FACE to FACE

DARLINGTON ENERGY COMPLEX REACTOR VAULT MOCK-UP AND RE-TUBE AND FEEDER REPLACEMENT (RFR)

As famed football coach Vince Lombardi once said, “Practice doesn’t make perfect, only perfect practice makes perfect.” In the select world of nuclear reactors, consider it a mantra, for nothing goes forward unless every minute detail has been perfectly orchestrated and approved. In 2011, Aecon Nuclear reached that level of achievement on a nuclear fuel channel mock-up and replacement project. Now the team’s earlier success has helped pave the way to the big leagues at Ontario Power Generation’s Darlington facility. Here, a massive 480-fuel-channel mock-up and larger overall scope have opened the doors for Aecon to prove just how perfect practice makes you.

THIS MOCK-UP IS AN EXACT REPLICA OF A CANDU NUCLEAR REACTOR UNIT. IT GIVES WORKERS THE ULTIMATE TRAINING TOOL TO HONE THEIR SKILLS BEFORE WE ENTER THE ACTUAL NUCLEAR FACILITY TO REFURBISH OPG'S REAL CANDU UNITS.

—JEFF PALMATEER, CONSTRUCTION MANAGER, AECON NUCLEAR

Three years ago and newly equipped with its well-deserved N-Stamp – the nuclear industry's official mark of approval – Aecon Nuclear set to work building a nine-piece fuel channel mock-up for the world's largest operating nuclear facility, the Bruce Nuclear Generating Station (BNGS). Bruce Power currently operates the BNGS under a lease agreement with Ontario Power Generation (OPG). Over the course of many months of concentrated effort, the project team built and subsequently trained up to 80 workers on the reactor face mock-up before successfully performing two fuel channel replacements the following year at Bruce Nuclear Generating Station in Kincardine, Ontario.

Fast-forward to the present day, and Aecon Nuclear, fuelled by its successes and lessons learned on that project, is now firmly ensconced in a new contract. This time around it's for client Ontario Power Generation and calls for deliverables that far exceed the team's inaugural mock-up and fuel channel replacements scope.

MOCK 2: ONTARIO POWER GENERATION

While it's often said that no two things are ever quite the same, that doesn't hold true for the newly commissioned nuclear reactor vault mock-up located at Darlington Energy Complex (DEC) in Clarington, Ontario. Here, everything must be exactly the same. And it is here that Aecon Nuclear, working with SNC Lavalin Nuclear (SLN) in a joint venture, has ensured it is. Since being awarded this prized EPC contract in 2012, the team has already successfully replicated a massive, fully functioning mock reactor face equipped with a whopping 480 fuel channels, as well as replicated the entire vault in which it's housed, walls and clearances included.

No small feat, the Darlington Energy Complex reactor vault mock-up is a first of its kind. Built in a newly constructed 28,800-square-metre building, the mock-up will now help the team train and prepare workers for a series of upcoming fuel channel and feeder replacements to take place at the real Darlington Nuclear Generating Station (DNGS), located just down the road

5 INDIVIDUAL FEEDER MOCK-UPS

13 FUEL CHANNEL MOCK-UPS

480 PERFECTLY ALIGNED FUEL CHANNEL SITES

28,800 SQUARE-METRE FACILITY

PROJECT FILE

Darlington Energy Complex Reactor Vault Mock-Up and Re-Tube and Feeder Replacement (RFR)

LOCATION: Clarington, Ontario

AECON DIVISION: Aecon Nuclear

CLIENT: Ontario Power Generation (OPG)

JOINT VENTURE: SNC Lavalin Nuclear (SLN) and Aecon

PARTNERS AND KEY SUPPLIERS:
OPG, SNC Lavalin Nuclear, NA Engineering (Kincardine, ON), Laker Energy (Burlington, ON), Handling Specialty (Grimsby, ON), Konecranes (Oakville, ON), BC Instruments (Schomberg, ON), Senior Calorstat (France), LP Customs (Stoney Creek, ON), Wessex (Galt, ON), Cintube (Mississauga, ON)

TIMING:
Reactor Vault Mock-Up: March 1, 2012–March 15, 2014
Tool Performance Testing: May 2014–March 2015
Training: March 2015–October 2016
Darlington Refurbishment Start: Late 2016

TYPE OF CONTRACT: Engineer, Procure, Construct (EPC)

CONTRACT VALUE: $35 million for mock-up component

SUMMARIZED SCOPE:
// Engineer, procure and construct a replicated mock-up of the Darlington Nuclear Generating Station reactor
// Using mock-up to train workforce for the fuel channel and feeder replacements of Units 1 to 4 at Darlington Nuclear Generating Station

NUMBER OF EMPLOYEES: 30 (at peak)

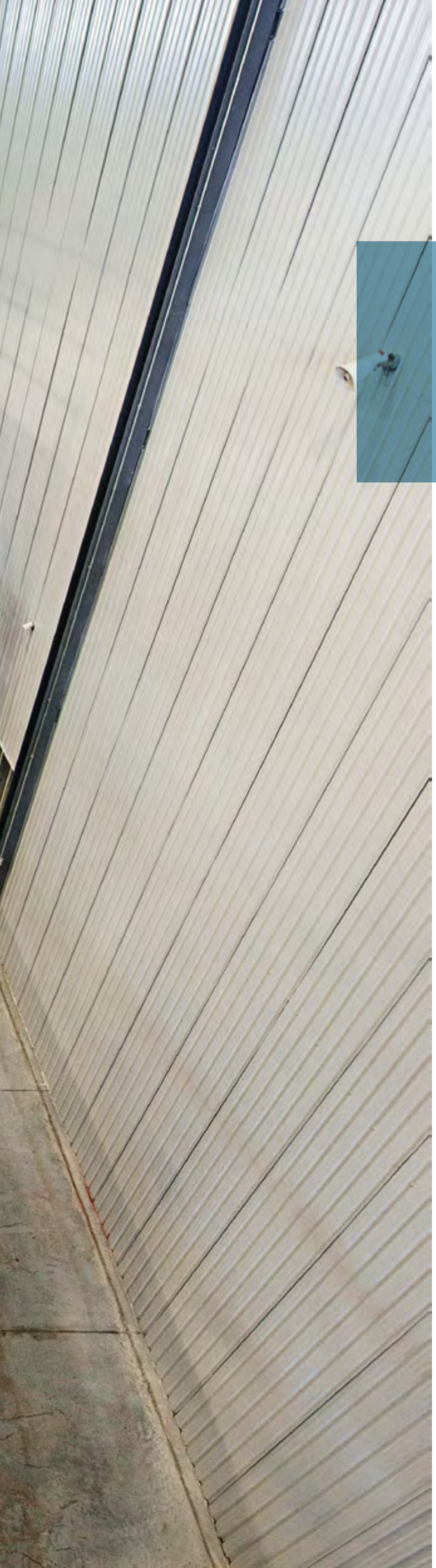
KEY EMPLOYEES:

Nuclear Construction
Robert Frasca, Project Manager
Jeff Palmateer, Construction Manager
Mina Khalil, Project Coordinator
Peter Kempton, Superintendent
Guy Krisza, Superintendent
Cory Wilson, Quality Control Supervisor
Kris Fairservice, Project Planner
Doug Templeman, Safety Advisor
Stacey MacPherson, Site Administration

Nuclear Fabrication
Eric Dyke, Project Manager
Patrick Gregus, Project Coordinator
Andrew Giralt, Project Coordinator

Nuclear Maintenance Services
Dan Olson, Project Manager
Matt Finn, Project Coordinator
Mike Kish, Project Coordinator


15,000 KG



USING THE LATEST IN LASER SCANNING TECHNOLOGY, ALSO KNOWN AS OPTICAL METROLOGY, THE INSIDE OF THE UNIT 2 VAULT WAS SCANNED TO PRODUCE A MODEL THAT WOULD ASSURE ALL DIMENSIONS, INCLUDING STRUCTURAL STEEL AND WALL TOLERANCES, WERE AS ACCURATE AS POSSIBLE.

from the mock facility. At the mid-point of its service life and, given Darlington's role as a key power contributor, a major refurbishment is in order to reach the end of the station's projected service life in 2055. Since fuel channel components are life-limiting factors of the reactor, critical components on the reactor core are on the docket for dismantling and replacing in a manner that calls for precision and targeted expertise.

Enter the SLN-Aecon project team.

Jeff Palmateer, Aecon Nuclear Construction Manager, explains that a significant portion of the larger EPC contract awarded to SLN-Aecon in 2012 has been the commitment to first build this full-scale mock-up in order for the team to subsequently carry out Darlington's fuel channel and feeder replacement (also known as RFR) deliverables.

"This mock-up is an exact replica of a CANDU nuclear reactor unit," he explains of the eight-metre-high reactor face, complete with 480 perfectly aligned fuel channel sites, feeder tubes and fuel channel assemblies." It's been invaluable in terms of planning the operation and perfecting the procedures we need to complete the replacement as efficiently and safely as possible. It gives workers the ultimate training tool to hone their skills before we enter the actual nuclear facility to refurbish OPG's real CANDU units."

The mock-up reached completion and was officially commissioned for service earlier this year (2014) ahead of schedule.

For the SLN-Aecon project team, the next two years are now all about tool performance and testing, as well as extensive workforce training on the mock-up unit in order to be fully prepared for the RFR replacement portion of the contract, scheduled to begin in fall 2016.

FROM START TO FINISH: HOW SLN-AECON BUILT A NUCLEAR REACTOR VAULT MOCK-UP

Replicating an entire facility, right down to the exact bend in every pipe, requires strict attention to detail. With OPG-provided drawings in hand, the SLN-Aecon team set to work digitally reconstructing an exact replica of Darlington's Unit 2 vault in 2012. Using the latest in laser scanning technology, also known as optical metrology, the inside of the Unit 2 vault was scanned to produce a model that would assure all dimensions, including structural steel and wall tolerances, were as accurate as possible. The drawings were then overlaid with the laser-scanned model to look for any discrepancies among the thousands of components.

"As joint venture partners, we felt very comfortable subcontracting the engineering portion of the project to SLN because we knew their nuclear experience wouldn't allow for even the smallest detail to be missed," notes Palmateer. "We also enlisted the support of NA Engineering, from Kincardine, who engineered replica components for us, like the mock-up fuel channel assembly."

Achieving an exact match in the design phase, Aecon submitted its final design for review to OPG in mid-December 2012. After receiving approval, Aecon set forth and mobilized on site in May 2013 – roughly nine weeks ahead of schedule – and began standing steel in June.

In order to move forward with recreating the reactor vault, many of the components first needed to be supplied or constructed by key vendors, some of which specialize in nuclear projects. The mock-up called for all relevant structural steel, vault cranes (provided by Konecranes Canada Inc. of Oakville), a fuelling-machine bridge (provided by Handling Specialty of Grimsby) and specialized arrays needed for feeder and fuel channel training, as well as tool proving. Cintube Limited of Mississauga bent all of the feeder tubes to precisely connect to the end fittings on the reactor face and the feeder headers, while maintaining tight tolerances.

Mock-up components requiring fabrication, such as the reactor face, mezzanines and feeder hubs, were built and modularized by Aecon's fabrication facility in Cambridge and brought on site for placement within the mock-up. The Aecon fab shop also manufactured framework, built support stands and railings, and provided five individual feeder mock-ups and 13 fuel channel mock-ups to be used for training, testing and troubleshooting purposes.

"This project implemented all of the lessons learned by OPG and the joint venture from previous refurbishment projects. Perfect coordination of all activities associated with the design, fabrication and installation phases of the mock-up were a key success factor for the project," notes Palmateer. "I'm proud to say we achieved most major milestones despite some engineering challenges and a few components arriving out of sequence. OPG's vision of this full-scale mock-up project – and our timely completion of it – now sets the stage for the next step, which is focused on training the reactor face crews."

Of course the main purpose of building a full-scale mock-up of this magnitude is to replicate the exact conditions the trained workforce will encounter when it comes time to perform at the live reactor face. Each of the workers using the mock-up will get a full taste of the

A PROJECT LIKE THIS COULD DEFINITELY SET AN INDUSTRY STANDARD FOR NUCLEAR WORK GOING FORWARD.

–JEFF PALMATEER, CONSTRUCTION MANAGER, AECON NUCLEAR

clearances and interferences found inside the Darlington Nuclear Generating Station vault as they try to perform tasks wearing full protective gear while hooked to a supply of oxygen.

Palmateer says providing an authentic experience also gives workers – many of whom may not have been in a reactor before – an opportunity to familiarize themselves with the tools required to complete the replacement. "Some of these tools are more than six metres long and extremely heavy, so you can just imagine how difficult it would be trying to complete a task without prior knowledge of the space."

Workers will receive training on the mock-up beginning in March 2015. Two crews will "leapfrog" as they alternate between training for a crew-specific task on the mock-up and actually performing it on site at the DNGS. That is to say, once a crew's task is complete on site, they will return to the mock-up for further training as the other crew is swapped in.

During their training, workers will be guided through the process and monitored by operators in a replica of the Re-tube Control Centre (RCC), a room built to simulate the base of operations where remote-controlled tools are used when removing reactor components. The RCC will feature all the required technology to monitor and control the tools during training.

Since reaching completion of the mock-up earlier this year, there's been no shortage of daily visitors wishing to take an in-depth tour of this one-of-a-kind facility.

"It really is a very high-profile project that's garnering lots of attention," notes Palmateer, rhyming off some of the notable visitors, who range from OPG senior executives and board members to media, government officials and industry suppliers. "A project like this could definitely set an industry standard for nuclear work going forward. Aecon Nuclear really has gone to great lengths to reproduce the level of detailed work required for this mock-up to ensure it was a high-fidelity facility."

STAND-ALONE MOCK-UP SEGMENTS, STATIONED OUTSIDE OF THE VAULT MOCK-UP, GIVE EASY ACCESS TO INTEGRAL COMPONENTS FOR EASE OF TRAINING

THE RE-TUBE TOOLING PLATFORM (RTP) IS USED TO PRECISELY POSITION SPECIALLY DESIGNED TOOLS ON THE REACTOR FACE

SETTING THE STANDARD

Having a mock-up of this size comes with serious benefits. The reality of working in a training area that doesn't actually house any nuclear material offers the SLN-Aecon joint venture the unique advantage of building expertise. Training workers how to properly complete inspections or how to efficiently change the feeder pipes on the mock-up without the radiation concerns is invaluable, not unlike the intense training Canadian astronaut Colonel Chris Hadfield went through in preparation for his space walk in the vacuum of space. Having the opportunity to work through the logistics of an issue outside the plant allows workers to identify and address a potentially threatening situation in a non-radioactive mock-up environment.

"Moving components and tools around in this type of environment inside the station always poses a challenge," notes Palmateer. "With the mock-up, we can recreate a potential roadblock and problem-solve it in the mock-up to mitigate any delays in the reactor vault on site. It also gives us a chance to prove out innovative solutions for increased time savings."

Strategically positioning workers inside the reactor vault, and instilling in them the importance of taking advantage of the many shielding schemes and personal protective equipment provided during reactor face work, can also drastically lower radiation doses. Training on the mock-up affords the joint venture an opportunity to enhance a worker's on-site orientation before going into the reactor. This principle is commonly referred to as ALARA (as low as reasonably achievable). Standing a few inches to the side could mean appreciably decreasing the total dose, a key tool toward improved worker safety.

One of the biggest benefits comes in the form of time and budget reduction. When an estimate is submitted to the client, it's a rough estimate of the time and money required to complete a contract. Performing practice runs on the mock-up gives a more accurate estimate of what to expect when performing the real thing.

TESTS, TESTS AND MORE TESTS

Tool performance testing is a critically important success factor for the RFR project. Specialty tools designed to perform specific tasks in the replacement process need to be thoroughly tested before they're deemed fit for service. Combining lessons learned from previous projects with feedback from the workers, the team will customize tools and improve where necessary during the year-long tool performance testing phase.

"If a tool were to break-down in the past, a critical path delay would occur, which is difficult to recover from when performing refurbishment work," notes Palmateer. "With this facility, we have the unique opportunity to rigorously test and improve the tools to make sure they're reliable before we're even conducting the actual replacement. It's really a hands-on approach that will enable workers to familiarize themselves with the tools and suggest improvements. This, in turn, will increase the effectiveness of the tooling and lead to or enhance worker engagement and buy-in."

In early May 2014, the joint venture will have begun testing the tools and refining the procedures. With an entire mock-up at the ready, tool performance testing will be more in-depth than ever before thanks to the unlimited potential in reactor face configurations and problem-solving possibilities. It also marks the first time the tool proving process will be conducted on such a detailed level.

"Each tool must be proven five times before it's cleared for use. We plan to run the tools through a timed exercise to ensure each tool performs as required as part of our tool performance guarantee. The data we gain from these exercises will form the basis of our refurbishment schedule for its duration."

FIVE INDIVIDUAL FEEDER MOCK-UPS WERE FABRICATED TO ADD AUTHENTICITY TO THE TRAINING

THE BIG DAY

All of the extensive tool testing and training will finally pay off in October 2016 when, according to plan, SLN-Aecon will begin the refurbishment phase of the first reactor at Darlington.

"The amount of precision and care required to perform an operation of this magnitude is immense," says Palmateer. "People and businesses rely on nuclear power, so we need to perform the replacement as efficiently and safely as possible to minimize the downtime. It's a big responsibility for us, but we're confident in our ability to deliver safely and on time."

The first phase in the reactor face replacement is the removal of target 30-year-old components. Any required temporary and permanent modifications will be made inside each of the reactor units based on any interferences, such as staircases, that may prevent work from being efficiently completed. Shielding bulkheads will be installed to seal off the two fuelling ducts on either side of the reactor face and to protect workers against radiation exposure. There will be a series of fuel bundle removal and drain/dry exercises where heavy water will be drained from the feeder pipes that run into the fuel channels. A platform, called the Feeder Platform, will be installed to help remove the feeder tubes. The feeder pipes will be cut into small, manageable pieces and lowered to the floor where they will be cut up even further for transport.

Once the feeder tubes have been removed using a large, elevating platform called the Re-tube Tooling Platform (RTP), the fuel channels will be cut in specific locations so the components can be pulled out and placed inside large shielded flasks, which help shield workers from the radioactive material. One by one and in sequential order, all 480 channels will be emptied of their components as the work progresses up the reactor face. After the removal, a series of inspections will take place in the calandria, a large cylindrical metal drum that normally contains the heavy water and houses the 480 fuel channels running through it. Robotic cameras will be used to inspect the various components and key areas to confirm all of the components are fit for continued service.

With the inspection complete, the installation of the new reactor components can finally begin. Beginning at the top of the reactor face, new calandria tubes will be inserted into position and rolled into the calandria tube sheet. In a clean room, end-fitting subassemblies are pre-rolled (one pressure tube rolled into an end-fitting) and transported to the vault, where they are installed into the calandria tube. The second end-fitting is then mated to the pressure tube, and final sealing of the fuel channel is completed. Workers will once again strategically work their way through each fuel channel, repeating the process 480 times per reactor unit.

With the channel components replaced, new feeder tubes will systematically be woven into the reactor face, welded to the feeder headers and bolted to the end-fittings.

Palmateer notes the tubes need to be placed and welded in sequence to avoid creating unreachable areas in the tight space. "There's literally no margin for error. Everything needs to go according to plan. Looking at this stage of the replacement, you can understand why the mock-up is such an important tool."

Once the reactor core and face are completely replaced and refuelled, heavy water will be reintroduced into the moderator and primary heat transport system. With everything back in order, the reactor will be on its way to return to service and will continue to provide the residents of Ontario with safe, clean and reliable electricity.

The fuel channel and feeder tube replacement portion of the SLN-Aecon contract is due to wrap up in 2023. To date, the team is well aligned with the overall project schedule and anticipates successfully delivering on its commitment. With far too much work still ahead to rest on its laurels, the team can nevertheless reflect with pride on the work accomplished to date, namely the exacting replication of a nuclear reactor face mock-up that has impressed both the general public and the nuclear industry at large.