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50 YEARS OF NUCLEAR - ELECTRIC POWER IN CANADA

TWO INCOMPARABLE FRIENDS
AND
THE MCMASTER CONNECTION

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PREAMBLE

In extending to me, on behalf of the McMaster University Branch of the Canadian Nuclear Society, an invitation to present a "talk" in recognition of 50 years of nuclear-electric power in Canada, Dr. Benjamin Rouben said to me: "I would like to know if you would be willing to give a history talk". I interpreted Ben's request to me to mean that I might say a "few words" about nuclear-electric generation in Canada in a historical context. Without exception, my wife, children, grandchildren, friends and neighbours (not a mutually exclusive categorization) would retort: "What, ask Jon, dad, Opa to say a "few words" ? That would be like asking an elephant if he or she would like a peanut? How about a couple of bushels of peanuts!

INTRODUCTION

On March 21, 2012 at a seminar conducted by the University of Ontario Institute of Technology Branch of the Canadian Nuclear Society, at a June 20, 2012 seminar conducted by the Chalk River Branch of the CNS and at a July 27, 2012 seminar for staff members and guests of the Canadian Nuclear Safety Commission, I made the following statement:

"The design, manufacturing, construction and commissioning of the NPD Generating Station was an outstanding example of how hundreds of Canadian companies working under the combined leadership of AECL, Canadian General Electric and Ontario Hydro demonstrated by scientific and engineering ingenuity, determination, drive, close cooperation and mutual understanding and respect the inherent characteristics and abilities of Canadians."

I'm confident that you will agree.

SOME MEMORABLE YEARS.

The Atomic Energy Control Act of Canada was proclaimed on October 12, 1946. Its preamble was an unmistakably demonstrative example of the literary skills and wisdom of one of its principal authors, Mr. Guy Jarvis, M.B.E., of the Department of Justice. Soon after, Mr. Jarvis was appointed the Secretary of the Atomic Energy Control Board and Controller of Radioactive Substances. I met him on several occasions and remained silent and attentive in his presence.

With the promulgation of the Act, General – Doctor A.G.L. McNaughton was appointed as the first President of the Atomic Energy Control Board (AECB). He served until 1948 at which time he was succeeded by his close friend and colleague Dr. C.J. Mackenzie.

The preamble to the Act read:

"Whereas it is essential in the national interest to make provision for the control and supervision of the development, application and use of atomic energy, and to enable Canada to participate effectively in measures of international control of atomic energy which may hereafter be agreed upon; Therefore, His Majesty, by and with the advice and consent of the Senate and House of Commons of Canada, enacts as follows:"

Certainly for me, and I believe for many others, the Preamble to the Act provided fundamental guidance about was expected of me as a member of the staff of the AECB and later as its President.

Until the AECB was established pursuant to Section 3 of the Act, the Chalk River Project and its forerunner, the Montreal Laboratory, were part of the National Research Council's Atomic Energy Division. With the creation of the AECB, the "Board", a federal Departmental Corporation, became the Government agency through which federal funds were appropriated for the Chalk River Project.

However, at the request of the AECB, the NRC continued to serve as the "operator" of the Project. This arrangement continued until the

creation of AECL in 1952 with Dr. C.J. Mackenzie, as the Company's first president.

1929

1929 stands out in history as a memorable year! It was, of course, the year of the "Great Depression".

One of the truly meaningful historical examples of cooperation between national governments is that of the World War II multi-faceted relationships between the United Kingdom of Great Britain and Northern Ireland, the United States of America and Canada. Their cooperation in the field atomic energy is a case in point.

As Canadians well know, quite apart from 1812, "T'was not always so."

On November 18, 1918, the United States Congress passed "The Wartime Prohibition Act" seven days after the signature of the Armistice that ended WW I. The sponsors of the Act had argued that it was intended to save grain for the war effort. It entered into effect on June 30, 1919, 7 ½ months after the Armistice was signed. July 1, 1919 became known, via radio and the printed media, as the "Thirsty- First".

In March 1929, a United States Coast Guard cutter sighted a Canadian schooner in the Gulf of Mexico. The "I'm Alone", a Lunenberg, Nova Scotia-based schooner, was alleged to be a "rumrunner", one of several hundred vessels suspected to be supplying that "Demon Rum" to thirsty Americans. The U.S. cutter chased the "I'm Alone" more than two hundred nautical miles out to sea, into international waters, and then sank her.

President Roosevelt ended the Prohibition in 1933 and in 1935 the United States apologized to Canada and paid damages to the owner, the Captain and the crew of the "I'm Alone".

In 1929, the first cyclotron proton accelerator was assembled at Berkley, California by a 29-year old physics professor Ernest Orlando Lawrence. Its accelerating chamber measured five inches in diameter and its magnet weighed 80 tons.

In 1939, Lawrence was awarded a Nobel Prize for inventing the cyclotron. During the intervening ten years he and his colleagues had assembled four larger cyclotrons with accelerating chambers of 11, 27, 37 and 60-inch diameters. Armed with his Nobel Prize, Lawrence immediately began the design of a 184 inch diameter accelerating chamber with a magnet weighing 4,000 tons.

1929 and 1939 were certainly memorable years. I would like to share an anecdote about an event that occurred in Ottawa in 1939 but first I would like to tell you a little about the two persons involved.

MCNAUGHTON AND MACKENZIE – TWO INCOMPORABLE FRIENDS

Andrew George Latta McNaughton was born on February 25, 1887 in Moosomin, Saskatchewan. He earned a B.A. at McGill in 1910 and an M.Sc. (Electrical Engineering) in 1912.

While at McGill, McNaughton enlisted in the non-permanent militia as a field gunner. He joined the 18 pounder-equipped, 4th Battery of the Canadian Expeditionary Force in 1914 and arrived in France in February 1915. He developed a target detection system that was the forerunner of radar and by March 1916 he was a twice-wounded Lieutenant-Colonel. In 1917, he was appointed the Counter Battery Staff Officer of the Canadian Corps and the day before the Armistice was signed he was promoted to Brigadier-General and appointed General Officer Commanding Canadian Corps Heavy Artillery. In 1920, McNaughton enlisted in the Canadian Army (Regular). He served as Chief of the General Staff from 1929 to 1935.

Following his military service, McNaughton served as the President of the National Research Council of Canada from 1935 to 1939.

Chalmers Jack Mackenzie was born on July 10, 1888 at St. Stephen, New Brunswick. He graduated from Dalhousie in 1909 with a degree in civil engineering. In 1912, while working as field engineer, the University of Saskatchewan appointed him as a session lecturer.

He earned a Master's degree in Civil Engineering at Harvard in 1915.

While serving in the Canadian Army from 1915 to 1919 Mackenzie was awarded the Military Cross for "gallant and distinguished services in action" in France.

After the War, Mackenzie returned to the University of Saskatchewan and was appointed Dean of Engineering in 1921. In 1935, he was appointed a member of the National Research Council's Honourary Advisory Council. Mackenzie quickly developed a close friendship with McNaughton well beyond their existing collegial relationship.

The friendship between "Andy" McNaughton and "Jack" Mackenzie was extraordinary. They were two very extraordinary Canadians.

At various times from 1962 to 1970, it was my privilege to meet Dr. Mackenzie when he visited his longtime friend and successor as President of the Atomic Energy Control Board, Dr. George Craig Laurence. I was not privileged to meet General – Dr. McNaughton.

I learned from Dr. D.J. Dewar, Scientific Adviser, AECB (1948-1974) about the anecdotal event of September 1939 that I referred to earlier. The "story" is about a telephone call between McNaughton and Mackenzie. It went something like this:

> **"Jack ? Is that you?**
> **Yes Andy.**
> **Jack, can you come to Ottawa?**
> **When?**
> **Can you be here by tomorrow afternoon?**
> **I'll try. Hopefully, I can get a flight on TCA."**

The next afternoon, Mackenzie arrived at McNaughton's office at 100 Sussex Drive and said:

> **"Andy, what are you doing in your general's uniform?**
> **Jack, I have been recalled to military duty and for the duration of the War you are the Acting President of the NRC."**

Prime Minister William Lyon Mackenzie King's Cabinet had previously and unanimously approved Dr. Mackenzie's appointment.

McNaughton had been given permission to inform Mackenzie pending the issuance of a formal Order-in-Council.

In September 1939, McNaughton assumed command of the First Canadian Infantry Division, a part of the British VII Corps. It later became a division of the 1st Canadian Corps and then, in 1942, the multi division corps became the 1st Canadian Army.

This angered General Sir Alan Brooke, the Chief of the British Imperial General Staff, who demanded that the Canadians serve under British generals. He mistakenly believed that Canadian generals were not capable of commanding divisions, or corps let alone an army.

McNaughton was admired by Prime Minister Churchill, who remembered Canada's incredible sacrifices and achievements during WW I particularly at Ypres, Passchendaele and Vimy Ridge and certainly McNaughton's very appreciable contributions to the science of gunnery. Mr. Churchill declared his approval of McNaughton's request that the Canadians be led by their own generals.

Under vigorously debated circumstances, McNaughton, a true gentleman determined to serve the interests of Canada, returned to Canada in December 1943. Almost immediately, he undertook the responsibilities of serving as Minister of National Defence.

General Harry Crerar had succeeded McNaughton as GOC 1st Canadian Corps, and in 1943, he became GOC 1st Canadian Army.

THE UNITED NATIONS ATOMIC ENERGY COMMISSION

In Washington on November 15, 1945, the United States, the United Kingdom and Canada issued what became known as The Agreed Declaration of 1945.

President Truman, Prime Minister Attlee and Prime Minister Mackenzie King had met to examine recommendations prepared by their officials regarding possible "international actions" intended to:

1. Prevent the use of atomic energy for destructive purposes; and

2. Promote the use of recent and future advances in scientific knowledge, particularly in the utilization of atomic energy, for peaceful and humanitarian ends.

The Declaration proved to be a fundamentally important step in the creation of the United Nations Atomic Energy Commission on January 24, 1946. On that day, the UN General Assembly adopted its first resolution, the main focus of which was international cooperation in the peaceful uses of atomic energy and in the elimination of atomic and other weapons of mass destruction.

Six member states of the UN General Assembly, the five "Allied Powers" of WW II and Canada, sponsored the Resolution and became the six Permanent Members of the UNAEC.

Thus, the "Nuclear Connection" was recognized from the outset of the UN's activities as a matter of first priority.

Prime Minister Mackenzie King had previously appointed McNaughton as Canada's Permanent Delegate to the United Nations. He was elected as the first chairman of the UNAEC.

After only a few meetings, it became clear to the Commission that the USSR did not share some of the views of the other five Permanent Members when it came to the development of a basis for international control and verification of atomic energy activities. The USSR proposed the immediate destruction of all existing atomic bombs and a system of periodic inspections of all atomic energy activities by an international agency. The other five Permanent Members of the Commission insisted that only by a system of continuous inspection would it be possible to detect clandestine activities and thereby provide meaningful assurance of effective verification.

Perhaps more importantly, the USSR made it clear that it would refuse to accept international measures of control that would impinge upon or interfere with its exercise of unimpeded state sovereignty.

The UNAEC began its work in earnest and submitted three reports to the General Assembly, one each in 1946, 1947 & 1948. The USSR abstained from voting on the First Report and voted against the Second and Third Reports. In taking these actions, the USSR continued to demand that a convention outlawing atomic weapons and providing for the destruction of existing weapons must precede any control agreement.

In frustration, the UNAEC submitted its Third and Final Report to the Security Council in May, 1948.

A little more than a year later, the USSR detonated its first fission device and in 1953 a thermonuclear device. The first British nuclear fission test was in 1952, the French in 1960 and the Chinese in 1964.

The failure of the UNAEC to achieve its undeniably important objectives did not deter many Member States of the UN who realized that they must continue to pursue the development of a "nuclear non-proliferation regime". However, progress in its development was snail-paced.

One of the primary reasons for the protracted deliberations in developing the non-proliferation regime was the U.S. policy of secrecy and denial. This policy was implemented via certain provisions of the U.S. Atomic Energy Act of 1946. The Act effectively denied U.S. cooperation with its wartime allies France and the United Kingdom. Not so Canada largely because of the U.S. dependence on Canada for uranium that continued even after deposits in Colorado and other States were brought into production. Except for the Belgian Congo, Canada was the only significant foreign source of uranium available to the United States in 1946.

THE MCMASTER CONNECTION

So far in this presentation, I have focused on certain historical events in the context of "atomic energy" developments in Canada and worldwide and on two of the persons who were principally involved. There were many others but few who made equally significant contributions. Dr.

Henry (Harry) George Thode was one of the equally significant contributors.

Harry Thode was one of several Canadians who were born or educated in Saskatchewan and enjoyed successful careers in nuclear science or engineering. The list includes Andrew McNaughton, Howard Johns, Sylvia Fedoruk, Lorne McConnell, Sam Horton, Elgin Horton and many others.

Hode was born in Dundurn, Saskatchewan in 1910. He earned BSc. and MSc. degrees at the University of Saskatchewan and in 1934 a Ph.D at the University of Chicago. He pursued his research work at Columbia University under the guidance of the discoverer of deuterium, Dr. Harold Urey who was awarded the Nobel Prize in Chemistry the year Thode received his Ph.D. Thode began his association with McMaster University in 1939 as an Assistant Professor in Chemistry. In 1942 he was promoted to Associate Professor, the year that the Montreal Laboratory became a reality as part of the Anglo-Canadian Project with the endorsement of the United States. Four "Divisions" of the Laboratory were established: chemistry, theoretical physics, applied physics and engineering.

Thode was well known to Mackenzie. In fact, it was Mackenzie who authorized the NRC funding of the mass spectrometer (the first in Canada) constructed at McMaster under Thode's direction.

Thode did not wish to move to Montreal. He insisted on remaining at McMaster. Eventually his laboratory at McMaster became a Division of the Montreal Laboratory. It played a vital role in the rapidly advancing Anglo-Canadian Project particularly after the Americans and British had settled some of their differences as witnessed by the signature on August 19, 1943, of the agreement entitled "Governing Collaboration between the Authorities of the U.S.A. and the U.K. in the matter of Tube Alloys". Although not a signatory, Canada quickly became involved in the implementation of the agreement.

Thode travelled between Hamilton and Montreal very frequently until the construction of facilities at Chalk River enabled the closure of the Montreal Laboratory and the transfer of the majority of its scientific, engineering and technical staff to the new "Project". Thode continued

to serve as a consultant to NRC's Atomic Energy Division and then to AECL after its establishment in 1952.

From 1945 to 1961, Thode served as a member of the newly established Defense Research Board and from 1966 to 1981 as a member of AECL's Board of Directors. During these years he continued his research and teaching at McMaster while also directing the planning, construction and operation of the McMaster Nuclear Reactor, the first research and testing reactor at a university in the British Commonwealth. He rose to become President and Vice Chancellor of the University.

Thode received many awards during his long career due to his dynamism, scientific brilliance and leadership. He was a fellow of the Royal Society of Canada (its president from 1959-60), the Chemical Institute of Canada and of the Royal Society of London. In 1946, he was named a Member of the British Empire and in 1967 he was the first scientist appointed as a Companion of the Order of Canada.

The National Research X-perimental Reactor

On July 22, 1947, the NRX reactor achieved initial criticality only three years after the tripartite decision to build it was made.

Quite likely, very few persons are aware that CP-3 (Chicago Pile 3) at Argonne was the first natural uranium fuelled, heavy water moderated reactor. It operated at power levels of up to 300 kilowatts from 1944 to 1954. The reactor kinetics and other physics data derived from CP-3 was undoubtedly a major factor in the design of NRX.

Just nine months after NRX started-up, the AECB's annual report listed the shipment of nine different radioisotopes to eight Canadian universities for research purposes. On October 27, 1951, the world's first cancer treatment with Cobalt-60 radiation took place under the leadership of Dr. Ivan Smith (whose name does not appear in The Canadian Encyclopedia) at the Victoria Hospital, London Health Sciences Centre.

Very rapidly, Canada's achievements in nuclear medicine (oncology, cardiology, neurology and research) became known internationally. One particularly important parallel development was the design,

production and world-wide availability of Cobalt-60–based facilities for the sterilization of single-use medical products, including surgical kits, gloves, gowns, drapes and cotton swabs. Similar facilities were developed for the sanitization of cosmetics, microbial reduction of pharmaceutical raw materials and food irradiation.

Both NRX and NRU produced Cobalt-60 and many other radioisotopes until NRX was permanently shutdown on April 8, 1993 after over 45 years of operation. NRU then became the principal source of radioisotopes for the world including upwards of two-thirds of the world's demand for technetium-99. Technetium-99 is currently used in about 30 million diagnostic procedures per year worldwide.

It is worth noting that NRX and NRU were not the only Canadian sources of Cobalt-60. Many years ago, AECL and Ontario Hydro designed Cobalt-59-loaded "adjuster rods" to replace, in some instances, the standard stainless steel neutron flux adjuster rods incorporated into CANDU reactor regulating systems. These "cobalt adjusters" have enabled the production of significant quantities of low specific activity Cobalt-60. The adjuster rods are removed during major maintenance outages.

In 1972, after 15 years of operation, the NRU reactor was shutdown for an extended maintenance outage due to the necessity to replace its calandria. This resulted in a serious interruption in radioisotope production particularly because technitium-99m had become the most widely used radioisotope for medical diagnostics. McMaster was aware of the planned outage and quickly offered to help. A three-year contract was negotiated with AECL's Commercial Products Division (CPD) under which the power level of the MNR was raised from 2MWt to 5MWt. The renewed availability of irradiated enriched uranium targets enabled CPD to further develop and to refine its molybdenum-99 extraction process.

The history of the 2007 and 2009 shutdowns of NRU is well known due to extensive media coverage and, more importantly, detailed and frequent status reports by AECL. Just prior to the June 19, 2009, announcement by the Government of Canada of the establishment of an Expert Review Panel on Medical Isotope Production, representatives of McMaster participated in hearings of the Parliamentary Committee on

Natural Resources to provide information indicating that the MNR could be transformed into a "high-volume isotope producer" at a cost of $30 million over five years. The Government did not pursue this option.

Triggered by the November 18 to December 16, 2007 shutdown of NRU, TRIUMF, the University of British Columbia and Advanced Applied Physics Solutions, Inc., with support from Natural Resources Canada convened a Task Force on Alternatives for Medical Isotope Production in 2008. The 28 members of the Task Force included Mr. David Tucker, Senior Health Physicist, McMaster University. The report of the Task Force, entitled "Making Medical Isotopes", was submitted to NRCan in November 2008.

The response to the Government's invitation to Canadian and international organizations to submit proposals regarding "new options to secure medium- to long-term supply of medical isotopes for the Canadian health system" proved to be very broad and prompt. I expect that McMaster will continue to be an important source of technical advice especially because of the expertise that it has developed in the production of Iodine-125.

One of the sometimes overlooked and perhaps not fully appreciated contributions that Harry Thode and his McMaster associates made to the CANDU program was in the resolution of the process control problems encountered at the Glace Bay and Port Hawkesbury heavy water production plants. The Glace Bay plant faltered due to a series of technical and managerial problems until eventually AECL assumed responsibility for major renovations and its operation. Port Hawkesbury also encountered a series of technical problems. Fortunately, AECL successfully assembled a steady-state computer simulation model integrating the entire operation of a heavy water production plant based on methods developed at McMaster. The model resulted in the determination of optimum settings of process system variables thereby enabling the operating staff to maximize production and to minimize the frequency and length of outages.

CONCLUDING REMARKS: RADIATION HORMESIS

Quite unfortunately, national and international nuclear regulatory agencies, radiological protection authorities and their governments continue to ignore the fallacy of the linear no threshold (LNT) hypothesis. This refusal to accept the extensive, multi-decade-long archival recording of epidemiological and research data refuting the validity of the LNT hypothesis has been a major factor in the tragedies of Chernobyl and Fukushima.

In 1989, three years after the series of failures that resulted in the destruction of Chernobyl Unit 4, the IAEA published an updated version of a pamphlet entitled "Facts About Low-Level Radiation". The pamphlet dwelt at length on such subjects as uncertainty about the effects of exposure to ionizing radiation at low dose and dose rate and what it termed "the low-level radiation controversy". It states: " ….. (this uncertainty) is because effects, if they exist at all, are masked by the normal occurrence of disorders which may or may not be due to radiation exposure".

The LNT hypothesis-based, universally accepted, recommendations of the International Commission on Radiological Protection prompted USSR authorities to predict, initially, that there would be about 4,000 excess cancer deaths as a result of Chernobyl and ordered the evacuation of about 135,000 persons living within a 30 km radius of the plant. Four months later, in August 1986, at an IAEA conference in Vienna, the Soviet Delegation tabled a revised estimate that about 200 of the 135,000 who were evacuated would die of cancer due to radiation exposure as a result of the accident or about 1% of the 17,000 persons who would die of cancer due to other causes. Prior to the end of the conference, the Soviet representatives conceded that their estimates of internal exposure via the food chain could be ten times too high.

What has not been documented is how many of the citizens of Belarus and Ukraine have suffered significant health effects as a result of being uprooted from their homes, their farms, their places of work, their towns and villages and their churches.

And then, a similar tragedy struck. On March 11, 2011, a massive earthquake occurred under the Pacific Ocean off the North-East coast

of Japan. The consequences of the earthquake, primarily due to the resulting tsunami, shocked the world and continue to be reported upon by the media, all too often technically incorrectly.

Without subsequent correction, the international media reported that a "tidal wave more than 14.2 metres in height" had struck Japan.

It was not a single wave.

The tsunami caused a rapid rise in sea level, particularly along the North-East coast of Honshu (the largest of the four islands that comprise a major part of the land mass of Japan) and the South-East coast of Hokaido (the northern-most of the four islands).
The sea level in proximity to the ten BWR unit, Fukushima-Daichi nuclear power station of the Tokyo Electric Company, was estimated to have risen about 14.2 metres.

In June 2012, the American Nuclear Society held its Annual Meeting in Chicago. One of the sessions, "The President's Special Session on Low Level Radiation and its Implications for Fukushima Recovery", attracted wide attendance. One of the participants, Dr. Wade Allison, Emeritus Professor of Physics, Oxford University, presented a paper entitled: "A Tragedy of Misunderstanding: There was No Major Radiation Disaster at Fukushima".

Another participant, Mr. Kazuaki Matsui, Executive Director, Institute of Applied Energy, Japan, stated that: "….. the earthquake and tsunami on March 11, 2011, left 25,000 dead, injured or missing. In contrast, there was probably minimal or no health effect from radiation from the damaged reactors. However, the ensuing evacuation disrupted more than 150,000 lives and has led to 13 suicides, along with 50 deaths of elderly evacuees. The prevalent widespread radiophopia has led to grotesque overreactions."

In a September 22, 2012 article in the Financial Post entitled "Thousands of Fukushima evacuees may be killed by severe stress", Lawrence Solomon (Executive Director of Energy Probe) made the following statements:

i) "According to Japanese government authorities, "disaster-related deaths" among the nuclear evacuees

number more than 700, a number that continues to rise. Most of the deaths were needless, a man-made disaster born of human ignorance and incompetence.";

ii) "These people died in a chaotic scramble to escape presumably deadly radiation. …….. Based on studies of other traumas involving relocations, the number of Fukushima evacuees who will die from the consequences of severe stress could number in the thousands; and

iii) "Radiation hormesis, if accepted by the public and adopted by emergency-preparedness authorities, would not only reduce the size of evacuation areas, it would also be a wet blanket for terrorists. Their perennial goal of taking out a nuclear reactor would lose its appeal, as would detonating a dirty bomb – the radiation lacing the bomb could act to save lives down the road, making it less deadly than a conventional bomb and costing terrorists one of their preferred instruments of mayhem."

From what I have learned to date, my understanding of radiation hormesis is that modest exposure to sunshine results in tanning of the skin and the in vivo synthesis (production) of vitamin D from cholesterol in the human and other species. Excess exposure to sunshine (a beneficial but potentially harmful component of which is ultraviolet radiation), particularly during cloudless (high rate of exposure) periods often results in "sunburn" (erythema of the skin). Low dose / low dose rate exposure to ionizing radiation stimulates the defenses of the human species (their immune systems).

In brief, low dose / low dose rate exposure to ionizing radiation is beneficial. The LNT hypothesis that all ionizing radiation, however low the exposure dose or dose rate, increases the probability of malignancy is false.

Perhaps McMaster might undertake a comprehensive study of radiation hormesis.