Egyptian legend pales into insignificance beside the extreme plant that is today's ISIS! Brian Tinham takes a peek at the pulsed neutron source's newly opened Target Station Two

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Duncan Couchman, who heads up ancillary plant management at ISIS – plant engineering is an ongoing, challenging and critical function, he observes

ISIS or Oracle

What has the opening of the £200 million second target station (TS2) at the Rutherford Appleton Laboratory's ISIS pulsed neutron source got to do with plant engineers? More than most mere mortals – apart, that is, from the world's scientific community, currently descending on the place. Because not only will this major achievement enable new engineering understanding, by opening our eyes to atomic interactions like never before, but the entire station is another feat of extreme plant endeavour, not dissimilar to CERN's Large Hadron Collider (Plant Engineer, November/December 2008).

TS2 extends ISIS by building on the success of TS1, which, since 1984, has been delivering pulsed neutrons to a very wide range of experiments, looking at everything from the microscopic causes of railway crashes to atomic movements in highly stressed gas turbine blades.

The new target station is designed to emit lower energy, longer wavelength, but also higher intensity pulsed neutron beams to enable much faster atomic imaging, but of 'softer' materials – from cheeses to spider threads, polymers, surfactants and advanced materials – in a range of experiments that can run simultaneously.

Taking a step back, ISIS is massive: major plant includes a linear accelerator (linac) designed to accelerate hydrogen ions up to 70MeV, using RF equipment pulsing 2MW for 500 microseconds every 20msec. After the linac, electrons are stripped out as the ions travel through an ultra thin aluminium oxide foil, leaving protons to be injected into the synchrotron. There, swept-frequency RF systems (1.3–3.1MHz) and high current, water-cooled dipole and quadrupole electromagnets bend, focus and accelerate two bunches of proton beams up to 800MeV, before they're kicked out by the kicker electromagnet (pulsed at 5,000A and 37kV) to the target stations – with TS2 getting one in five pulses.

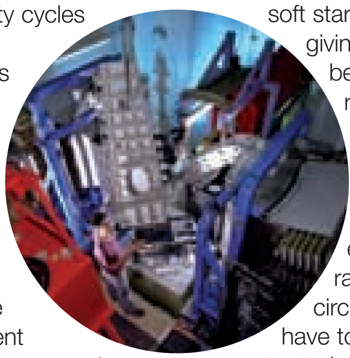
The targets themselves (TS1 and now also TS2), which are fabricated from tungsten, are then hit by the high-energy proton beams and, as a result of spallation, radiate waves of millions of neutrons. These, in turn, are moderated – harnessing water, hydrogen or methane – to reduce them to usable energies for the experiments, which occupy a ring around each of the targets. Each experiment is at the end of its own specially designed, 10–35m long rectangular, super-mirrored glass, low-vacuum beam guide tube. Each has its own ultra-precise, pulse-synchronised, high-speed rotating beam chopper (driven by Bosch Rexroth inverter drives with shaftless, frameless motors) to 'cut' the beam back to the wavelengths needed. And each experiment is also independently equipped for whatever sample conditions (cryostat cooling, RF fields etc) are required.

From an engineering perspective, Alan Stevens, head of ISIS accelerator operations and responsible for safe, high-availability 24/7 running, explains that we're looking at highly stressed, big and complex plant. "In the synchrotron, for example, we have lots

Pointers

- Neutron beam choppers at ISIS are powered by inverter drives and shaftless, frameless motors
- Equipment is ATEX certified and equipped with interlocks to hazardous area specifications
- ISIS is a big variable speed drive user: on pumps, large fans and compressor plant
- Simplicity is key for cooling circuits involving high levels of radioactivity, and sealless magnetic pumps work very well

of very large electromagnets to focus the proton beam down the evacuated beam tube. So there are many, many vacuum systems, with backing and roughing pumps, Maglev turbo pumps, ion pumps, Penning gauges etc. But there are also lots of high- and low-voltage power supplies, as well as low- and high-power RF systems, and their duty cycles are quite arduous. On the linac, just switching the RF on and off creates its own challenges. And we also run water- and air-cooling services across the plant."



All of that is managed under PLC and processor control, with SCADA (supervisory data acquisition and control) systems – much of the equipment COTS (commercial, off the shelf) stuff – providing critical instrument data to the control hub. As for the instrumentation, it's mostly conventional process temperature, flow and differential pressure devices – monitoring, for example, cooling water and control valve position data – but also instruments delivering proton beam characterises, such as losses and profile for diagnostics purposes. And there are the usual trend alarms and annunciator systems.

Stevens makes the point that some of this links to machine interlocks that prevent, for example, powering of electromagnets in the absence of water cooling, or beam circulation if losses are becoming too great and risking irradiating other equipment. Also, given the presence of hydrogen and methane in the target areas, we're talking about nominated hazardous areas, so ATEX certified equipment, instrumentation and power supplies, as well as interlocks and access controls to prevent breaches.

Some of this is familiar territory, with familiar issues. ISIS ancillary plant manager Duncan Couchman talks, for example, of the water recirculation system, with its three-cell, forced ventilation cooling tower, running at 3MW and maintaining temperatures at 22°C – although sliding up to nearer 27°C in the summer months. That serves the entire site's cooling needs, from ultra-high purity demineralised water for the RF circuits, magnets and beam scraper circuits, to cooling for four 350kW ICS screw compressors providing local chilling, three TurboCore centrifugal compressors providing air conditioning in the synchrotron hall, and the site's Sulzer cryogenic compressor.

"We can't quite get the efficiency we would like on the cooling towers, despite installing ABB inverters for speed control on the fans. Temperature control is very smooth, but there isn't quite the capacity for hot summer days. But we're very into variable speed drives: they're on all the main pumps for the cooling water circuits, the TurboCore compressors and so on. We also use them on the synchrotron air conditioning input and extract fans. These are eight feet across, so we're using the drives as glorified soft starts, effectively with speed control giving us infinite ramp time. That saves on belts, bearings and gears, and we're ready to move up to full flow control."

Incidentally, some of the water lines are interesting in their own right: for example, because the target windows in TS1 and TS2 are exposed to the full force of the radioactive proton beam, their cooling circuits are totally sealed. "Those circuits have to be very reliable, so they've been constructed using a very simple design – a header tank, very few pipes, minimal bends to trap air and sealless magnetic pumps. Although you have to bleed them carefully, the benefit is that, if they need new bearings or a motor, you just bolt off the back. You don't have to break into the water side."

ISIS' Target Station Two schematic – on the receiving end of pulsed, high-energy protons, transformed into neutrons on impact with the central target, for scientific experiments around its circumference

Challenging plant

Couchman observes that, apart from all of this, there are many of the usual plant challenges, even on ISIS. He cites, for example, the guaranteed air supply, with its compressors, backups and receivers, providing power for the safety equipment. "Managing that is about people and process: one of the jobs for my plant attendants is ensuring that scientists and others in TS2, for instance, don't inadvertently tap into air lines, because they're all finite resources."

Also on TS2, he talks of modifications made by his team to suit the way ISIS works. "For example, the water circuits were all installed pressurised, with small header tanks. But our visiting scientists need to be able to plug into cooling circuits for their experiments, so we needed a buffer and that meant bigger header tanks. So we've changed those and now sensors remotely monitor what's happening at the header tanks, so we can deal with emerging problems before the plant starts tripping out. That's important, given that we need to keep ISIS available as much as possible during operational cycles, so that the scientists' experiments aren't spoiled and they don't lose their allocated slots."

And another thing: "On TS2, our plant equipment is largely on the fourth floor and the lift only goes to the second. Also, it was designed with the pumps positioned in one of the corners, with everything else in front. Unless engineers specifying plant actually work on it, they don't understand the problems they can cause. You try pulling a five tonne pump around in a confined space that's nowhere near a door!" PE