MEDICAL ISOTOPES AND THE FUTURE OF NEUTRON SCATTERING IN CANADA

BY DOMINIC RYAN

John Katsaras and Ron Rogge of the Canadian Neutron Beam Centre (CNBC) working at the N5 triple-axis spectrometer

NRU has been at the centre of Canadian research for fifty years. It has supported fundamental research in materials, engineering, physics, chemistry and biology. The NRC's Canadian Neutron Beam Centre (CNBC) has also established Canada as the world-wide leader in providing access to industry from key sectors: nuclear, aerospace, automotive and manufacturing. The unique knowledge obtained using neutron beams helps companies to develop more competitive products that are safer, more reliable and less expensive to manufacture. Neutron scattering at NRU has enabled engineering studies of production technologies, corrosion, stress cracking and welding techniques. In-core work at NRU has supported Canada's nuclear power industry and contributed to the orderly stewardship of our fleet of CANDU reactors. NRU enabled the creation of a medical isotope business that saw us supplying 40 % of the world's needs for ^{99}Mo (for several extended periods NRU was actually supplying as much as *80 %* of the total market) and essentially all of the high specific activity ^{60}Co used for cancer treatments. Almost every person in Canada knows at least one person who has *benefited directly* from radioisotopes produced in NRU.

Despite the remarkable impact of NRU and the quality research carried out by the many people who worked at or visited the facility, NRU has been allowed to decline and age, with no succession plan in place. Over a decade of lobbying and reports from organisations such as NSERC, NRC, CAP and CINS (my own organisation, the Canadian Institute for Neutron Scattering) has produced no tangible results. Since the 1980s, funding cuts at AECL led to the death of Chalk River Laboratories as a National Laboratory, and its place as a key component of Canada's infrastructure for science and industry was diminished. TASCC was closed, the neutron scattering group was abandoned (only intense lobbying by CAP members saved them from termination), commercial in-core activities were ended and the ill-conceived, and ultimately doomed, MAPLE program was created to hive off the medical isotope business. Even in this crippled state, NRU continued to support research in nuclear technology; neutron beams continued to be available (thanks to substantial funding from NRC and NSERC) and were used extensively for basic and applied research in support of academic and industrial users; critical radioisotopes were produced and exported around the world; and NRU just got older.

With no formal vision for the future, benign neglect became the operating principle: NRU could not be closed because there was no other source of the essential medical isotopes that it produced, but renewal was kept to the minimum required to satisfy the regulators, and no coherent plan for a replacement was developed. Successive governments became distracted by "the future of AECL" and saw NRU as simply part of the "AECL problem". The Canadian Nuclear Safety Commission (CNSC)-driven shut-down of NRU in the winter of 2007 precipitated an immediate isotope crisis and led to direct government

SUMMARY

Last May, a thunderstorm caused a power trip at Chalk River Laboratories in Ontario and during the re-start inspection, a heavy water leak was discovered in the reactor vessel. The National Research Universal (NRU) reactor has been down ever since. Canadian neutron scatterers have been without a home base for ten months and tens of thousands of patients around the world have gone without critical diagnostic procedures and essential treatments. *Finally* the issue of a replacement for our 52 year old research reactor is in the news and at the centre of government.

Dominic Ryan, (P.Phys.), <dhryan@physics.mcgill.ca>, Professor of Physics, McGill University, President, Canadian Institute for Neutron Scattering

intervention to re-start the reactor. Even after this clear warning, no real action was taken, no succession plans were developed. With NRU shut down again, and not expected to return to service until April of 2010, the government is still working on privatising AECL and now appears to view NRU simply as an "isotope issue".

Students learning to use neutron beams at Chalk River.

NRU is not, and never has been, just an isotope reactor. Nor is it just a development platform for AECL. NRU was designed and built as a major piece of *research* infrastructure that has supported Canadian science and industry for over fifty years. It is long overdue for replacement, and only a flexible, multi-purpose research reactor can properly fulfil the many missions that NRU currently supports. Indeed, flexibility may be the most important feature needed in the new facility, since none of the key missions currently carried out by NRU really existed when the reactor went critical. Nuclear power reactors were just starting to appear, Brockhouse was just beginning his Nobel Prize winning research, radiation therapy for cancer was in its infancy and nobody was thinking of using radioisotopes for medical imaging.

While we welcome the attention that the current shortage of medical isotopes has focused on the aging NRU reactor, and do not want to be seen as in any way minimising the seriousness of the situation, we do need to remember that medical isotope production is just one of the missions fulfilled by NRU, and there is a real danger that by fixating on a single-mission solution, we will be distracted from the bigger picture and miss this golden opportunity to re-invest in Canada's future. The ill-fated MAPLE project is one example of a failed single-mission solution (they were intended solely to produce ^{99}Mo for MDS-Nordion and had no other mission or capabilities). The current crop of opportunistic "accelerator options" being touted as "solutions" to the medical isotope problem is another dangerous distraction from the bigger picture with little prospect for success. Such limited single-mission "solutions" could irrevocably damage our prospects of developing a coherent strategy for building a new research reactor facility for Canada that will support Canadian science, Canadian industry, Canadian research and Canadian health. As with the failed MAPLEs before them, accelerator projects are being presented as cheap, single-mission solutions with no regard for the wider implications. Furthermore, since these accelerator facilities would be single-mission installations — ^{99}Mo production only — their construction would represent a massive government subsidy for a commercial activity that exports most of its output to the US.

The central role of proton cyclotrons in the production of a wide variety of essential proton-rich medical isotopes for PET imaging etc. is undeniable. However, ^{99}Mo is a neutron-rich isotope that is produced at very high efficiency through fission of ^{235}U by thermal neutrons (approximately 6 % of all fission reactions create a ^{99}Mo nucleus [1]). The cross sections for all other production reactions for ^{99}Mo are four to five orders of magnitude smaller — including *all* of the accelerator-based reactions [1]. Reactor-based production of ^{99}Mo is a commercially demonstrated technology backed by decades of experience. Several countries, most notably Australia whose ^{99}Mo is licenced for use in Canada, have now moved to using low-enrichment uranium in their process, eliminating proliferation issues associated with the use of highly-enriched uranium.

Small-scale accelerator-based production routes are unattractive for several reasons: (i) They carry a significant risk as they rely on unproven techniques and have not been demonstrated on a commercial scale. These are research projects, not production technologies; (ii) By aiming to supply only the Canadian market they do nothing to enhance the security of the *global* isotope supply. We would no longer contribute to the rest of the world, but would remain dependent on external supplies in the event that our system failed; (iii) As a single-purpose facility, they would serve only to supply a single medical isotope, with very limited additional benefits. They would be either government-run or government-subsidised factories; (iv) Most importantly, they would be completely unable to support the rich diversity of fundamental and applied research activities that a multi-purpose research reactor could, and NRU currently does. By failing to replace NRU with a modern multi-purpose facility, we would be walking away from over fifty years of leadership and expertise.

In-situ studies of welding on C2, the powder diffractometer.

WHAT SHOULD BE DONE?

The panel of experts that was assembled by the Minister of Natural Resources to investigate and report on solutions to the isotope supply problem recognised that a single-purpose facility could not be justified on economic grounds. They further recognised that the various accelerator production routes were largely unproven and would demand a significant R&D effort before their viability could be determined, making them a high risk path. As a result, their primary recommendation was: [2]

> "The lowest-risk path to new Mo-99/Tc-99m production capacity is to build a new multi-purpose research reactor. The research reactor also promises the most associated benefits to Canadians based on its multiple purposes."

The role of government is to provide infrastructure for science and industry that will enable Canadians to carry out research and develop their businesses. As far back as 1994, the Bacon report (commissioned by NSERC) recommended that "Canada should make an immediate commitment to develop a new fully equipped reactor-based national source for neutron beam research". The need for neutron facilities has certainly not diminished. In 2008, we at the Canadian Institute for Neutron Scattering proposed in our report "Planning to 2050" [3] that Canada should build the Canadian Neutron Centre, a new multi-purpose research reactor that will serve Canadians as a key piece of infrastructure for science and industry. While last November, the isotope panel stated: [2]

> "We recommend that the government expeditiously engage in the replacement of the NRU reactor as we believe a multi-purpose research reactor represents the best primary option to create a sustainable source of Mo-99, recognizing that the reactor's other missions would also play a role in justifying the costs. With the National Research Universal (NRU) reactor approaching the end of its life cycle, a decision on a new research reactor is needed quickly to minimize any gap between the start-up of a new reactor and the permanent shutdown of the NRU."

The multi-purpose research reactor concept builds on the successes of NRU and is aimed at drawing together all of the current stakeholders while maintaining the flexibility to serve new and emerging needs. By combining in-core research facilities for nuclear engineering, with high-flux irradiation ports for isotope production and world-class neutron beam instruments, the Canadian Neutron Centre would support a wide range of industrial and research activities. Industrial users would be able to build their businesses around the facilities offered, obtaining services on a realistic, full cost-recovery basis, so that revenue from these activities could be used to offset the operating costs of the facility.

A new world-class facility would be a magnet for talented engineers and scientists in Canada. It would become the heart of a renewed National Laboratory at Chalk River. Our continued leadership in nuclear engineering and neutron based research, both fundamental and applied, would be assured. A stable, reliable source of medical and industrial isotopes would be put in place.

HOW SHOULD WE PROCEED?

To make this project a reality, we must establish a formal engineering design, in collaboration with all of the stakeholders, and develop an accurate costing estimate for the project so that the construction can be undertaken in a transparent and responsible manner. A suitable Federal Agency should be identified that can undertake such a project. It should be given both the mandate and the appropriate funding to coordinate a multi-departmental working group and bring forward a properly costed design proposal as soon as possible. Canada will then be properly prepared to consider an investment in a future Canadian Neutron Centre as a world-class resource for science and industry for the next 50 years.

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