mayflower Hotel, Washington, D.C. Contact: Denise Bell, **Nuclear Energy Institute**, telephone: (202) 739-8039, email: registrar@nei.org.

14. Radiation Protection Forum, July 29-August 1, 2018, Naples Grande, Naples, Florida. Contact: : Denise Bell, **Nuclear Energy Institute**, telephone: (202) 739-8039, email: registrar@nei.org.

15. Utility Working Conference and Vendor Technology Expo, August 5-8, 2018, Omni Amelia Island Plantation, Amelia Island, Florida . Contact: Alivia Payton, **American Nuclear Society**, email: registrar@ans.org.

16. International Conference on Technological Innovations in Nuclear Civil Engineering, August 29-31, 2018, Paris-Saclay, France. Contact**: French Nuclear Energy Society**, website: www.sfen-tince2018.org

17. **World Nuclear Association** Symposium, September 5-7, 2018, Park Plaza Westminister Bridge, London, United Kingdom. Contact: WNA, website: www.wna-symposium.org

18. **International Atomic Energy Agency** General Conference, September 17-21, 2018, Vienna, Austria. Contact: IAEA, website: www.iaea.org

19. International Conference on Dismantling Challenges: Industrial Reality, Prospects and Feedback Experience, October 22-24, 2018, Avignon, France. Contact: **French Nuclear Energy Society**, website: www.sfen-dem2018.org/

20. International Uranium Fuel Seminar, October 28-31, 2018. Sheraton Boston, Boston Massachusetts. Contact: Denise Bell, **Nuclear Energy Institute**, telephone: (202) 739-8039, email: registrar@nei.org.

21. 1st International Conference on Generation IV and Small Reactors, November 6-8, 2018, Ottawa Marriott Hotel, Ontario, Canada. Contact: Bob O'Sullivan, Canadian Nuclear Laboratories, telephone (416) 977-7620, email: cns_office@cns-snc.ca.

22. 2018 **American Nuclear Society** Winter Meeting and Nuclear Technology Expo, November 11-15, 2018, Hilton Orlando Bonnet Creek, Orlando, Florida. Contact: ANS, telephone: (708) 352-6611. ■

Research & Development

Spray on Sensor

Soon, it may be possible to spray or paint an ultrasonic sensor on power plant components for tracking their degradation and structural health. An EPRI study reports that the "sol-gel" coating is ready for initial field testing.

Traditionally, workers scan plant components periodically with handheld ultrasonic sensors. This approach is costly, and comparing inspection results can be hampered by discrepancies in the sensor's position or orientation.

With sol-gel technology, a chemical slurry is applied and sintered onto a component, forming a film on its surface. An electric field is applied to align the dipoles in the film—a process similar to magnetizing a material. Electrodes in the film connect to a data acquisition system. When voltages are subsequently applied to the film, the dipoles elongate or contract, changing the film's shape and sending sound waves into the component. Sound waves reflected by the component's internal structures reshape the dipoles and film, resulting in a voltage across the sensor electrodes. The data acquisition system measures these voltages to construct an image of the component's interior. Unlike conventional sensors, sol-gel sensors can endure high temperatures (above 200°C) and radiation, be fabricated directly on a component, and conform to a component's geometry.

EPRI developed and lab-tested several sensor prototypes and found that there appear to be no "showstoppers" for field deployment. Researchers advanced the technology in several ways. When earlier prototypes caused corrosion of carbon steel, EPRI worked with Penn State University to identify a binder to mitigate that. The team investigated ways to improve the sensor's signal strength, such as optimizing sol-gel constituent proportions and stacking sensors. The technology can be customized for specific applications such as higher temperature environments. It is potentially applicable in any type of power plant, including nuclear, coal, natural gas, and wind.

Researchers report that more research is needed on the sensors' long-term performance at high temperatures as well as on "repoling."

Contact: EPRI, email: techexpert@eprijournal.com.

Augmented Reality

For the U.S. electric power industry, its mutual assistance network is essential in responding to destructive hurricanes, tornadoes, and winter storms. For decades, this nationwide, voluntary partnership among electric companies has expedited outage restoration through the network's access to workers and equipment. The track record is strong but includes this fundamental challenge: Visiting line workers may be unfamiliar with the area, and this can hamper and delay work.

"You have a lot of people who come to a service territory to do storm restoration, and usually it is the first time they've ever been there," said Aleksandar Vukojevic, manager of Duke Energy's Emerging Technologies Office.

Since 2014, Duke Energy and EPRI have been testing a tool that could help employees and visiting recovery crews quickly grasp the lay of an unfamiliar land: augmented reality–enabled smart glasses. Their collaborative research with telecommunications company Verizon equipped a team of line workers with glasses during a simulated storm

A Duke Energy line worker wearing augmented reality–enabled smart glasses as part of a simulated storm damage assessment with EPRI. Photo courtesy of Duke Energy.

response. Made by RealWear, the glasses use geographic information systems (GIS) to provide workers with information critical for repairing damaged utility infrastructure.

"When you come to a particular area, these glasses tell you where all the components should be located, whether it be a downed utility pole or the equipment attached to that pole," said Vukojevic.

"The GIS has detailed information on each component," said EPRI Technical Executive John Simmins. "It knows a pole's height and what it's made of—metal or composite material."

The glasses can automatically send an order to a utility warehouse for the equipment needed for repairs. "While wearing the glasses, a user can indicate that a pole or other part is missing," said Simmins. "The information is sent to the warehouse, where parts are packaged and sent out on the next truck. This takes hours out of the process and reduces errors."

Results from the simulated storm response were encouraging to the R&D team. The line workers found the smart glasses easy to use, adjusting to them in just minutes. Workers using the glasses completed tasks more quickly, with fewer errors relative to workers using pen and paper to document storm damage.

The Promise of Augmented Reality for Nuclear Plant Construction

In July 2017, EPRI released a study evaluating augmented reality's potential to improve the productivity, efficiency, reliability, safety, and security of nuclear power plant construction and operation.

"As the nuclear industry in the United States grapples with economic headwinds driven by low natural gas and renewable energy costs, a key strategy for successful plant construction involves using technology to reduce construction timelines, improve quality and repeatability, and increase worker safety," said EPRI Senior Technical Leader Eric Harvey.

EPRI researchers reviewed more than 2,000 studies on augmented reality, interviewed 10 experts, and surveyed 32 nuclear utilities. A key takeaway: The nuclear utilities expressed significant interest in augmented reality, with nearly 80% indicating that augmented reality–enabled applications should be an integral part of the tool kit of operations and maintenance workers. However, more focused studies on the application of augmented reality are needed. Many expressed concerns about an uncertain business case. Researchers found that the building and construction industries in general have already taken the initiative to adopt the technology.

The study points to specific ways that augmented reality could reduce construction time and worker mistakes as well as improve safety. Among the potential applications:

- Connect field technicians with subject matter experts via wireless communication for real-time instruction on complicated tasks.
- Project a 3-D model of a nuclear plant onto a table or physical model to facilitate discussions about construction or to deliver training to construction workers.
- Use electronic boundaries to alert plant workers to radiation hazard zones.

Much work remains before augmented reality can be adopted broadly in nuclear plants. Owners, operators, and construction teams will need to conduct demonstration projects, assess costs and benefits, make a solid financial case, address privacy and cyber security, and potentially overhaul traditional construction and maintenance workflows.

Regardless of the challenges, EPRI's Simmins is confident that augmented reality will become a versatile tool across the utility industry. "Think about the maps on your cell phone that give you street-by-street instructions. They enable an ease of navigation that is not possible with paper maps," he said. "Augmented reality will be the same way. Years from now, people will say, 'How in the world did we do this before augmented reality?'

Contact: John Simmins or Eric Harvey, EPRI, email: techexpert@eprijournal.com.

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Emphasis on Operational Safety

By Jacques Regaldo, World Association of Nuclear Operators.

Jacques Regaldo

Jacques Regaldo has an engineering degree from the "Ecole Nationale des Ponts et Chaussées". He has 33 years experience, mainly inside Nuclear Operation area. He also worked in Fossil and Hydro Generation and also Human Resources and employment Management.

He joined EDF in 1980 and held various positions: head of Golfech Nuclear Power Plant, form 1991 to 1996 ; head of Cruas Nuclear Power Plant, from 1996 to 1998 ; Human Resources Manager of EDF Industry Branch, from 1998 to 2001 ; head of Fossil and Hydro Generation Division, from 2001 to 2005 ; head of Employment Department of EDF Group, from 2005 to 2007 ; Operating Senior Vice-president of EDF Generation Department from 2007 to 2013.

He was elected as WANO Chairman in October 2012 and took this position the 1st March 2013.

A phone interview by Newal Agnihotri, Editor of Nuclear Plant Journal on March 21, 2018.

An Update on WANO's Priorities

1. *What is your collaboration with IAEA?*

We have worked closely with the IAEA for several years and signed a formal memorandum of understanding with them in 2012. However, our collaboration with the IAEA begun much earlier, as we worked with them long before this MOU was signed. We collaborate with the IAEA in a few different areas. For example, we share information on events reported by the nuclear operators. Furthermore, we also ensure that there is close coordination between the two organizations for the safety evaluations carried out by IAEA (OSARTs) and by WANO (Peer Reviews). At least once a year, we organize a general meeting between the two organizations. In summary, we have an excellent relationship and a long-term cooperation with the IAEA and we know each other very well.

2. *What is your collaboration with the OECD NEA?*

We also signed a memorandum of understanding with the OECD Nuclear Energy Agency (NEA) in 2017 in Paris. This cooperation between our two organizations is related to safe operation of nuclear power plants. For example, we cooperate on topics like nuclear safety culture. Here we are examining how we can work together to have a common understanding and international language on the definition of nuclear safety culture. Very recently, in January 2018, we attended a workshop organized by the Nuclear Energy Agency in Sweden to explore this theme.

For the NEA and IAEA, one of our top common interests is how we can support newcomers to the nuclear industry, for example Bangladesh and Turkey. These countries already have relations with, for example, the IAEA, and for some of them, the OECD NEA. We can, for example, in the future, organize common workshops with these newcomers, with the NEA, or with the IAEA to accompany them on the journey to safe and reliable production of nuclear power.

3. *Do you have your own training school where you train all your inspectors?*

We are not inspectors as such - we are here to help the industry rather than regulate. Our peer reviewers conduct peer reviews to help members compare themselves against standards of excellence through an in-depth, objective review of their operations by an independent team from outside their organisation. We have qualified peer reviewers and team leaders, which is very important for a peer review or safety evaluation. For these team leaders and reviewers, we have our own training courses to teach about WANO programmes, the WANO performance objectives and criteria, and how we carry out our peer review safety evaluations. Yes, we have our own training courses.

4. *Where is this training school located?*

Each WANO region, Atlanta, Paris, Moscow, and Tokyo, organize these training courses for our staff, for our qualified reviewers and team leaders and peer review team leaders. Every WANO region organizes its own training courses, but of course focuses on the same WANO programs and performance objectives and criteria throughout the world.

5. *Please describe WANO's priorities for the new as well as the aging plants.*

Our October, 2017 Biennial General Meeting was held in Gyeongju, South Korea. We worked on different topics of common interest. In my speech, I said that we have several objectives. For example, we often inspect organizations with aging plants. Our peer reviews are well suited to evaluate the safety level of plants of all types and ages, but we often have to give special attention to the older plants. Safe operation of aging plants is, in a way, a priority for many of our members, and this dictates that it is a priority for the support that WANO must bring to them.

Another priority is new projects. This may be new projects, for example, in the UK, China or Russia, but also

projects for countries new to nuclear power, for example as I previously mentioned, Bangladesh and Turkey. These two countries are building their first nuclear reactors. It is a priority for WANO to help them, to accompany them and to bring support for the training of the staff, for the qualification of the operating teams and for the preparatory work of the commissioning of these units.

Another objective for us is to bring the best support throughout the world. For the majority of planned new nuclear power plants, there will be a shift from the West to the East – most of the new reactors that will be built in the future will be in the East. Indeed in just 15 years, possibly around 50% of the reactors in operation will be in Asia. For that reason, we need to organize the right resources to support all these members and power plants. That's one of the reasons why we're thinking about a second center in Asia that could be located in China. We are currently working on this project and it's a key priority for WANO.

6. *I see immense confidence in nuclear energy after Fukushima. Every operator has great confidence that nuclear energy is safe. Is it because of the digital revolution, or is it because of the new fuel which is being loaded, or it is because of safety concerns which have been addressed?*

We believe that nuclear energy will continue to be a significant part of the energy mix in the future. But for that, we have one major focus, which is to ensure the highest levels of nuclear safety. And it is important that we drive standards even higher and do not become complacent. We are always working to improve nuclear safety and to increase the safety margins.

WANO's mission is to maximise the safety and reliability of nuclear power plants worldwide. After Fukushima, our members made significant design improvements and carried out technical modifications to improve safety margins. In Europe we call them stress tests. Performing these stress tests, they improve the design of the plant and powered up modifications. At the same time, with the support of WANO, we have tried to improve parts of the software, safety culture, safety evaluations through the peer reviews, systematic pre-startup reviews for new reactors. That's the way WANO contributes also to nuclear safety. Digital Control Systems (DCS) can be a source of improvement, but we are very careful to check that every operator monitors and correctly masters these new technologies. We have organized workshops on DCS, and we are working on a kind of framework to evaluate the way companies take into account DCS in normal operation. We must check that this new technology is well implemented and that the operating team staff is well trained to use them.

7. *Is WANO responsible for checking the quality of maintenance during peer reviews?*

Yes. It's clearly part of the WANO focus when we conduct safety evaluations, because member plants carry out maintenance, especially during outages, which is very important for nuclear safety during the life of the plants. So for us, maintenance is in the scope of our peer reviews and it is part of what I call nuclear safety in operations during the life of the plant. It is clearly in our court.

8. *Is it the same thing with procurement also?*

Yes. Procurement, is in the scope of the WANO peer reviews. It is very important for safety and operations.

9. *In the United States, the Nuclear Energy Institute (NEI) has a program, called "Nuclear Promise", which tries to lower the cost of operation and increase productivity of the plants, so that these plants remain viable. Otherwise, they are shutting down. Is that causing any challenge for WANO?*

Not really. The role of NEI is to promote the American nuclear industry. We have a relationship with them and we share information between our organizations, but our focus is different. Our focus is nuclear safety in operations. For example, when they want to improve the performance of existing plants or to increase life in operation, we are not against, but we just need to check that the plants are still operating safely. So, if they review their operational expenses, why not? But we'll check that the plants are still safe.

10. *It looks like every country and every company is developing SMRs and advanced reactors. Are you getting involved in their design so that your inspectors are well trained, and they know WANO, they are sensitive to WANO requirements?*

Of course we are aware of new design projects for SMRs in different countries but according to what I know, up to now, there is no SMR reactor under construction. So, we must be ready to train on that because later we will help these SMR reactors to prepare their commissioning, and we will start our pre-startup reviews and later our peer reviews.

There are a lot of different projects throughout the world. There are SMRs in the US and projects such as these in the UK and other European countries. In Russia they are working on the idea of floating nuclear reactors. We are following these projects, these ideas, and as soon as the first reactor will be licensed and the new projects will be constructed, of course, we will have to involve ourselves. If there are new companies we will encourage them to join WANO and help them to prepare for the commissioning of the reactors.

11. *Concluding Comments.*

I think we talked about our most important priorities. At the same time, established nuclear countries, like the USA or those in Western Europe, are facing life extension issues or financial pressure. Our mission is to check that these companies and their power plants are still operated safely, even if there is economic pressure and even if they're extending the life of the power plant. On the other hand, we have, especially in Asia, a lot of new reactors and newcomers, and part of the future of the nuclear industry lies in these countries. The second priority is to be sure that these reactors are well prepared, will operate safely, and that the companies that are newcomers are well aware of the challenges of what is the mission of an operating company starting its first power plant. That's also another priority for WANO in the years ahead.

Contact: Tim Jeffery, World Association of Nuclear Operators, WANO London, Level 35, 25 Canada Square, London E14 5LQ, United Kingdom; telephone: 44 (0)20 7478 9207, email:tim.jeffery@wano.org. ■

Nuclear Engineering Research at VCU

By Sama Bilbao y León, Virginia Commonwealth University.

Sama Bilbao y León

Sama Bilbao y León, PhD, MBA, is currently the Director of Nuclear Engineering Programs and Associate Professor in Mechanical and Nuclear Engineering at Virginia Commonwealth University (VCU). Previously she was the Technical Head for Water Cooled Reactors Technology Development at the International Atomic Energy Agency (IAEA), and a Nuclear Safety Analysis Engineer at Dominion Energy. Sama serves as Chair of the Board of the Virginia Nuclear Energy Consortium (VNEC) and in the INPO National Accreditation Board.

Eleven years ago, Virginia's nuclear companies were forced to recruit nuclear engineering talent out of state, because there weren't any nuclear engineering programs in the Commonwealth of Virginia. Given the large number of nuclear related stakeholder located in Virginia (Dominion Energy, BWX Technologies, Framatome, Newport News Shipbuilding, etc.), this resulted in quite a bit of turnover as new engineers did not have strong ties to Virginia. Virginia Commonwealth University (VCU) initiated in 2007 new graduate and undergraduate programs in nuclear engineering in direct response to the request of our local nuclear enterprise, and to the growing demand for nuclear engineers in the nuclear power industry, national laboratories and the federal government. In January 2008, the State Council of Higher Education for Virginia (SCHEV) approved a new MS degree program in Mechanical and Nuclear Engineering at VCU. Since the first MS class graduated in December 2010, VCU has graduated more than 100 MS in Mechanical and Nuclear Engineering. In the fall of 2009, the first class of students was enrolled in a new undergraduate nuclear engineering major concentration within mechanical engineering. The first undergraduate class graduated in May 2012, and a total of 94 students have completed the program to date. VCU obtained a separate Accreditation Board for Engineering and Technology (ABET) accreditation for its nuclear engineering major concentration in August 2013. In September 2012, VCU's new PhD degree in Mechanical and Nuclear Engineering was approved by SCHEV. This hybrid degree is the first of its kind in the United States. Currently about 70 students (sophomores and above) are enrolled in the undergraduate nuclear engineering major concentration and approximately 115 graduate students are enrolled in the new mechanical and nuclear engineering MS and PhD programs. Steady enrollment trends in both the undergraduate and graduate programs have been observed, with a long term projected steady-state enrollment of 250 students (100 undergraduate and 150 graduate). VCU is currently the only university in Virginia to offer a full suite of nuclear engineering degrees, including an ABET accredited BS and SCHEV approved MS and PhD.

In support of these new nuclear engineering programs VCU's Department of Mechanical and Nuclear Engineering has actively pursued the recruitment of new faculty members, bringing the current number of full time nuclear engineering focused faculty to six. This team of faculty constitutes a strong core in nuclear engineering education and research, and they have been able to assemble a strong ABET accredited nuclear engineering curriculum and to secure research funding from several sources. One of the challenges associated with the creation of a new nuclear engineering program is the need for infrastructure, computational and particularly experimental, to pursue cutting edge research at a level competitive with the other nuclear engineering programs in the US, most of which have been functional for more than fifty years. VCU has managed to attract a great group of trailblazers, willing to open their own research paths and to contribute to the development of joint research infrastructure. At the same time, these faculty are willing to step outside of their comfort zones to explore truly multidisciplinary innovative research opportunities.

One of these pioneers is Prof. Supathorn Phongikaroon. For the last five years, Dr. Phongikaroon and his team of undergraduate students, graduate students and post-doctoral researchers have worked tirelessly to build completely from scratch VCU's Radiochemistry & Used Nuclear Fuel Reprocessing Laboratories. Dr. Phongikaroon's laboratories are among the best equipped in the US for the performance of research work on pyroprocessing (also known as electrochemical separation) for used nuclear fuels (UNF), and to study the physics of molten salts in general. The chemical reprocessing of UNF, an area of intense research in the US, would

allow us to separate the various useful radionuclides present in that fuel, re-use the recycled fuel in a reactor, and consequently close the nuclear fuel cycle. The processes that have been considered to complete the reprocessing of used nuclear fuel can be grouped in two main approaches: Aqueous separation and pyroprocessing. While aqueous separation, in particular the Plutonium Uranium Redox EXtraction process (PUREX) method, is the standard process currently being used around the world to separate uranium and plutonium from used nuclear fuel, there are numerous potential benefits to the use of pyroprocessing technology. For example, its overall process would be more compact and would generate less low-level waste in comparison to the solvents used in the PUREX process. At VCU, Dr. Phongikaroon and his team have been working to better understand all the relevant electrochemical parameters taking place in an electrorefiner, and to improve its efficiency from fundamental approaches and to provide correlations that can help advancing an engineering design. Because one of the controversies associated with used nuclear fuel reprocessing is its potential contribution to nuclear proliferation or its vulnerability to nuclear terrorism, Dr. Phongikaroon is also working on nuclear materials detection and accountability. One of the techniques under study is the use of Laser Induced Breakdown Spectroscopy (LIBS) to perform near real-time in-line measurement and characterization of nuclear materials. Once perfected, this technique will allow technicians and inspectors to accurately and in quasi real time measure the isotopic composition of a batch of used nuclear fuel undergoing reprocessing.

PhD Student Hunter Andrews working in Dr. Phongikaroon's Used Nuclear Fuel Reprocessing Laboratory.

A relatively new addition to the VCU team is Dr. Braden Goddard, who has brought his substantial experience in industry, national laboratories and international safeguards. Dr. Goddard leads the VCU Nuclear Security and Nonproliferation Laboratory, which in addition to having broad research capabilities includes a strong educational focus, training undergraduate and graduate students in both the engineering and the policy aspects indispensable for a nuclear security expert. Together with research professor Dr. Manit Shah, Dr. Goddard works in subjects such as assay measurements from environmental samples, non-destructive multi-actinide assay techniques, and potential UAV threats to nuclear facilities. One of the most impactful areas of focus for Dr. Goddard and his team, is the development of a proliferation-resistant nuclear fuel cycle that could be implemented

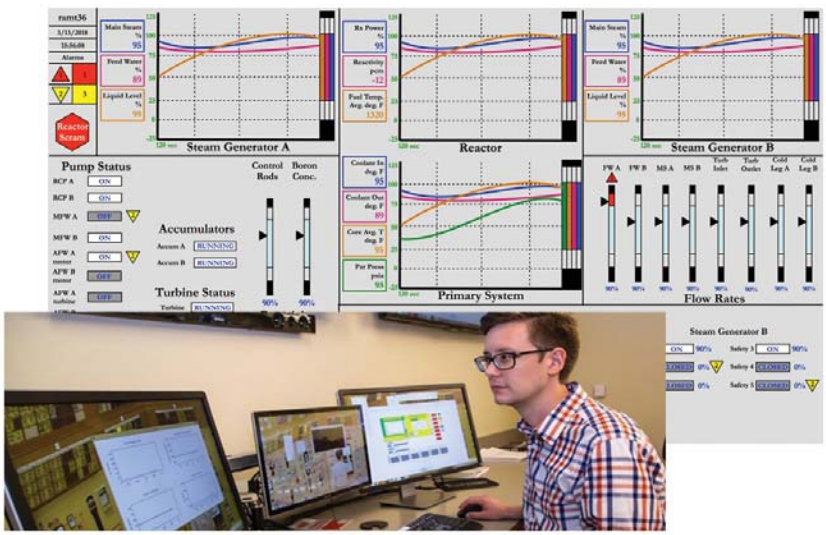
(Continued on page 24)

Nuclear Engineering...

(*Continued from page 23)*

with relative ease for used nuclear fuel, stockpiles and fuel in existing power plants, and of course to fuel in future nuclear reactor designs. If successful, this research could result in a significant reduction of the risks and costs associated to nuclear proliferation and nuclear security.

VCU professor Jessika Rojas is working on the integration of nanotechnology with nuclear engineering for a very innovative set of research applications. In the area of nuclear medicine, Dr. Rojas and her team are studying the use of nanomaterials as radioisotope carriers in targeted radioimmunotherapy (RIT) and medical diagnostic imaging. The group is currently also investigating radiation effects on ultrahigh temperature ceramics to enable their use in nuclear power generation applications. Intimately related to this last application, Dr. Rojas is looking into the radiation effects on nuclear components fabricated using additive manufacturing techniques. This last application is of particular interest as nuclear utilities carefully consider the use of additive manufacturing for the replacement of certain components in an effort to optimize maintenance schedules and spare parts inventories.



Daniell Tincher at VCU's Nuclear Simulator Laboratory.

In the more traditional areas of nuclear thermal-hydraulics, reactor physics and nuclear safety, VCU professors Zeyun Wu and Sama Bilbao y León are collaborating in the development of enhanced models for the design and safety analysis of sodium cooled fast reactors. In particular, they are interested in the characterization of the phenomena of thermal mixing and thermal stratification in large sodium pools. Prof. Zeyun Wu is also working in the development of more efficient computational reactor analysis methods in support of the deployment of advanced nuclear reactor designs. Prof. James Miller is leading the work in the development of a toolkit that will allow real-time event-driven execution of licensed production codes. The use of this toolkit will significantly enhance the capabilities of these codes that, although robust and well validated, are often not very user friendly. This toolkit provides endless possibilities for analysts to perform complex evaluations quickly and intuitively, yet using licensed tools.

The use of machine learning algorithms is one of the areas that all VCU nuclear engineering focused faculty are starting to integrate into their respective areas of research. Thanks to a very close collaboration with VCU computer science professor Milos Manic, these powerful computational methodologies are helping VCU nuclear engineering faculty to develop innovative contributions for the nuclear enterprise. For example, Dr. Phongikaroon routinely uses Artificial Neural Intelligence (ANI) to develop predictive algorithms based on existing electrorefiner experimental data for pyroprocessing. The concepts of the digital thread and machine learning, have started to be used in the manufacture of nuclear grade systems and components to optimize and reduce the cost and complication of current quality assurance processes. Using the abundant experimental data and Computational Fluid Dynamics (CFD) simulations for phenomena such as critical heat flux in nuclear fuels, will also allow Dr. Bilbao y León the "training" of the algorithms, and may result in deep learning models capable of predicting the behavior of advanced nuclear fuels under normal and off-normal operating conditions. Another application of data analytics and deep learning currently under development by VCU nuclear engineering faculty uses the more than 35 years of plant computer data and maintenance logs available at most nuclear power plants to forecast future trends, predict catastrophic failures and optimize maintenance schedules.

These are just a few examples of the research work currently being performed by VCU nuclear engineering focused faculty. This relatively small team has managed to develop in a record time a very innovative and comprehensive set of research initiatives, all of which can potentially have immediate and cost effective implications for the US nuclear power enterprise.

Contact: Sama Bilbao y Leon, Virginia Commonwealth University, Dept. of Mechanical & Nuclear Engineering, 401 W. Main Street, Room E3252, Richmond, VA 23284; telephone: (804) 828-2570, email: SBilbao@vcu.edu. ■

RAPID – A Real-Time Accurate Neutronics Simulation Web App

By Alireza Haghighat, Virginia Tech.

Abstract

This paper introduces the novel RAPID code system and its Virtual Reality System (VRS) for neutronics simulation and analysis of nuclear systems in real time on a laptop, ipad, or smart cell phone. The paper briefly discusses the background and theory of RAPID and its VRS system, and provides the results of sample benchmarks, including an experimental subcritical reactor, a spent fuel cask, and a PWR core. VRS-RAPID is a powerful tool for the design of advanced reactors, fuel management of existing reactors, and monitoring and safeguards of spent fuel pools/casks. Its VRS provides a unique interface that eliminates the laborious input preparation and output processing associated with the standard neutronics codes, and enables immersive virtual visualization for analysis and training. Interested readers are encouraged to view a demo at https://bit.ly/2H2X6sH.

Alireza Haghighat

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He is the former Department Chair at the University of Florida (UF), and faculty member at Penn State.

Objective

The objective of this paper is to inform the readers of the RAPID (Real-time Analysis for Particle transport In-situ Detection) software that enables performing neutronics simulation of large complex nuclear systems (reactor cores, spent fuel pools/casks) in real time. In addition to the novel RAPID algorithm, the reader will be introduced to a collaborative, interactive, and 3D virtual-reality web application that provides a powerful interface for preparation of input, execution of RAPID simulations, and processing and display of outputs in various forms including tables and 2-D and 3-D images.

Introduction

Neutronics simulation of nuclear systems is performed using deterministic and/or statistical particle transport approaches. For the deterministic approach, the linear Boltzmann equation[1] or its approximation (e.g., the diffusion equation) are solved. For the statistical approach, the Monte Carlo method[2] is used. Both approaches require significant computation resources, if detailed 3-D distributions are needed. Since the inception of the Manhattan project, particle transport specialists have been developing efficient and accurate computational methods by using advanced numerical techniques and parallel computing hardware.

Over the past 31 years, the author and his students have developed different novel algorithms and codes for solving real-world problems. Between 1986 and 2003, their efforts resulted in a number of computer codes including: i) PENTRAN (Ref. 3), a 3-D parallel discrete ordinates code with hybrid domain decomposition capability; ii) A^{3}MCNP (Ref. 4), based on the CADIS methodology that performs a consistent source and transport biasing by automatic calculation of an approximate importance function distribution to speed-up a Monte Carlo simulation; and, iii) TITAN (Ref. 5), a discrete ordinates and characteristics code with angular domain decomposition capability. These codes have been extensively benchmarked based on various real-world problems. However, obtaining detailed solutions requires the use of significant computational resources – processing power (10-1000s of cores on a parallel computer), memory (10-100s GB), and time (hours – days). Consequently, such codes have had limited use for real-world application by the nuclear industry. To overcome this shortcoming, since 1998, the author and his group have been searching for novel methodologies, and their efforts have resulted in the development of the physics-based Multi-stage Response-function Transport (MRT) methodology[6]. Since the year 2003, they have developed different codes using the MRT methodology, including: i) INSPCT-s (Ref. 7), a spreadsheet-driven software that can be used for inspection of spent fuel pools; ii) AIMS (Ref. 8), a tool for determination of gamma response as part of an active interrogation system for identification of special nuclear materials hidden in a shipping container; iii) TITAN-IR (Ref. 9), an image reconstruction software for a SPECT medical device using a special version of the TITAN code system; and iv) RAPID (Ref. 10), that is the subject

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of this paper. The common thread among all these codes is the ability of obtaining accurate results in real-time that consequently enables their use in a real-world setting for the analysis of complex nuclear systems.

The goal of this article is to describe the RAPID code system and its capabilities and provides sample results for a number of real-world problems.

Description of RAPID Formulation

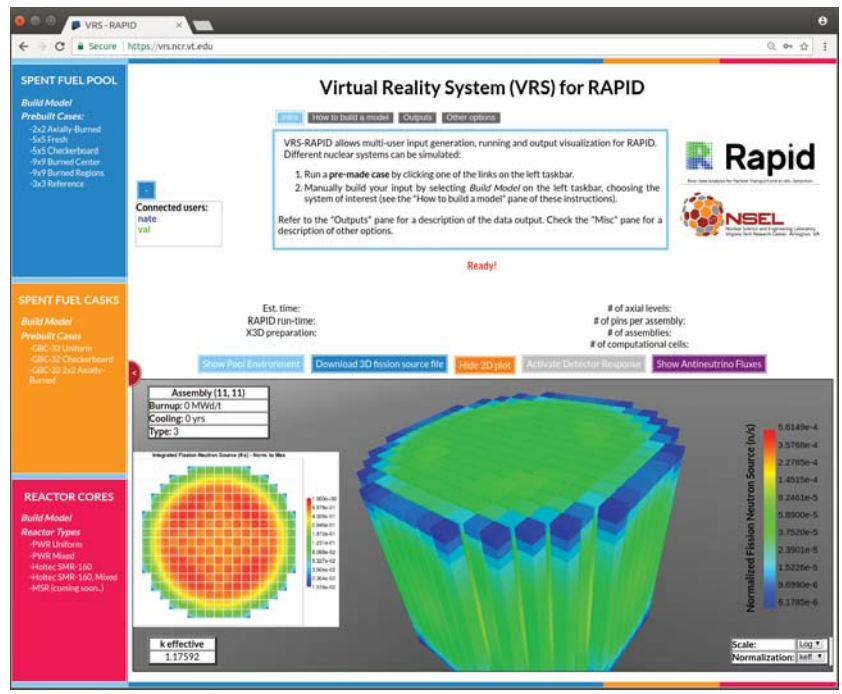
The RAPID's MRT methodology is based on the Fission Matrix (FM) method, detector response function (DRF) and the adjoint function methodology. The FM approach[1] is derived by re-casting the linear Boltzmann equation for neutron transport into a linear system of equations. These equations effectively condense all the particle transport information, including material cross sections and interaction rates, into a coefficient matrix that has to be pre-calculated for a wide set of parameters, such as burnup, cooling time, and/or enrichment of the nuclear fuel. The coefficients can then be interpolated to obtain results for model configuration changes, without the need to perform the detailed and time consuming transport calculation again.

To calculate the coefficient matrix, a series of independent fixed-source Monte Carlo calculations are performed using a utility software, pRAPID (Pre- and Post-Processing for RAPID), that builds input files, executes a Monte Carlo code, and processes its outputs for direct use by RAPID. pRAPID works with either MCNP (Ref. 11) or Serpent (Ref. 12) code systems. Note that the coefficients that represent the coupling between regions are highly localized, and can be calculated using geometric similarities and symmetries. Hence, an MRT strategy[13] has been developed for calculating a highly sparse matrix at a relative short computation time and small amount of memory.

Virtual Reality System (VRS) for RAPID

RAPID has been incorporated into a Web application referred to as the Virtual Reality System (VRS) for RAPID. VRS-RAPID provides a collaborative Virtual Reality environment for a user to build models, perform simulations, and view 3-D diagrams in an interactive mode. Additionally, VRS-RAPID can be coupled with an immersive visualization facility such as the VT's HyperCube System.

VRS-RAPID couples RAPID with a web-based interface for intuitive input preparation and an interactive, 3D virtual reality-based output visualization using X3D. VRS-RAPID benefits from the real-time capability of the RAPID code system to immediately display the results of the neutronics simulation of nuclear systems such as reactor cores, spent fuel pools and spent fuel casks. Additionally, through RAPID's detector response formulation, VRS-RAPID provides an in-situ monitoring capability that is highly beneficial for materials inventory and safeguards applications. It is important to note that the VRS can be adapted to work with any other physical phenomenon in any geometry by implementing suitable input/output elements.[14]



VRS-RAPID's interactive screen in which the user can select a problem type, modify the problem, execute the problem, and process and examine results.

Benchmarking of RAPID

RAPID has been benchmarked against standard Monte Carlo codes (such as MCNP and Serpent) for a subcritical experimental reactor, spent fuel storage casks, and a reactor core. Below, is a small subset of these benchmarking studies:

1) US Naval Academy subcritical experimental reactor: This reactor contains 268 natural uranium fuel rods that are placed in a cylindrical pool of radius 60.94 cm and height of 154.20 cm. The pool is filled with water, and contains a PuBe source that is placed at the center of the pool and axial location of 15 cm from the bottom of the pool. RAPID subcritical multiplication calculations were performed[15] and the fission source and subcritical multiplication factors have been compared to those predicted by the MCNP code system. The subcritical multiplication factors were within 1%, and the relative differences of the fission source values were within ±4%. The RAPID calculation was completed in only 50 seconds on one computer core, while the MCNP calculations required ~19 hours on 16 cores. A series of in-core and ex-core measurements were made using He-3 detectors and demonstrated that experimental results agree with calculation predictions within the combined experimental and calculation uncertainties.

2) GBC-32 (General Burnup Credit) Computational Benchmark Cask: This cask contains 32 PWR assemblies and is filled with water. All the assemblies are surrounded by absorbing racks containing Boral plates. Each assembly contains 264 fuel pins and 25 guide tubes. For the RAPID calculations, in addition to the system eigenvalue, fission source was calculated[16] for each pin at 48 axial levels, for a total of 405,504 regions. For the Serpent calculations, in order to achieve a reasonable statistical uncertainty, only 12 axial level per pin, i.e., 101,376 regions were considered. Different models containing varying burnup distributions were examined including the cask loaded with all fresh fuel, all burned fuel at different burnup levels (5, 10, 20, 30, and 40 GWd/MT), and a radial checkerboard pattern with difference configurations of fresh and burned fuel (alternate combinations of 10, 20, 30, and 40 GWd/MT). Calculated multiplication factors for the RAPID for all cases were within the statistical uncertainty (about 30 pcm) of the Serpent predictions. The computation times of the RAPID code varied between 92-140 seconds on one computer core, while Serpent required about 6.6-7.5 hours on 16 cores. Hence, speedups in a range of 180-270 were achieved. It is important to note that, in spite of a coarser (by a factor 4) axial mesh used for Serpent, its predicted fission source values at the top and bottom of the fuel pins had large uncertainties on the order of ~10%. For this study, 295 pre-calculations were performed; each calculation requires ~36 minutes on one core.

3) NEA/OECD Monte Carlo Performance Benchmark Problem. The model is a PWR core of 241 assemblies with 264 fuel pins per assembly. All the assemblies are considered to have an average burnup of 24 GWd/MT, and boron is added to the coolant to obtain a multiplication factor of about 1. The RAPID calculation is performed[17] to calculate the fission neutron density for each fuel pin at 100 axial levels that results in 6.4 million regions. The RAPID calculated eigenvalue was 1.000912 ±1.4 pcm which is within 5.3 pcm of the Serpent-predicted eigenvalue of 1.000855 ±1.0 *pcm*. The RAPID calculation was completed in 13.8 minutes on one computer core, while the Serpent calculation was completed in 2.5 days on 16 cores. This means a calculational speedup of about 4,165 was achieved. It is important to note that, in spite of the long calculation time, the fission neutron source predicted by Serpent on the top and bottom of the fuel pins still suffers from uncertainties higher than 10% that generally is not acceptable. This study analyzed the performance of RAPID on different cases that featured variation of water temperature and radial enrichment distributions. The required FM coefficients database for these different parameters were obtained by performing 195 calculations at 50 min per calculation, on a single core.

Conclusions and Future Work

This paper has introduced a novel neutronics tool that significantly contributes to the real time analysis of existing nuclear systems and the design of advanced reactors. Its VRS system provides a unique capability that simplifies neutronics analyses and therefore enables performing detailed sensitivity and parametric studies necessary for design, licensing, and operation of nuclear systems. Additionally, its detector response calculation capability provides an excellent tool for practitioners in areas of nuclear monitoring and safeguards.

Finally a novel burnup algorithm has been developed for determination of 3-D fuel burnup as a function of exposure time and specific power. This algorithm, referred to as bRAPID, is currently being benchmarked. Further work is underway, on the benchmarking of the DRF methodology, and its application to different environments and detectors. To enable RAPID for simulation of reactor kinetics and molten salt fueled reactors, the development of a transient algorithm based on the Transient Fission Matrix (TFM) methodology has been started.

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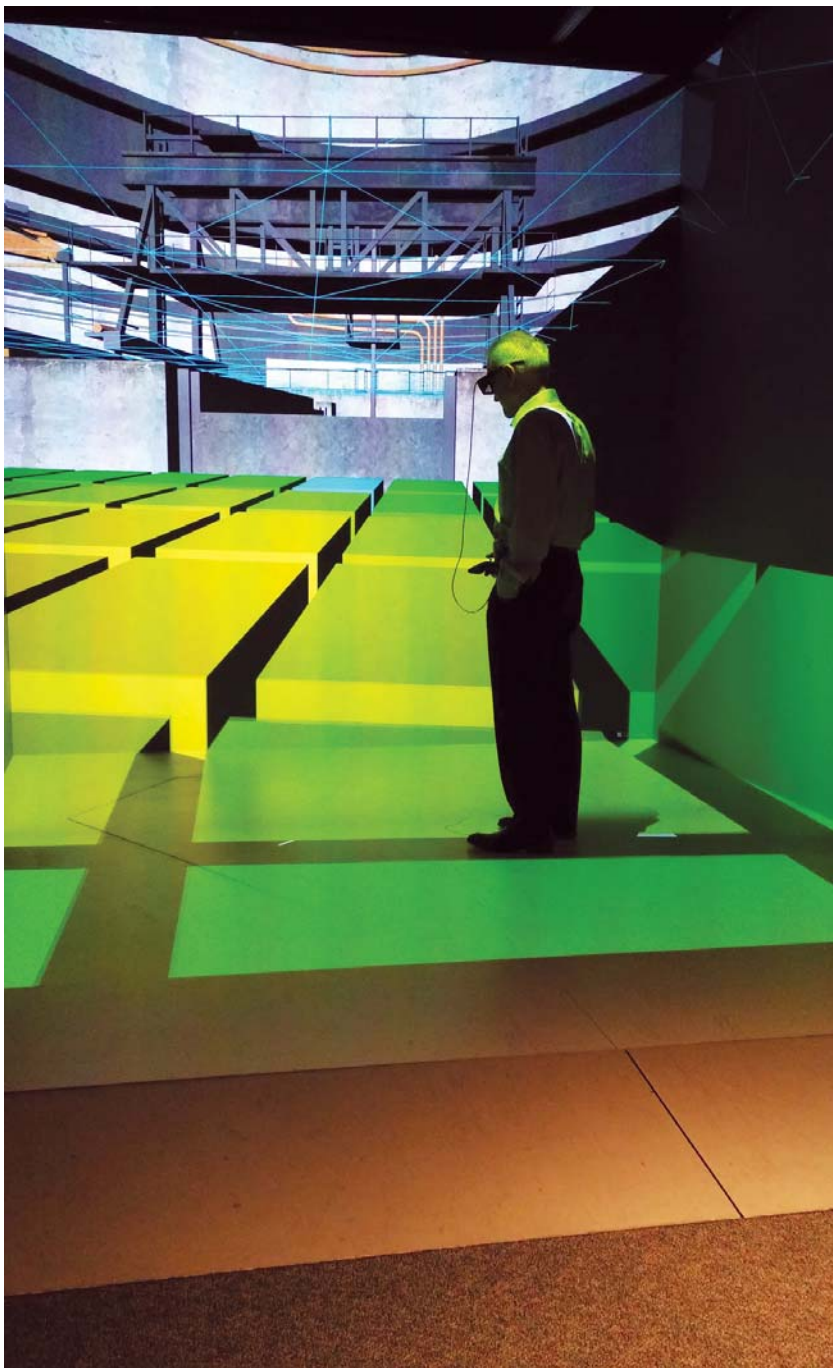

Immersive Visualization of author is inspecting a virtual spent fuel pool by walking on the top of fuel assemblies which are represented by their fission neutron density distributions that was calculated by RAPID.

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Predictive Analytics with Big Data-Spark Framework

By Himanshu Upadhyay, Leonel Lagos, Santosh Joshi, Mohammed Esoofally, Florida International University and Kevin Cooper, Indian River State College.

Himanshu Upadhyay

Dr. Himanshu Upadhyay is working with Florida International University's Applied Research Center as Senior Research Scientist for the past 17 years, overseeing the Information Technology, Cybersecurity and Data Science research groups. Dr. Upadhyay has more than 27 years of experience in cybersecurity, data science, information technology, management and engineering to his role, serving as Co-Principal Investigator for multimillion - dollar cybersecurity research project for the Department of Defense and knowledge/waste management research project for the Department of Energy's Office of Environmental Management. Dr. Upadhyay has published multiple papers in the area of cybersecurity, machine learning, knowledge management, data science, nuclear waste management and service-oriented architecture. His current research focuses on cyber forensics, malware analysis, cyber analytics/visualization, big data and machine learning / deep learning.

Objective

The nuclear energy industry, while operating under high levels of safety, capability and reliability, is experiencing a steady increase in electric generation costs. Nuclear power plants are expected to run every unit at maximum capacity at all times, efficiently utilizing assets with minimal downtime. Corrective and predictive maintenance has become a need to reduce the plant maintenance costs for the much higher availability and reliability required of the nuclear power plant equipment. Analyzing the big data generated by various sensors on the components of the power plant equipment is a trivial solution for predicting equipment failures to increase the power plant efficiency. Predictive Analytics involves building a big data framework to continuously monitor asset performance through sensor data analytics to provide advance warnings of equipment failures. The level of data influx from different temperature sensors, pressure sensors, and other parts of nuclear sub system is huge; hence a big data framework coupled with machine learning can be implemented to solve this problem. Identifying problems before they occur helps to reduce unscheduled downtime, better plant maintenance and optimize asset performance.

Abstract

The system will extract and analyze meaningful information from the data generated by the various sensors on the Nuclear Power Plant equipment and process them using the big data Spark [1] framework in near real time using In-Memory analytics and traditional machine learning algorithms. The continuous stream of data generated by temperature sensors, pressure sensors, sensors that interact with the plants physical equipment and other real-time sources are compelling nuclear plant owners to imagine what they could do with this huge amount of data. The term "big data" applies here because the data is humongous in terms of volume (data size), velocity (speed of change) and variety (different forms of data). As more and more data is generated and collected, data analysis requires scalable, flexible, and high performance tools to provide insights really quick. Thus integrating a big data platform into the nuclear power plant ecosystem is a one stop solution. This article focuses on proposing a design for building an open source predictive analytics system using Apache Spark. Real-time analytics coupled with machine learning can keep the plant owners up-to-date on the current performance and of potential risks that will arise by analyzing patterns in the data. The models used for machine learning can be built from larger volume of historical / real time nuclear plant sensor data. The trained model can be used to predict variations in the power plant equipment performance and maintenance.

Introduction

As the nuclear power ecosystem digitally grows, the amount of data being created and collected is growing and accelerating significantly. Analysis of this ever-growing data becomes a challenge with the traditional tools. We require a framework to bridge the gap between data being generated and data that can be analyzed effectively. Big data tools and technologies offer opportunities to analyze this data efficiently to better understand the performance of a nuclear power system and gain full advantage of its assets by significantly reducing the downtime of the equipment. The design proposed can be implemented for near real time collection and analysis of sensor data coupled with machine learning to gain insights from available data. The distributed computing power of Spark Streaming can be utilized to handle continuously generating stream of sensor data. Spark is highly scalable; as the model can also be deployed on a cloud cluster to achieve scalability as per demand. The applications can easily scale up and down based on demand. As requirements change, the environment can easily resize, without having to change the core design. Spark also reduces the number of disk

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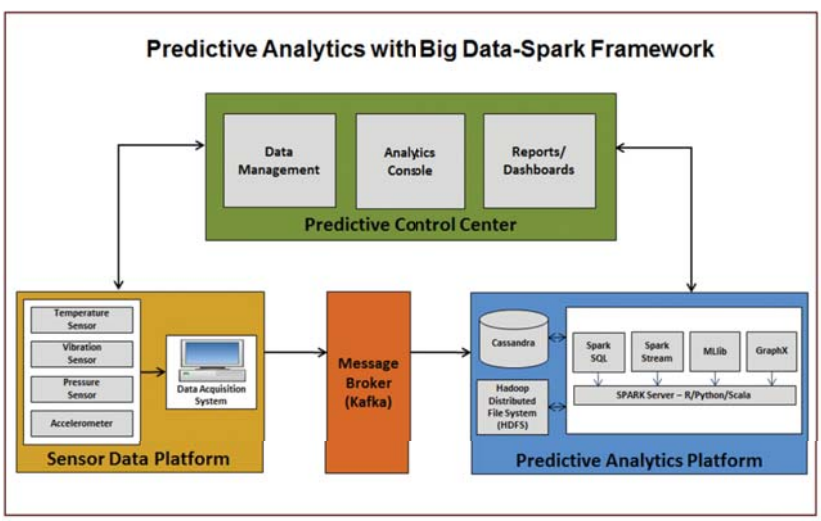
input/ output operations as it process the data in memory. The open source Apache spark ecosystem can be utilized for batch and stream processing and comprises of libraries providing support for machine learning, graph processing and SQL querying.

Spark Framework

Spark is a high performance in-memory distributed computing framework to process structured, semi-structured, unstructured and streaming data. Spark has a master slave architecture, where the analysis task is divided into smaller sub-tasks and assigned to worker nodes for computation. It provides libraries for diverse workloads - traditional and streaming ETL, interactive or ad-hoc queries (Spark SQL), machine learning (MLlib), graph processing (GraphX), and streaming (Spark streaming) - all running within the same engine.



Spark SQL: This is Apache Spark's module for working with structured data. Spark SQL allows the querying structured data inside Spark programs, using either SQL or a Data Frame API. Data Frames and SQL provide a common way to access a variety of data sources.

Spark Streaming: Spark streaming brings Apache Spark's language-integrated API to stream processing to implement streaming jobs. Spark streaming also allows reusing the same source code for batch processing, joining streams against historical data, and running ad-hoc queries on the stream state to build powerful interactive analytics applications. Spark streaming is an extension of the core Spark API that enables scalable, high-throughput, fault-tolerant stream processing of live data streams.

Spark MLlib: This is a Spark's scalable machine learning library. Apache Spark provides a general machine learning library MLlib which is designed for simplicity, scalability, and easy integration with other tools. With the scalability, language compatibility, and speed of Spark, it can iterate through large amount of data faster. MLlib supports advanced machine learning algorithms and utilities, including classification, regression, clustering, collaborative filtering and dimensionality reduction algorithms such as Linear models (SVMs, logistic regression, linear regression), Naive Bayes, Decision trees, Ensembles of trees (Random Forests and Gradient-Boosted Trees), Collaborative filtering, Alternating least squares (ALS), and Clustering.

Spark GraphX: It provides support for various graph operations such as subgraph, joinVertices, and aggregateMessages to transform the graph data. It provides several ways of building a graph from a collection of vertices and edges in an RDD. GraphX also includes a number of graph algorithms and builders to perform graph analytical tasks.

Proposed System Architecture

The proposed system is a predictive analytics big data platform to capture and analyze the heterogeneous data from the various sensors on the Nuclear Power Plant equipment. As shown in figure 1, the system will import streaming data from temperature sensors, vibration sensors, pressure sensors and accelerometers and other subsystems of the nuclear power plant into Hadoop Distributed File System (HDFS) [2]. The system will then process them using the Spark framework using in-memory analytics and machine learning algorithms to build models and predict the condition of nuclear equipment.

System Platforms: The four major platforms of the proposed system are:

- Sensor Data Platform: It consists of nuclear plant equipment and various sensors such as temperature, vibration, pressure and accelerometers installed on equipment and data acquisition system, which will be the data source for the analytics module.
- Message Broker: Data interface layer based on Kafka [3].
- Predictive Analytics Platform: It consists of Hadoop Distributed File System, Spark Server/ framework.
- Predictive Control Center: This Platform consists of Data Management, Analytics Console, Dashboard and Reports.

Sensor Data Platform: Data Acquisition System on this platform will collect the data from various sensors from the nuclear power plant and transfer to the message broker (Kafka) system for further processing.

Message Broker (Kafka): This is a Data Interface which will collect, transform and load the sensor data from Data Acquisition System into the HDFS. Kafka is a high-throughput, distributed, publish-subscribe messaging system to capture and publish sensor stream data. Kafka acts as the central hub for real-time streams of sensor data and are processed using complex algorithms in Spark Streaming.

Predictive Analytics Platform: This platform consist of a storage HDFS distributed file system to store streaming data generated by various sensors installed on different nuclear power plant equipment . It also consists of the big data processing framework Spark and its associated libraries to perform in-memory analytics on sensor data. The stream data is analyzed by building various predictive models using ML algorithms like Regression, Classification and Clustering from MLlib library. Predictions are performed using these models and results are stored in to HDFS.

Predictive Control Center: It is a centralized application to manage the overall system. The Data Management module manages various data sources and data movement across the different platforms. The Analytics Console module is a user interface to manage predictive analytics platform to build and store ML models and predictions. Predictive results will be visualized using Dashboard and Reports.

Conclusion

The proposed system has adapted a predictive maintenance for Nuclear power Plant equipment using, powerful Big Data processing framework Spark to build data driven predictive machine learning models by analyzing the streaming data generated by the various sensors on the nuclear power plant equipment. The prediction results will be near real-time as the models and predictions are built using streaming data. The proposed system will provide nuclear industry operators alerts and views of equipment failures, wear and tear of parts, small deviations in equipment operations and maintenance of the machineries. Integrating predictive analytics in the nuclear ecosystem will provide engineers the ability to spend less time looking for potential issues and more time taking actions to achieve the greatest return on every asset.

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Leonel E. Lagos

Dr. Leonel E. Lagos, is the Director of Research at Florida International University's Applied Research Center (FIU-ARC) and Principal Investigator of a multi-year Cooperative Agreement between the U.S. Department of Energy (DOE) and FIU in support of DOE's environmental restoration program. Dr. Lagos is also the Principal Investigator for the Department of Defense's Cybersecurity technology development program at FIU. Dr. Lagos is founder and Director of the DOE-FIU Science and Technology Workforce Development Program (http://fellows.fiu.edu) and Department of Defense Cyber Fellows Program. As director to these prestigious signature workforce development programs, Dr. Lagos trains and mentors FIU science, technology, engineering, and math (STEM) minority students and provides them with "hands-on" applied research, internships, professional development, and employment opportunities.

During his tenure at FIU-ARC, Dr. Lagos has developed environmental technologies for the treatment of radiological contaminated surfaces and disposal of nuclear waste. His research has resulted in U.S. and European patents of a Mobile Integrated Piping Decontamination and Characterization System.

Dr. Lagos is the co-chair of American Nuclear Society (ANS) Executive Committee of the Robotics and Remote Systems Division (RRSD). Dr. Lagos also serves as a member of the Program Advisory Committee (PAC) in support of the Waste Management Symposia (WMS).

STP Units 1&2 License Renewal

Chairman Dennis Bley: At this time, we turn to the South Texas Project License Renewal Application and I turn the meeting over to Dick Skillman.

Member Gordon Skillman: This is Agenda Item 2, License Renewal Application for the South Texas Project. This morning, we will hear presentations from the Division of License Renewal and the applicant, South Texas Nuclear Operating Company.

Our License Renewal Subcommittee previously met to discuss this matter. At the conclusion of that meeting, there was one open item and that item had to do with the selective leaching of aluminum bronze.

Today, we will hear from the applicant on addressing closure of this item. And with that, I call upon and welcome George Wilson to begin the presentation.

Mr. Wilson: I am George Wilson, the Director of the Division of License Renewal. With me at the table is Sheldon Stuchell, the Branch Chief for the Projects Branch.

Presenting for the NRC today will be Lois James, the Senior Project Manager for South Texas, Bill Holston, the Senior Mechanical Engineer, and Dr. Allen Hiser, the Senior Level Advisor for License Renewal.

We look forward to a productive discussion while presenting our safety evaluation report for the South Texas Project Units 1 and 2, which determined that the requirements of 10 CFR 54.29(a), "Standards for issuance of a renewed license", have been met for the license renewal of South Texas Project Units 1 and 2.

During the subcommittee, we discussed one open item associated with the Selective Leaching of Aluminum Bronze Aging Management Program. This item is now closed and the staff will be discussing its resolution during our presentation.

Mr. Dave Renucrrel: We believe that we have developed a robust, high-quality License Renewal Application, that our Aging Management Programs provide the reasonable assurance for the continued safe and reliable operation of our station.

I am the Senior Vice President of Operations. My current position at the staff after 29 years is I am responsible for all the major projects on-site, all the construction activities, and then the contracts associated with those. Part of those projects is the license renewal project.

Mr. Michael Murray: I have been in the industry for 42 years. I have been at STP for 32 years, I was there for startup of both units. So, I had the opportunity of actually working in the startup of the units.

Mr. Ron Gibbs: In 2013, I joined the Operations Management Team. I was the senior license at the South Texas Project for about two years and transitioned in April to my current position, which is Ops Manager in Training.

Mr. Arden Aldridge: I've been in the South Texas Project for 25 years in various engineering roles. Currently, the License Renewal Application Project Lead and am the License Renewal Implementation Coordinator.

Mr. Rencurrel: The South Texas Project Nuclear Operating Company is a company that parks on top of the asset. We don't own the asset. We operate the asset and maintain the asset for three owners. And our license is assigned to the South Texas Project Nuclear Operating Company. Our three owners are NRG Texas, the City Public Service Board of San Antonio or CPS Energy, and the City of Austin or Austin Energy.

Our owners are committed to providing the right level of resource support and oversight to ensure that we have safe and reliable operation at South Texas and that we maintain and that we stay a critical long-term power generator for the State of Texas.

Our initial license was granted in 1987 and 1988, respectively, for Unit 1 and 2. Since that time, our owners have invested heavily to position our station for long-term, safe, reliable operation. We have changed out our steam generators. We have updated our low pressure turbines. We've replaced our reactor vessel heads. For the the main electrical generators, we both replaced the stators and the rotors. We completed our Alloy 600 program with the mechanical stress improvement process -- complete might not be the right word but feel committed to exercising the Alloy 600 program.

We also have changed out our main transformers and are in the process of changing out our large feedwater heaters. And so we are positioning the unit for long-term reliable operation.

In regards to the Aging Management Plan and the commitments in the Aging Management Plan, the governance that we use is that we have what is called a Plant Investment Plan which is incorporated into our business plan. What that Plant Investment Plan does is it ensures that we have the right funding and the right resources committed to ensure that the commitments of the Aging Management Plan are carried out appropriately and they are carried out in a way that they will be completed well before the expiration of the current operating period.

Mr. Gibbs: The South Texas Project is in a rural area in Matagorda County, which is about 90 miles southwest of Houston and we are about 15 miles inland from the Gulf.

We have a 7,000-acre main cooling reservoir, which we sit on a 12,000-acre site. The main cooling reservoir is made up from the Colorado River to the east of the plant.

Operators are licensed on both units and we use common operating procedures.

Containment structures are semispherical heads with steel liners

Excerpt of the transcript of the U.S. NRC's Advisory Committee on Reactor Safeguards (ACRS) meeting on July 12, 2017, related to license renewal application for the South Texas Project (STP) Units 1&2.

and flat bottoms. Each unit has three independent safety-related trains. That includes all our pumps, piping, valves, and diesel generators, and each unit has four auxiliary feedwater trains; three electric-driven pumps and one steam driven pump for each unit.

Mr. Aldridge: We submitted our application in October of 2010 and during that time, we have completed all the different reviews, annual updates, integration of operating experience through the Interim Staff Guidances and responses to Requests for Additional Information from the NRC staff.

The Generic Aging Lessons Learned (GALL) Consistency Table tells us that we have 41 Aging Management Programs; 8 new ones and 33 existing programs.

The STP License Renewal Application addressed all the lessons learned identified in GALL Rev. 2 and all the other requirements of the standard review plan.

Out of that review and through that process of the license renewal, we established 47 commitments and those commitments are included in the Safety Analysis Report (SAR) supplement, which is Appendix A of the License Renewal Application and will be managed through the South Texas Licensing Commitment Management administrative processes.

Eight of those commitments have already been implemented and 39 commitments remain to be completed. Those commitments represent 22 procedural enhancements or new procedures, 13 inspection scopes, 2 replacement scopes, and 2 additional analysis updates specifically around fatigue cycle counting.

We have an implementation plan, a schedule and budget to complete all the remaining commitments on their scheduled due dates, prior to entering the period of extended operation in 2027 and 2028.

We have three activities that were incorporated. The first one was, we clarified the selective leaching of Aluminum Bronze Management Program to close this open item. And we identified and optimized the use of a non destructive examination to manage the age-related degradation of the aluminum bronze weld materials.

The second one is we revised the Steam Generator Aging Management Program to incorporate lessons learned from interim staff guidance 2016-01, "Changes to Aging Management Guidance for Various Steam Generator Components" and in that, we added additional steam generator component scope inspections to the program.

And then the third one is we updated the Bolting Integrity and External Surfaces Monitoring Aging Management Program to add some additional clarification for inspection methods to be used to detect leakage associated with closure bolting in air filled and gas-filled systems.

Mr. Rencurrel: We are committed to the safe, long-term, reliable operation of South Texas. Many of us have really dedicated our lives and our efforts to make sure this station is successful and this is a big part of what we wanted to do. So, we thank you very much for this opportunity.

Member John Stetkar: Can you give us your rationale about why you feel that those inspections provide adequate information to understand what's going on on the below-ground welds?

I understand you are going to do episodic examination -- or I don't want to say examinations. You are going to check things if you have to ever excavate the pipe but that is on an opportunistic basis. Your program is primarily organized around the readily accessible above-ground piping.

So what gives you confidence in the status of the below-ground welds?

Mr. Aldridge: The difference between the above-ground and below ground, as we established, the below ground components, as far as the piping and the valves are not susceptible. They are out of rock material that don't dealloy like the castings. That addresses the overall system. To specifically address your question on welds, which the welds are the same, whether they are below ground or above ground, is we are doing a sampling of all the above-ground welds, which represent the total population. And

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STP Units 1&2...

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based on the as found conditions, the initial criteria is the weld material itself is not -- it's susceptible but we have had no operating experience of significant dealloying in the welds at the station after the initial startup. So, we have that to start with.

The second thing that we have is the margin of between the stress requirements of the below-ground and above-ground, we have about a two times margin of available stress margins between the above-ground and the below-ground. So if we find anything on the above-ground, we have the opportunity to expand the scope, which is part of the Aging Management Program, to below-ground scopes.

So, the program doesn't ignore them but it uses the above-ground as the leading indicators and we have sufficient time to be able to do a recovery.

Ms. Lois James: I am the License Renewal Project Manager for the South Texas License Renewal Safety Review. We are here today to discuss the South Texas Project License Renewal Safety Evaluation Report, which was issued just a month ago.

Joining me here at the table are Dr. Allen Hiser, the License Renewal Senior Level Advisor; Mr. William Holston, Senior Mechanical Engineer; and Ms. Phyllis Clark, Project Manager.

South Texas Project Nuclear Operating Company submitted its application for South Texas Projects Unit 1 and 2 in October of 2010. The staff issued two Safety Evaluation Reports with Open Items, one in February 2013 and one in October of 2016.

We presented the SER with Open Items to the ACRS subcommittee in November 2016.

The staff closed the final open item and issued the final SER on June 8, 2017.

The applicant identified four Aging Management Programs in its application and subsequently added an additional existing program in response to Requests for Additional Information (RAIs) issued by the staff, based on interim staff guidance.

All plans were evaluated by the staff for consistency with the GALL Report or the Standard Review Plan, as appropriate. The applicant may enhance existing programs to be consistent with the programs, as described in the GALL, or they may take exceptions to these programs.

Throughout the staff's review, AMPs were updated and revised based on RAI responses on the application, as amended; changes to the plant, as documented in the annual updates; and RAI responses, based on generic issues identified by the staff during reviews of other license applications.

Since the subcommittee meeting in November of 2016, several AMPs have changed disposition categories.

Mr. Holston: The staff has closed the open item associated with the Selective Leaching of Aluminum Bronze Aging Management Program.

During the ACRS subcommittee meeting, the staff discussed the closure of many aspects of the open item. And examples of those were the extent of the destructive examinations that were going to be conducted, acceptance criteria, et cetera. However, the remaining open portion of that open item was that the AMP did not adequately address corrective actions associated with inspection results, demonstrating that structural integrity requirements would not be met.

The applicant developed a plant specific Aging Management Program to address selective leaching of aluminum bronze and its essential cooling water system. That report has an existing Aging Management Program, AMP 33 for Selective Leaching; however, the purpose of that program is to determine whether you are experiencing selective leaching at the plant and it addresses more than just aluminum bronze; it addresses copper, alloys greater than 15 percent zinc; it addresses cast iron or gray cast iron.

The applicant, recognizing that it had specific operating experience related to selective leaching of aluminum bronze, developed this plant specific Aging Management Program.

Loss of material due to selective leaching of aluminum bronze principally occurs if the aluminum content is at greater than eight percent and if there is a slow cool down rate of the casting or the weld. And what occurs, if the cool down rate is slow enough, your form susceptible beta and gamma-2 phases in the lattice structure and the alpha phase is not susceptible. So that's what occurs. These welds and/or castings had beta and gamma-2 phases that were susceptible.

So at South Texas, they have approximately 350 remaining castings that are susceptible. They have susceptible welds due to the filler metal aluminum content. And the piping material, as the applicant already described, is not susceptible; that aluminum content is low enough.

So, since 1987 and through 2015, 55 through-wall casting defects have occurred as a result of loss of material due to selective leaching. The applicant has developed an existing program that they have been implementing for the current period of operation that does routine visual examinations, that they detect indications of leakage. They have an extrapolation where they say you know if we see a little line about this long along a casting, then they extrapolate the volume of the internal selective leaching. That extrapolation was based upon six samples that they conducted, where they destructively examined it and actually measured the extent of the dealloying.

They then put that volume into a structural integrity evaluation, determined if it meets structural integrity requirements. If it does, they submit for code relief because they have a leak, so it doesn't meet Section 11 Class 3 components. And the NRC has typically accepted those code release and granite relief and then they replace the component at the next refueling outage. So, that's what they have been doing with castings.

And they have had no leaks since. ■

KHNP's Design Certification Application

Mr. Y. Kim: So engineer safety feature materials are selected for compatibility with core cooling components and containment spray solution.

For the containment system the containment of APR1400 is pre stressed concrete with a cylindrical shell and dome. It is designed such that peak pressure is less than the design pressure and well below half of the peak pressure within 24 hours after the accident. The leakage of containment is also below the design leakage rate.

For the APR1400 containment pressure and temperature analysis GOTHIC is used with assumption and initial conditions to maximize the containment peak pressure and the temperature. The analysis are performed for a total of LOCA and steam line break case feature selected for sensitivity study on barriers, break size and power levels.

For the containment sub-compartment analysis, we analyzed at the place with use of COMPARE-MOD1A in response to high energy line break in each sub-compartment. Through the analysis, we also performed the map.

The structure test is based on ASME CC-6000, "Structural Integrity Test of Concrete Containments," and the leak-tight test is based on Reg Guide 1.163, “Performance-Based. Containment Leak-Test Program,”. The containment heat removal system reduces pressure and the transient following steam line break and LOCA.

The function of combustible gas control in containment is to control the hydrogen concentration in containment and In-containment Refueling Water. Storage Tank (IRWST) below 10 percent by volume during severe accident with Preliminary Amendment Requests (PARs) and igniters.

The safety injection system consist of four independent trains and two diagonal trains. Trains 1 and 3 or trains 2 and 4 are required to mitigate the loss of coolant accident. KHNP got approval for the fluidic device topical report recently. The operability of safety injection system is checked through Tech Spec 3.5.1 through 5.

For the hability system the APR1400 are designed to allow control room operators to remain in the control room envelope and take action to operate the plant safely under normal and maintain it in a safe condition under design-basis accident conditions. And the APR1400 hability system protect control room operator from outside airborne radioactivity.

Member Dana Powers: I am still unsure how you look at the dispersion under DBA conditions of radioactivity under DBA conditions to the main control room.

Mr. Sangho Kang: My name is Sangho Kang, KEPCO E&C In the DCD Section 2.3.4 we calculated the on-site dispersion of the LOCA condition of radioactive material, so based on the ARCO 96 model, which is developed by U.S. NRC, the concentration at the intake location of the main control room is calculated.

Mr. Y. Kim: So the exposure to MCR personnel meet the occupation dose limit of 50 millisievert.

The APR1400 engineered safety feature filter system are designed to mitigate the consequence of postulated accident by filtering radioactive particulate and iodine from air and meet the requirement of Reg Guide 1.52, “Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Post-Accident Engineered-SafetyFeature Atmosphere Cleanup Systems in Light-Water-Cooled Nuclear Power Plants,” and ASME N509, "Nuclear Power Plant Air-Cleaning Units and Components" and ASME AG-1, " Code on Nuclear Air and Gas Treatment."

The filter system include control room emergency makeup air cleaning system, auxiliary building controlled air emergency exhaust system and the fuel handling area emergency exhaust system.

For the containment spray system TSPs stores at the holdup volume tank that enabled the IRWST remains above pH 7 during 30 days in LOCA condition.

Member Powers: I am not sure why I should be confident that the pH will remain above 7 for 30 days.

Mr. Kang: Our program’s calculation to see the capability to maintain the pH of greater than seven was performed. The purpose of this calculation was to estimate the time to reach the pH greater than seven. But during the staff’s review we got the comments that how can we make sure that the pH value can last for the whole duration of the accident? That’s why we performed the analysis. The pH value of greater than seven is maintained during the 30 days after the loss of coolant accident. It was responded by our RAI response to the staff’s issue.

Member Powers: What did you use for G values for nitric acid formation, G values for cable insulation decomposition, and especially how you treat phosphate precipitation by interaction with containments coming into the Incontainment Refueling Water Storage System (IRWS)?

Mr. Kang: So in order to calculate the pH value we have considered the adverse effect from the Hypalon which is the material of the cable. Also the HECR and nitric acid which comes from the composition material of the containment, inside the containment. We take into account all of this adverse impact materials.

Mr. Y Kim: For the in-containment water storage system that consists of a storage tank and holdup volume tank and the cavity flooding system. The IRWST is protected, reliable and safety-related source of borated water for containment spray system and the shutdown cooling system and the safety injection system. The IRWST is also used to prepare the

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Briefing and discussion on June 7, 2017 by Korea Hydro & Nuclear Power (KHNP) related to their APR 1400 Advanced Power Reactor Design Certification Application.

This article is an excerpt of the transcript of US NRC's Advisory Committee on Reactor Safeguards (ACRS) meeting.

KHNP's Design...

(*Continued from page 35)*

refueling pool in support of refueling operation.

The holdup volume tank collected and stored coolant during the accident condition.

The function of a cavity flooding system is to flood the reactor cavity in the event of a severe accident.

And IRWST have minimum level of IRWST to support safety injection and containment spray pump operation during the accident condition.

Member Joy Rempe: When we discuss Chapter 19 we learn that even though you have this cavity flooding system, you did not take credit for it. You assumed the vessel failed to be conservative. And it's still unclear to me how much you didn't take credit for it. In the PRA do you assume that the water still goes to the cavity. Did you assume good heat transfer from the vessel to the water? It wasn't clear how this evaluation was done.

And I believe when we discussed the Chapter, you indicated, well, when we do severe accident management guidance, that will be something the COL applicant will take care of. How the COL applicant will look at the certified design and take care of what actions should be considered, is unclear to me. Could you give me any clarification on that interface?

Mr. Andy Oh, KNHP: We have two features of the mitigation feature. I think, Member Rempe, you mention that the thing is not that CF is – cavity flooding system. That is IVREVC, in-vessel retention ex-vessel cooling system.

That we didn't credit it, so it's a COL action item. COLAs, they will develop their strategy to implement that system, however, cavity flooding system is certified severe mitigation strategy. So it is included in our design.

Member Rempe: So the PRA takes credit for that the water would be injected. And so what I'm kind of -- there's sometimes unintended concerns about external reactor vessel flooding. For example, if you don't take credit for it, does the staff still review to make sure that the structures are robust to withstand what would be needed for external reactor vessel cooling?

And so this interface puzzles me because if you say, well, we don't take credit for it, then you don't have to worry about it. Is the insulation strong enough to withstand that chugging that would occur? When the APR1000 or the AP600 was looking at this, they had to consider how it operated.

And maybe this is also something the staff would clarify, but I'm just not sure how carefully the flooding system was reviewed and the strategy was reviewed, because you actually could have less heat transfer from the vessel.

Mr. Oh: Yes, all that is relevant to support IVREVC, not the CFS system.

Member Rempe: What is the cavity flooding system for?

Mr. Oh: Cavity flooding system is just to open a valve from the holdup volume tank and provide water to the cavity. Probably, it's a depth about five feet or six feet. But the difference from the IVREVC is that we have to inject the water using a shutdown cooling to the cavity. And the flood level, probably it's more than 14 and 16, 17 feet. So those two strategies are totally different.

Mr. Y. Kim: This is end of the Chapter 6. In-containment water system we have a swing panel. Four vent stacks are located on the top of IRWST and three swing panels per vent stack are provided to protect overpressure and the vacuum of IRWST. Two swing panels per overpressure protection and one swing panel for vacuum protection.

Those same panels are self-actuated by IRWST pressure and provided for hydrogen venting during the severe accident also. Those same panels also prevent vacuum in the IRWST during ECCS and the containment space inflation.

For the functionality of IRWST swing panels we got some request for additional information, so KHNP is trying to provide a response for this issue. So we are working on it.

Mr. Kang: My name is Sangho Kang, KEPCO E&C. I'm going to briefly talk about the overview of Chapter 12.

In order to ensure that the occupation radiation exposure ALARA for APR1400 provides a structure to effectively implement radiation protection policy for any review that are consistent with the operational and maintenance requirement to Reg Guide 14 1.8, 1.33, 8.8 and 8.10.

The design policy of the APR1400 is to implement the ALARA during the early stage of the design. The APR1400-specific ALARA design guide specify the approach, method and implementation guides for the designers to take into account. In the design of equipment, the ALARA design guidelines applies to easy removal of contamination, enhancement of reliability to reduce maintenance and minimization of corrosion. And the layout design of the ALARA design guide requires to separate the radioactive equipment from the non-radioactive equipment and to provide sufficient areas for inspection and maintenance.

As for the radioactive source term, the reactor core fission products are estimated using ORIGEN-S computer code based on the thermal power of 102 percent. The source term of spent fuel is calculated based on 100-hour decay time before the movement from the core.

The reactor coolant system fission product source terms provided in Chapter 12 are determined based on the fuel defect rate of 0.25 percent using DAMSAM code and used for the design of shielding and ventilation. The CVCS source terms are calculated using SHIELD-APR computer program assuming that the gas stripper is not operated to maximize the gaseous sources.

The source terms of the shutdown cooling systems are calculated assuming that the systems stop operation at four hours after shutdown. The design base source system in the spent fuel pool water is determined assuming that the primary cooling water is mixed with spent fuel pool water after 48 hours of shutdown cooling operation. ■

Transform the Maintaining the Plant Organization

Currently multiple handoffs are required between the development of a work plan and the maintenance craft team execution of work in the field. These handoffs create delays and impede the efficient execution of the work, resulting in lost productivity, increased maintenance cost incurred by the industry, and frustration by the craft team.

This efficiency bulletin dated December 18, 2017 transforms the maintaining of nuclear stations into a more autonomous entity that minimizes the number of handoffs and increases maintenance ownership of preventive maintenance activities. This transformation is dependent on maximizing the benefit from previous enabling efficiency bulletins.

Summary of Efficiency Opportunity

Desired end-state—Each nuclear station is maintained by an autonomous group of professionals that execute work in a highly efficient manner to improve plant productivity and equipment reliability at a reduced cost. This maintaining organization entails a self-directed professional workforce comprised of the following staff:

- A highly proficient Maintaining workforce
- Component/subject matter experts embedded within the Maintaining organization
- Component/subject matter experts who own the preventive maintenance technical basis for non-critical components
- Strategic Engineering (formally Systems Engineering) who own single point vulnerability mitigation and the preventive maintenance technical basis for critical components
- Predictive maintenance personnel
- Full-time Operations, Radiation Protection, and Supply Chain personnel who support the FIN process
- Work Management personnel who manage emergent work
- An engineering rapid response team

Value proposition (vision of excellence)—Initial savings will primarily be realized from efficiency gains in maintenance support functions (such as eliminating Foreign Material Exclusion rework, work management process simplification, and reduced maintaining organization reliance on engineering. Additional efficiency gains will be achieved through the full implementation of enabling efficiency bulletins that reduce or eliminate low-value preventive maintenance. Implementing other enabling efficiency bulletins and INPO "Industry Cumulative Impact Short-Term Actions" guidance will also increase work efficiency gains.

These efficiency gains are achieved by the following:

- Improving the identification of core tasks and objective work load estimates by the affected organizations as identified in NISP-EN-03, "Supporting Guidance for Optimizing Programs and Design Organizations"
- Identifying and addressing the potential impact and risk of reorganizing
- Identifying implementation enablers and risk mitigation strategies
- Developing a comprehensive change management plan that contains appropriate measures and monitoring
- Reducing the level of support from vendors and suppliers

Why it is important?—Currently, plant work activities can require up to 20 individuals, 13 weeks and over six handoffs to complete a work activity. This process is inefficient and hampers the capabilities of our craft work force. Continued viability of our nuclear plants requires streamlined maintenance processes that do not diminish nuclear safety and equipment reliability. This efficiency bulletin meets these objectives by providing:

- Increased efficiency through minimizing hand-offs and delays
- Increased craft decision-making for equipment reliability
- Improved, and more consistent response to site and fleet-wide issues, including the ability to redirect resources for emergent critical needs
- Increased focus on the most important issues that impact plant equipment
- Increased collaboration between Maintenance, Work Management, Strategic and Program Engineering core business functions and equipment reliability

Industry benchmarking values—Equipment reliability and overall station performance will remain at current high performing levels. Critical and non-critical maintenance backlogs will be reduced. Weekly schedule completion will improve, safety-system outage performance will be maintained or improved, and system and component availability to Operations will improve.

The measure of effectiveness:

- Equipment reliability index (ERI) and Maintenance and Work Management area indices will continue to meet or exceed current performance
- Maintenance human performance and technical fundamental errors will be reduced
- Critical skills and proficiency will be maintained
- Maintenance backlogs are maintained at low levels

Background

Other technical industries and international nuclear stations have a more autonomous or self-sufficient maintenance organization, requiring fewer handoffs or external support groups. In the U.S. nuclear industry, it takes numerous individuals from various organizations (Work Planning, Operations, Scheduling, Radiation Protection, System Engineering, Supply Chain, etc.) to support maintenance team fieldwork. Additionally, maintenance activities can take several work crews from various shops to perform both simple and complex tasks, resulting in

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Credit: Efficiency Bulletin 17-23, "Transform the Maintaining the Plant Organization" has been initiated by Nuclear Energy Institute.

Transform the...

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multiple handoffs and delays. Several maintenance organizations in other technical industries leverage their workers' expertise, promote self-reliance for all aspects of maintaining equipment, and are held accountable for the effective use of resources with the right skill set to achieve greater levels of work efficiency while maintaining high quality. In many of these industries maintenance does a majority of the troubleshooting, not engineering. Over the years, the U.S. nuclear industry has diluted worker responsibility for work performance through rigorous process controls that limit worker flexibility and the application of their knowledge and skills. In contrast, a few domestic nuclear plants with appropriate staffing levels exhibit high degrees of teamwork, collaboration and worker autonomy. These plants leverage the use of multi-skilled craft and engineers, and composite crews in maintenance activities and project management.

This bulletin defines an autonomous site Maintaining organization aligned on an efficient maintenance process. Maximum benefit can only be obtained from this efficiency bulletin when the following enabling guidance documents are fully implemented:

Base Enablers (Use caution and evaluate implementing this efficiency bulletin (17-23) without these efficiency bulletins fully implemented):

- INPO Industry Cumulative Impact Short Term Actions, (November 2013)
- EB 16-01 Eliminate Administrative Changes to Preventive Maintenance Work Orders
- EB 16-02 Implement Graded Approach to Walkdowns
- EB 16-10 Reduce Cumulative Impact from the Corrective Action Program
- EB 16-13 Perform Self Briefs for Low Radiological Risk
- EB 16-15a Work Screening Process
- EB 16-15b Utilizing Minor Maintenance
- EB 16-15c FIN Team Efficiency
- EB 16-16 High-Cost Non-Critical PM Reduction
- EB 16-22 Implementing an Effective and Efficient Work Management T-Week Process
- EB 16-25 Critical Component Reduction
- EB 16-31 Pre-Approval Criteria for Work Execution
- EB 17-03a PMP 003: Value Based Maintenance
- EB 17-03b PMP-001: Embracing Cultural Shifts for Value Based Maintenance
- EB 17-12 Reducing Burden through Empowering First-Line Supervisors
- EB 17-13 OJT/TPE
- EB 17-14 Improving the Effectiveness of Issue Resolution to Enhance Safety and Reliability
- EB 17-18 Optimizing Strategic Engineering, Engineering Response Team and Component Maintenance Support
- EB 17-19 Optimizing Program and Design Engineering Organizations

Several additional improvement opportunities are being considered by the industry that could provide additional efficiencies. These include the following:

- Advanced remote equipment monitoring
- Maintenance rule changes
- Reduction in maintenance programs
- Emergency response requirements
- Technology needs for the life of the plant: scoping for modifications and digitalization

Relevant Standards

Performance Objectives and Criteria (INPO):

- OR.1, Station and corporate managers are aligned on the required support and allocation of resources needed to achieve and sustain high levels of nuclear, radiological, industrial and environmental safety performance.
- OR.2, Managers provide the staffing and resources for each department or functional area to support the accomplishment of their assigned responsibilities as well as to facilitate cross-functional responsibilities. They consider and mitigate the potential effects of organizational changes and staff reductions before these are initiated.
- OR.3, Change management processes are implemented when applicable and the progress of changes is systematically monitored to verify the intent of each change is met and to identify possible unintended consequences.
- NP.1, Nuclear professionals apply the essential knowledge, skills, behaviors, and practices needed to conduct their work safely and reliably.
- LF.1, Leaders, by commitment and example, inspire, motivate and align the organization to achieve safe and reliable station operations, event-free outages, and effective emergency response. They establish and reinforce standards of excellence based on industry top performance to continually strive for improvement and intervene to correct performance at early signs of decline.
- MA.1, Maintenance personnel apply the essential knowledge, skills, behaviors and practices to improve equipment performance, contributing to safe and reliable operation.
- MA.2, Maintenance activities are conducted in a manner that promotes safe and reliable plant operation.
- EN.1, Engineering personnel apply the essential knowledge, skills, behaviors, and practices needed to ensure equipment performs as required, the plant is maintained within design requirements, margins are controlled, and the plant is operated safely and reliably.
- EN.2, Engineering personnel recognize and accept their responsibility to address plant technical issues and act as the site technical conscience. They uphold the plant design and licensing bases and ensure a margin of safety is maintained.
- OF.1, Station personnel and programs are aligned to identify and prioritize the resolution of operational problems.
- OF.3, Organizational roles, responsibilities, processes,

procedures and infrastructure are established such that unexpected operational conditions are managed promptly and safely.

- WM.1, Work activities are managed during both on-line and outage periods to support safe and reliable operation.
- ER.1, High levels of reliability is achieved for equipment that supports nuclear safety, plant reliability and emergency response capability.
- ER.2, Preventive and predictive maintenance and performance monitoring are used to prevent failures of equipment important to safety, reliability and emergency response.
- ER.3, Equipment is managed to maintain long-term equipment reliability.
- ER.4, Activities are implemented to preserve materials and components in a manner that supports long-term, reliable plant operation.
- INPO 10-005, Principles for Maintaining an Effective Technical Conscience.
- INPO 15-005, Leadership and Team Effectiveness Attributes.
- INPO 17-04, Principles for Excellence in Corporate Performance.

Recommended Industry Actions

Perform the following actions to implement a transformed Maintaining organization:

- Evaluate that the efficiency bulletins listed as "Base Enablers" in the "Background" section above have been satisfactorily implemented. Effective implementation of the bulletins including change management plans is essential for a transformed organization.
- Redesign the Maintaining organization to include the following attributes:
  - The Maintaining organization becomes the "first responders" to address all operations concerns and address all equipment issues without engineering hand-offs. The new organization will perform the following:
    - Conduct simple and complex troubleshooting thereby eliminating the need to involve strategic engineering in issue resolution
    - Facilitate decision-making and quick response to emergent equipment issues, minimizing hand-offs between and within maintenance disciplines and engineering.
    - Transition maintenance to a more autonomous organization:
      - Work Management and Maintenance planners are embedded in the organization.
      - Full-time Operations personnel are assigned

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Transform the...

(*Continued from page 39)*

to support the organization that report to Operations.
    - Full-time Supply Chain personnel are assigned to support the organization to quickly respond to emergent parts issues and concerns.
    - Full-time Radiation Protection personnel are assigned to the organization as appropriate based on plant type (PWR/BWR) and workload demands.
    - Full-time Rapid Response Team with engineering expertise is assigned to support the organization.
    - Full-time component/ subject matter experts are assigned to support the organization.
- Ownership and accountability for equipment performance is within the Maintaining organization. The new organization:
    - Owns all non-critical PM bases and change processes.
    - Owns predictive maintenance program and resources.
    - Empowers maintenance first line supervisors to make real-time decisions in the field.
- A streamlined work management process is in place that simplifies planning, preparation and work execution:
    - The on-line schedule is fixed and set for a cycle based on known preventive maintenance and surveillances with required frequencies.
    - Emergent work is managed by the new organization.
    - The FIN process is used as the most efficient and effective process to prepare and execute the majority of work.
    - The T-week cycle process is streamlined and minimized to focus on PMs, surveillances, and long-term life cycle management.
    - Work management meetings are minimized and scheduling of work is simplified by implementing the simplified work management process of AP-928 Rev.5.
    - Maintenance materials are quickly identified and long-lead parts within a two-year or 18 month cycle plan are identified and ready.
- Review the following actions for station and labor agreement applicability to reduce work management handoffs and increase the Maintaining organization self-sufficiency:
    - Identify and train maintenance craft on a concise set of fundamental maintenance activities that can be performed by any technician. The goal of this enabler is an autonomous work crew with minimal supervisor oversight such that any maintenance technician could perform this set of maintenance tasks without requiring cross discipline maintenance support. Integrate work crew skill sets through the use of composite crews or groups for specific projects, modifications, or important emergent work.
        - Process automatization should be optimized, including electronic work packages, smart procedures, and automatic assembly of performance indicators and management meeting materials.
- Review site/utility specific prerequisite actions for transforming the Maintaining organization that could hinder or impact full implementation of this efficiency bulletin. These actions include resolution to labor agreements or emergency plan requirements, and inclusion and tracking of these actions in change management plans.
- Review planned site actions to fully transform the Maintaining organization for potential impact on required corporate resources. For example, if additional emergency preparedness resources are required at corporate headquarters to support reductions in site staffing levels, ensure these resources are available and trained to perform these functions.
- Review site-specific position descriptions, roles and responsibilities, and organization charts as appropriate. Details on modified or expanded roles will likely require updates to site-specific documents to allow maximum value to be achieved from the transformed organization. Failure to take full advantage could result in performance impacts, gaps in execution of transformed work process or restraint of potential resource optimization.
- Review hiring and training practices for new and existing employees to ensure the right knowledge and skills are properly accounted for to support the transformed organization. Consider using the guidance in EB-17-13 "OJT/TPE Process" and ACAD 91-006, Rev. 2, "Guidelines for On-The-Job Training and Evaluation" to use OJT/TPE preferentially versus using classroom training.

Report Your Site's Results

Please report your company's implementation of this improvement opportunity, including the date of completion. Send this information along with your company point of contact to EfficiencyBulletin@NEI.org.

Industry Contacts

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Industry Standardized Performance

Summary of Efficiency Opportunity

- Desired end-state—A hierarchy of industrywide performance indicators is established that collectively provides an accurate and comprehensive perspective of industry performance. The set includes higher tiered indicators controlled by the U.S. NRC, INPO, and WANO to measure overall station performance; middle tiered indicators used by utility and INPO employees for monitoring functional area performance; and lower tiered indicators that address unique station or fleet performance monitoring needs. An industry procedure will be put in place to control the standardized performance indicators. The indicator data will be maintained and managed in a central data management system when it becomes available.
- Value proposition—Establishing an optimum set of common performance indicators will enable consistencies in measuring and comparing industry performance, decrease the number of performance indicators, and reduce the administrative burden and costs associated with maintaining indicators. Implementing a common process, including an industry oversight panel, will provide effective governance and oversight for these performance indicators.
- Why it is important?—A common set of indicators ensures effective monitoring of performance and provides a solid foundation to compare performance across the industry.
- Measures of effectiveness:
  - There are no unidentified or untimely recognition of performance declines in station performance resulting from the implementation and use of the new indicators.
  - Reduction in the required resources assigned to data input and performance indicator reviews.

Credit: Efficiency Bulletin 17-24, "Industry Standardized Performance" has been initiated by Nuclear Energy Institute.

Background

Performance indicators are used extensively in the industry to monitor the safe and reliable operation of nuclear power plants. Over the past several decades, the number of industry indicators has grown substantially to the point where some indicators provide duplicative information or are no longer important or necessary for monitoring activities. This bulletin dated December 18, 2017 streamlines and reduces the number of existing indicators. Additionally, it establishes an indicator hierarchy and the processes for governing future indicator development, modification, and deletion.

There are four levels of indicators–Level A through Level D.

Level A are controlled by the U.S. NRC, INPO, and WANO. Examples include the NRC Reactor Oversight Process performance indicators, the INPO Index, and the WANO Chemistry Performance Indicator.

Level B represents the industry's selection of standardized performance indicators that provide a comprehensive perspective of station performance in key functional areas.

Level C are controlled by INPO to support ongoing oversight programs, such as continuous monitoring of station and industry performance in order to quickly identify and arrest plant declines. It is recognized that efforts by INPO and the industry to reduce Level C indicators will be undertaken after this bulletin is issued.

Level D are unique and discretionary indicators developed by a utility—for a utility—and are not shared across the industry. These indicators provide flexibility to use the central data management system when it becomes available rather than maintaining desired indicators in utility databases. Piloted indicators are also considered Level D. The number of Level D indicators should be limited to minimize the burden of customized indicators.

Controlling procedure NISP-PI-01, "Control of Standardized Performance Indicators," addresses the hierarchy of indicators and provides the administrative controls for Level B and D indicators. Level A and Level C indicators are not controlled by this governing document.

All indicators will eventually reside in a central data management system that will become operational in March 2019 as described by Efficiency Bulletin 17-17, "Standard Indicator: Central Database." Bridging strategy options were developed to maintain industry alignment with Level B indicators while providing flexibility for the industry to efficiently manage the administrative workload associated with performance indicators.

Relevant Standards

- INPO 12-013, "Performance Objective and Criteria," Monitoring - criteria 8 through 14
- INPO "Portfolio of Indicators Summary"
- World Association of Nuclear Operators (WANO) MN 2014-2, "WANO Performance Indicator Programme Reference Manual"
- INPO 04-004, "CDE Data Element Manual"

Change Management Considerations

Industry Activities

- Conduct regional webcasts to provide an overview of this efficiency bulletin, "Industry Standardized Performance Indicators," and the related nuclear industry process NISP-

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Industry Standardized...

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PI-01, "Control of Standardized Performance Indicators."

- Conduct oversight of the Standardized Performance Indicators in accordance with the industry procedure NISP-PI-01, "Control of Standardized Performance Indicators." This procedure will be periodically updated to reflect operating experience.

Company Actions

- Utilize the applicable change management process to ensure integration of the Standardized Performance Indicators into applicable procedures, processes and meeting forums, as appropriate. Select the bridging strategy appropriate for your company until the central data management system is available for use.
- Managers and supervisors monitor for unrecognized or untimely identification of performance declines associated with the implementation of this efficiency bulletin.
- Managers and supervisors should closely monitor the transition points in this efficiency bulletin where errors could be introduced (i.e., changing from existing indicators to those established by this efficiency bulletin and transitioning to the central data management system).

INPO Actions

- Initiate review and disposition of remaining Level C performance indicators upon approval and implementation of the new Level B performance indicators.

Guiderails

- Assess effectiveness of new indicators in management meetings when performance indicators are reviewed. If not effective, contact utility DNP Coordinator to share concern with the industry and notify the Standardized Performance Indicator Panel.
- Managers and supervisors monitor for unrecognized or untimely identification of performance declines associated with the implementation of this efficiency bulletin. Utilities should immediately report problems in the timely recognition of performance declines to utility DNP Coordinators and the Standardized Performance Indicator Panel.
- Utility oversight and performance improvement personnel should focus on behaviors and human performance during implementation of bridging strategies identified as the bridging period poses increased vulnerability to data review input errors.
- INPO performs continuous monitoring of station and industry performance in order to quickly identify and arrest plant declines that may not have been detected by the indicators established in this efficiency bulletin.

Report Your Site's Results

Please report your company's implementation of this improvement opportunity, including the date of completion. Send this information along with your company point of contact to EfficiencyBulletin@NEI.org.

Industry Contacts

- Industry Champion for this Issue: Darin Benyak, (724) 650-7320, dbenyak@firstenergycorp.com
- INPO Contact: Gary Waldrep, (770) 644-8626, waldrepg@inpo.org
- NEI Contact: Chris Earls, (202) 739-8078, cee@nei.org
- On the web: http://www.nei.org/bulletin1724 ■

Value-Based Maintenance Strategy

By John Langskov, Arizona Public Service Company.

John Langskov

John Langskov brings 30+ years of experience to the electrical generation industry. In addition to having been licensed as a reactor operator in the Navy, he has worked as a leader in all aspects of work management from scheduling to planning. He is currently leading the PM optimization effort at Palo Verde, the largest nuclear generating site in the United States. His team is focusing on reducing overall maintenance overhead while maintaining equipment failures to acceptable levels using "Preventance", a commercialized software program that uses EPRI based reliability science. Business intelligence software is used to monitor the PM program effectiveness by tracking labor, cost changes, and equipment degradation over time.

Nuclear Energy Institute's Top Innovative Practice Process Awards highlight the nuclear industry's most innovative techniques and ideas.

This innovation was one of the 2017 Top Industry Practice Award winners.

The team members who participated included John Langskov, Preventative Maintenance Programs Section Leader and Glen Smith, Maintenance Planning Senior Advisor.

Working with Asset Performance Technologies (APT) and Qlik, Palo Verde has implemented an innovative Preventive Maintenance (PM) strategy that has increased safety, improved power production and generated cost savings by eliminating or extending the frequency of PMs. This strategy, Value Based Maintenance (VBM), evaluates specific equipment failure modes, maintenance that can be applied to address those failure modes and risk in performing or not performing the maintenance. Maintenance effectiveness, in terms of cost and expected equipment reliability, is then measured with an expected economic value. Palo Verde's VBM strategy aligns with the industry's efforts to deliver the Nuclear Promise through efficiency, effectiveness and innovation.

Innovation

When Palo Verde first came on line in the 1980s, preventive maintenance (PM) schedules were based on manufacturing recommendations for the nuclear industry. Over the course of time, Palo Verde engineers, craftsmen and technicians worked together to adjust PM strategies based on experience. An eight year project using the Reliability Centered Maintenance (RCM) approach was completed in 2008. During that time, the PM strategy decisions were made by experienced cross-functional teams, but contained no financial justifications. That all changed when Palo Verde transitioned to the VBM strategy. The VBM strategy ensures the required amount of equipment reliability at the minimum cost. Two major software tools are used to streamline the process and to ensure the strategy adds value to the company:

- Preventance from Asset Performance Technologies (APT) takes Electric Power Research Institute (EPRI) content and applies a mathematical algorithm, using RCM science, to determine the optimal PM strategy for a given piece of equipment. Palo Verde began working with APT on the usability of this software in 2008 and put it into production in 2011.
- Qlikview from Qlik is used to analyze data for initial set-up of the cost benefit model and to analyze the effectiveness of the program once decisions have been made.

The evaluation process is performed by setting a dollar amount to failure of the equipment and applying historical corrective and preventive costs, and then adding collateral costs associated with failure that would be incurred by support groups, de-rates, dose, the Corrective Action Program, Maintenance Rule and others. Calculating a change in the probability of failure for a strategy change allows a cost comparison to determine the net benefit of the strategy change.

Simply put: if it costs $10,000 per year to mitigate $1,000 worth of consequence, then the net benefit of the strategy adds negative value to the company. If it costs $1,000 per year to mitigate $10,000 worth of consequence, then the strategy has a positive benefit to the company. Critical equipment has larger consequences of failure, and therefore will contain more robust PM strategies than non-critical components generally would.

Assigning a dollar value to failure consequence is not an exact science. However, utilizing Qlikview, Palo Verde has developed a "cost basis." The cost basis monitors the effectiveness of the station's strategy decisions. It helps analyze whether there is benefit in driving costs down in corrective maintenance (CM) to more effectively utilize the asset, or to drive costs into PMs because it increases reliability. Palo Verde has set up a number of performance indicators that work with the cost basis to monitor program effectiveness.

Productivity/Efficiency

Through the implementation of VBM strategies, Palo Verde has seen a measurable reduction in the annual man-hours associated with PMs, without negative impacts to power production. In fact, over the last three years, the station has experienced record power production. The overall PM manpower

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Value-Based...

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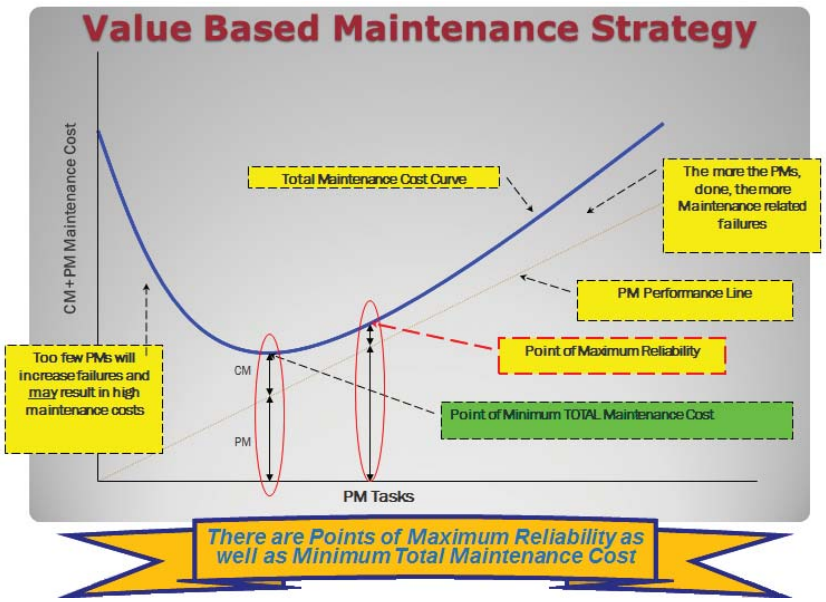
required to keep Palo Verde's three Units running has decreased by 37% over the six year implementation period of the VBM Strategy.

Cost-Savings Impact

The VBM strategy has created measurable cost-savings for Palo Verde. The strategy has resulted in an annual cost-saving of $10 million, which represents a 20% cost decline, despite rising material costs. Delivering the Nuclear Promise Efficiency Bulletin 16-25 will serve to re-define which equipment is considered "critical," and will enable a larger, more costly population of components to be optimized using the VBM approach. This will increase savings efficiencies even more.



Safety

The Palo Verde VBM strategy improves safety by reducing unnecessary maintenance activities. By working on less equipment, the station experiences higher levels of critical equipment availability, thereby improving nuclear safety and the station's risk profile. From a radiological safety perspective, the reduction of work on equipment in radiological controlled areas has contributed to lower personnel dose. In comparing dose tracked by work orders in 2010, the year before the VBM strategy was implemented, to 2016, Palo Verde's annual ALARA dose has decreased 57%. This dose reduction is directly tied to the work in the field.

Transferability

The Palo Verde VBM strategy script was transferred to CHAMPS Analytics, and used as the basis for a pilot data collection process involving 10 different plants in the U.S. nuclear fleet. The pilot was successful and data is now being collected at EPRI for use across the entire U.S. nuclear fleet. EPRI is currently developing the infrastructure to auto-collect data from the U.S. nuclear plants using Qlikview and provide a platform where the U.S. nuclear fleet can share data in an effort to continuously improve together.

The data collected will capture mistuned strategies, cost deviations and work histories across the industry. Qlikview provides work history mapping, which helps define equipment wear-out times and improve mathematical models in preventative maintenance.

The pilot team made a number of recommendations for improvements on APT's Preventance software to allow for quick updates to the calculation which will make the net benefit of the PM strategy more accurate. The recommendations have been incorporated and a number of plants have purchased licenses to the software to capitalize on the information EPRI is providing:

- Duke – Corporate Licenses
- Exelon – Corporate Licenses
- FPL – Corporate Licenses (Option for 3 years)
- Xcel – 3 years, Unlimited licenses
- Southern – Corporate Licenses
- Palo Verde – Unlimited licenses
- PG&E – 3 years, Unlimited licenses
- Callaway – 3 years, Unlimited licenses
- Energy Northwest – 3 years, Unlimited licenses

Vision and Leadership

Part of the Palo Verde Leadership Model, which contains the station's vision and roadmap for improving and sustaining high performance, states that Palo Verde strives to employ solutions that effectively solve its problems and meet its needs at a low cost, but without ever compromising safety, effectiveness or quality. The VBM strategy aligns with this philosophy by improving safety, maintaining equipment reliability and supporting continuous, reliable power production while reducing man-hours and generating cost-savings. The management team at Palo Verde supported the VBM strategy's years-long development and implementation because they believe that the viability of the nuclear industry is rooted in innovative efforts that yield efficiencies to propel our business.

Contact: John Langskov, APS, telephone: (623) 393-1972, email: john.langskov@aps.com. ■

Blocking Device for HGA Model Relays

By Kevin Steimer, NextEra Energy.

Kevin Steimer

Kevin Steimer is currently the Instrumentation and Controls Maintenance Department Head at the NextEra Energy Duane Arnold Energy Center in Palo, Iowa. He has over 30 years of experience in the nuclear industry and has served in leadership roles in Operations, Design Engineering, Systems Engineering, Training, Outage Management, and Maintenance. He was a licensed Senior Reactor Operator and certified Shift Technical Advisor.

Kevin holds a B.S. degree in Civil Engineering from the University of Nebraska – Omaha and Lincoln. He was the Team Lead for the HGA relay block project.

Nuclear Energy Institute's Top Innovative Practice Process Awards highlight the nuclear industry's most innovative techniques and ideas.

This innovation was one of the 2017 Top Industry Practice Award winners.

The team members who participated included Kevin Steimer, I&C Maintenance Department Head; Ben Carolan, I&C Technician; Collin Steimer, High School Student; Maxwell McChesney, High School Student.

Local High School Collaboration

Duane Arnold Energy Center Instrumentation and Controls (I&C) technicians engaged local high school students to allow them to actively participate in the design and fabrication of a relay block tool that the site was intending to use in support of logic system surveillance testing. The partnership with the high school was part of the site's community engagement and talent strategy to increase awareness of potential engineers and scientists. The collaboration with a local high school was "first of a kind" for the station and allowed a young class of potential future engineers to learn and connect with nuclear power in a very non-traditional way. The students investigated the problem, designed and tested the new tool, and Duane Arnold technicians are currently using it to successfully perform logic system surveillance testing.

This tool reduces the risk of unit trips and unintended system actuations/isolations during logic testing and thereby improves nuclear safety. The tool provides cost savings by reducing the potential for generation loss and the prevention of additional regulatory oversight and fees.

These devices are transferable to any boiling water reactor, pressurized water reactor, or fossil fuel power plant where common General Electric HGA model relays are installed. Surveillance testing and maintenance on control components and logic systems frequently necessitates the use of blocking devices on relays to prevent any undesired system and component actuations. These blocking devices are typically fitted over the contacts of relays and are called "relay blocks." They are portable, reusable and made from of non-conductive material. The longstanding relay blocks used at Duane Arnold were challenging to fit on the prevalent General Electric HGA model relays due to their physical restrictions. This led to inadvertent contact activations causing the isolation of a plant safety system on more than one occasion.

As part of the site's engagement strategy, Duane Arnold I&C personnel partnered with local high school students enrolled in a Computer Integrated Manufacturing class to design an improved relay block to be used on GE HGA model relays. This provided the students an opportunity to solve a real world problem by creating a design using a computer, and then print their designs using a 3-D printer. These young students provided a fresh perspective to assist the plant team in the solving of this current plant reliability problem. The students worked through a couple of designs before the final tool was ready for testing. Tests were successful and the new tool has improved the Duane Arnold I&C personnel's ability to successfully complete the surveillances.

I&C technicians use HGA relay blocks regularly, so improving the use of it was critical to productivity. The new block is much easier to install and remove as it snaps in place easily and fits securely. These improvements have enhanced the technician's ability to successfully complete the surveillances without any undesired plant consequences.

Innovation

Engaging high school students to obtain a fresh and unbiased perspective to help solve a technical problem is unique and innovative, and it supported the site's engagement and talent strategy The station knew it needed a better design but it tended to look to simply modify existing tooling and also limited the solutions to within fabrication capabilities the station had on site. In contrast, these students drafted a design on their computer and produced the design using a 3-D printer. Therefore, the students were limited by only their own imagination and problem solving skills. The students tested the tool for fit and function to produce the highly functioning final design. Technicians at

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Blocking Device...

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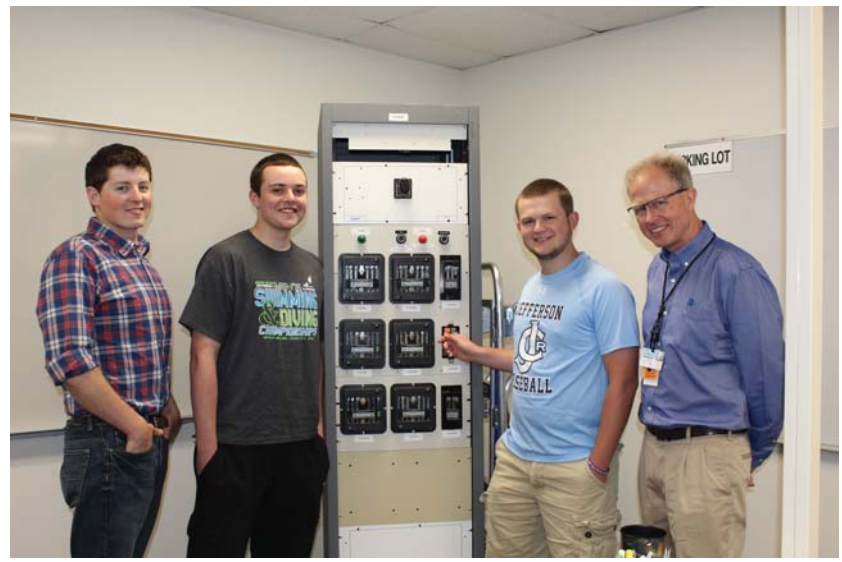
the station then bench tested the relay and checked for its electrical insulation properties. The tools went into service in February 2015.

In May 2015, Duane Arnold invited the class for a field trip to the station to show their appreciation. The students had the opportunity to learn more about nuclear power and its benefits and see how important relays are in the functioning of the plant. They toured the simulator, and discover the role engineers serve at the nuclear power plant.

This innovative approach to solving a plant issue can be applied in several different areas across many different industries. This approach also served to improve NextEra Energy Resources Duane Arnold's community relationships through cooperation with the high school. This cooperative effort was also featured in the local newspaper to further enhance the company's image and also promote nuclear power.



Student Testing Tool on Mockup Panel.

Labeled Relay Block.

Safety

This tool reduces the risk of unit trips and unintended system actuations/isolations during logic testing and thereby improves nuclear safety. Use of the new HGA relay block would have prevented a recent inadvertent safety system isolation, had it been in use during the July 2014 surveillance test on the High Pressure Coolant Injection (HPCI) Safety System. There is operating experience in the industry where logic testing involving HGA relays resulted in a unit trip. The use of this new relay block has reduced the risks of unplanned system activations and isolations. The station had classified all surveillance testing involving HGA relay blocks as a "high risk" following the unplanned HPCI isolation. Those same surveillances have since been downgraded from "high risk" since the use of the new relay block was institutionalized.

This tool reduces the risk of unit trips and unintended system actuations/isolations during logic testing and thereby improves radiological safety. The collective amount of dose that the Duane Arnold

workers receive is directly proportional to the number of outages the plant experiences. This is because an outage affords the plant the opportunity to perform work inside containment and other locked high radiation areas that are not normally accessed during plant operations.

This improves industrial safety because employees will have less dose exposure. During plant outages, industrial safety injuries are a major concern for the station due to the high volume of workload over a short period in areas of the plant not regularly accessed. All of the material handling, scaffold erections, and infrequent evolutions increase the likelihood of an injury.

Cost-Saving Impact

The tool provides cost savings by reducing the potential for generation loss and the prevention of additional regulatory oversight and fees. An unplanned forced outage typically requires 3 days of shutdown and results in lost revenues of approximately $300,000 per day. There will be additional costs associated with overtime, contractors, and consultants to support the shutdown.

Plant transients and unplanned safety system isolations require immediate reporting to the Nuclear Regulatory Commission. The Regulatory Oversight Process drives increased oversight based on declining performance. Inspectors charge their time to the station at approximately $300 per hour.

Productivity/Efficiency

This project provided an improved tool for completing required tasks. This has increased the reliability of being able to successfully complete maintenance activities, thereby reducing potential rework and resulting plant consequences.

Transferability

General Electric HGA model relays are a commonly installed relay throughout the electric power industry. They installed in both nuclear and fossil fuel power plant. The new HGA relay blocks can be used at any station where HGA relays are installed.

Communications

This approach served to improve NextEra Energy Resources and Duane Arnold's community relationships and image through cooperation with the high school. This cooperative effort was also featured in the local newspaper to further enhance the company's image and also promote nuclear power.

Vision & Leadership

This project utilized our employees of the future in the form of high potential high school students. By inspiring this next generation of potential employees and informing them of what the nuclear industry has to offer, we have increased the likelihood that they will pursue a career within the industry. This effort was directly linked to the site's engagement and talent strategy that is embedded in the NextEra Energy Marketing, LLC (NEM).

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Defender Plus

By Jim Head, Scott Stanchfield, David Smith and John Vukovics, Entergy and Gerry Latter, Patty McCumbee, Paul Cantonwine, Kim O'Connor and Brandon Smith, GNF.

Innovation

In 2015, seven debris leakers occurred in GNF fuel at two Entergy plants, which led to a self-assessment of performance at both Entergy and GNF. After considering the value of short-term and long-term fuel design innovations, GNF embarked (with the full support of Entergy) on a short-term development program to increase the robustness of GNF2 by adding additional debris mitigation technologies. To provide Entergy with relief as soon as possible, the objective of the program was to design and qualify modifications that could be implemented in the River Bend reload in spring 2017. This was a very aggressive timeline for both of us. In less than a year, GNF developed improvements to the Defender lower-tie-plate (LTP) filter and the GNF2 spacer that are expected to decrease the occurrence of debris leakers, updated the design basis and licensing documents, procured and qualified reload quantities and Entergy evaluated and confirmed the modifications were interchangeable with the previous approved design from the plant perspective.

Nuclear Energy Institute's Top Innovative Practice Process Awards highlight the nuclear industry's most innovative techniques and ideas.

This innovation was one of the 2017 Top Industry Practice Award winners.

The team members who participated included Jim Head, Senior Engineer, Entergy; Scott Stanchfield, Senior Manager Fuels, Entergy; David Smith, Senior Staff Engineer, Entergy; John Vukovics, River Bend Reactor Engineering Supervisor, Entergy; Gerry Latter, Technical Lead, GNF; Patty McCumbee, Product Line Leader, GNF; Paul Cantonwine, Manger, Fuel Performance and Design, GNF; Kim O'Connor, Customer Project Manager, GNF; Brandon Smith, Engineer, GNF.

Debris Filtering Effectiveness

The new innovative GNF2 bundle, called GNF2.02, was delivered to River Bend in January 2017. The modified Defender LTP filter in GNF2.02 is called Defender Plus, and the innovative changes provide more than double the debris filtering effectiveness at the smaller debris sizes that are known to pass through Defender. The spacer was also modified by removing potential debris-catching features in the original GNF2 spacer band and band to divider assembly locations.

To ensure implementation in the shortest timeframe, an important requirement was that both the Defender Plus filter and the modified spacer were interchangeable with the previous components from a mechanical, thermal-hydraulic and licensing perspective. Rapid prototyping of components with the new features (as well as other conceptual derivatives) were produced using 3D printing both in plastic and in metal. The prototypes allowed the design team to think, build, test and repeat until the design was optimized. It also allowed the production component fabrication to proceed in parallel with the final testing and documentation because confidence in the design was already validated.

Safety

Fuel failure has a significant impact on nuclear safety at a plant site. When a fuel rod fails radioactive fission gas is initially released. If failure is not located and suppressed, secondary damage can occur followed by degradation. When a fuel failure degrades, the fuel pellet begins to dissolve into the coolant, and the released radioactive particles can collect in pipes on the plant side. This is a much more significant consideration in BWRs with their open cycle which permits wide spread plant contamination. Thus, fuel failures can significantly affect worker dose.

The dose impact of the fuel failures at Grand Gulf were minimal because the failures were located and suppressed. In this case, secondary damage and fuel degradation did not occur and there was minimal impact on plant dose. The situation at River Bend was fortunate bit different. In the last cycle River Bend had to shut down for two mid-cycle outages to replace degraded fuel because of the impact the failure had on the contamination levels of the plant. In addition to the dose concerns, the added fuel moves and generic outage work significantly increased the risk of a work accident.

While proper failed fuel management is a very safe process, decreasing the risk of debris fretting in the fuel is a much better abatement. By reducing the risk of fret related debris failures, which is the only observed failure mechanism for GNF2, the implementation of GNF2.02 at River Bend had increased safety.

Cost-Savings Impact

The increased fuel reliability associated with improved filtering of debris, while difficult to clearly quantify, has a huge cost-savings impact considering the resources that are required when a fuel failure does occur. Mid-cycle outages to remove failed fuel are extremely costly, and decreasing the probability of these events has a real cost savings .

In the case of Grand Gulf, while the fuel failures had a minimal dose impact, each fuel failure required a power reduction of a few days for failure detection and suppression. Power losses of several million dollars resulted. Other associated costs included reduced fuel utilization, premature fuel discharge, added refueling outage activities to locate and inspect the failures, increased control blade depletion, etc.

For River Bend, the fuel failure impact was even more significant. Just in term of power production, the two mid-cycle outages resulted in more than one month of power lost, with an economic impact in excessive of $20M.

In conclusion, even pessimistically if the GNF2.02 prevents just one future fuel failure, cost savings of the order of millions of dollars will result.

(Continued on page 50)

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Defender Plus...

(*Continued from page 48)*

Productivity/Efficiency

The introduction of GNF2.02 provides several opportunities for increased productivity and efficiency. The option of pre-channeling the fuel at the supplier allows for less handoffs and increased efficiency gains because of the decreased burden on the plant site to organize and complete fuel channeling. Pre-channeled fuel saves O&M costs, pre-outage critical path time on the overhead crane usage and dose. In addition, the increased filtering effectiveness from the Defender Plus filter will lower the probability of fuel failures which can require mid-cycle outages which majorly affect the productivity of the plant.

Transferability

GNF2.02 has been fully licensed through GNF's GESTAR process, and is now available for all other utilities. A second utility is currently in bundle build for a GNF2.02 reload campaign in 2017. GNF is offering limited quantities of the new enhanced bundle for fabrication in 2017 and expects at least 4-5 additional reloads built in 2H2017 for spring 2018 outages. It is expected that in 2018, the remainder of the GNF customers will transition to GNF2.02.

Additionally, the new Defender Plus filter will become standard in our next generation fuel product, GNF3. Many of the design features from the modified GNF2 spacer were already incorporated into the GNF3 spacer design plus and GNF3 will incorporate even more debris mitigation features into the spacer.

Communications

Communications was key to the success of this project. First, GNF provided updates to Entergy on the status of the new technology in periodic teleconferences and at the annual BWR Symposium in early summer 2016. These communications provided Entergy with an understanding of the benefits and schedule. Once the technology was developed, additional time was needed to complete the engineering work for the final technical justification of the change. Because of the tight schedule, GNF had a contingency plan to build GNF2. This provided Entergy with the time to evaluate the change and confirm that GNF2.02 was interchangeable with GNF2 for their plant specific reviews. GNF & Entergy talked weekly and sometimes daily on the status, risks and progress of the project. One key communication route to complete this evaluation was the technical documentation including a change summary document with references that GNF provided to Entergy. In addition, after providing the documentation for the change, follow up communication via email and/or teleconference was critical to answer all questions.

Entergy and GNF worked as a team to ensure that the change was fully tested, documented, justified at both sites, and the new fuel design met all licensing requirements. Both companies utilized their respective change management processes to evaluate and document the design upgrade and associated process changes.

Vision & Leadership

Leadership at both Entergy & GNF were forward looking and stretched the teams to push the limits in terms of design and speed to market in order to solve a huge customer pain point.

The vision of the GNF's fuels team to understand that they had to respond quickly and mobilizing a project team and solution with aggressive effectiveness and timing targets is unprecedented. Likewise, Entergy's ability to support and have confidence in the fastest product launch in GNF's history was paramount.

Both companies took informed risks with low impact/high value outcomes and the contingency planning and communication between the teams was crucial. Both teams also had accountability to the dates and needs of the other. Transparency and trust were key attributes that made this project successful and both were exhibited by Entergy and GNF teams at all stages of the project.

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Corporation...

(*Continued from page 13)*

U.S. Department of Energy's Enhanced Accident Tolerant Fuel program to be installed in a commercial nuclear reactor.

GNF developed the ARMOR coating, which is applied to a standard zirconium fuel rod, to provide debris resistance and more oxidation resistance than standard zirconium cladding. Both advanced technology materials are part of GNF's portfolio to solve industry challenges.

The installation of IronClad material at Plant Hatch includes two variations of the iron-chromium-aluminum material. One material will be in fuel rod form but will not be fueled while the other material is in the form of a solid bar segment. ARMOR lead test assemblies that contain fueled coated zirconium rods will be installed in the same reload at Plant Hatch. Lead test assemblies that include both IronClad and ARMOR fueled rods are planned for 2019 installation at Exelon Generation's Clinton Power Station.

Contact: Jon Allen, GNF, telephone: (910) 819-2581, email: jonathan.allen1@ge.com.

Fuel Supply

Westinghouse Electric Company and its eight European consortium partners announced the successful completion of an EU funded project targeted at diversifying the nuclear fuel supply to VVER-440 reactors in Europe.

The consortium has developed a conceptual fuel design and determined how the manufacturing and supply chain can be reestablished to build and ship VVER-440 fuel assemblies, similar to what was done by Westinghouse and ENUSA for the Loviisa Nuclear Power Plant in Finland in 2001-2007. In addition to the fuel design, the consortium has set up and verified the associated methods and methodology to be applied for the licensing and use of a new fuel design.

Contact: Sarah Cassella, Westinghouse, telephone: (412) 374-4744, email: cassels@westinghouse.com. ■

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