

# Executing the Darlington refurbishment project—Year I

*The Darlington refurbishment project passed its first major milestone and hit other important targets by the end of the critical first year of its execution.*

By Dick Kovan

**O**n October 15, 2016, Ontario Power Generation (OPG) shut down Unit 2 at its Darlington Nuclear Generating Station to begin the refurbishment of the first of the plant's four CANDU units. As of the beginning of September 2017, the Unit 2 refurbishment was a quarter of the way through its planned 40-month duration, on budget and on schedule.

The station's four units are 878-MWe CANDU 6 pressurized heavy-water reactors that began operation between 1989 and 1993—Unit 2 in November 1989, Unit 1 in October 1990, Unit 3 in November 1992, and Unit 4 in March 1993.

For a CANDU reactor to operate beyond 30 years, it must undergo a major mid-life refurbishment to replace the main reactor components, doubling its service life. Each Darlington reactor consists of a large, heavily shielded vessel, or calandria, containing 480 horizontal fuel channels and 6,240 bundles of uranium fuel encased in Zircaloy sheathing. Each unit will be out of service for about three years to complete its refurbishment program.

The main refurbishment work is included in a retube and feeder replacement work package covering the removal and replacement of the reactor pressure tubes, calandria tubes, feeder pipes, and end fittings. This is the largest work package, accounting for about 60 percent of the total

cost, and is central to the success of the project.

Other major activities include the renovation of steam generators, turbine generators, and fuel handling equipment, as well as a variety of system improvements and plant upgrades. The focus of these activities is to ensure operation for another 30 years, as well as to meet current regulatory requirements.

## Project schedule and cost

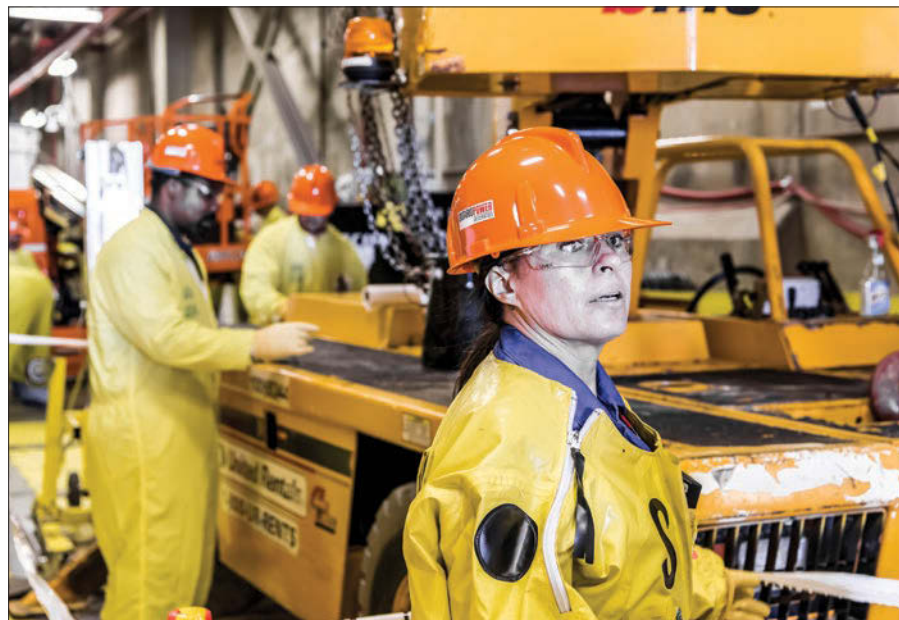
The sequence of the refurbishment outages is Unit 2, 3, 1, and 4. OPG's target timeline chart shows that work on Unit 2 is to be completed before the start of work on Unit 3 to ensure that the lessons learned will be implemented during the second refurbishment. The chart also shows work on Units 1 and 4 starting before the previous one has been completed.

Prior to the start of each unit's outage, OPG will develop detailed unit-specific cost, schedule, risk, and other plans. The initial defined schedule for each unit will be used to measure project performance.

Funding will be released on a unit-by-unit basis, providing an opportunity to review project performance prior to proceeding to the next unit. According to OPG, this makes it imperative to succeed on each unit in order to obtain approval to proceed to the next.

In June, OPG reported that the cost to complete Unit 2 remains within the approved budget of Can\$3.417 billion (about \$2.77 billion), including contingencies.

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Refurbishment workers perform radiation checks prior to equipment exiting Unit 2.

**Opposite page:** Workers undergo training in the Darlington mock-up facility for the safe removal of fuel bundles.



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Yellow plastic suits are used to protect workers in potentially radioactive environments.

### Project prep, execution

The focus over the past five years has been on project planning and preparation. Considerable effort was made to develop tools, train personnel, prepare detailed work procedures, and produce detailed plans that are ready to execute.

“The up-front work—the planning and

preparation—are the keys to success when it comes to project excellence,” said Scott Berry, communications manager for the Darlington refurbishment. “We are now reaping the benefits of the effort put in place long before the execution phase began.”

In planning the project, the execution phase was organized into five major work

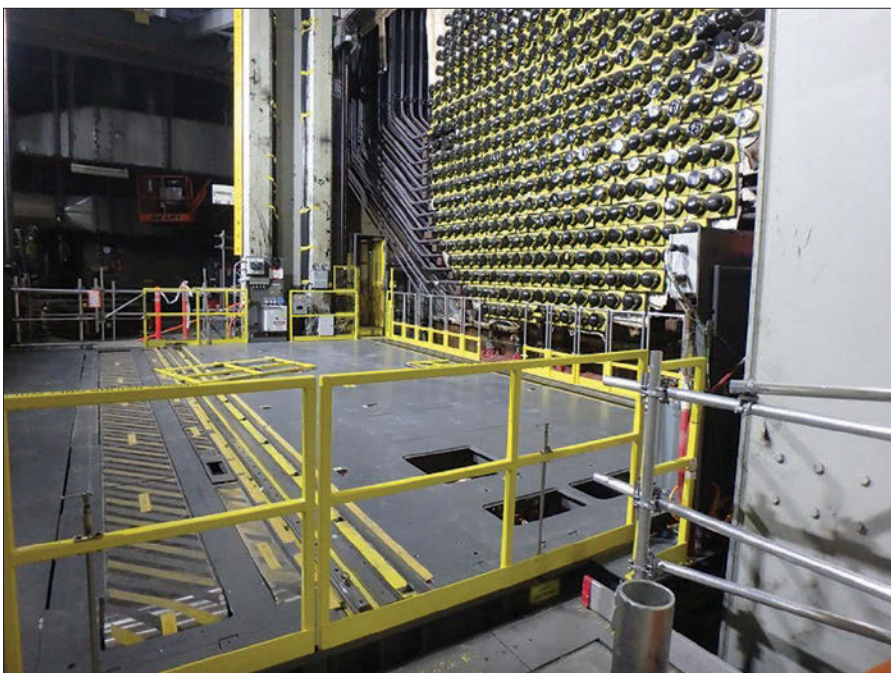
phases, or segments. Segment 1 focuses on preparing for the reactor refurbishment.

Starting with reactor shutdown, Segment 1 included defueling the reactor, draining the heavy water, and then isolating the plant from the station’s three operating units to allow the main refurbishment work to proceed at Unit 2 while the other units continue generating power. Isolating the plant, also referred to as “islanding,” involves putting up a system of physical barriers and controls to safely achieve the separation. In early April, the successful completion of a containment pressure test marked the end of Segment 1.

### The start of Segment 2

With the unit safely isolated, the reactor vault’s two airlocks could be opened for the first time since the unit was connected to the grid to allow for the unhindered movement of tools, equipment, and personnel. Workers could then focus on preparing the reactor vault by removing any “interferences,” or obstructions, and installing the critical “work tables”—two massive retube tooling platforms (RTP)—in readiness for the first big refurbishment effort.

The 100-metric-ton RTPs, one for each reactor face, consist of an elevating work surface connected to four massive columns that allow the platform to move across the reactor face, transporting



The retube tooling platform is shown under construction inside the Unit 2 reactor vault.

workers and tools. On the platform, specialized tools mounted on rails are able to move horizontally across the reactor face, providing access to each of the 480 fuel channels. The tooling platform is operated remotely from the retube control center.

Because of their size, the platforms must be brought into the reactor vault in pieces and assembled. To prepare for this critical activity, the RTPs were first assembled and disassembled in Darlington's full-scale reactor mock-up, then set up in a replica of the Darlington reactor vault, allowing for extensive practice by the team involved. The components were subsequently taken to the station and into the actual vault through the airlocks.

"As always, safety is key," said Ken Brown, director of retube and feeder replacement. "The team has planned and practiced for this work, which meant the learning curve happened at the training facility, not on the reactor face."

### Feeder pipe removal

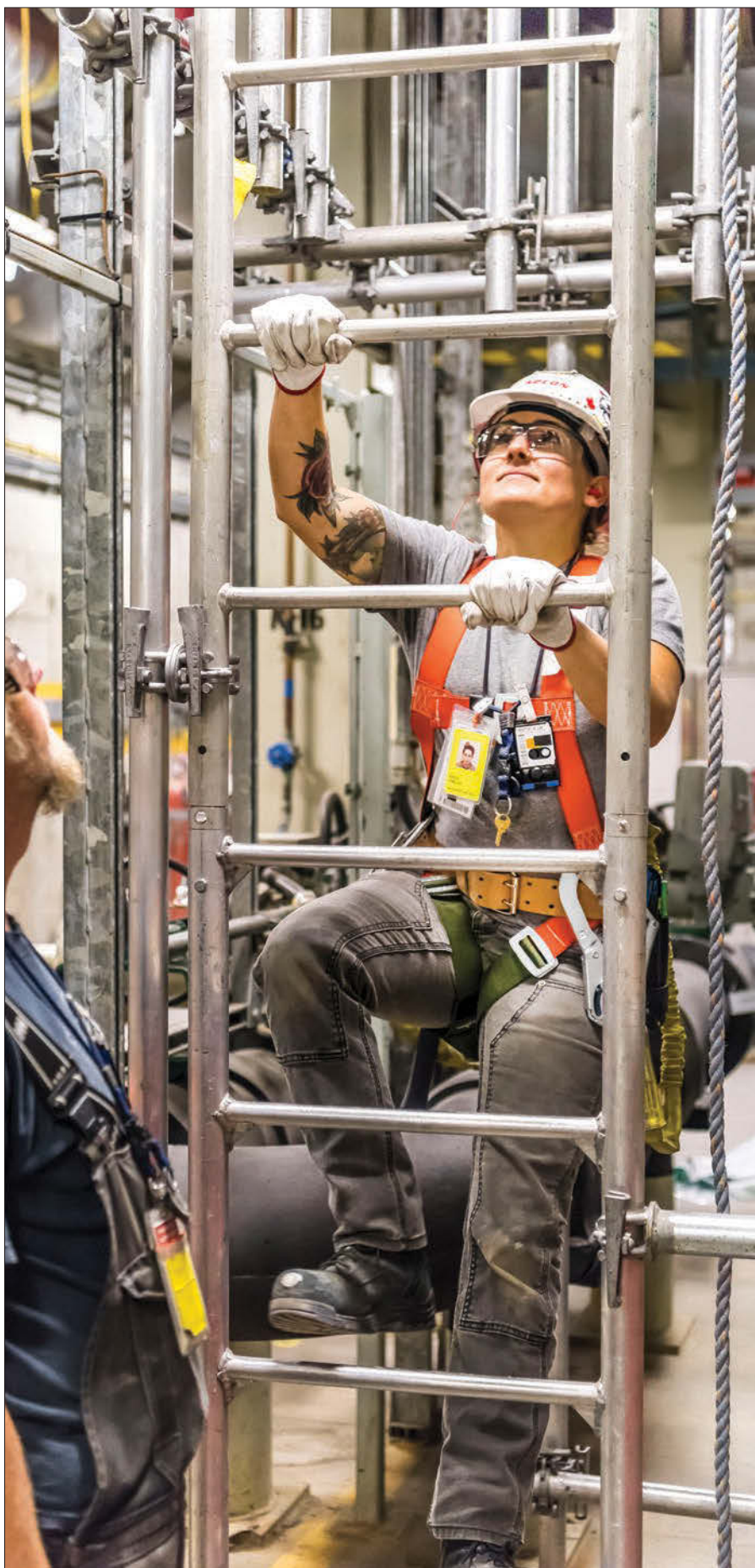
With the RTPs assembled and in operation, reactor disassembly could begin, starting with the feeder pipes and associated components. In total, there are 960 feeder pipes connected to the reactor, 480 on each face. These pipes feed water that is heated in the reactor to the boilers, and then back into the reactor. Removal of the feeder pipes requires removing other components as well, including the fuel channel closure plugs at each of the fuel channel lattice sites. Once these components are removed, the feeder pipes can be disconnected from the channel end-fittings. The pipes are then cut into pieces, placed in boxes, and shipped out of the vault to a waste storage area.

The feeder pipe removal was expected to be completed in late September. The remaining task to be carried out in Segment 2A is to sever the end fittings from the pressure tubes. This sets up the work to be performed in Segment 2B—the removal of the end-fittings, pressure tubes, and calandria tubes—which is expected to start in mid-November and to take 22 months.

While this highly repetitive work has been done before, those carrying it out have been practicing the procedures on the full-scale mock-up over the past year and a half.

### Training and testing

The full-scale reactor mock-up is not only used for training, but also to test the use of more than 400 highly specialized tools during the refurbishment. These are first tested at the manufacturers' facilities against performance requirements. Each tool is then taken to the mock-up to be tested, including the "human interface" aspect of using the tool. This provides



Scaffolding allows refurbishment workers to access components inside the defueled Unit 2 reactor vault.



Overlooking the Darlington-2 reactivity deck, where shutdown safety systems are located.



A low-level waste container is placed inside a shielded container for shipment to a licensed facility for storage.

information for determining procedures and work patterns for the tool's use.

Having a full-scale mock-up also provides opportunities to optimize the use of the tools. For example, a tool that had needed to make 14 or 15 cuts to sever a pressure tube now requires only three cuts. Given the number of tubes at the plant, considerable savings can be expected. The mock-up has also provided greater confidence that the project schedules will be met and project goals reached, Berry said. The facility is also used for developing contingencies when an activity does not go as planned.

### Vendors and contractors

The Darlington refurbishment project uses many highly qualified vendors and contractors from across Canada. There are now over 5,000 supplemental workers on-site, Berry said, with all of Canada helping to deliver the largest clean energy project in the country. The Darlington project is pulling workers without nuclear experience from the construction trades, including boilermakers, carpenters, welders, electricians, and pipefitters. OPG has a highly effective onboarding setup that includes training in nuclear safety culture. "It has been remarkable to see the diversity and skills coming from across Canada to help with this endeavor," Berry said.

Given the time lapse since the plant was originally built, reinvigorating the supply

chain to support the refurbishment project has been a challenge, according to Berry. However, many manufacturers across Ontario, he said, have had the courage to invest in new technology and expanded facilities and to hire more staff, believing that this will translate into success. "The project has tight deadlines, and they are being met," Berry said. "Our vendors are fully with us in this project. We really do have a 'one team, one approach' here."

### Risk: Lessons learned

An important part of the preparation, as well as a vital element in good project management, is identifying and managing risk. Previous projects were studied—both those that went well and those that did not—including nonnuclear megaprojects around the world. The lessons learned have been applied, particularly to identify risks and minimize and mitigate them. Examples of these lessons include ensuring that sufficient front-end planning is done, using mock-ups for training, and engaging the supply chain early on to ensure that materials are on-site well in advance of when they are needed. Managing processes and having good controls in place are particularly important in order to avoid delays and cost surprises. "We have a lot of oversight on this project, which provides independent insights on ways to improve," Berry noted. These are already being used in the existing project and in planning for subsequent refurbishments as well.

"We're managing risks," Berry stressed, "building in the right contingencies and having plans in place to put into action when things don't go well." An example he mentioned involved a problem that arose during the defueling of the reactor. Having pre-identified potential risks, there was a plan on the shelf that was put into play, resulting in the successful completion of the defueling days ahead of schedule.

At the same time, Berry said, "We are still looking for opportunities in our existing schedule to find possible innovations, efficiencies, optimizations, and other improvements." As risk mitigation is still the priority, however, before accepting a new innovation, possible downstream effects must be considered. Any risk should be manageable, with safety being preserved, he said, and added, "But if there are opportunities to optimize schedules or costs, we want to take advantage of them."

Good project management relies on good data, Berry said, and a "relentless focus on metrics." Real-time data are collected at Darlington to identify emerging trends or issues, thereby allowing action to be taken before a bigger problem arises down the road, and performance is measured daily. "I think strong project management and excellence are really about vigilance, on having your eyes on the ball at all times," he said. "We need to know where we are and where we should be all the time." **NN**