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# "The Slowpoke Nuclear Research Reactor – A Brief History"

**by Ian J. Slater**

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CSME History Committee

WORKING PAPER 13/1998

# THE SLOWPOKE NUCLEAR RESEARCH REACTOR - A BRIEF HISTORY

by

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June 1998

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## Abstract

This Paper is based on a series of interviews carried out by the author with engineers and scientists involved with low power Slowpoke reactors and on material originating with Atomic Energy of Canada Limited (AECL). The basic questions answered are related to the design and construction of Slowpokes and their international sales in competition with the American Triga reactors, which were on the market before the Slowpokes, and the Chinese MNSR reactors, which were essentially copies of Slowpoke. Most of the 'action' took place in the 1970s.

The two illustrations on pages 14 and 15 originated with AECL.

This Paper was presented by the author at the CSME History Committee Seminar at Ryerson Polytechnic University on 22 May 1998.

## About the Author

Ian Slater began his university career at Carleton University in aerospace engineering. But after two years he left engineering and transferred to the bachelor's program at the University of Toronto, where his subject was the history and philosophy of science. After graduating, he returned to Carleton where he obtained a master's degree in philosophy, with concentration on the philosophy of science. He is currently in the first year of a doctoral program at the Institute for the History and Philosophy of Science and Technology (IHPST) at the University of Toronto. His area of research interest is the history of early 20th century nuclear technology and, specifically, non-military applications and questions concerning the relationship between technology and society.

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This paper is based upon a series of interviews with engineers and scientists that have been involved with the Slowpoke nuclear research reactor. My initial interest in this subject was sparked by the planned shutdown of the Toronto Slowpoke facility. When I heard about the closure, I decided that a history of the reactor could be timely and interesting. Some of the information you will be hearing today is anecdotal, and some is based upon AECL material. The question that has focussed my research from the beginning is a simple one: what factors (both + & -) contributed to the distribution of the Slowpoke, nationally and internationally?

In order to provide context for the later historical details, I want to briefly run through a few technical details about the reactor. The Slowpoke (an acronym for Safe Low Power (K)ritical Experiment) has an operating power of 18-20 kW, it uses approximately 1100g of low enriched (~ 20%) $U^{235}$ Uranium Oxide fuel, it has a beryllium reflector (which can be augmented to extend the life of the core), and uses light water as a moderator.

Presently, the reactor has several standard applications. Its primary application is Instrumental Neutron Activation Analysis, which involves irradiating samples in the reactor's neutron flux and taking a gamma ray spectrograph of the irradiated sample. Elements produce "spikes" on the spectrograph, and up to 74 elements can be "read off" by identifying the spikes so produced. Trace elements in substances can be identified in this manner, and substances of unknown composition can also be analysed. This analysis can be non-destructive (by making the radioactivity of the samples short lived), and is of considerable use to those who wish to retain their samples (analysts in forensics or archeology for example)

Slowpoke can also produce short lived isotopes by irradiation, that can be used as tracers in pharmacological and medical research. The RMC Slowpoke has been rigged for neutron radiography, by use of a special neutron screening device, and it has been used to successfully radiograph small aircraft parts. The Jamaica Slowpoke is used for geochemical mapping, where soil and rock samples are taken from mapped areas to determine trace amounts of valuable subterranean metal deposits. The high sensitivity of the Slowpoke makes this application very valuable. The Saskatchewan Research Council Slowpoke is used primarily for uranium purity analysis. Finally, the reactor is used for undergraduate training, due to its inherent safety and relative simplicity of operation.

The reactor is inherently safe. It has negative temperature and void coefficients in the core, which means that the light water moderator boils off when the reactor overheats, slowing the reaction down. Thus, if the cooling system completely failed, the reactor would simply settle down to an extremely low operating power. Additionally, the reactor has low excess reactivity, and the core is sealed, access being restricted to licenced AECL engineers. It is physically impossible for the reactor to explode or melt down, barring the planting of explosives around or in the reactor core.

The fuel rods in the Slowpoke are a uranium / aluminium alloy, and are highly radioactive once installed. Thus, in order to "steal" the uranium from a Slowpoke to make a bomb (a concern that has been voiced by foreign governments and various environmental groups), the core would have to be unsealed (which is difficult, as it would be highly radioactive at the time), and the aluminium / uranium alloy rods (which would also be radioactive) would have to be chemically separated (which is a difficult process even when the two substances are not irradiated). All of these factors make proliferation concerns somewhat irrelevant. Due to the inherent safety of the reactor, it is licenced for unsupervised operation (under remote surveillance) for up to 24 hour periods.

Presently there are 8 Slowpoke's at large, at Dalhousie University, Ecole Polytechnique, Royal Military College, the University of Alberta, the University of Toronto, the University of the West Indies, the Saskatchewan Research Council, and at AECL Kanata. The AECL Kanata reactor was decommissioned in 1992, and the U of T reactor is scheduled for decommissioning by January of 2000.

The history of the reactor can be traced back to Eisenhower's "Atoms for Peace" movement in the 1950's. Due to the U.S. government's desire to find peaceful uses for nuclear power, research reactors were distributed worldwide. The American research reactor of choice in the 1960's was the "Triga", and the Americans gave away most of the 60-70 Triga research reactors that are now in use as part of "Atoms for peace."

In 1967, a paper published by George A. Jarvis and Carroll B. Mills of the Los Alamos Scientific Laboratory suggested that the lowest value for critical mass in a reactor assembly was 250 grams of $^{235}U$ in a polyethylene core surrounded by a thick beryllium reflector. Based on this information, John Hilborn (the inventor of the Slowpoke) and R.B. Lyon submitted a proposal later that year for a low-cost neutron source that could compete with the accelerators that were popular at the time. The proposal was not immediately pursued.

Bob Jervis, an engineer at U of T, had worked on Neutron Activation Analysis at Chalk River (with the NRX and NRU), and was interested in getting a research reactor for the University of Toronto Department of Chemistry and Chemical Engineering. Dr. Jervis had worked with John Hilborn at Chalk River, and he sent Dr. Hilborn down to General Atomics in San Diego to make a technical evaluation of the Triga reactor on behalf of U of T in 1969-1970. Although technically excellent, the Triga was and is expensive. After some digging, Dr. Hilborn determined that the operating costs (basically the cost of fuel + supervision) were too high. Dr. Hilborn returned to U of T with the news, and the Slowpoke concept was given a boost.

By 1971 a prototype Slowpoke reactor had been built and was brought to the University of Toronto for analytical testing. This was a much smaller reactor than the "commercial" Slowpoke that is used today. Work was then commenced on upgrading the power and flux of the Slowpoke to meet the needs that would have been filled by the Triga, and in 1975 AECL Commercial Products built a prototype commercial Slowpoke at Tunney's pasture in Ottawa to determine feasibility. Five were built at the same time, four to be installed in Canada (at Toronto, Dalhousie, Ecole Polytechnique and Alberta), and one was earmarked for the University of Cologne in Germany. By 1976 federal funding was obtained for the four initial Canadian reactors, and they were installed over the period of 1976-1977. The Saskatchewan Research Council obtained their reactor in 1981, the AECL's reactor was moved from Tunney's pasture to Kanata in 1984, and was subsequently decommissioned in 1992. The Slowpoke at the University of the West Indies was commissioned in 1984, and RMC obtained their reactor in 1985.

That is the basic story of the startup of the reactor. At this point I want to delve into a bit more detail about the attempts to sell the reactor internationally. The sale in Jamaica was the only successful international sale of a Slowpoke. This seems odd, things got off to a fast start, there were initially many candidates for international sales (U.S., Mexico, Europe, South America and China to name a few), and in the beginning AECL was aggressively marketing the reactor. So what happened? I will start with the story of the reactor planned for the University of Cologne in Germany, which was built with the original four reactors in 1975.

Negotiations were started with the University and the German government in 1975, 7-8 years later (the figure varies depending on where you draw the line) the deal was abandoned by both parties. What had happened, and what took so long?

Briefly, there were several factors that combined to frustrate the sale. The post WWII German government had extremely strict nuclear proliferation regulations, which caused delays. Additionally, there were three separate levels of government nuclear regulation: Federal, "state" and regional, and one independent technological regulatory organization called the "TUV", all of whom had to approve the deal. Both the strong "green" movement in Germany, and the government itself, treated the Slowpoke as they would have treated a power reactor, under the assumption that all nuclear technology is equally problematic due to the potential consequences. This led to extra safety features and considerable concerns about "containment", which are obviously irrellevant considering that the reactor simply cannot explode. All of this drove up costs and caused delays.

By the time the 7-8 year negotiation period was over, the University was told by AECL that the price had gone up considerably (there was high inflation in Canada at the time and thus the costs to AECL were high). AECL (specifically Commercial Products) was not willing to lower the price to the original level, treating the reactor as a "loss leader"for example, as they felt that the European market was not promising. The deal was then closed. The failure of the German deal was a result of misunderstanding of the nature of the reactor, and fairly strict government anti-proliferation legislation. My next story, related to the failed Chinese Slowpoke sale, is even more interesting.

There were indications in the mid-70's that China was interested in purchasing several Slowpoke reactors from AECL, and Commercial Products sent over customer information concerning the reactor and its support infrastructure to the Chinese government, as they would for any potential client. Around this time, a graduate student from the University of Ottawa phoned George Burbidge at Commercial Products and told him that he (the graduate student) had been chosen by the Chinese government to study research reactors to determine which one to purchase, and that he wanted to obtain information on the Slowpoke. The student was given a tour of the reactor, along with the standard handouts and promotional literature.

Soon after the student started calling and asking detailed questions about the reactor fuel system. For example, he asked for exact measurements of the distance between fuel pins in the core, and for exact distances between certain elements of the reactor assembly. After several weeks of these sorts of questions, Commercial Products decided to stop answering his questions. Unbeknownst to the people at Commercial Products, at the same time other visiting students and professors were making similar inquiries at several of the other Slowpoke installations in Canada, with varying amounts of success. Then, the questions stopped and nothing more was heard from the Chinese government for several years.

Back in China, the customer information was combined with published papers and the information gathered by students and professors, and a copy of the reactor was "back engineered." The Chinese version of the Slowpoke (called the Miniature Neutron Source Reactor- MNSR) was unveiled at an international research reactor meeting in Bejing. At that time there was no acknowledgement that the reactor was a copy of the Slowpoke, but later it was admitted that it was based upon a Canadian design. As a rather ironic side note, shortly after the Chinese students and professors left Canada, John Hilborn received a call from CSIS, warning him about giving out technical information to foreign sources (students, visitors, scientists)

The MNSR is a direct copy of the Slowpoke, it has been described to me as accurate "right to the bolt" by Slowpoke engineers; even the olive metal colour of the control panel has been duplicated exactly. Oddly enough, the only significant difference between reactors is efficiency. The MNSR uses approximately 400g more uranium than the Slowpoke, MNSR uranium is 90% enriched (the Slowpoke now uses 20% enriched fuel), the MNSR requires 30kW to obtain the same neutron flux as a Slowpoke, and the beryllium the MNSR uses is less pure.

With respect to the expected sales in China, things did not go well after the appearance of the MNSR. Five Chinese universities had expressed an interest in buying a Slowpoke independently of the original government inquiries. These universities have not installed an MNSR to date, nor have they bought a Slowpoke due to an interesting catch-22. The Chinese government and the IAEA will not give them funding to buy a Canadian Slowpoke, and they do not want what they perceive to be an "inferior" copy.

According to one of the people I spoke to, AECL had an opportunity to "make up its losses" in this situation. By the time the Chinese had the MNSR on line, AECL had a low-enriched fuel for the Slowpoke, if the AECL had set up a co-operative program they could have supplied fuel and maintenance for the MNSR. Considering international restrictions on enriched reactor fuel, this could have been lucrative.

AECL decided against co-operation, and instead threatened sanctions and refuse to co-operate with the Chinese, and we lost the opportunity to supply fuel for their reactor. This seems odd in light of the fact that we have agreed to let Chinese students come to Canada and train on the Slowpoke for later work on the MNSR. Perhaps views have mellowed with time...

The Chinese did not waste any time taking advantage of their new technology. They decided to finance and distribute the MNSR to third world countries as a way of paying their IAEA dues. As many of these countries were potential Canadian sales (that were not aggressively pursued in the beginning, largely due to the fact that the AECL was waiting for the IAEA to provide funding to these countries to purchase a Slowpoke), Slowpoke exports to poorer countries were effectively terminated. Further, MDS Nordion no longer bids on research reactor contracts that involve Slowpoke reactors, as they realize that they can be undersold by the MNSR, and bidding itself is a costly process.

The China Institute for Atomic Energy in Beijing sold MNSR's to Iran, Pakistan, Syria, Ghana and Nigeria. The future director of the Nigeria MNSR came to U of T to train on the Slowpoke, and Halifax, Montreal, and U of T have all had senior scientific people from the "third world" come to train on their Slowpokes. Unfortunately, the Chinese have not provided any technical or maintenance support after their sales, and due to a bottleneck in IAEA funding, several third world countries have inactive reactors. The AECL has attempted to aid in the IAEA application process, in order to help these countries get their research reactors back on line.

I shall tell a much briefer story about the Jamaica reactor. Dr. Gerald Lalor at the University of the West Indies applied to CIDA for a grant to purchase a research reactor in 1978. CIDA felt that Jamaica was too "backwards" to handle something as technologically complex as a research reactor, and turned down the application (despite the fact that the Slowpoke would be in the running). Lalor went to the EEC and obtained funding. In the end Canada made no financial contribution to the reactor facility, and the Canadian Ambassador to Jamaica did not even show up to the opening.

The competition for the reactor was narrowed down to three competitors, the American Triga, the Slowpoke, and a "paper reactor" being proposed by a French company (one that has not been built to this day). Slowpoke won the competition (due to cost concerns with the Triga and general concerns with the French reactor), and the reactor was ordered in 1980. It was installed in 1984, but it took two further years after installation to get fuelling approval as the U.S. State Department intervened with new enriched uranium proliferation legislation. At the time all Slowpokes used 90% enriched uranium for fuel. The AECL had a good history with the AEC in the U.S. up until this time, the U.S. supplied Canada with enriched uranium for NRX and NRU, and we sent back plutonium for their weapons program.

The new legislation stated that all existing research reactors change to low enrichment fuel, but a special deal was arranged with the Jamaica reactor to have enriched fuel, as long as

AECL would undertake a program (at their own expense) to redesign a low enriched fuel for all their research reactors. Again we see a fundamental lack of understanding concerning both the low levels of uranium being used in the Slowpoke, and the difficulty (if not impossibility) of removing the fuel. Proliferation concerns should not have affected Slowpoke, but it was all research reactors or none, and as a result all Slowpokes today have low 20% enriched fuel. Incidentally, both the Jamaican Slowpoke and the Canadian low-enriched fuel program were resounding successes. In the latter case, AECL did the design and supervision, Westinghouse did the work, and AECL now owns the design for the low-enrichment fuel system.

My final historical discussion concerns the attempt to build a 2MW Slowpoke upgrade for heating purposes, known to some as the "superpoke." The idea came about during the oil crisis in the 1970's, and the plan was to design a larger reactor that was safe and simple like the Slowpoke, that could be used for off grid heating in remote northern communities, or anywhere where heating fuel transportation costs were prohibitive. A 2MW reactor could heat a community of approximately 150 houses, or a small grouping of buildings (say a hospital or a small university). The heat has to be piped or distributed, so a community of houses would be much more expensive than a small building complex.

By the mid-70's the Superpoke project was up and running. The AECL committed millions to research and development, at one time there was a team of 27 scientists and engineers working on the design at Chalk River. Design concessions were made in the attempt to make the reactor as safe as the Slowpoke. For example the coolant temperature was limited to 100 degrees, the boiling point of light water at normal pressure, so there would be no need for a pressurized system. This was a major safety advantage, but it was also a major disadvantage for electricity production. Thus the reactor would be restricted to heat production only. Another major technical problem was Xenon poisoning. When you increase the flux of a uranium reactor at a linear rate to get a higher power density (KW per Litre), Xenon (which is a neutron absorber) is produced at a geometric rate. This necessitates more safety equipment to ensure safe transition from cold shut down to hot operating, it requires more attendants, and it drives up the operating costs. The increased operating costs from safety features, combined with the end of the oil crisis, damaged the market for the reactor.

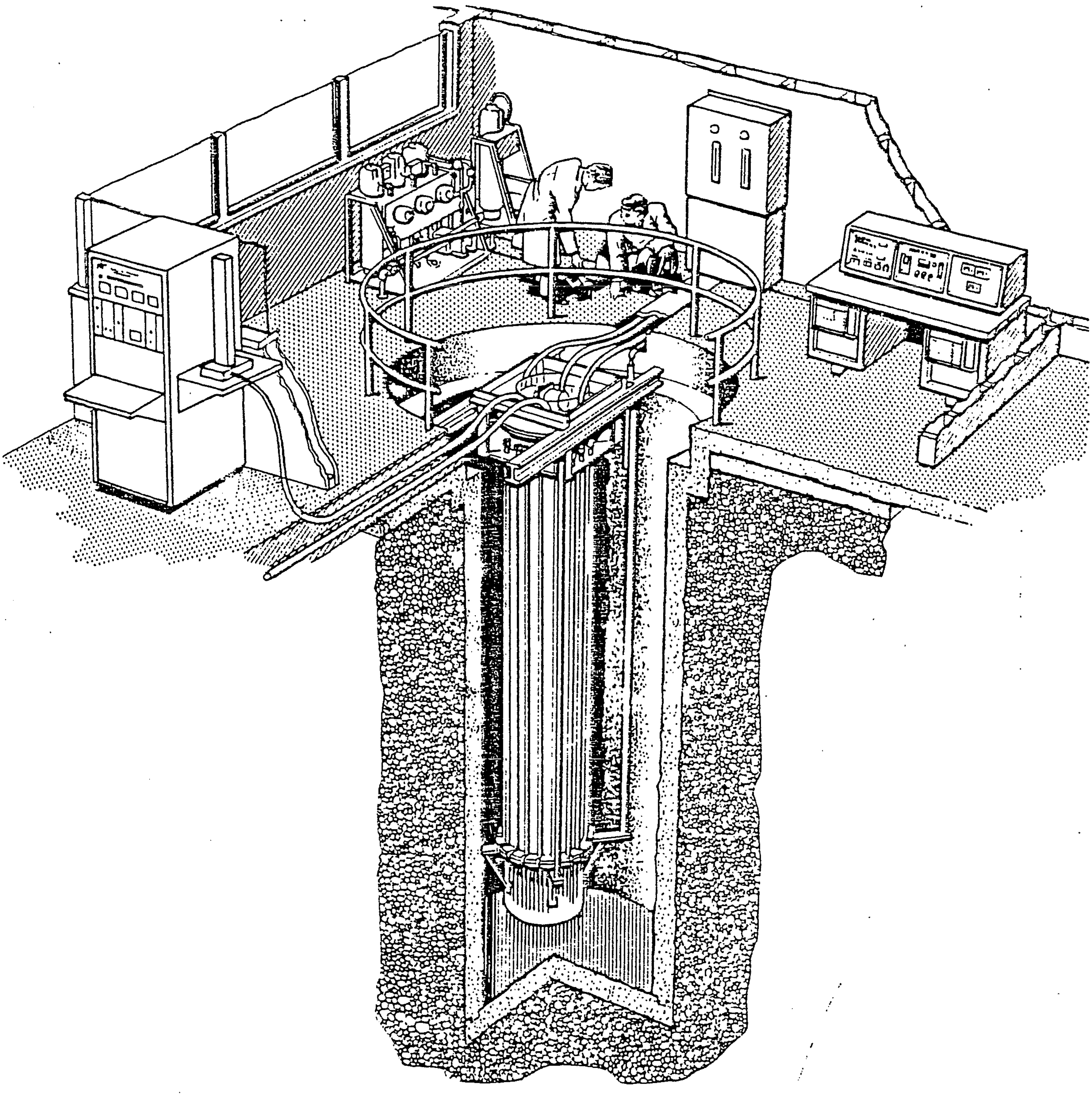
However, there were other internal factors that also contributed to its untimely death. Before the 2MW prototype was ready, AECL had put together a team to design and market a 10MW commercial version, in the hopes of securing advance industrial funding. A huge amount of money was spent on design and marketing of the 10MW version when there was not an operating and proven 2MW or 10MW version to demonstrate to potential buyers.

There were also political factors at work. By late 1978 / early 1979 there was a site at Chalk river licenced for the 2MW prototype, and the reactor was about 90% finished. All of the pipes had been laid to provide heating for the Chalk River facilities with the 2MW prototype. At this time, the president of AECL, Bob Hart, approached John Hilborn and asked about the costs associated with moving the project to Whiteshell. Despite the warnings of high costs and time delays, the decision was made to move the project to Whiteshell. Several years of setup time and millions of dollars were lost in this move. It ends up that there had been an internal row between AECL and AECB over safety authorization procedures. AECB was looking to take over responsibility for all Chalk River safety regulation and approval (which was previously done internally), and the decision was made by AECL to move the project to Whiteshell.

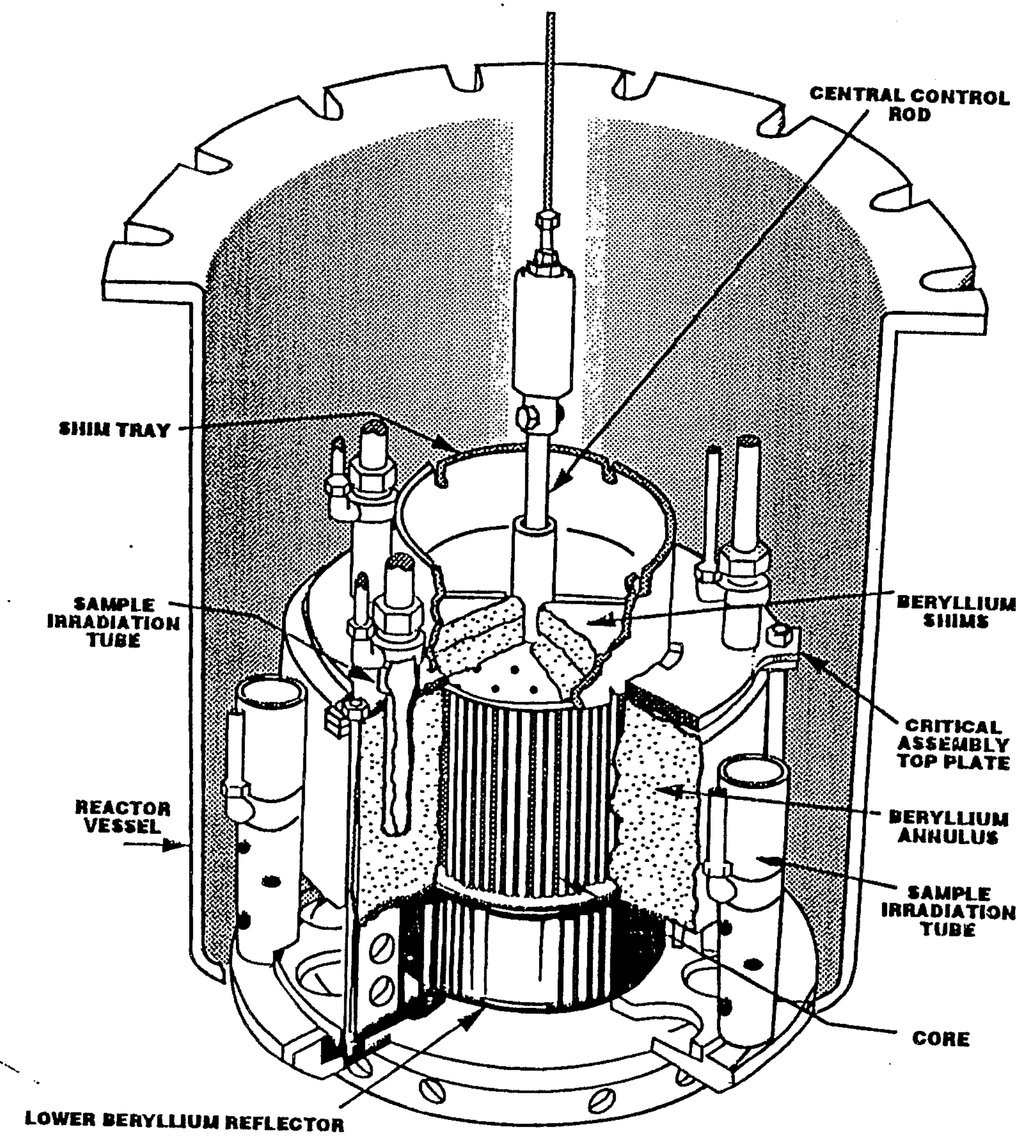
If expensive safety features, overambitious marketing and internal politics had not killed the project, perhaps bad publicity would have. In 1987 the AECL entered into negotiations with the University of Sherbrooke to install a 10MW reactor on campus. The university's hospital facility in particular was being targeted for the potential radioisotope production capacity of the reactor. When the public (and the anti-nuclear groups) heard about the plan, a massive campaign was mounted to stop the deal. One of the key problems in this event was the inability of the AECL to account for all contingencies with the reactor, as the design was not finalized. Eventually the project was abandoned due to various factors, including more economical heating options with fossil fuels. Unfortunately many key scientists and engineers associated with the Slowpoke were upset as the upgrade was referred to by the AECL as a "Slowpoke", despite the fact that it did not possess the inherent safety of the smaller version. For all technical and practical purposes, a 10MW reactor is not a Slowpoke, and unfortunately there are now many people in Quebec that don't know the difference between the upgrade and the original.

In summary, there are several factors that contributed to the lack of success for the Slowpoke reactor since its inception in the early 1970's, beyond marketing errors and government infighting. The narrow range of applications for the reactor, and by extension its ability to produce only very short lived isotopes, not the isotopes that are presently in demand in the medical industry, is a problem. These limitations in versatility are largely due to the simplicity and safety of the reactor. The more simple and safe the technology, the less variety is possible. The Slowpoke came into the game too late, the U.S. Triga, which was virtually given away by the AEC, had taken up a considerable portion of the international market, and all of the U.S. market, before Slowpoke was even on the drawing board. The Chinese MNSR, has effectively taken over most of the remaining international market. With such a small market left, it is virtually impossible to achieve an "economy of scale" for the reactor that would justify a large marketing, administrative and manufacturing effort.

All of these factors are more or less beyond the control of the AECL and MDS Nordion, however, general ignorance about the technical aspects of the reactor can be found on almost every front, the AECL, the AEC, the German government, and environmental groups all failed to understand what the inherent safety of the Slowpoke reactor implied. The resulting delays and cost increases did nothing to aid in the distribution of the reactor. It may simply be the case that the only way to make the Slowpoke a widespread success would have been to provide heavy government subsidies the way the Americans did for the Triga. Perhaps it is the fate of all small scale, safe and simple technologies that no one will take the time to understand the technical details, as there is not enough profit involved. Perhaps, but hopefully not.



ARTIST'S CONCEPTION OF
A SLOWPOKE INSTALLATION




# SLOWPOKE-2 Reactor Core