First published in tce **www.tcetoday.com**
News & views from the process industries, published monthly by the Institution of Chemical Engineers

Bruce A reactor restarts – raising the bar for the future

Kevin Routledge discusses the project management behind one of the largest and most challenging engineering projects in North America

Pictured top: Steam generators at Babcock & Wilcox Canada fabrication facility in Cambridge, ON

ONTARIO is one of the largest nuclear markets in North America, with nuclear reactors providing 51% of electricity in the deregulated market. The nuclear industry there is undergoing a significant resurgence, driven by the Ontario government's determination to phase out coal power to reduce emissions and contribute to Kyoto targets for carbon dioxide. Four mothballed reactors in Ontario have been restarted in recent years, and the current "Bruce Project" is to restart two more, units 1 and 2.

The Bruce A power station on the shores of Lake Huron, Canada, houses four CANDU pressurised heavy water reactors that were commissioned between 1977 and 1979. Unit 2 was taken out of service in 1995 and unit 1 in 1997, when the then owner Ontario Hydro decided to concentrate resources on operating its other reactors. There was also a contamination issue with one of the unit's steam generators.

AMEC NCL has a contract with Bruce Power, Ontario's largest independent nuclear generator, to project manage the restart of units 1 and 2.

This restart is one of the largest and most challenging engineering projects to take place in North America. The project is extremely challenging technically, since the plant has been shut down for a long period with limited maintenance. Also, some of the critical aspects of the work have never been attempted before.

The work includes a series of refurbishments, upgrades and enhancements to the two reactors. The aim is to improve safety and increase generation capacity and reliability. Upon completion, the project will enable up to 25 additional years per unit of safe, economical power generation.

The project budget is C$2.75b ($2.43b) and will take in excess of four years to reconnect both units to the grid. The work includes:

- reactor internal pressure tube and calandria tube (moderator) replacement (480 in each reactor);
- replacements of half the length of feeder pipes;
- steam generator replacement (8-110 t vessels in each unit);
- electrical systems upgrades;
- main condenser refurbishment;
- turbine refurbishment;
- feed water heater refurbishment;
- shutdown system 2 (SDS2) enhancement; and
- significant other maintenance on both nuclear and other plant equipment.

The two units are maintained in a safely laid-up state with the objective of preventing equipment degradation, thereby facilitating return to service. The steam generator feedwater/condensate/turbine flow paths have been drained and maintained dry through the use of fans, dryers or dry instrument air. The generator and auxiliaries have been drained and kept dry using desiccant dryers. Vault dryers are in normal operation. Negative pressure containment is maintained.

The heat transport system in unit 1 remains filled with heavy water, while that of the other unit has been drained and vacuum dried. Therefore the challenge is different on each unit. So the project plan is to work on both units in parallel, with work on unit 2 proceeding about six months ahead of that on unit 1.

fuel channel and steam generator replacement

Within a CANDU reactor, a tank of moderator known as the calandria is pierced by an array of horizontal tubes called calandria tubes. Each of these, in turn, contains an inner pressure tube in which fuel bundles are positioned. Collectively, the pressure tube/calandria tube systems are referred to as "fuel channels".

Each unit contains 480 pressure tubes and 480 calandria tubes, along with associated feeder piping, end fittings, shield plugs, inserts and closure plugs. Bruce Power is replacing most fuel channel components using cutting, crushing, chopping and packaging as appropriate before transporting them to the on-site waste storage facility.

Each unit has eight steam generators, which are approximately 12 m tall and

weigh over 100 t each. The generators, which penetrate the reactor vault, will be removed intact through the roof of the powerhouse and replaced.

Such a complete pressure tube replacement has only been completed once before, in the early 1980s by Ontario Hydro at its Pickering site. The calandria tubes have not previously been replaced on a CANDU, nor the feeder pipes or the steam generators. Combined, these unique project work items constitute the majority of the project budget and the project critical path. The residual work largely replicates work done on previous refurbishments in Ontario.

upgrades

Nuclear systems comprise both nuclear steam supply systems such as heat transport, moderator, steam supply and fuelling systems, and nuclear safety systems, for example containment and shutdown systems. As part of the restart, a number of refurbishments, upgrades and enhancements will be undertaken, including repair and replacement of valves, motors and instrumentation.

Throughout the remainder of the plant – the balance of the plant – opportunities exist to upgrade and enhance other nuclear and non-nuclear systems. For example, 30 transformers in the two units contain polychlorinated biphenyls (PCBs). These will be removed and replaced with non-PCB transformers.

With both nuclear and non-nuclear systems refurbished, upgraded and enhanced to help ensure safe and economic operation, Bruce Power will request Canadian Nuclear Safety Commission (CNSC) permission to refuel units 1 and 2. During refuelling, the reactor will be loaded with natural uranium fuel, except for a small number of depleted uranium fuel bundles at specific locations (depleted uranium is used to fine-tune reactivity in the fresh core). Each reactor will require 5760 22.5 kg fuel bundles or approximately 260 t of fuel for the initial refuelling.

Refuelling will require a license amendment enabling Bruce Power to move the reactors from safely laid-up state to a guaranteed shutdown state. Refuelling and associated operations such as refilling the primary heat transport system, final system integration, and commissioning will precede synchronisation to the power grid by approximately five months.

The Bruce A power station has one building housing all four reactors – big enough to hold nearly five football fields. This means that work on two reactors must take place while the other two remain operational, which is particularly challenging because the reactors share common systems.

Many key contractors in Canada and major players from the US are involved in the Project. AMEC NCL is the overall project manager, providing project, contract, and construction management, as well as engineering acceptance and the health, safety and environment programmes and oversight.

Bruce Power itself is undertaking some critical tasks, such as training operators to run the units. AECL is replacing the fuel channels of the reactors, B&W Canada is supplying the steam generators and installing bulkhead plates to isolate the units, and SNC Lavalin is removing and installing the steam generators. Meanwhile Siemens Canada is responsible for refurbishing the turbines and electrical systems, and there are important roles for Acres Sargent Lundy, E S Fox, OPG, AECON, RCMT, Comstock, Black & MacDonald and Crossby Dewar. Each contractor understands the crucial significance to the nuclear industry in Canada to making this project a success.

the story so far

The project commenced on 31 October 2005, although some long lead items were ordered prior to that start. Just over a year later, the project remains on schedule, with some significant achievements:

- a construction island has been created around units 1 and 2, with separate processes and procedures from the operating units;
- an offsite training facility has been set up and operated, with over 2000 workers trained in project processes, prior to them starting work on site;
- the first five new steam generators have arrived on site;
- unit 2 has been fully isolated from the other units, and decontaminated, enabling work at the reactor face to be undertaken in "civvies";
- major offices and warehousing facilities are in place for the project;
- holes have been made in the reactor roof and the removal of systems around the steam generators is in progress; and
- the environmental assessment has been approved, without negative interventions.

Though it is a cheaper and quicker option, it is more complex to refurbish the reactors than it would be to build a new nuclear power station. There is always the risk of the unexpected – in addition, the task of removing steam generators, as well as pressure tubes, calandria tubes and feeder pipes at the same time significantly increases the challenge.

Though nuclear power currently provides just over half of Ontario's electricity, the nuclear fleet is ageing. The Bruce A restart is the first stage of a C$4.25b ($3.76b) programme to extend the life of the station by Bruce Power.

Environmental assessment applications have also been announced for a nuclear new build by Bruce Power and Ontario Power Generation at the Bruce and Darlington sites respectively. Critical to all these plans is a successful Bruce A units 1 & 2 restart; it will then provide a model for other projects to secure Ontario's energy future. tce

Top to bottom:The turbine Hall under refurbishment ; A worker cleaning the bridge in front of the reactor face

Opposite: This 1600 t capacity crane will be used to lift the steam generators (100 t vessels approximately the size of a school bus!) through the roof of the powerhouse

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