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Submission to

The Canadian Nuclear Safety Commission

on

The Proposed Transport of

16 Radioactive Steam Generators

by Bruce Power

to Sweden

by

The Canadian Coalition for Nuclear Responsibility

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September 28-29, 2010

Ottawa Ontario

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The Canadian Coalition for Nuclear Responsibility was founded 35 years ago.

CCNR believes that the Canadian population and Canadian political leaders deserve to be told the unvarnished truth about the dangers as well as the benefits of nuclear technology. We do not believe that this is being done at present by the nuclear industry or by CNSC, the regulatory agency.

Creative efforts are needed to demystify difficult scientific concepts and clarify the nature of the genuine risks that are associated with radioactivity, nuclear reactors, uranium mining, radioactive wastes, and the dangers of the inadvertent proliferation of nuclear weapons through the spread of civilian nuclear technology. Frankness and honesty are indispensable.

To foster a truly democratic decision-making process, and to ensure that the nuclear enterprise is politically accountable, we need an agency that is dedicated wholeheartedly to the public interest – not only protecting the health and safety of the public and the environment, but assisting us all to understand the nuclear issues from a public interest perspective.

We believe that the CNSC shouldn't be facilitating the nuclear industry to carry out actions which are not demonstrably in the public interest. We are opposed to the transport of 1600 tonnes of radioactive waste to Sweden for the purpose of recycling radioactively contaminated metal into scrap that is intended for unrestricted use, and the subsequent return of some 400 tonnes of the most radioactively contaminated portions overland to Bruce.

The CNSC has ample technical and procedural reasons for withholding permission for this shipment. First and foremost, the shipment exceeds the maximum recommended limits for radioactivity in any single shipment. It is our understanding that this would be the case even if the steam generators were shipped one at a time. This being so, the CNSC is not obligated to grant a licence to Bruce Power, and, in our view, should not do so.

Part 1 of our submission gives other reasons why a licence should not be granted to Bruce Power for this export of radioactive waste from Canada.

Part 2 provides a critique of the CNSC presentation to Owen Sound City Council on the subject of the proposed transport of 16 steam generators.

Part 1: Reasons for refusing to grant Bruce Power a licence

On behalf of the Canadian Coalition for Nuclear Responsibility, I call upon the CNSC to refuse to issue a licence to Bruce Power for the overland transport of 16 radioactive steam generators from the Western Waste Management Facility to Owen Sound, and for the shipment of those same 16 steam generators from Owen Sound to Sweden. CNSC staff admit that the proposed transport exceeds the radioactive limits for a single shipment.

Other reasons for refusing the licence are:

(1) No justification has been given for the transport in terms of reducing radioactive exposure to workers or the public or to the environment. In fact the transport will invariably increase all three types of exposure, given the fact that the metal in the steam generator will be disassembled, sand-blasted, and melted in order to bring about some slight economic benefits for the two companies involved.

The Canadian Nuclear Safety Act establishes the CNSC as a protector of the public interest and not as an adjunct of the nuclear industry. All unnecessary exposures to ionizing radiation are to be avoided unless there is some clear societal benefit. It is not the job of CNSC to help the industry make money at the expense of increased radiation exposures.

The following description of the benefits of Studsvik's services is taken from Studsvik's web page. Those benefits are expressed almost entirely in terms of saving money and improving public relations for the industry.

Waste Volume Reduction at Studsvik Nuclear AB January 2010
http://www.winsverige.se/arsmotet_2009/2010-01%20Studsvik%20Waste%20Treatment.pdf

Drivers and Customer Benefits

Optimal and final conditioning of LLW

- **Minimizing cost** for final disposal
- **Avoiding interim storage**, free up space for other business
- **Minimizing on-site waste treatment**
- Minimizing legacy waste and **reducing future unknown costs**
- Effective conditioning by volume reduction vs. large volume disposal causing higher **long term cost**

- Waste Volume Reduction & Recycling of valuable materials reduces environmental burden
- Create **good public impression** of the nuclear industry
- Long term sustainable strategy
- Waste volume reduction will prolong repository life time and **reduce cost**

The sole environmental consideration in this list of benefits is the claim that *"volume reduction and recycling of valuable materials reduces environmental burden,"* but this claim is not justified.

If the process of volume reduction requires atmospheric radioactive emissions during melting, radioactive dust and liquid effluents from the use of various decontamination methods, and radioactive residues ending up in consumer goods from the still-contaminated scrap metal for unrestricted use, then the environmental burden has been increased, not reduced.

(2) *There is an alternative plan for the steam generators which was laid out by Bruce Power in its 2006 Environmental Impact Statement for the Refurbishment of the Bruce A reactors and approved by the CNSC following the publication of the Screening Report in 2007. No reason has been given for deviating from this plan, other than the highly questionable assertion that Bruce Power will "reduce its environmental footprint" (by making it a global radioactive footprint?)*

BPEA page 3-30 Waste Handling:

There will be 16 old steam generators in total from Units 1 and 2 refurbishment and another 16 from Units 3 and 4 refurbishment. These will be transported and stored at the WWMF following removal…

BPEA Page 3-17

Non-radioactive wastes will be re-used or recycled to the degree possible…. [but] the steam generators will be sealed and transferred to the WWMF.

BPEA Page 3-17 [box 2 in middle column] **CNSC Page 25 [box 2 in right column]**

The steam generators will be processed and prepared to meet OPG's requirements for acceptance at the WWMF.

BPEA Page 3-17 [box 4 in middle column] **CNSC Page 25 [box 4 in right column]**

The steam generators will be sealed and transferred to the WWMF….

(3) Neither the Canadian Government nor the CNSC has ever adopted a policy that allows for the export or import of radioactive waste to or from another country. This licence would establish a precedent which could be used to justify further imports or exports of radioactive waste within a policy vacuum.

Indeed, the contract between Bruce Power and Studsvik calls for the transport of 32 radioactive steam generators, so this licence is just the first in a series of licence requests having to do with the export and import of radioactive waste.

Both Bruce Power and the CNSC have previously confirmed that the steam generators are in fact radioactive waste:

BPEA Pages 3-28 & 3-29

[The] steam generator replacement will generate LLW [low level waste] and ILW [intermediate level waste], including the steam generators themselves...

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***Both phases of the Project will produce radioactive waste. For the purposes of the assessment, "low level waste (LLW)"* consists of industrial items that have become slightly contaminated with radioactivity and are of no further use, but also *include the steam generators*, feeder pipes and insulation wastes.**

CNSC page 101

Issue [CNSC]: **At what point during the refurbishment will the steam generators be removed?**

Response [BP]: ***The steam generators* will be removed about halfway through the refurbishment activities. These *are considered low level waste*.**….

(4) Both Bruce Power and the CNSC staff seem to trivialize the penetrating gamma radiation from the radioactive steam generators, as there is little or no discussion of serious and potentially expensive efforts to limit the unnecessary exposures to a level as low as reasonably achievable – a phrase which is too often used to limit the cost to the licensee rather than the radiation exposure to the worker.

In a 2002 press release on used steam generators by the US Dept of Energy, describing a report entitled **Shield design guide developed for construction of old steam generator storage facilities**, we read:

> "In order to properly store decommissioned steam generators, mausoleums or storage vaults are designed to minimize the radiation release and exposure to plant personnel and the public. The focus of the design guide is to reduce the gamma radiation exposure through the use of concrete walls, floors and roofs. The guide also addresses the more difficult problem of long-range skyshine dose rates, or the radiation escaping the storage vaults and scattered in the atmosphere, and then reflected back to personnel at ground level."
>
> DOE News Release, July 30, 2002,
> http://newsdesk.inl.gov/press_releases/2002/07-30steam_generator.htm

The lack of any such discussion in the Bruce Power application and in the CNSC staff document, combined with dismissive statements made publicly about the radiation levels from the steam generators by representatives of the licensee, do not inspire confidence. CNSC should not grant a licence when the safety culture of the licensee is clearly inadequate. This is the company that last year exposed over 200 workers to alpha contamination which they did not take the trouble to measure until it was too late.

(5) *Both Bruce Power and the CNSC staff seem to misrepresent the radioactive contents of the steam generators, by adopting a slap-dash unscientific approach when characterizing the radioactive inventory. Numerous important radionuclides are completely absent from the tables, and there is no indication of the very large error bands associated with the activities in the inventory in Table 1.*

Not only does Table 1 fail to list any of the four uranium isotopes, but it also omits any mention of such important nuclides as

niobium-95 (present to the tune of about 33,000 becquerels),
ruthenium-106 (responsible for about 70,000 becquerels),
plutonium-241 (representing as much as 100,000 bequerels),
yttrium-90 (responsible for another 47,000 becquerels)

These four isotopes alone, if added to CNSC's list of nuclides in a Unit 1 steam generator, would almost double the estimated radioactive inventory.

(The figures in the previous paragraph were all derived from Bruce A data in the table on page 50 of OPG's August 2008 Report entitled "Reference Low and Intermediate Level Waste Inventory for the Deep Geologic Repository" http://www.nwmo.ca/uploads_managed/MediaFiles/539_ReferenceLowandIntermediateWasteInventoryfortheDGR.pdf)

The point is that nobody really knows the radioactive inventory of the steam generators. Bruce Power and CNSC staff do themselves no credit by giving guesstimates without any methodology or error bands or disclaimers attached.

In the absence of any reliable radioactive inventory, it is of course impossible to know what percentage of that inventory is ultimately returned to Bruce Power by Studsvik. The difference between the radioactive inventory sent to Sweden and the radioactive inventory returned to Bruce represents the amount of radioactive waste that has been dispersed into the air, into the water, into the workers, or into consumer goods – but no one will ever know what that amount is. In the worst-case scenario, one might say that it's the perfect crime.

CNSC would be remiss in its duty to the population of Canada and the world, and CCNR believes it would be derelict in its duty as a regulatory agency, to licence such an unquantifiable release of radioactive waste material. If Bruce Power believes that there is non-radioactive metal in those steam generators that can be safely and hygienically recycled, let them do the separation on-site so that all of the radioactive waste material remains isolated, contained, and managed properly for the long term, and only non-contaminated metal is removed from the site.

CNSC Page 75

Some of the waste is directly recyclable; however, the largest waste quantities are associated with the pressure-tube/calandria-tube replacement and *steam generator replacement, since the replaced components cannot be recycled and must be disposed of at the WWMF*….

(6) There is no market for radioactively contaminated metal. Nobody wants it. In fact the United Nations and other world bodies have expressed great concern over the alarming increase of radioactivity in scrap metal, which is of no benefit to anybody – except Studsvik.

From the Executive Summary of a 2006 United Nations publication entitled "Recommendation on Monitoring and Response Procedures for Radioactive Scrap Metal", we read:

> Radioactive substances can become associated with scrap metal in various ways and if not discovered they can be incorporated into steel and non-ferrous metals through the melting process. This can cause health hazards to workers and to the public as well as environmental concerns and it can also have serious commercial implications. Numerous incidents have occurred in recent years involving the discovery of radioactive substances in scrap metal and, in some cases, in metal from the melting process. These incidents have proved to be very costly in relation to the recovery and clean-up operations required but also in terms of the potential loss of confidence of the industry in scrap metal as a resource.

Here is what the Steel Manufacturer's Association has to say about radioactively contaminated scrap metal – taken from the following : http://www.steelnet.org/public_policy/public_policy_environment.html

> **No Contaminated Scrap from Decommissioned Facilities**
>
> For the past 25 years the US Department of Energy (DOE) has maintained a policy of "free release" of obsolete equipment and materials at weapons production and research facilities across the country. Free release means that the material is cleaned, and if necessary, declassified, and then released into the stream of commerce for unrestricted use.
>
> In the past, the amount of such material released was not significant. Following the end of the Cold War, DOE is decommissioning and dismantling several facilities across the nation and expects to release hundreds of tons of scrap metal from these facilities for recycling at steel companies without any dose-based clearance standards.
>
> SMA member companies have not, and will not, accept scrap that is known to be radioactively contaminated.
>
> SMA members would be the primary intended recipients of this scrap, much of which is radioactively contaminated, and stand to suffer serious economic injury from this policy. SMA members are trying to keep

radioactivity out of their mills and therefore oppose free release. DOE's policy is simply inequitable and shortsighted and could develop into a public policy disaster.

Free release of radioactive scrap could adversely affect the marketability of steel products made from recycled scrap. The public perception is that any level or type of radioactivity is unsafe. Metal recycling industries have worked hard to build public confidence in the safety and utility of products made from recycled metal. This confidence would be lost if the public, rightly or wrongly, perceives such products to be unsafe. For this reason, SMA member companies have not, and will not, accept scrap that is known to be radioactively contaminated.

Furthermore, the unrestricted release of radioactively contaminated metal from nuclear facilities for recycling would tarnish the image of recycling, and potentially lead consumers to avoid products made of steel, especially those with a high recycled scrap steel content.

DOE should adopt a policy of restricted release of scrap, provided the scrap meets specified health-based standards. Restricted release should be specifically limited to either of the proposed eligible uses:

> Recycling or recovery at a dedicated, licensed facility for use only at an NRC-licensed fuel cycle facility or at nuclear facilities operated by the DOE where the use of low level radioactive material is not an issue; or
>
> Disposal into licensed radioactive waste landfills, or into municipal or industrial landfills, as long as the material meets the specified health-based levels. If these levels are met, the landfill need not be licensed as a radioactive waste landfill.

DOE should not authorize any release of material from nuclear facilities until it establishes health-based standards that reflect sound science. NRC is currently evaluating whether and how to establish dose-based clearance levels that will adequately protect health and safety. It is expected that DOE would follow NRC's standards. It is prudent public policy that material not be released until firm, publicly accepted standards and procedures for attaining and measuring compliance are developed through the standard setting process.

CNSC should not be granting a licence to allow the further radioactive contamination of the world's scrap metal supplies.

(7) The risks of accidental releases from radioactive steam generators has not been adequately assessed. In the original 2006 EA, the CNSC identified the dropping of a steam generator as one of the two credible scenarios that could result in on-site and off-site radiation exposure to workers, the public and the environment. Given the much more ambitious plan now before the CNSC, another environmental assessment would be required to adequately characterize the risks of this operation – which would have to extend to the Baltic Sea area and include the Studsvik operations.

BPEA Page 3-37

***A transportation-related accident during the transfer of . . . the old steam generators* between Bruce A and the WWMF may occur *leading to a radiological contamination that could reach on-site workers and members of the public.... Materials present as a gas or as very fine powders are more likely to escape.... Carbon-14* is the most abundant radionuclide and would probably be present either as a gas or as a very fine particulate....**

BPEA Page 3-18 **CNSC Page 25**
[box 3 in middle column] ***[box 6 in right column]***

Based on the screening of possible conventional malfunction and accident scenarios, it was determined that two events are credible, namely a *steam generator drop* and a refurbishment waste container drop, both during loading/uploading operations.... *Other postulated potential accidents are found to have very limited potential to result in radiological consequences*....

[from CNSC page 32 : containers "are designed to survive a 4 metre drop with minimal loss of contents." Is the same true of steam generators?]

[from CNSC page 65 : these are the ONLY two malfunctions or accident scenarios "involving nuclear materials" that are credible during the refurbishment phase}

(8) The characterization of the steam generators as "low level radioactive waste" and therefore suitable for decontamination and recycling is misguided and dangerously unrealistic. In fact, the very long-lived high-toxicity alpha emitters present inside the steam generators, all of them transuranic actinides, require that the SGs be classified as TRU [transuranium-contaminated wastes] or at least as GTCC [Greater than Class C] radioactive wastes. Such wastes are suitable only for isolation and perpetual storage under strict control.

According to CNSC data (Table 1), about 15 percent of the radioactivity contained within each Steam Generator is due to transuranic isotopes. These are all high-toxicity man-made alpha-emitters whose atomic numbers are greater than 92, the atomic number of uranium.

The majority of these transuranic isotopes have exceedingly long half-lives and therefore constitute a potential long-term threat to the environment:

Transuranic Element	Half-Life	Megabecquerels (for all 16 SG)
Americium-241	430 years	234 400
Americium-243	7 400 years	272
Curium-244	18 years	74 560
Neptunium-237	2 100 000 years	13
Plutonium-238	88 years	62 480
Plutonium-239	24 400 years	84 800
Plutonium-240	6 500 years	120 640
Plutonium-242	380 000 years	122
		=======
		577 287

The activities given above are calculated for all 16 steam generators -- 8 from Unit 1 and 8 from Unit 2 -- using the figures given by CNSC.

In terms of disintegrations per second, the transuranic isotopes correspond to 577 287 megabecquerels; that is 15.7 percent of the total activity in all 16 Steam Generators, given by CNSC as 3.67 terabecquerels.

Each alpha disintegration is much more energetic -- usually by about one order of magnitude -- than a gamma disintegration [e.g. 5 MeV per alpha particle compared with 500 keV for a gamma photon or beta particle]. Thus the transuranic isotopes in the Steam Generators represent about twice as much ionizing energy as that of all the gamma and beta emitters combined -- 577 287 x 5 = 2 886 435 Mev of ionizing energy from alpha emitters, compared with 3 092 713 x 0.5 = 1 546 360 Mev of ionizing energy from gamma and beta emitters. In fact, the transuranics represent about two-thirds of the total ionizing energy inside the steam generators.

It is also well known that, per unit of ionizing energy deposited in living tissue, alpha particles are about 20 times more biologically damaging than gamma rays or beta particles. Thus, in terms of risks to human health and to the environment, the alpha-emitting contents of the steam generators are the predominant risk by far.

For this reason, we believe that these steam generators should not be classified as low level radioactive waste or as SCO-1 wastes, but as TRU wastes -- Transuranium Contaminated Wastes -- unsuitable for anything but permanent storage at a designated waste storage site. Such wastes should not be recycled and sold as scrap metal for unrestricted use. Nor should they be transported through the Great Lakes for that purpose.

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http://www.epa.gov/rpdweb00/docs/radwaste/402-k-94-001-tru.html

Transuranic Radioactive Waste

Sources and Volume

"Transuranic" refers to atoms of man-made elements that are heavier (higher in atomic number) than uranium. The most prominent element in most TRU waste is plutonium.

Some TRU waste consists of items such as rags, tools, and laboratory equipment contaminated with radioactive materials. Other forms of TRU waste include organic and inorganic residues or even entire enclosed contaminated cases in which radioactive materials were handled.

Some TRU waste emits high levels of penetrating radiation; this type requires protective shielding. However, most TRU waste does not emit high levels of penetrating radiation but poses a danger when small particles of it are inhaled or ingested. The radiation from the particles is damaging to lung tissue and internal organs. As long as this type of TRU waste remains enclosed and contained, it can be handled safely.

Another problem with TRU waste is that most of its radioactive elements are long-lived. That is, they stay radioactive for a long time. For example, half of the original amount of plutonium-239 in the waste will remain harmful after 24,000 years. Disposal must be carefully planned so the waste poses no undue threat to public health or the environment for years to come.

TRU : Site Selection for Storage and Disposal

In the past, much of the TRU waste was disposed of similarly to low-level radioactive waste, i.e., in pits and trenches covered with soil. In 1970, the Atomic Energy Commission (predecessor to the DOE) decided that TRU waste should be stored for easy retrieval to await disposal at a repository. Federal facilities in Washington, Idaho, California, Colorado, New Mexico, Nevada, Tennessee, South Carolina, Ohio, and Illinois are currently storing TRU waste.

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The following web site defines GTCC wastes: Greater-Than-Class-C.
http://www.gtcceis.anl.gov/guide/gtccllw/index.cfm

NRC Category	Description	Disposal Method
Class A	Least hazardous - short & long-lived waste that will not endanger inadvertent human intruder beyond 100 years	Near-Surface
Class B	More hazardous - short-lived wastes that will not endanger inadvertent intruder beyond 100 years	Near-Surface with 300 year waste stability
Class C	More hazardous short and long-lived wastes that will not endanger inadvertent intruder beyond 500 years	Near-Surface with 300 year waste stability, and greater depth or 500 year intruder barrier
Greater-Than-Class C	Most hazardous of LLRW - dangerous to inadvertent intruder beyond 500 years. Must be disposed in geologic repository unless alternate method proposed by DOE and approved by NRC	To be determined

Even if the steam generators do not fall into the technical definition of TRU wastes, they would at any rate be GTCC wastes and therefore not suitable for recycling -- only suitable for long-term isolation and management. No licence for transport and recycling should be given.

Part 2: A Critique of CNSC's Presentation to Owen Sound City Council
on July 26 2010

Foreword:

Bruce Power plans to transport 16 Radioactive Steam Generators (each weighing more than 100 tonnes) overland to Owen Sound, and then by ship through Georgian Bay, Lake Huron, Lake St-Clair, Lake Erie, Lake Ontario, the St. Lawrence River, the Atlantic Ocean and the Baltic Sea to Sweden.

The objective of this operation is to have 90 % of the contaminated metal melted down and sold as "clean" scrap metal for unrestricted use in commercial products of all kinds. Such an operation is not authorized in North America, but it is taking place in three countries: Sweden, Ukraine and Russia, where the regulations are more lax.

In its 2005 Environmental Assessment of the Bruce A Reactor Refurbishment Project, Bruce Power states that the old steam generators are radioactive waste, not suitable for recycling, and as such they will be stored on site as radioactive waste in the Western Waste Management Facility (WWMF) owned by Ontario Power Generation (OPG), a provincially-owned crown corporation which is also the owner of the Bruce reactors and the old steam generators.

The Canadian Nuclear Safety Commission made a presentation to the Owen Sound City Council on Monday, July 26, 2010, about the proposed transport of radioactive steam generators.

The following critique of the CNSC presentation is intended to help citizens understand some of the important issues surrounding the transport of these corroded radioactive boilers (the steam generators) through our precious fresh-water and marine waterways.

I take full responsibility for any errors and will be happy to correct them if they are pointed out. Feel free to disseminate this document or to quote from it. No special permission is required.

Gordon Edwards, Ph.D., August 6 2010.

The CNSC Presentation to Owen Sound City Council

On July 26 2010, Mr. Ramzi Jammal, Executive Vice-President and Chief Regulatory Officer of the Canadian Nuclear Safety Commission, made a presentation to Owen Sound City Council entitled "***Transport of Steam Generators to Sweden***". His powerpoint slides (in pdf format) are found at:
http://www.nuclearsafety.gc.ca/eng/pdfs/Presentations/VP/2010/2010_07_26_Ramzi_Jammal_Transport_of_Steam_Generators_to_Sweden-Owen_Sound_e.pdf

While Mr. Jammal's presentation provides background about the CNSC, steam generators, and radiation exposures, it does not address important questions regarding the potential risks to humans and the environment from the steam generator transport project. In what follows I have identified a number of serious oversights in the CNSC's reassuring presentation.

Oversight #1. Lack of Context.

Mr. Jammal does not mention that CNSC conducted an Environmental Assessment in 2005-2007 related to the refurbishment of the Bruce A nuclear reactors. In the EA documents Bruce Power states that old steam generators are classified as low level radioactive waste, and as such will not be transported off site but will be moved along on-site roads to OPG's Western Waste Management Facility (WWMF) for permanent storage. *[See EA documents at* http://www.brucepower.com/pagecontentU12.aspx?navuid=3041 *.]*

In those same EA documents, Bruce Power maintains that only non-radioactive materials are suitable for re-use or recycling, and that radioactive components -- such as old steam generators -- can not be recycled "for safety and environmental reasons". *[See Appendix 1.]*

It is a matter of record that CNSC concurred with those statements by Bruce Power and approved the plan laid out by Bruce Power at that time.

Bruce Power's current plan to transport the old steam generators along public roads to Owen Sound, then ship them to a plant in Sweden nearly halfway around the world, where 90 percent of the contaminated metal would be recuperated and released as scrap metal for unrestricted use – this represents a radical departure from Bruce Power's previous plans and contradicts some of Bruce Power's previous statements in the official EA.

This context is important. Why is it missing from CNSC's presentation?

Oversight #2. Incomplete Description of CNSC Mandate.

In slide #2, Mr. Jammal's presentation accurately describes two of the three responsibilities of the CNSC as laid down in the Nuclear Safety Act: to protect the health, safety and security of persons and the environment, and to respect Canada's international commitments vis-à-vis nuclear energy.

However, the law also requires CNSC "to disseminate objective scientific information" on the nature of the hazards associated with facilities, materials and activities licenced by the CNSC. This responsibility is not referred to anywhere in the CNSC presentation.

The Canadian Coalition for Nuclear Responsibility (CCNR) has found that the CNSC is often deficient in fulfilling the latter obligation. In our judgment, little or no objective scientific information has been disseminated or made readily available to the public by the CNSC about the specific hazards associated with radioactive materials such as the nuclear contaminants inside the old steam generators.

On July 14, I addressed the following questions to the CNSC, asking for a prompt reply:

(1) who is the designated officer that will rule on the licence application of Bruce Power to ship the old steam generators to Sweden?

(2) what other shipments of radioactive steam generators have been made from North America to Sweden?

(3) what radionuclides are contained inside the steam generators, and how many becquerels of each are there in the most contaminated of the steam generators, including alpha-emitters and beta-emitters.

On July 15, I asked the CNSC to provide CCNR with the maximum surface contact dose (radiation dose) from the most contaminated of the 16 steam generators that Bruce Power wishes to ship this fall.

It is now more than two weeks since I first asked these questions. More questions were posed by me the following week, based on excerpts from the 2005 EA. There are no replies to any of my queries as of July 30.

Does CNSC accept its duty to disseminate objective scientific information?

Oversight #3. Lack of Transparency.

In slide #4, Mr. Jammal claims that the CNSC operates as a quasi-judicial tribunal with independent Commission members and public hearings that are webcast. In the view of many Canadians, the independence of the Commission was destroyed when its chair, Linda Keen, was fired in 2008 for enforcing safety regulations enshrined in licensing documents. At any rate, for this particular licence application, there has been no quasi-judicial public process, nor have the Commission members deliberated on the matter, nor has the process included public hearings that are webcast.

The decision to approve Bruce Power's licence application, we have been told, will be delegated to one person: the Designated Officer (DO). The licensing process in such a case would be far from transparent. The CNSC should have realized beforehand that the transport of radioactive waste – even low-level radioactive waste – is an issue of great public concern, not a routine matter to be settled quietly behind closed doors.

In the 1990s, a decision to transport radioactively contaminated soil from a Scarborough subdivision to a military base met with an opposition so strenuous that the plan had to be abandoned.

The decision to transport low-level radioactive waste from Port Hope to a willing Ontario host community led to the formation of a federal agency called the Siting Task Force, which spent three years and millions of taxpayer dollars in a vain attempt to move wastes away from Lake Ontario. Over $250 million has now been allocated to consolidate and store those wastes close by Port Hope, with minimal transport of radioactive materials.

Given this history, and recognizing the precedent that would be established by transporting radioactively contaminated reactor wastes through the Great Lakes for the first time, we believe the CNSC has failed to learn from the past by not setting up a suitable public process to address the Bruce plan.

Bruce Power's plan could impact not only citizens of Ontario, Quebec, the Maritimes and the U.S.A., but also First Nations and Tribes along the transportation route, as well as Swedes and others concerned about potential contamination of the Atlantic Ocean or the Baltic Sea -- especially since Bruce Power will transfer to Studsvik all responsibility (and liability for accidents?) for the steam generators, once loaded on an ocean-going ship.

Oversight #4. Competency in Health Matters.

No doubt the CNSC employs many highly qualified personnel (slide #6) including lots of professional engineers. But the health sciences are not strongly represented in CNSC. Even though the health of people and the environment is its central mandate, CNSC has no Health Department.

The nuclear industry has always been dominated by engineers and physical scientists, and the same appears to be true for the regulatory agency. Expertise in engineering is essential, but there is cause for concern when health considerations and health expertise receive short shrift.

Recently, hundreds of workers involved in the refurbishment of the Bruce A reactors were internally contaminated with alpha radiation by inhaling an invisible radioactive dust coming from the corroded pipes. Many were told they needed no protective clothing or other safety equipment for the job because measured levels of radioactivity were considered insignificant.

The supervisors evidently did not understand that alpha-emitting radioactive materials are among the most radiotoxic materials known, although they give off non-penetrating radiation and are often difficult to measure.

The family of alpha-emitting materials includes radon gas, one of the most powerful carcinogens on earth; radium, which killed hundreds of people long before the first reactors were built; polonium-210, used to murder Alexander Litvinenko and considered responsible for up to 90 percent of the deaths attributed to cigarette smoking; and plutonium, which has a fearsome reputation as a highly toxic radioactive substance.

According to reports, most of the workers at Bruce and even most of the supervisors knew little or nothing about alpha radiation as a threat during refurbishment. As a result, hundreds of men are internally contaminated with long-lived radioactive materials -- a body burden for years to come.

This incident has an eerie resemblance to an earlier one, where workers at Pickering were contaminated with radioactive carbon-14 dust and tracked the contamination into their homes for weeks before anybody noticed. Bedclothes and furniture were removed from homes and disposed as radwaste.

In both these cases, the harmful radioactivity was not detected by ordinary monitoring equipment. Alpha rays have very short tracks, and the same is true of the weak beta rays from carbon-14., so both are easily missed by the monitors. Inside the body, however, alpha rays are about 20 times more effective in causing cancer and other diseases, per unit of energy deposited, than either penetrating gamma rays or intermediate level beta rays.

Moreover, the alpha emitters found in a nuclear reactor generally have very long half-lives. Plutonium-239 has a 24,000 year half-life; neptunium-237 has a half-life of two million years. Even carbon-14, a beta-emitter, has a 6,000 year half-life, and it can enter freely into the chemical structure of organic molecules including DNA molecules.

These are among the materials that one might find in the primary cooling circuit of a nuclear reactor, and it is highly likely that they would be found as well inside an old steam generator. But the presence of these materials inside cannot be detected by measurements made from outside.

Oversight #5. Contamination Levels.

The Canadian Coalition for Nuclear Responsibility believes that citizens are entitled to know the facts about radioactive contamination, and that CNSC has a responsibility to provide those facts in an objective scientific manner.

It is not truly objective or scientific to say (slide #16) that the contamination levels in a used steam generator are "low". Low compared to what? Compared to a kitchen counter in a normal household? Compared to pressure tubes from the reactor core that must be shielded and stored for centuries?

On page 3-37 of Bruce Power's 2005 EA document, we read the following:

Accident Scenario: ***A transportation-related accident during the transfer of . . . the old steam generators between Bruce A and the WWMF may occur leading to a radiological contamination that could reach on-site workers and members of the public***.... ***Materials present as a gas or as very fine powders are more likely to escape***....

. . . and on page 3-38 of the same EA document, we read:

Although the steam generator is a potential source for release of some radioactivity due to a seal rupture, several factors limit the amount of radioactivity that would be released. Since there will be no volume reduction step, the majority of radioactivity will remain in a tightly sealed adherent film, which is spread out over the internal surfaces. Therefore, the size of the steam generator will limit the amount of radioactivity that would be released if a seal fails.

The CNSC is supposed to represent the interests of people at risk more than the interests of the nuclear industry. Shouldn't they be explaining the nature of the radioactive contamination inside the steam generators?

Aren't there dozens of different radionuclides involved? Is there a list? Can we be told which ones emit alpha, or beta, or gamma, or neutron radiation? Or which ones can be released as a gas or as a powder? Or which ones are sealed in an "adherent film" – and how can we tell that they ***are*** sealed?

Citizens should be told that some radioactive materials emit non-penetrating radiation that cannot be detected from outside the steam generator, but are biologically harmful when inhaled, ingested, or absorbed through the skin.

CNSC should give the Becquerel count (disintegrations per second) for each radioactive contaminant, or else admit that they do not know the exact level of contamination in the 5000 tubes inside each vessel. [See appendix 2.]

Oversight #6. Radiation Shielding.

Too often citizens are given soothing reassurances that are short on facts.

It is true, for example (slide #16) that most of the radioactive contamination in a steam generator is "confined to the inside"; however it is not true that the outside is free of contamination, to the best of our knowledge.

A video of the removal of a Bruce A steam generator shows that there is external contamination, as workers repeatedly wipe the outside surface to remove as much radioactivity as possible, but the decontamination is not perfect. [See http://www.youtube.com/watch?v=8QnIiUVNdOc&feature=related]

Accordingly, on page 3-38 of the 2005 EA we read:

Screening of Postulated Radiological Malfunctions and Accidents: Steam generators will not be moved over sensitive buildings or equipment. Activities will not be carried out during inclement weather (i.e. gusty wind conditions)….

Nor is it true that "because the steam generators are sealed, movement is safe." (slide #27) From the Bruce EA and the CNSC Review of that EA:

Based on the screening of possible conventional malfunction and accident scenarios, it was determined that two events are credible, namely a steam generator drop and a refurbishment waste container drop, both during loading and uploading operations…. Other postulated potential accidents are found to have very limited potential to result in radiological consequences….

On page 65 of the CNSC Review document, we read that these are the only two malfunctions or accident scenarios "involving nuclear materials" that are credible during the refurbishment of the Bruce reactors.

These accident scenarios are limited to on-site operations only, because, as it is stated on page 3-17 of the EA (and repeated throughout the EA):

Non-radioactive wastes will be re-used or recycled to the degree possible…. [but] the steam generators will be sealed and transferred to the WWMF.

Evidently the current plan to transport the steam generators along off-site roads, off-load them in Owen Sound, load them onto an ocean-going ship and then sail them through the Great Lakes, along the St. Lawrence River, and across the Atlantic Ocean to Sweden, offers many more opportunities for accidents and numerous potential drop scenarios that were never considered in the original EA or the CNSC Review of that EA.

It is sobering to realize that nuclear operators elsewhere are much more concerned about the external radiation dose from used steam generators even in the absence of any malfunction or accidents. From a 2002 Press Release of the U.S. Department of Energy we read:

In order to properly store decommissioned steam generators, mausoleums or storage vaults are designed to minimize the radiation release and exposure to plant personnel and the public.

The focus of the design guide is to reduce the gamma radiation exposure through the use of concrete walls, floors and roofs. The guide also addresses the more difficult problem of long-range skyshine dose rates, or the radiation escaping the storage vaults and scattered in the atmosphere, and then reflected back to personnel at ground level.

To what extent the Bruce steam generators resemble the U.S. steam generators is unclear, but surely CNSC has an obligation to discuss what gamma radiation shielding, if any, is considered necessary for the storage, overland transport and shipment of the Bruce steam generators.

Oversight #7. "Safe" Radiation Levels.

CNSC refers to its "safe dose limits" (slide 21) that have been adopted from the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA), without informing people that neither of these international bodies believe that those dose limits are safe. We feel CNSC is not giving objective scientific information on this matter.

In a 2007 press release announcing the publication of the U.S. National Academy of Sciences Report on the Biological Effects of Ionizing Radiation, (BEIR-VII) we read:

WASHINGTON (June 2007) — A preponderance of scientific evidence shows that even low doses of ionizing radiation, such as gamma rays and X-rays, are likely to pose some risk of adverse health effects, says a new report from the National Academies' National Research Council.

"The scientific research base shows that there is no threshold of exposure below which low levels of ionizing radiation can be demonstrated to be harmless or beneficial," said committee chair Richard R. Monson, associate dean for professional education and professor of epidemiology, Harvard School of Public Health, Boston.

The International Commission on Radiological Protection (ICRP) makes the same point in a publication that is featured on their web site:

It [is] impossible to make a clear distinction between 'safe' and 'dangerous', a fact that causes problems in explaining the control of radiation risks. The major policy implication . . . is that some finite risk must be accepted at any level of protection. Zero risk is not an option.
http://www.icrp.org/docs/Histpol.pdf

Conclusion

It should be a matter of concern that the CNSC, the one agency in Canada responsible for protecting citizens and the environment from the potentially harmful effects of atomic radiation and radioactive materials, has devoted so much effort in this public presentation to reassuring people without informing them about any of the legitimate concerns that do exist.

How does the CNSC view its legal obligation to disseminate objective scientific information about the nature of the hazards associated with licenced nuclear facilities and nuclear materials? If the CNSC is content to merely echo the views of the nuclear industry, then who is responsible for educating and informing the public about the nature of radioactive materials, the biological effects of exposure to atomic radiation, and the potential impacts of nuclear accident scenarios?

There are larger questions involved here that go beyond the CNSC's legal mandate as a regulatory body. They are policy questions -- issues that are fundamentally political in the best and most inclusive sense of the word.

Should we be allowing shipments of radioactive waste materials from dismantled or refurbished nuclear reactors to be transported through the Great Lakes and St Lawrence Seaway? Should we be allowing the dissemination of radioactively contaminated materials into consumer products by releasing contaminated scrap metal for unrestricted use?

A growing number of Non-Governmental Organizations, aboriginal groups, political representatives, and ordinary citizens are saying, "No." These are matters that cry out for public discussion and political debate.

Gordon Edwards, Ph.D., Montreal, July 30, 2010.

APPENDIX 1: Quotations from

Official Environmental Assessment Documents

about

Radioactive Steam Generators

Bruce Power is a privately owned company. It leases eight nuclear power reactors from Ontario Power Generation, a company that is wholly owned by the Government of Ontario.

In 2005, Bruce Power submitted an Environmental Impact Statement to the federal nuclear regulatory agency, the Canadian Nuclear Safety Commission (CNSC), detailing its plans to "refurbish" two of the Bruce nuclear reactors, at a cost of more than five billion dollars.

In it Bruce Power describes the 16 used steam generators that have been replaced as "radioactive waste" and asserted that these bulky pieces of contaminated equipment will be stored on-site as radwaste.

But Bruce Power now plans to send the 16 steam generators, about 1700 metric tones altogether, to Sweden, where the radiation-laced metal will be melted down and about 90 percent of it will be sold as scrap metal for unrestricted use. The remaining 10 percent will be returned to Bruce Power for long-term radwaste management.

A large and growing public opposition to this plan is based on two main concerns: that nuclear reactors wastes not be allowed to be transported on the Great Lakes and St. Lawrence River, and that radioactive wastes not be disseminated into consumer products.

Gordon Edwards, Ph.D., President,
Canadian Coalition for Nuclear Responsibility
August 2010

The initials "CNSC" and "BPEA" refer to the following documents respectively.

Canadian Nuclear Safety Commission Screening Report on Environmental Assessment of the Bruce A Refurbishment

March 2006

Available at http://www.brucepower.com/uc/GetDocument.aspx?docid=2226

Bruce Power Environmental Assessment Study Report, Bruce A Refurbishment – Volume 1: Main Report

December 2005

Available at http://www.brucepower.com/uc/GetDocument.aspx?docid=2199

Point #1: The steam generators are a form of radioactive waste.

CNSC Page 24

Both phases of the Project will produce radioactive waste. For the purposes of the assessment, "low level waste (LLW)" consists of industrial items that have become slightly contaminated with radioactivity and are of no further use, but also ***include the steam generators***, feeder pipes and insulation wastes.

BPEA Page 3-31

As noted, ***refurbishment activities are expected to generate LLW [low level waste] and ILW [intermediate level waste] including*** pressure tubes and calandria tubes, ***the old steam generators*** and miscellaneous components.

BPEA Page 3-29

The ***steam generator replacement will generate LLW [low level waste] and ILW [intermediate level waste], including the steam generators themselves***….

CNSC Page 101

Issue: At what point during the refurbishment will the steam generators be removed?

Response: ***The steam generators*** will be removed about halfway through the refurbishment activities. These ***are considered low level waste***.

Point #2: The steam generators are to be stored on-site at WWMF.

NOTE: The exact same wording appears in both of the documents cited above….

BPEA Page 3-17 **CNSC Page 25**
[box 2 in middle column] ***[box 2 in right column]***

The ***steam generators will be processed and prepared*** to meet OPG's requirements ***for acceptance at the WWMF***.

BPEA Page 3-17 **CNSC Page 25**
[box 4 in middle column] ***[box 4 in right column]***

The ***steam generators will be sealed and transferred to the WWMF***….

BPEA Pages 3-28 & 3-29

Following removal, the ***steam generators will be temporarily stored on-site***, prepared to ensure that they meet OPG's requirements for acceptance at the WWMF, lifted onto transporters with a temporary gantry system ***and then transferred to the OPG's WWMF***.…

BPEA page 3-30

Waste Handling: This includes ***preparation of removed steam generators for transportation . . . loading of old steam generators onto multi-wheeled transporters; and transportation of steam generators to OPG's WWMF. There will be 16 old steam generators in total from Units 1 and 2 refurbishment and another 16 from Units 3 and 4 refurbishment. These will be transported and stored at the WWMF following removal….***

Point #3: The steam generators are potential sources of exposure.

From CNSC Page 31

Radiological Malfunctions and Accidents, which are ***events that involve radioactive components*** (i.e. processing, handling and storing nuclear wastes; ***removal and preparation of steam generators for transportation)*** and the ***potential for release of radioactivity***.

BPEA Page 3-37

Accident Scenario: ***A transportation-related accident during the transfer of . . . the old steam generators*** between Bruce A and the WWMF may occur ***leading to a radiological contamination that could reach on-site workers and members of the public***.… ***Materials present as a gas or as very fine powders are more likely to escape***….

BPEA Page 3-38

Screening of Postulated Radiological Malfunctions and Accidents

Steam generators will not be moved over sensitive buildings/equipment. ***Activities will not be carried out during inclement weather (i.e. gusty wind conditions)….*** Although ***the steam generator is a potential source for release of some radioactivity*** due to a seal rupture, several factors limit the amount of radioactivity that would be released. Since there will be no volume reduction step, the majority of radioactivity will remain in a tightly sealed adherent film, which is spread out over the internal surfaces. Therefore, ***the size of the steam generator will limit the amount of radioactivity that would be released*** if a seal fails.

CNSC Page 101

Issue: How will you minimize the amount of ***contamination released to the environment when the steam generators are removed***?

Response: … the removal of steam generators will be ***completely segregated from the ongoing operations***…..

BPEA Page 3-18 ***[box 3 in middle column]***

CNSC Page 25 ***[box 6 in right column]***

Based on the screening of possible conventional malfunction and accident scenarios, it was determined that two events are credible, namely a ***steam generator drop*** and a refurbishment waste container drop, both during loading/uploading operations…. ***Other postulated potential accidents are found to have very limited potential to result in radiological consequences***….

[from CNSC page 32 : containers "are designed to survive a 4 metre drop with minimal loss of contents"]

[from CNSC page 65 : these are the ONLY two malfunctions or accident scenarios "involving nuclear materials" that are credible during the refurbishment phase}

Point #4: The metal in steam generators cannot be recycled.

BPEA Page 3-17

Non-radioactive wastes will be re-used or recycled to the degree possible…. The ***steam generators will be sealed and transferred to the WWMF***.

BPEA Page 4-55

Radioactive wastes from Bruce A are transferred to WWMF….. All ***non-radioactive, non-hazardous solid waste is transported to the on-site conventional waste landfill for disposal or off-site for recycling, processing and/or disposal*** at facilities licensed to handle such materials.

CNSC Page 75

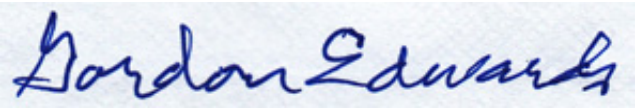
Some of the waste is directly recyclable; however, the largest waste quantities are associated with the pressure-tube/calandria-tube replacement and ***steam generator*** replacement, since the ***replaced components cannot be recycled and must be disposed of at the WWMF***….

Statement: *July 25 2010*

I have examined the above-cited documents by searching for each and every occurrence of the phrase "steam generator.

Nowhere in these documents is there the slightest indication that the old steam generators will ever be transported off-site. On the contrary, both Bruce Power and the Canadian Nuclear Safety Commission repeatedly state that the old steam generators are a form of radioactive waste, which will be transported to the Western Waste Management Facility, on-site.

Nowhere in these documents is there the slightest indication that the contaminated metal of the old steam generators will be considered suitable for recycling as scrap metal intended for unrestricted use.



Gordon Edwards, Ph.D., President,
Canadian Coalition for Nuclear Responsibility.

Appendix 2: Internal Contamination of Steam Generators

The danger from transport of the old steam generators is not limited to the penetrating gamma radiation that they give off, which is a temporary and passing danger -- nevertheless a serious one -- but also includes the radioactive contaminants inside the steam generator vessel that could be released into the Great Lakes in the event of an accident.

Within the last year some 200 workers at Bruce suffered unanticipated bodily contamination with alpha-radiation emitting radioactive materials given off as an invisible fine dust from the old feeder pipes that had been detached from the core of the reactor. The supervisors were unaccountably unaware that these materials were present in the pipes and they told the workers they did not need any protective clothing or equipment.

Those same materials are present in the old steam generators, as well as other radioactive materials which are beta-radiation emitting or gamma-radiation emitting materials. And it is well known that the alpha-emitting materials are among the most dangerous of all radioactive materials once inside the body, though they are virtually harmless outside the body. That's because alpha radiation has very little penetrating power, but does about 20 times more damage (per unit energy) as gamma or beta radiation.

Please read the following letter from Dr. Frank Greening to the CNSC back in February of this year. Dr. Greening worked for 23 years at Pickering as a specialist in corrosion of metallic components in nuclear reactors. You will note that, in this e-mail, sent to the CNSC, he calls attention to the presence of alpha-radiation emitting radioactive materials found in "feeder pipes, pressure tubes and steam generator components removed from CANDU reactors here in Canada."

To understand his letter, reproduced on the next page, one needs to know that Pu, Am, and Cm are chemical symbols for the man-made transuranic elements Pu=plutonium, Am=americium, Cu=curium, all of which are dangerous alpha-radiation emitting materials. These materials are not found in nature; they are created inside operating nuclear reactors.

Gordon Edwards, Ph.D.,
July 30 2010.

From: "Frank Greening" <greening@sympatico.ca>
Date: February 17, 2010 6:57:09 AM EST (CA)
To: "Interventions" <Interventions@cnsc-ccsn.gc.ca>
Subject: Alpha Contamination at Bruce NGS

To whom it may concern,

As a former analytical chemist for OPG I was surprised to hear that alpha-emitting particulate was "accidently" released to the vault air of Bruce Unit 1 in November 2009 during "routine" refurbishment operations. I was especially concerned when I read that this release of alpha-activity was caused by "grinding operations" on feeder pipes. I trust that Bruce Power is not claiming that such feeder pipe contamination was *unexpected* because OPG and AECL have been well aware of this issue for many years and its not long ago that Bruce Power nuclear reactors were operated by OPG.

I discovered alpha contamination on Pickering feeder pipe and pressure tube samples many times during my 23 -year career at OPG. Thus, in the early 1980s I reported surface concentrations of Pu-238, Pu-239, Am-241, Cm-242 and Cm-244 (in the nCi/mg range) in the oxide scale on several Pickering Unit 2 inlet feeder pipes -- see Ontario Hydro Research Division Report 84-262-K issued August 13, 1984.

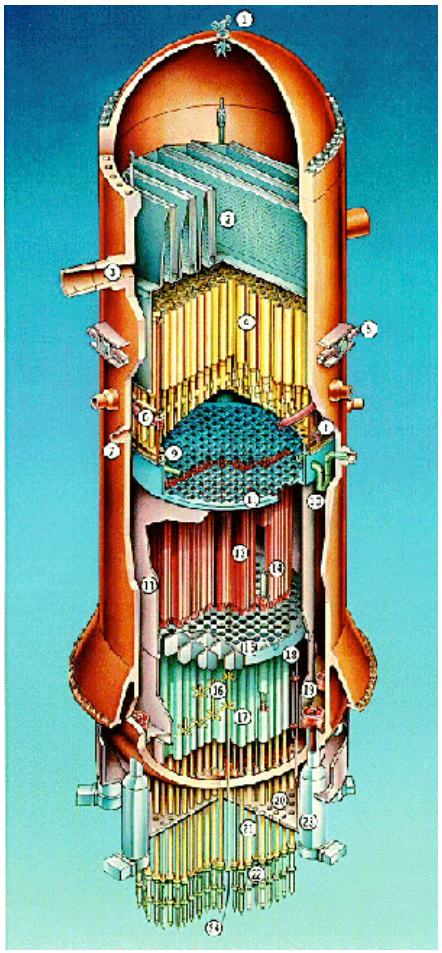
I request that this information be passed on to the CNSC staff who are looking into this incident and ask them to please ensure that health physicists at Bruce Power are made aware of the level of alpha contamination that is to be expected on feeder pipes, pressure tubes and steam generator components removed from CANDU reactors here in Canada.

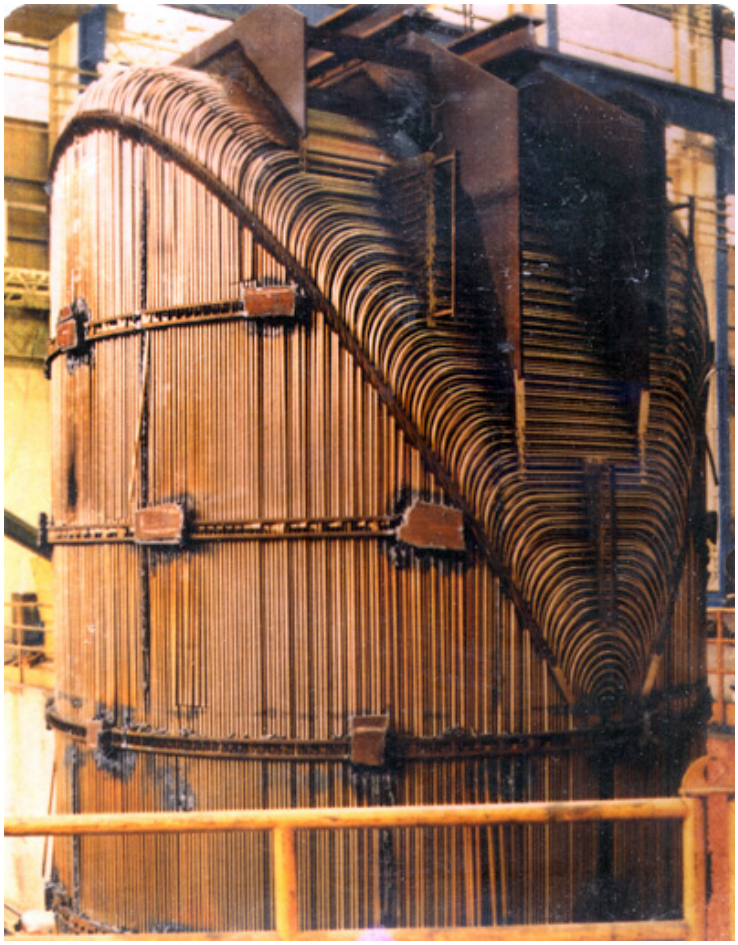
Sincerely,

Dr. F. R. Greening

Nuclear Intestines

Inside each of the old steam generators from the Bruce reactors are 5000 radioactively contaminated tubes, similar to those shown here.





A nuclear steam generator (these are US models, not CANDUs) is an enormous vessel with steel walls. It is a nuclear "boiler". However, the water from the core of the reactor (called the "primary coolant") is not allowed to boil; instead, the primary coolant runs through thousands of small tubes that act as heating elements to boil other water called "secondary coolant". The steam from the secondary coolant is then used to spin a turbine and generate electricity.

The picture on the right shows the thousands of long narrow tubes inside a steam generator. The tubes become corroded and radioactively contaminated over time; eventually the entire steam generator has to be replaced.

Radioactive materials are deposited on the insides of these tubes by the primary coolant which comes directly from the core of the reactor. And when these tubes spring leaks the radioactive contamination passes from the "primary side" (inside the narrow tubes) to the "secondary side" (outside those tubes).

Gordon Edwards, Ph.D.

Radioactive contaminants in decommissioned nuclear steam generators

Here is a partial list of radioactive contaminants inside a used steam generator from one of the Bruce reactors. The amount of radioactivity is expressed in becquerels per cubic metre; one becquerel corresponds to one radioactive disintegration every second. (Source: OPG)
http://www.nwmo.ca/uploads_managed/MediaFiles/539_ReferenceLowandIntermediateWasteInventoryfortheDGR.pdf (p. 50)

For Scientists / Engineers			*For Citizens / Decision Makers*		
Symbol	Half-Life	Amount	Name	Half-Life	Amount
	(y)	(Bq/m3)		(years)	(becquerels per cubic metre)
Ag 108	1.3E+02	2.3E+02	Silver-108	130 y	230
Am-241	4.3E+02	5.9E+07	Americium-241	430 y	59 000 000
Am-243	7.4E+03	3.8E+04	Americium-243	7 400 y	38 000
C-14	5.7E+03	7.6E+07	Carbon-14	5 700 y	76 000 000
Cl-36	3.0E+05	1.4E+04	Chlorine-36	300 000 y	14 000
Cm-244	1.8E+01	1.4E+07	Curium-244	18 y	14 000 000
Co-60	5.3E+00	1.2E+09	Cobalt-60	5.3 y	1 200 000 000
Cs-134	2.1E+00	1.9E+06	Cesium-134	2.1 y	1 900 000
Cs-135	2.3E+06	2.2E+01	Cesium-135	2 300 000 y	22
Cs-137	3.0E+01	2.2E+07	Cesium-137	30 y	22 000 000
Eu-152	1.3E+01	1.8E+06	Europium-152	13 y	1 800 000
Eu-154	8.8E+00	1.6E+07	Europium-154	8.8 y	16 000 000
Eu-155	5.0E+00	3.0E+07	Europium-155	5 y	30 000 000
Fe-55	2.7E+00	5.8E+09	Iron-55	2.7 y	5 800 000 000
I-129	1.6E+07	6.3E+00	Iodine-129	16 000 000 y	6.3
Nb-94	2.0E+04	2.9E+05	Niobium-94	20 000 y	290 000
Ni-59	7.5E+04	2.0E+05	Nickel-59	75 000 y	200 000
Ni-63	9.6E+01	2.9E+07	Nickel-63	96 y	29 000 000
Np-237	2.1E+06	1.8E+03	Neptunium-237	2 100 000 y	1 800
Pu-238	8.8E+01	1.0E+07	Plutonium-238	88 y	10 000 000
Pu-239	2.4E+04	1.2E+07	Plutonium-239	24 000 y	12 000 000
Pu-240	6.5E+03	1.7E+07	Plutonium-240	6 500 y	17 000 000
Pu-241	1.4E+01	5.5E+08	Plutonium-241	14 y	550 000 000
Pu-242	3.8E+05	1.7E+04	Plutonium-242	380 000 y	17 000
Ru-106	1.0E+00	8.4E+08	Ruthenium-106	1 y	840 000 000
Sb-125	2.8E+00	2.1E+07	Antimony-125	2.8 y	21 000 000
Se-79	1.1E+06	7.6E+01	Selenium-79	1 100 000 y	76
Sm-151	1 9E+01	7.6E+01	Samarium-151	19 y	76
Sn-126	2.1E+05	1.2E+02	Tin-126	210 000 y	120
Sr-90	2.9E+01	1.8E+07	Strontium-90	29 y	18 000 000
Tc-99	2.1E+05	2.8E+03	Technetium-99	210 000 y	2 800
U-234	2.5E+05	1.9E+04	Uranium-234	250 000 y	19 000
U-235	7.0E+08	3.2E+02	Uranium-235	700 000 000 y	320
U-236	2.3E+07	3.6E+03	Uranium-236	23 000 000 y	24 000
U-238	4.5E+09	2.4E+04	Uranium-238	4 500 000 000 y	24 000
Zr-93	1.5E+06	3.8E+02	Zirconium-93	1 500 000 y	380
TOTALS					
Long half-lives only (> 1 y)		**8.7E+09**	**Long-lived only (> 1 y half-life)**		**8 700 000 000**
Including short half-lives		**1.6E+10**	**Including all radionuclides**		**16 000 000 000**

According to this OPG document (see the last 2 lines), in each cubic metre there are over eight BILLION radioactive disintegrations taking place every second if we consider only the long-lived radioactive contaminants. Each disintegration releases an alpha ray, a beta ray, or a gamma ray; so there are more than eight billion of these rays emitted every second. That's more than 31 trillion rays per hour – over 274 quadrillion (274 000 000 000 000 000) rays per year!

There are five plutonium isotopes found in the steam generators. In each cubic metre there are about 39 million alpha rays given off each second from four of these five plutonium isotopes. One thousand years in the future, if the steam generators were just stored on-site as radioactive waste for that entire period, these plutonium isotopes would still be giving off about 27 million alpha particles per second, per cubic metre. Sixteen steam generators have a combined volume of about 1000 cubic metres, so multiply by this factor to get the total.

Gordon Edwards, Ph.D.

[NWMO = Nuclear Waste Management Organization; OPG = Ontario Power Generation]