CANADIAN NUCLEAR SOCIETY

Bulletin

DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

DECEMBER 2018 DECEMBRE VOL. 39, NO.4

• Recent Tour of Chernobyl • Small Modular Reactor Conference a Sellout
• 8th Simulation Symposium • CNS and General News

Chernobyl Remembered

The photos in John Fraser's Chernobyl Tour (included in this edition of the Bulletin) reveal the horror and devastation to humans and their communities, long lasting even a generation later. Such is the tragedy that can occur when an organization fails in a very simple mission: taking care of business in a responsible manner. I'm talking about the importance of having a good, strong Safety Culture.

The term 'Safety Culture' was coined by the international investigators after the accident. Safety Culture (not my favourite choice of words but it will do) is not a corporate slogan. It has deep meaning when it is entrenched in an organization from top to bottom, not as the title of some policy or procedure, but as a personal set of values and attributes held dear by everyone, be they the CEO or a 'grease monkey'. Safety Culture extends not just within the organization, but with all parties be they contractors, supply chain, regulator or customer.

Chernobyl was a game-changer for the nuclear industry, a significant emotional event for sure. Disasters have occurred before, and more will in the future, but none have had such an impact on Nuclear Safety Culture than has Chernobyl.

On April 26, 1986, the Chernobyl reactor #4 was about to shut down for a planned maintenance outage. Prior to the shutdown, a safety test was conducted, as planned, while the reactor was held at 50% power. The test was to address the safety issue of a loss of electric power that can lead to a station blackout. In Nuclear Reactor parlance, it is referred to as a 'Loss of Class IV Power', meaning power from the outside grid is disrupted. When that happens, the backup power system starts automatically, driven by diesel generators. The diesels, however, they take a few minutes to get up to speed; hence, there is a critical time delay when there is no power to run the cooling pumps. To address this safety gap at Chernobyl, the plan was to test the ability of a new voltage regulator that would allow residual momentum from the spinning turbo-generator to provide on-site power long enough for the emergency back-up diesel generator to take over.

It was a well documented procedure and the plan seemed straight forward. But all plans rely on expected circumstances. They did not expect, for example, that an unrelated problem in a far away power station would compromise the Ukrainian power grid, that grid control would instruct Chernobyl to hold off on the power reduction already in progress, that this would in turn lead to swings in nuclear flux for which the computer would be unable to compensate, that the reactor operators would take compensatory measures, etc., etc.

A good safety culture would dictate that the test be aborted and the reactor shut down or at least maintained in a steady safe state. But in the former Soviet regime such a decision might afford the station manager an all expense paid vacation in Siberia! We can speculate on why the safe action wasn't done, but we do know what was actually done. The result was catastrophic.

But after three decades has 'Safety Culture' become a cliché?

Every organization that deals in hazards claims to embrace a 'Safety Culture'. But consider the reality of just the last ten years. In 2008, Sunrise Propane had a Safety Culture at the time of the propane explosion in Toronto. In 2010, British Petroleum had one at the time of the Gulf Oil Spill disaster. In 2012 Via Rail had one at the time of the deadly derailment in Burlington, Ontario. In 2013 the US -based Montreal, Maine and Atlantic Railway had one at the time of the Lac-Mégantic derailment and explosion in Québec. These accidents were not 'accidental', but the direct result of unsafe human decisions.

The above examples are arguably 'non-nuclear' incidents. But consider Fukushima in 2011: had KEPCO and its nuclear regulator embraced their safety culture in sincerity, the recommendations of a 2002 risk assessment would have been implemented, avoiding the disaster.

Safety Culture must never be regarded as a passing fad or the buzz-word of the decade. It applies not just to industrial operators; Governments more than any other organization have an obligation to abide by its principles. We are in this together!

In This Issue

Summaries of two CNS conferences are included, and the one on Small Modular Reactors was sold out in advance! The world is moving closer to adopting SMR to replace diesels, especially in remote areas, and the nuclear regulator is keeping up with the trend.

Two former nuclear industry professionals recently attended a tour of Chernobyl and they bring to the CNS some fantastic photos and an exciting commentary. In addition, a technical paper provides solid evidence that the long-held theory called 'Linear No Threshold' is wrong! Although high doses of radiation are harmful, low doses over long periods are shown to be beneficial to human health.

As always your comments and letters are welcome. Have a safe and happy holiday!

From The Publisher

It can be argued that the Canadian Nuclear Society (CNS) just had its largest most successful technical conference ever. The CNS just organized and held its 1st International Conference on Generation IV and Small Reactors in Ottawa, November 6-8, 2028 in Ottawa.

Several things stand out. The first is that Natural Resources Canada (NRCan) took the opportunity of the conference to release its national roadmap for small reactors. NRCan Minister Amarjeet Sohi started the conference by announcing the release of the roadmap and providing an overview of the current and future importance of nuclear power in Canada. This importance was elaborated upon throughout the conference by a host of experts, from government, industry and civil society, as to the need for nuclear.

Particularly trenchant were the remarks of some 1st Nations speakers. In all too many cases, their communities are entirely dependent upon diesel fuel that must be shipped in on a frequent basis. In all too many cases, this must be delivered by air freight, making the energy supply of a community both hazardous and fragile.

Regardless of environmental reasons, the need for small reactors is abundant for remote communities off grid and never will have access to an electricity grid.

The second item which stands out from the conference is that the CNS was forced to close registration a week prior to its taking place. This may be the first occasion in which the CNS has sold out the house for a technical conference.

Let's go back over that once more.

The CNS sold out a technical conference. Industry and governments and civil society alike understand just how important small power reactors can be to their lives and livelihoods. Small reactors offer the possibility of permanent alleviation of the threat of energy starvation to tens of thousands of Canadians in remote communities.

The third item which stands out is that the antinuclear industry understands well the threat that small reactors pose to their shibboleths about nuclear power. The November conference was the first time in many years that a CNS conference attracted an antinuclear demonstration. It was the subject of a Parliament Hill press conference in which all the usual expected political types said all the usual silly things.

The threat to the antinuclear industry is that small reactors may demonstrate success in providing affordable, reliable power to remote communities without being dependent upon expensive fossil fuels that have to be airlifted in. So their response is to plead to kill the initiative before it's even explored for use by Canadians. They don't want Canadians to know that small nuclear power may solve the essential energy problems of tens of thousands of their fellow citizens. After all, they live in comfortable regions of the country amply supplied by the national energy infrastructure.

So there they were on Wednesday morning, demonstrating not only against small nuclear power, but as usual, against the needs of their fellow citizens.

Naturally it was raining on their parade. A cold, hard Ottawa rain.

CGH

Contents

~ Cover Photo ~

View of the New Safe Confinement (NSC) structure for the Chernobyl Reactor in Ukraine, as seen from the public access area. The NSC was constructed some distance from the original Sarcophagus and then slid into place on Teflon rails. It is the largest object ever moved on land. At 108m high, the Statue of Liberty would fit inside.

Photo courtesy of John Fraser. His full report is in this edition of the Bulletin.

CANADIAN NUCLEAR SOCIETY

bulletin

DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

ISSN 0714-7074

The *Bulletin of the Canadian Nuclear Society* is published four times a year by:

The Canadian Nuclear Society
998 Bloor St W., #501
Toronto ON M6H 1L0
Telephone (416) 977-7620
E-mail: cns_office@cns-snc.ca
Web: www.cns-snc.ca

Le Bulletin SNC *est l'organe d'information de la Société Nucléaire Canadienne.*

CNS provides Canadians interested in nuclear energy with a forum for technical discussion. For membership information, contact the CNS office, a member of the Council, or local branch executive. Membership fee for new members is $82.40 per calendar year, $48.41 for retirees, free to qualified students.

La SNC procure aux Canadiens intéressés à l'énergie nucléaire un forum où ils peuvent participer à des discussions de nature technique. Pour tous renseignements concernant les inscriptions, veuillez bien entrer en contact avec le bureau de la SNC, les membres du Conseil ou les responsables locaux. Les frais d'adhésion par année de calendrier pour nouveaux membres sont 82.40$, et 48.41$ pour retraités.

Editor / Rédacteur
Ric Fluke Tel. (416) 592-4110
e-mail: richard.fluke@kinetrics.com

Publisher
Colin Hunt Tel./Fax (613) 742-8476
e-mail: colin.hunt@rogers.com

The comments and opinions in the CNS Bulletin are those of the authors or of the editor and not necessarily those of the Canadian Nuclear Society. Unsigned articles can be attributed to the editor.

Printed by The Vincent Press Ltd., Peterborough, ON

Canada Post Publication Agreement #1722751

Government of Canada Unveils SMR Roadmap at CNS G4SR-1 Conference

by COLIN HUNT

Natural Resources Minister Amarjeet Sohi announced the release of the plan of the federal government for development of small reactor technology in Canada. The announcement was made at the Canadian Nuclear Society's (CNS) G4SR-1 Conference in Ottawa on Wednesday, November 7, 2018.

In his remarks, Minister Sohi noted a number of Canadian advantages in small reactor development. These included: strong existing nuclear operations and practice; a strong and effective nuclear reagulatory agency, the Canadian Nuclear Safety Commission (CNSC); an extensive research and supplier chain and infrastructure; and Canada's development and implementation of full radioactive waste disposal through the Nuclear Waste Management Organization (NWMO).

The Minister noted that 10 projects were undergoing review by the CNSC.

The plan, called *"A Call to Action: a Canadian Roadmap for Small Modular Reactors"*, was developed by NRCan Director Diane Cameron in consultation with a host of Canadian nuclear organizations and government agencies. The plan calls for a series of steps to be taken in developing new nuclear power technology in Canada.

Through the six-month Generation Energy dialogue in 2017, Natural Resources Canada (NRCan) heard that Canadian partners would need to work together to realize the potential for SMRs. In response, NRCan convened the SMR Roadmap Project with interested provinces, territories and power utilities. The Project is a ten-month program of engagement with the nuclear industry, as well as potential end-users such as Northern and Indigenous communities and heavy industry stakeholders, to explore the potential scope for a national path forward for SMRs.

Future steps in the plan were outlined by a number of plenary speakers at the conference, including: Mark Lesinski, President & CEO of Canadian Nuclear Laboratories (CNL); Peter Elder, Canadian Nuclear Safety Commission (CNSC); Fred Dermarkar, President of CANDU Owners Group (COG); and Jeff Lehmann, Vice President of New Nuclear Development, Ontario Power Generation (OPG).

Mr. Lesinski clarified what the Roadmap was.

"The Roadmap is about policy," Mr. Lesinski said.

He outlined a number of areas in which the Roadmap will work, specifically to inform the public about what small reactor technology is and how it works, and to listen to the concerns that may be brought forward.

Mr. Lehman outlined the steps that OPG is taking. He noted a recent agreement among OPG, Bruce Power and NuScale to explore development of small modular reactor technology.

A large panel chaired by John Stewart of the Canadian Nuclear Association (CNA) offered a variety of views by a large number of potential users of small modular reactors. These included potential applications for northern and remote off-grid use, incorporation into small electric utilities, and use in providing power to remote industrial mining locations.

Additional plenary panels during the conference offered the views of current SMR developers both in Canada and from around the world. The state of the current project development was discussed by Terrestrial Energy, NuScale Power, CNEA in Argentina, and SNC Lavalin. The conference was heavily attended by representatives from outside Canada. Particularly strong interest came from Massachusetts Institute of Technology (MIT), the United Kingdom, and Argentina. Dr. Jacopo Buongiorno of MIT gave a detailed presentation of MIT's study on the use of small reactors in a carbon-constrained world. Alasdair Harper of the UK Government's Department of Business, Energy and Industrial Strategies outlined future energy needs to be met by nuclear in the UK. Ignacio de Arenaza outlined development of the CAREM nuclear system in Argentina.

Dr. Buongiorno's presentation included a number of important conclusions. First, that deep decarbonization cannot be undertaken without a large role for nuclear power. Second, that all of the least cost scenarios include a large share of nuclear power, and that the size of nuclear's share of the carbon reduction scenarios grows substantially as the cost of nuclear power shrinks.

Two days of parallel technical sessions supported the unveiling of the Roadmap. These included studies on regulatory requirements, safety design, public communications concerns, areas of research and development needed, fuel design and production, waste management, and reactor economics.

The G4SR-1 Conference was held in Ottawa, November 6-8. The event was fully booked, with the CNS having to close registration a week prior to the conference. The conference was attended by representatives from 10 nations: Canada, US, UK, China, Argentina, Belgium, Denmark, Finland, Romania and Sweden.

As Conference Co-Chair Wilson Lam remarked, "I think this is the first time that the CNS has sold out a technical conference."

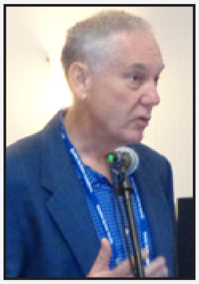
The Conference was chaired by Wilson Lam, Chair of the CNS Generation IV and Small Reactor Division, and Dr. Bronwyn Hyland, Program Manager Small Reactor Division at CNL.

Principal Sponsors of the conference included: Canadian Nuclear Laboratories (CNL), Ontario Power Generation (OPG), Bruce Power, SNC-Lavalin, Westinghouse, Hatch, and ES Fox. Exhibitors included: Black & McDonald, Jensen-Hughes, Canadian Nuclear Laboratories (CNL), Westinghouse, Moltex Energy, U-Battery, and Cymru Wales.

Scenes from the Conference

CNS 8th Simulation Conference Highly Successful in Ottawa

by COLIN HUNT



Executive Conference Chair Adriaan Buijs

Technical Program Chair Eleodor Nichita

The Canadian Nuclear Society (CNS) held a highly successful conference, the 8th Simulation Conference on Simulation Methods in Nuclear Science and Engineering in Ottawa on October 9-11, 2018. More than 100 delegates attended the conference.

The conference commenced with four workshops on October 9: DRAGON by Ecole Polytechnique, Scale by Oak Ridge National Laboratories, SuperMC by the China Institute for Nuclear Energy Safety Technology, and COBRA-TF by North Carolina State University.

DRAGON is a software for nuclear reactor lattice simulation developed and maintained by Polytechnique Montréal. SCALE is a comprehensive modeling and simulation suite for nuclear safety analysis and design developed and maintained by Oak Ridge National Laboratory. Super Multi-functional Calculation Program for Nuclear Design and Safety Evaluation (SuperMC) is the large-scaled integrated software system for neutronics design. COBRA-TF is being developed and improved by the Reactor Dynamics and Fuel Modeling Group (RDFMG) at the North Carolina State University (NCSU) in cooperation with Oak Ridge National Laboratory (ORNL). COBRA-TF is a thermal-hydraulic simulation code designed for LWR vessel analysis.

Dr. Liangzhi Cao, School of Nuclear Science and Technology, Xi'an Jiaotong University, China

The full conference commenced on Wednesday, October 10. Conference delegates were welcomed by Executive Conference Chair Adriaan Buijs, Plenary Program Chair Wei Shen, and Technical Program Chair Eleodor Nichita. The conference featured two half-day plenary sessions during the mornings, with both afternoons occupied by parallel technical sessions. Both plenary sessions included a wide range of speakers and institutions from across Canada and around the world.

The conference concluded on Friday, October 12 with a tour of the Canadian Nuclear Laboratories (CNL) facilities at Chalk River, Ontario. The tour included visits to the Thermalhydraulics, Hydrogen Production and Fuel Channel laboratories.

The conference was sponsored by Ontario Power Generation (OPG) and the FDS Team of the China Institute of Nuclear Energy Safety Technology, China Academy of Sciences.

At the same venue, the CNS hosted its Nuclear 101 course. More than 50 people attended the N101 course given by Dr. Ben Rouben.

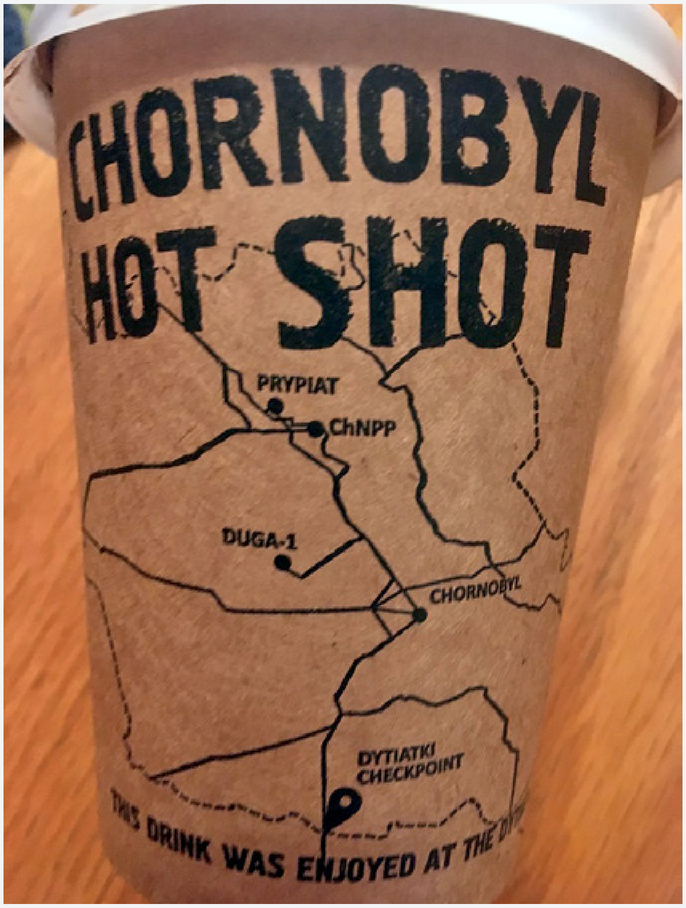
The opening panel discussion on CANDU Thermalhydraulics simulations.

Chernobyl Tour

by JOHN FRASER, CNS Ottawa Branch

[Ed. Note: John Fraser and Gerry Armitage, retired after decades in the Canadian Nuclear Industry, took the initiative to attend a tour of Chernobyl in October 2018 organized by Ukraine Tour of Toronto. John has kindly shared their experience with the CNS.]

The Chernobyl reactor accident in Ukraine is well documented in the nuclear power literature. However, a tour of the Chernobyl area is a very interesting and sobering experience as you can see the magnitude of the accident impact, even after all these years. Our two day tour was worthwhile and well organized through Ukraine Tour (ukrainetour.com) in Toronto. This is in recognition of their arrangements which went very well, as another group spent six hours at the outer check point, because their paper work was not in order.



Ukraine is not a wealthy country in spite of its size. They appear to have taken a positive approach to tours of the area, with vehicles waiting at the outer exclusion area check point at Dytiatki, 30km south of the reactor site. The souvenir booth is busy; items include coffee cups with an exclusion area map. It gives a good idea of the 30km exclusion zone (dashed line), shows the check point, the town of Chernobyl, the nuclear reactor site and the abandoned town of Pripyat. There is an inner check point at 5km from the reactor, inside of which permanent habitation is not permitted. For meals and overnight accommodation, visitors have to leave the 5km zone to go to the town of Chernobyl.

The background radiation at the 30km check point is typical of the whole tour route, about 0.12 micro sieverts per hour (μSv/h). In downtown Kiev, the background was 0.15 μSv/h, higher due to the granite in the buildings and the ground. During the tour, at the Ferris Wheel in Pripyat, it was higher at 0.9 μSv/h.

[Ed. Note: Background radiation in Toronto is about 0.2 μSv/h, and about 0.5 μSv/h in Winnipeg.]

The Life for Life memorial, beside the road to the plant, commemorates those who gave their lives in combatting the initial fires and releases so that others could live. The very first responders trying to extinguish the fires on the turbine hall roof were only about 30 meters from the burning reactor. They were closer to a nuclear inferno than the residents of Hiroshima or Nagasaki, as the bombs were detonated at a height of about 600 meters or 2000 feet. Their faces are shown, not hidden behind their breathing gear, as the faces represent actual people who passed away from their injuries.

An overview picture from the 11th floor roof of a Pripyat apartment building shows the scope of just a portion of the affected area. Abandoned buildings are in the foreground with the New Safe Confinement (NSC) building in the distance. In the middle of the picture are the upper chairs of the Ferris wheel in Pripyat. On the horizon to the left of the NSC is the flat top of the Unit 5 cooling tower that was under construction.

The abandoned kindergarten building in Kopace, about 1.5km south of the plant, is typical of buildings in the exclusion zone. They are desolate, and looted of pretty well anything of value. Most of the buildings in this particular area were made of wood, and were buried or even burned. The radioactivity in the area had to be made manageable as Units 1 to 3 were returned to service, the last one being shut down in 2000. The cleanup was massive, as a year after the accident a senior officer [1] reported: -

"More than 500 residential communities, nearly 60,00 buildings and structures and several dozen million square metres of exposed surfaces of technological equipment and internal surfaces at the station itself have been decontaminated."

The abandoned children's respirators in a Pripyat school remind one of the haste with which the evacuation occurred. As it was carried out in a time of the "command economy", the necessary arrangements were quickly made and on April 27th, "*Pripyat's 45,000 people were packed into 1,100 buses with a minimum of personal belongings … the evacuation took two hours and twenty minutes, and the convoy leaving the town stretched for 20 kilometers … the people were told that their resettlement … was only temporary.*"[2]

The Wormwood Star memorial building near the

town of Chernobyl includes a tribute to the many people evacuated due to the accident. The memorial path shown is lined with the names of the communities that had to be abandoned, some immediately and some later, as the scope of the accident was recognized. It gives a sobering appreciation of the human upheaval caused by the accident.

The New Safe Confinement (NSC) structure *[shown in the Cover Photo]*, as seen from the public access area, gives a view of the front of the building and the security fence. It shows an awning-like structure, the North Ventilation Centre, which was moved into place as part of the NSC [3]. The vent stack was also attached to the building before it was moved. After it was in place, construction continued on the Technological Building, tucked under the front of the arch, and extending from it, the Control Building and Electrical Equipment Building.

The rear of the NSC abuts Unit 3 and the red/white striped vent stack. The hinged panels on this side were raised when it was slid into place then lowered remotely, by cables, to provide a better seal against the existing building. A similar set of hinged panels on the other side of this face, fulfilled the same role. This view also shows the roof of Unit 3. Unit 4 had a similar roof and underlying structure which was blown off in the accident, giving an appreciation of the magnitude of the reactor explosion.

The NSC is the largest object ever moved on land. At 108m high, the Statue of Liberty would fit inside. It was constructed 300m from the original Sarcophagus to minimize radiation dose to the workers. It was slid into place on Teflon rails, using two hundred hydraulic jacks, each individually controlled, to ensure the NSC moved smoothly into place.

The NSC has a sealed "double skin" roof that contains all the load bearing trusses, and has a design life of 100 years. The roof structure interspace has a special climate control ventilation system to minimize corrosion, helping to ensure the design life is achieved. There is another sophisticated ventilation system to prevent leakage of contamination from the NSC.

Inside the roof arch is a two crane system that can carry remote tooling to dismantle the Sarcophagus and some parts of the original building. The deconstructed material will be brought to the Technical Building for decontamination before being put into flasks and removed for burial. Redundancy is built into the system, for instance, each crane can rescue the other if needed. At present the plan is to not remove the remains of the reactor core, in the hope that future technology will make it feasible to deal with it.

North of the plant, on the road to Pripyat, is the Red Forest and the majority of the early fallout landed in this area. The trees all turned red and died. The forest has regrown with two of the original dead trees left standing. We drove through the area twice, with the driver giving a running commentary on background dose rates which were 10 and 12 µSv/h inside the van, the highest during the tour.

In central Pripyat is the iconic Ferris Wheel, as the town was planned as a model community complete with entertainment and sports facilities. One of the tour's radioactive "hot spots", measuring about 100 µSv/h, is on one of the seats. As the spot is not easy to find, or reach with a gamma meter, it is fortunate there is no loose contamination. During the tour, the only contamination warning given was when walking inside the incomplete Unit 5 cooling tower. We were warned to stay off the moss growing on the ground as it tended to concentrate any loose contamination.

Another hot spot, of 70 µSv/h, is on the "Claw", sitting beside an abandoned factory. It was used in the cleanup of Unit 3. This spot can be reached with a bit of effort, and it is safe to do this as there was no loose contamination there either. It appears there were extra metal plates welded to the inside of the Claw fingers, to help pick up the radioactive debris.

Further into the town is the abandoned sports centre with a gymnasium. The windows are broken out, the floor is covered in broken glass and the aluminum window frames all taken by scavengers. There is even a tree growing out of the floor boards! In the same complex an Olympic size pool is sitting abandoned.

A final stop at the end of the tour was the partly completed Unit 5 building. The red steel plates on the structure were added in one day! Initially, the hope was that construction would be completed on Unit 5 and 6. However, work never resumed and it has stood still ever since and two of the cranes have fallen down over the years.

On leaving the site, personnel and vehicles are monitored for contamination at both the inner and outer check points. When approaching the outer check point on departure, visitors are advised to ensure they have all their belongings from the overnight stay as there is no turning back after passing through the final check point.

Incomplete Unit 5 cooling tower, with a painting of one of the many "Liquidators" who worked to clean up the site so that Units 1 to 3 could be restarted".

References

[1] *Chernobyl, The Real Story*, Mould, R.F., Pergamon Press; Oxford (UK) 1988; ISBN 0-08-035719-9 (page 93)

[2] *The Chernobyl Disaster*, Haynes, V. and Bojcun, M., Hogarth Press; London (UK) 1988; ISBN 0 7012 0816 3 (page 53)

[3] Emails from *Bechtel Corp.* staff

Evidence of a Dose Threshold for Radiation-Induced Leukemia

by JERRY M. CUTTLER

[Ed. Note: The following paper, submitted by the author, was previously published in the journal, Dose-Response, October-December 2018:1-5. https://journals.sagepub.com/doi/10.1177/1559325818811537]

Abstract

In 1958, Neil Wald presented data on the incidence of leukemia among the Hiroshima atomic bomb survivors. These data, which suggested a dose-response threshold for radiation-induced leukemia, were included in the first UNSCEAR report (1958). However, this evidence of a threshold was not recognized. It was obfuscated and concealed. In 2010, Zbigniew Jaworowski identified these data as evidence of radiation hormesis. A letter to the editor in 2014 and 2 articles in 2014 and 2015 presented a graph of these UNSCEAR 1958 data, which revealed a threshold at about 500 mSv. Since the blood-forming stem cells of bone marrow are more radiosensitive than most other cell types, it is reasonable to expect thresholds for inducing other types of cancer by ionizing radiation—their thresholds are likely higher than 500 mSv. A careful examination of the Wald data reveals the surprisingly low incidence of radiogenic leukemia, only 0.5% of the survivors who were in the high radiation zones. Many articles on radiation risk have been published since 2015 by other authors, but none make reference to this evidence of a threshold, either to challenge or endorse it. In this commentary, the author addresses the comments from a colleague.

Keywords: ionizing radiation, Hiroshima atomic bomb survivors, dose-response threshold, leukemia, cancer, hormesis

Introduction

Widespread fear of low-dose ionizing radiation (LDIR) began in 1956 when the U.S. National Academy of Sciences (NAS) recommended that the linear no-threshold (LNT) dose-response model be used to assess the risk of radiation-induced mutations.[1] Nuclear power plants and all applications of LDIR, especially in medicine, began to be linked to a risk of dreaded cancer. Prior to this NAS publication and the associated publicity, there had been 60 years of extensive experience using X-rays and radium to image and treat many millions of patients. The dose-rate limit (tolerance dose) for protecting radiologists against overexposures was based on a threshold model, and it was satisfactory.[2,3] There were no reports of elevated cancer levels, when the early radiation protection standards were followed. On the contrary, lower cancer mortality and increased longevity were observed in follow-up studies of radiologists and nuclear workers.[4,5]

In addition to the diagnostic applications, many treatments with LDIR were discovered and employed on many millions of adults and children against very serious diseases, including a variety of cancers, infections and inflammations.[2] Low radiation doses were observed to be stimulatory (beneficial). A National Cancer Institute review of nasopharyngeal radium irradiation (NRI) reported that worldwide studies have not confirmed a definite link between NRI and any disease.[6]

It was recently discovered that the 1956 NAS recommendation was ideologically motivated and was based on the deliberate falsification and fabrication of the research record. This NAS scientific misconduct led to governments adopting the LNT model for cancer risk assessment.[7-9] Many scientists wanted to stop the ongoing development of nuclear weapons after two atomic bombs were used to end WWII. Radiophobia was promoted as part of a political strategy to stop all atomic bomb testing, which releases radioactive materials (fallout) into the environment. More than 60 years have passed since that NAS recommendation, but the fear of radiation is sustained by regulatory disregard of the large amount of evidence that contradicts it.[10]

This commentary reviews the UNSCEAR 1958 data and endeavours to understand why this evidence of a threshold for radiation-induced leukemia is being ignored by other authors, even those who have been challenging the validity of the LNT model of radiation carcinogenesis. They do not make reference to this UNSCEAR information, either to challenge or endorse it. In this commentary, the author addresses the comments from a colleague.

Incidence of leukemia in the Hiroshima survivors

In 1958, Niel Wald summarized the results of the leukemia survey in Hiroshima as of December 1957. The numbers of cases for the years 1950 through 1956 are fairly accurate; however, the numbers that arose

Table 1. Leukemia in Hiroshima atomic bomb survivors who were residents of Hiroshima City at the time of diagnosis, as of December 1957.[11]

Year of onset	Total	Distance from hypocenter (meters)				
		Under 1000	1000-1499	1500-1999	2000-2999	3000 and over
1945						
1946						
1947	3		1		2	
1948	7	2	4		1	
1949	5	1	1	1	1	1
1950	9	3	5			1
1951	11	3	7	1		
1952	11	3	5	1		2
1953	12	2	6	2	1	1
1954	6	2	2	1	1	
1955	8	1	4	2		1
1956	6		1	1	1	3
1957	5	1	3			1
Total	83	18	39	9	7	10
*Estimated population**						
	95,819	1,241	8,810	20,113	32,692	32,963
Number of cases with onset in 1950-1957						
	68	15	33	8	3	9
Estimated person-years at risk						
	766,552	9,928	70,480	160,904	261,536	263,704
Annual incidence of leukemia per 100,000						
	8.9	151.1	46.8	5.0	1.1	3.4

**Based on Hiroshima Census Bureau's daytime population census of Hiroshima City, 3 June 1953.*

in the preceding years are significantly understated. With respect to 1957, there were likely additional cases discovered.[11] Table 1 is the original table of this information and Figure 1 is a graph of the number of cases versus year.

Wald's data were included in the first UNSCEAR report (1958), Annex G, Table VII (Table 2 below).[12] Zbigniew Jaworowski, representative of Poland in UNSCEAR, referred to these data in an article advocating the use of radiation hormesis as a remedy for fear.[10] He stated on page 266, "hormesis is clearly evident ... in a table showing leukemia incidence in the Hiroshima population, which was lower by 66.3% in survivors exposed to 20 mSv, compared to the unexposed group (p.165). This evidence of radiation hormesis was not commented upon."

A graph was made of these data, Figure 2, and this evidence of a threshold at about 500 mSv was presented in a letter to Archive of Toxicology and an article in Dose-Response.[13,2] A year passed and it became apparent that this very important evidence was being ignored by the scientific community and the media. Another article was prepared in 2015 that criticized a 1957 paper by Edward Lewis. This article demonstrated that Lewis had misled the scientific community by combining 2 exposed population groups, averaging their doses and concealing the evidence of the threshold.[14] (A threshold would have contradicted the LNT model.) Although this article has been viewed 8810 times on the Internet and referenced by the author in several additional articles, it has not been cited by other authors.

Review of the 2015 Paper by a Colleague

A recently published critical evaluation of the NCRP

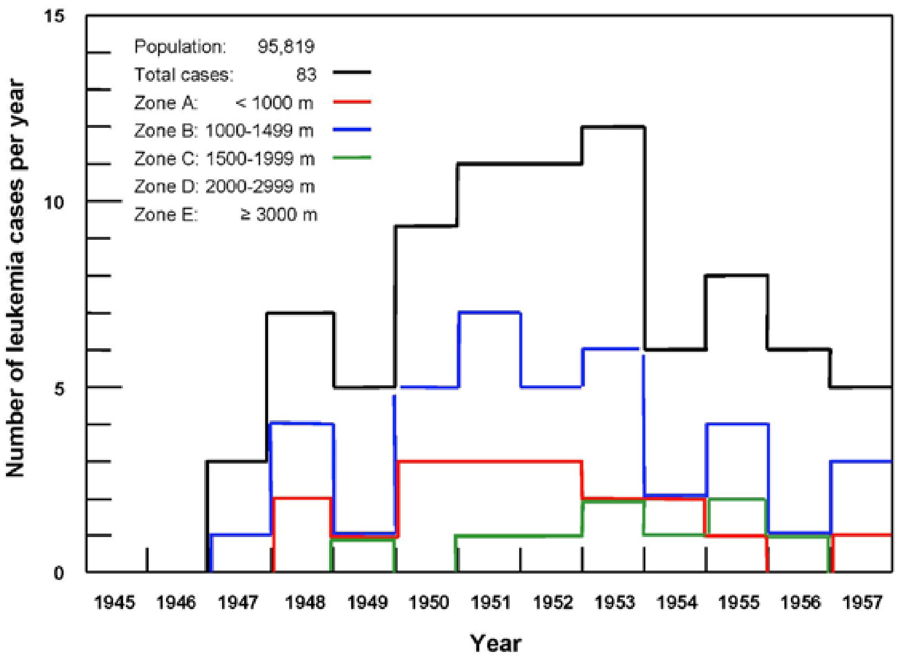


Figure 1. Number of leukemia cases per year.

Commentary 27 endorsement of the LNT model[15] did not mention the UNSCEAR 1958 evidence of a threshold for radiogenic leukemia that appears in the 2015 article.[14] When the author of the evaluation was asked why this important evidence had been omitted, he provided the following comments.

The conclusion that the acute dose threshold for leukemia is 500 mSv is extraordinary. It is in stark contrast to conventional knowledge–the difference being about one or two orders of magnitude.

Skepticism is created by changing the Zone C dose from the calculated value of 0.5 Sv to the value 1 Sv, to address the footnote: "almost all cases of leukemia in this zone occurred in patients who had severe radiation complaints, indicating that their doses were greater than 50 rem." A more careful reading led to an understanding of the rationale for this change and the acknowledgement that the Zone C dose could have been raised even higher.

The conclusion that the radiation thresholds for other cancer types are expected to be higher than the 500 mSv threshold for excess leukemia is of significant concern. There exists an additional 42 years of follow-up leukemia data that should be discussed. To extend that claim to other types of cancer would require an evaluation of the most recent solid cancer incidence/mortality data, which was not carried out.

There is no discussion of the optimum time window for detecting putative radiation-induced leukemia, which is the first 10-15 years following an acute exposure. The idea that including years of data afterward just dilutes the effect merits further discussion. The initial leukemia signal is most visible in that time window, and fades toward the null of no effect, as more and more naturally-occurring leukemia cases accumulate in both the exposed and the control groups with the passage of time. The RERF data updates should have been analyzed.

Responses to the Reviewer's Comments

Indeed, the reported threshold dose to induce leukemia, about 500 mSv, is 1 or 2 orders of magnitude higher than the currently accepted level of significant risk. Conventional knowledge is based on applying the LNT model, which continues to be discredited. The threshold is a factor of 5 higher than the 100 mSv value that many radiation protection people seem will-

Table 2. UNSCEAR 1958. Table VII. Leukemia incidence 1950-57 after exposure to Hiroshima[a]

Zone	Distance from hypocentre (metres)	Dose (rem)	Persons exposed	L (Cases of leukemia)	$\sqrt{L}$	N[b] (total cases per million)
A	under 1,000	1,300	1,241	15	3.9	12,087 ± 3,143
B	1,000-1,499	500	8,810	33	5.7	3,746 ± 647
C	1,500-1,999	50c	20,113	8	2.8	398 ± 139
D	2,000-2,999	2	32,692	3	1.7	92 ± 52
E	over 3,000	0	32,963	9	3.0	273 ± 91

[a] Based on data in reference 13 (Wald N. Science 127:699-700. 1958). Prior to 1950 the number of cases may be understated rather seriously.

[b] The standard error is taken as N times ($\sqrt{L}/L$).

[c] It has been noted (reference 15, 16) that almost all cases of leukemia in this zone occured in patients who had severe radiation complaints, indicating that their doses were greater than 50 rem.

ing to accept. Up until the 1960s, millions of patients received repeated radiation doses in range from about 0.1 to 1 ED (erythema dose ≈ 6000 mSv) to cure many life-threatening diseases. There are no reports of a significant increase of leukemia incidence following such treatments.[6] Many Chernobyl firefighters suffered from very high radiation doses; 134 of them were treated for acute radiation syndrome. Of them, 28 died within weeks and 106 recovered. Follow-up of these 106 survivors after 19 years showed no increase in their overall mortality or their cancer mortality compared with unexposed workers.[3] And there have been other accidents involving exposures of many people to high radiation levels that resulted in serious burns but no evidence of elevated cancer incidence. Doss has suggested that there is a fundamental weakness in the somatic mutation model of cancer being used. He recommends more attention be given to the immune suppression model of cancer.[16] Indeed, it is well known that a high dose of radiation suppresses immunity and increases the risk of cancer.[17] Since the acute lethal dose for humans ranges from 3.5 to 5 Gy,[18] a threshold for onset of radiogenic leukemia at about 1 Gy is credible.

Changing the dose for Zone C was very important because a dose that is based on actual human symptoms is much more credible than a dose that is calculated using a primitive model of atomic bomb radiation.

The Hiroshima evidence of radiogenic leukemia can be modeled by a hormetic dose-response model.[2,14] Since we know that LNT is wrong, it is likely that the other radiogenic cancer types can be modeled likewise. It is reasonable to expect the threshold doses for other cancer types to be higher than for leukemia because of the discussion in the 2012 paper by Fliedner et al. on the high radiation sensitivity of hemopoietic stem cells compared with the radiation sensitivities of stem cells in other organs.[19]

The long-term studies on radiation-induced leukemia mortality and the mortality of other cancers among the bomb survivors lack credibility because the LNT model is invalid. Cancer and the effects of radiation on cancer mortality are not well understood. The confounding factors that affect radiogenic cancer mortality are not known and, if they were, it would be impossible to control them over many decades. There is no value to be gained in analyzing RERF data updates.

An assessment of the 1958 to 2000 bomb survivor leukemia data[20] was not included in the 2014 and 2015 papers,[2,14] and unfortunately no explanation was given for this omission. It was known that radiogenic leukemia has a short latent period. The excess cases appear a few years after the irradiation and reach a peak by 5 to 7 years. Most radiogenic leukemia cases occur in the first 15 years. Solid tumors show a longer latency, from 10 to 60 years or more.[21] Clearly, the inclusion of the leukemia data from 1958 to 2000 would have *diluted* the burst of radiogenic leukemia cases with 43 years of naturally-occurring leukemia cases, about 3 per 100,000 per year, masking the evidence of the radiogenic leukemia dose threshold.

Table 1 shows the leukemia data of the 95,819 survivors from 1945 until the end of 1957.[11] Figure 1 shows that the radiogenic cases began to appear in 1948 and peaked from 1950 until the end of 1953. In the 2014 and 2015 articles,[2,14] it was appropriate to do as the UNSCEAR-1958 report[12] did–examine the cases in the 8-year interval 1950-1957 to evaluate the dependence of radiation-induced leukemia on dose. Figure 2 shows the leukemia incidence response to radiation dose. A threshold for radiogenic leukemia is apparent at an "equivalent" dose of about 0.7 Sv, or 0.7 Gy (70 rad) in "absorbed" dose units, assuming the RBE = 1. The 32,963 people who were in the outermost Zone E are regarded as the non-exposed controls. Their annual (natural) leukemia incidence is 3.4 cases per 100,000, as given in Table 1.

The uncertainty of the threshold can be gauged by noting that 0.7 Gy is 30% below the assumed 1 Gy dose for severe radiation pain, the spread of which is likely the same as the human LD_{50} range, 3.5-5 Gy.[18]

Conclusions

The data on the incidence of leukemia among the Hiroshima atomic bomb survivors, which were summarized by Neil Wald and included in the 1958 UNSCEAR report, are evidence of a dose threshold for radiogenic leukemia.

The authors of many recent articles about radiation risk appear to be ignoring this evidence of a threshold. They do not challenge, endorse, comment on, or reference the recent publications that presented this evidence.

A colleague provided the following important comments on the 2015 article. The magnitude of the threshold is surprising high. Changing the value of the radiation dose in Zone C because of the severe pain of the leukemia patients creates misgivings. Supporting evidence is needed for the statement that radiation thresholds for other cancer types are expected to be higher than for leukemia. An explanation is needed for the omission of 42 years of follow-up leukemia data. The RERF data updates should be analyzed. Responses to these comments are given in the previous section.

The additional information in this article should remove the concerns that deter other scientists from accepting and referencing this evidence of a high threshold dose for radiation-induced leukemia. They may consider the possibility of higher thresholds for other cancer types.

A careful examination of Table 1 reveals the surprisingly low incidence of radiogenic leukemia among the atomic bomb survivors. It is only 0.5% of the population in the high radiation Zones A and B, shown in Table 1 (only 15 + 33 = 48 cases among 1241 + 8810 = 10,051 people).

References:

1. National Academy of Sciences (NAS)/National Research Council (NRC). The biological effects of atomic radiation (BEAR): a report to the public. NAS/NRC, Washington. 1956. Published as, Genetic effects of atomic radiation. Science. 124:1157-1164; 1956.
2. Cuttler JM. Remedy for radiation fear–Discard the politicized science. Dose-Response. 2014; 12(2):170-184.
3. Cuttler JM. Health effects of radiation exposures. Part B of intervenor report to Pickering NGS Public Hearing. Canadian Nuclear Safety Commission. CMD 18-H6-35; 2018. http://www.nuclearsafety.gc.ca/eng/the-commission/hearings/cmd/pdf/cmd18-h6/CMD18-H6-35B.pdf
4. Cameron JR. Longevity is the most appropriate measure of health effects of radiation. Radiology. 2003; 229:14-15. https://pubs.rsna.org/doi/full/10.1148/radiol.2291030291
5. Sponsler R, Cameron JR. Nuclear shipyard worker study (1980-1988): a large cohort exposed to low-dose-rate gamma radiation. Int J Low Radiation; 2005; 1(4):463-478.
6. Queens Cancer Center. Nasopharyngeal Radium Irradiation (NRI): Fact Sheet. 2003. http://www.queenscancercenter.com/SpecificCancers/Brain/ReadingRoom/45,25786-1
7. Calabrese EJ. LNTgate: How scientific misconduct by the U.S. NAS led to governments adopting LNT for cancer risk assessment. Environ Res. 2016; 148:535-546.
8. Calabrese EJ. LNTgate: The ideological history of cancer risk assessment. Tox Res Applic. 2017; 1:1-3.
9. Calabrese EJ. The linear no-threshold (LNT) dose response model: a comprehensive assessment of its historical and scientific foundations. J Chemico-Biological Interactions. 2018; in press.
10. Jaworowski Z. Radiation hormesis - A remedy for fear. Human Exper Toxicol. 2010; 29(4):263-270. http://journals.sagepub.com/doi/pdf/10.1177/0960327110363974
11. Wald N. Leukemia in Hiroshima city atomic bomb survivors. Science. 1958; 127:699-700.
12. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). 1958. Report to the General Assembly. New York: United Nations. Annex G, p 165. Table VII.
13. Cuttler JM. Leukemia incidence of 96,000 Hiroshima atomic bomb survivors is compelling evidence that the LNT model is wrong. Arch Toxicol. 2014; 88:847-848.
14. Cuttler JM, Welsh JS. Leukemia and ionizing radiation revisited. J Leukemia. 2015; 3:4. http://dx.doi.org/10.4172/2329-6917.1000202
15. Ulsh BA. A critical evaluation of the NCRP Commentary 27 endorsement of the linear no-threshold model of radiation effects. Environmental Research. 2018; 167:472-487.
16. Doss M. Changing the paradigm of cancer screening, prevention and treatment. Dose-Response. 2016; 14(4):1-10.
17. Sakamoto K. Radiobiological basis for cancer therapy by total of half-body irradiation. Nonlinearity in Biology, Toxicology, and Medicine. 2004;2(4):293-316. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2657505/
18. Metting N. Ionizing Radiation Dose Ranges (Sievert). Office of Biological and Environmental Research. U.S. Department of Energy. Office of Science. 2010. http://www.dcfpnavymil.org/Library/tables/DoseRanges.pdf
19. Fliedner TM, Graessle DH, Meineke V, Feinendegen LE. Hemopoietic response to low dose-rates of ionizing radiation shows stem cell tolerance and adaptation. Dose Response. 2012; 10(4):644-663.
20. Richardson D, Sugiyama H, Nishi N, et al. Ionizing radiation and leukemia mortality among Japanese atomic bomb survivors, 1950-2000. Radiat Res. 2009; 172(3):368-382.
21. Hall EJ, Giaccia AJ. Radiobiology for the radiologist. Philadelphia: Lippincott Williams & Wilkins; 2012. Chapter 10.

CFD Modelling of Fire and Evacuation for Nuclear Applications

by L. SUN[1], K. PODILA[1], Q. CHEN[1], Y.F. RAO[1], J. ALEXANDER[1]

[Ed. Note: The following paper was presented at the Canadian Nuclear Society 8th International Conference on Simulation Methods in Nuclear Science and Engineering, Ottawa Marriott Hotel, Ottawa, ON, Canada, 2018 October 9-11.]

Abstract

The nuclear industry has seen an increased use of Computational Fluid Dynamics (CFD) technology as a high-fidelity tool for design-basis and beyond-design-basis accident simulations. Among its applications, CFD modeling of fire and smoke propagation in confined zones (e.g., a main control room) emerged promising, since detailed experimental investigation under various accident scenarios would be difficult. Egress analysis taking into consideration of human behaviors is of significant importance to an effective accident mitigation strategy, and high-fidelity analysis tools now encompass these parameters in the simulation and design of emergency evacuation. In the present study, the fire and smoke propagation in a main control room is modelled using the Large Eddy Simulations (LES) code FDS, along with an evacuation module EVAC to simulate the emergency egress under the cabinet fire scenario. The FDS results presented in this paper constitute the first step at CNL in advancing the CFD modeling of fire and evacuation for nuclear applications.

1. Introduction

For fire hazards, detailed experimental investigation in a realistic environment is often impractical, which necessitates the need for using analysis tools that can provide accurate predictions. The currently used methodologies for fire modelling include empirical correlations (hand or spreadsheet calculations), zone models, and field models such as CFD [1]. The use of hand calculations introduces a large degree of empiricism due to the correlations specific to experimental conditions. Zonal models in codes (e.g. NIST CFAST,EDF MAGIC) has been more prevalent in the industry as they solve conservation equations (albeit for energy and mass only). However, they cannot predict three-dimensional (3D) effects and are applicable only when complex geometries are simplified to rectangular compartments with flat ceilings.

High-fidelity, multi-dimensional CFD simulations can provide more accurate predictions of fire propagation and its consequences, including all contributing and mitigating effects, in full detail and under real geometry conditions. In addition, accurate simulations of the unsteady 3D fire and smoke spread, in conjunction with evacuation analyses, can be used to establish effective emergency evacuation strategies. Due to the advanced capabilities of CFD technique, international organizations and nuclear regulatory bodies such as IAEA, OECD/NEA, and U.S. NRC/EPRI are supporting its assessment through various international collaborations and benchmarks, such as PRISME project and PIRT exercise[1] [2][3] [4]. CFD codes that are generally used for modelling the fire and smoke propagation include NIST Fire Dynamics Simulator (FDS)[5], Siemens STAR CCM+[6], Open FOAM[7], ANSYS CFX/FLUENT[8], and

IRSN ISIS[9]. Most of conventional codes for fire modelling based on the CFD approach primarily use the Large Eddy Simulation (LES) approach to resolve the inherently unsteady, coherent turbulent structures in the fire and smoke propagation. However, the RANS based turbulence models (including URANS) are in general far more widely used in industries for solving turbulent flows in industry-scale, complex geometrical configurations. Therefore, other turbulence modelling approaches such as URANS (or hybrid ones) will be assessed in the next phase of the present study, especially when the surface (or wall) effects are significant regarding the fire and smoke propagation. The comparative study should determine the suitability of these turbulence models for different fire configurations and accident scenarios.

Recently the Canadian regulator CNSC identified the need for a better understanding of human performance, integrated with fire modelling, in an emergency response to a nuclear fire related accident[10]. Similarly, a task force report by U.S. NRC[3] concluded that taking human behaviors into consideration in the event of fire and its modelling, i.e., egress design and analysis, is of significant importance to nuclear facility and safety. Although the regulatory provisions governing egress design are prescribed in building codes, the actual performance of the evacuation systems is generally difficult to assess, and require cross verification to ensure the accuracy of the design[11]. Therefore, application of CFD coupled with models that can include human performance has been increasingly used. For instance, advanced agent-based simulation techniques in 3D environments often allow for the simulation of more complex behaviors and thus a better decision making process. A comprehensive review of the available evacuation models was undertaken by NIST [12]; some of the models have been implemented in codes such as Pathfinder[13] and FDS+Evac developed at VTT Technical Research Centre of Finland [14] to study the effect of fire on the human egress.

The objective of this ongoing work at CNL is to demonstrate the utilization of high-fidelity CFD tools (NIST FDS, Siemens STAR-CCM+, Open FOAM, ANSYS suite etc.) to substitute for the conventional tools used in nuclear industry (e.g. CFAST, other zonal codes), and, to aid in better formulation of egress strategies for a fire incident. To accomplish the objective, planned tasks will be executed in phases. During the first phase of this study, which is reported in this paper, a scenario of cabinet fire in a main control room (MCR) was simulated using the CFD code FDS, version 6.6.0[5]. Note that the human factors and evaluation of egress strategies have not yet been included. The FDS predictions were not assessed against measurements; rather, the results reported in[1] were used to undertake code-to-code comparisons. This step serves as a verification to determine if the modelling options in FDS have been correctly exercised before the tool is used to simulate new scenarios.

The second phase of the study (not discussed here) will involve benchmarking of the FDS code with commercial CFD codes, such as STAR-CCM+, that provide a wider selection of turbulence models. The results from the URANS by STAR-CCM+ will be compared with the LES results by FDS, and against available experiments (e.g.,[2] [4] [14]) as well. Apart from assessment of turbulence modelling approaches, predictions from these CFD codes (FDS and STAR-CCM+) will be exported to evacuation codes (Pathfinder or FDS+Evac) for the simulation of human egress. These assessment results will also contribute to the identification of existing gaps in the CFD modelling of fire and evacuation. Based on the modelling deficiencies identified, recommendations to improve the accuracy of the predictions and a path forward will be proposed. Throughout the execution of the study, it is anticipated that the knowledge derived from these high-fidelity CFD analyses will also be used to improve the models in the traditionally (1D and zonal) used fire analysis techniques.

2. Selected Fire Scenario: Cabinet Fire in Main Control Room

For nuclear industry applications, a list of fire scenarios is presented in [15] by U.S. NRC and EPRI for

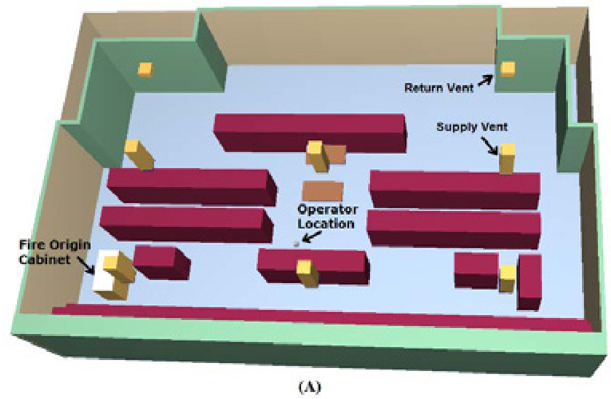


Figure 1 Computational domain of MCR

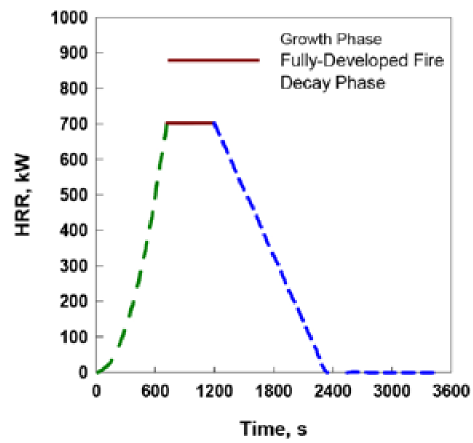


Figure 2 Time history of HRR in MCR fire scenario[1]

V&V of selected fire models. The sources of fire in these scenarios are representative of the typical configurations in most NPPs. In an event of fire in the MCR (that houses instrumentation critical to plant control), damage to the instrumentation and control circuits could put the reactor operation in jeopardy. Hence, within the IPEEE program, the need for improved fire risk assessments for the MCR was emphasized, as the MCR could be a potentially dominant contributor of fire (in addition to the switch gear room).

Analyses of fires in the MCR present unique challenges, including the timing of fire detection, smoke generation and its migration, rate of flame propagation and habitability (including visibility and concentration of species). Accurate prediction of these parameters depends primarily on the ability to correctly capture the inherently unsteady turbulence characteristics associated with the fire and smoke propagation. Therefore, an MCR fire scenario that is broadly applicable to an NPP control room was selected for testing the capability of models within the CFD framework (see Figure 1 for the configuration). The MCR fire scenario, designed to evaluate CFD models, was discussed in detail in [1]; all the fire scenario elements that are pertinent to a CFD simulation were accounted for in

Table 1 Geometry and dimensions of MCR

Geometry	Material	Dimensions (m)
Room	Space	6.2 × 24.6 × 5.2
Floor	Concrete slab covered with carpet	slab thickness 0.5, carpet thickness 0.01
Exterior walls	Concrete	wall thickness 0.9
Interior walls	Gypsum board	wall thickness 0.016
Cabinets	Steel	thickness 0.0015, height 2.4, with varying dimensions in width and depth
Tables	Wood	height 0.5 (area 2 m^2)

the present work. The assessment parameters, as suggested in [1] for CFD predictions, included the smoke concentration (which affects visibility, toxicity), heat flux from the hot gas layer (HGL), and gas temperature, which are crucial to the safe human egress.

As specified in [1], the MCR fire scenario elements comprised of an electrical malfunction in bundles of qualified XPE/neoprene cables inside an isolated control cabinet, designated as the fire origin in Figure 1. Since the current CFD codes are not able to model the fire growth to calculate the fire heat release rate (HRR), the time history of HRR, given in Figure 2, was specified in the simulations based on the t-squared (t^2) fire power law, which was consistent with the guidelines in [16].

As shown in the HRR curve (Figure 2), the fire propagation in enclosures may generally be categorized into three phases. In the fire development phase, the fire grows in size from a small incipient fire from time 0 to 720 s. If fire suppression measures are not taken, it will grow to its full size (fully-developed fire from time 720 to 1200 s at a peak value of 702 kW). The size of the fire is affected mainly by the amount of fuel present (fuel controlled) or the amount of air available through ventilation openings (ventilation limited). As all of the fuel is consumed, the fire will decrease in size during the decay phase from time 1200 to 2340 s.

In the present scenario, ventilation is a key factor that influences the fire behavior in the compartment, with six supply vents and two return vents installed in the MCR as shown in Figure 1. However, only the no-vent case simulations are presented in this paper; the ventilation and door effects will be investigated in a follow-up study.

3. Problem Setup in FDS and Assessment Methodology

The MCR geometry was modelled, including all the associated components (interior and exterior walls, 11 control cabinets, 8 ventilation ducts, floor, and 2 tables) and smoke detectors. The computational domain (Figure 1) was developed using the specifications provided in [1], as listed in Table 1. For the current study, the fire suppression system was not included in the computational model. All the MCR components were modelled using the material properties from the FDS library. Note that open drop ceiling was not modeled because it is assumed to provide a negligible resistance to heat and air flows.

The Smagorinsky eddy viscosity subgrid closure was applied in large-eddy simulation (LES) of turbulent shear flow of smoke and fire propagation [17]. A value of 0.2 was used for the Smagorinsky coefficient, values of turbulent Prandtl and Schmidt numbers were set to the recommended vales of 0.5. The ratio of the fire's characteristic diameter to the size of a grid cell greatly influences the accuracy of the LES approach. The higher the ratio, the better the resolution of fire dynamics, resulting in higher accuracy of the predictions. The ratio was maintained at about 6.4 in the current study, which is well within the suggested range of 5 to 10 [16] for problems where gross smoke movement is of interest.

A mesh of rectilinear grid was generated using PyroSim code [18] (a pre-processor utility for FDS) to discretize the computational domain. A three-dimensional Cartesian coordinate system was assumed with length along the X-direction, width along the Y-direction, and height (top of the ceiling) along the Z-direction. The total mesh count for the entire compartment comprises of 151,000 cells with an average cell size of 0.26 m. Conformal meshes were developed to avoid interpolation and ensure numerical stability. At the fire origin region, smaller cell size (~0.13 m)

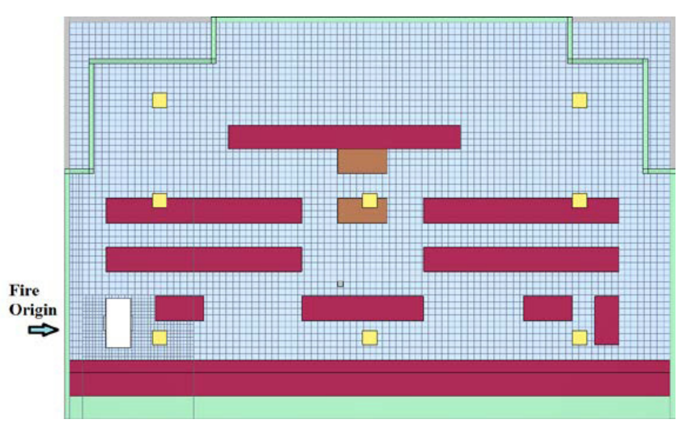


Figure 3 Mesh used in the current study.

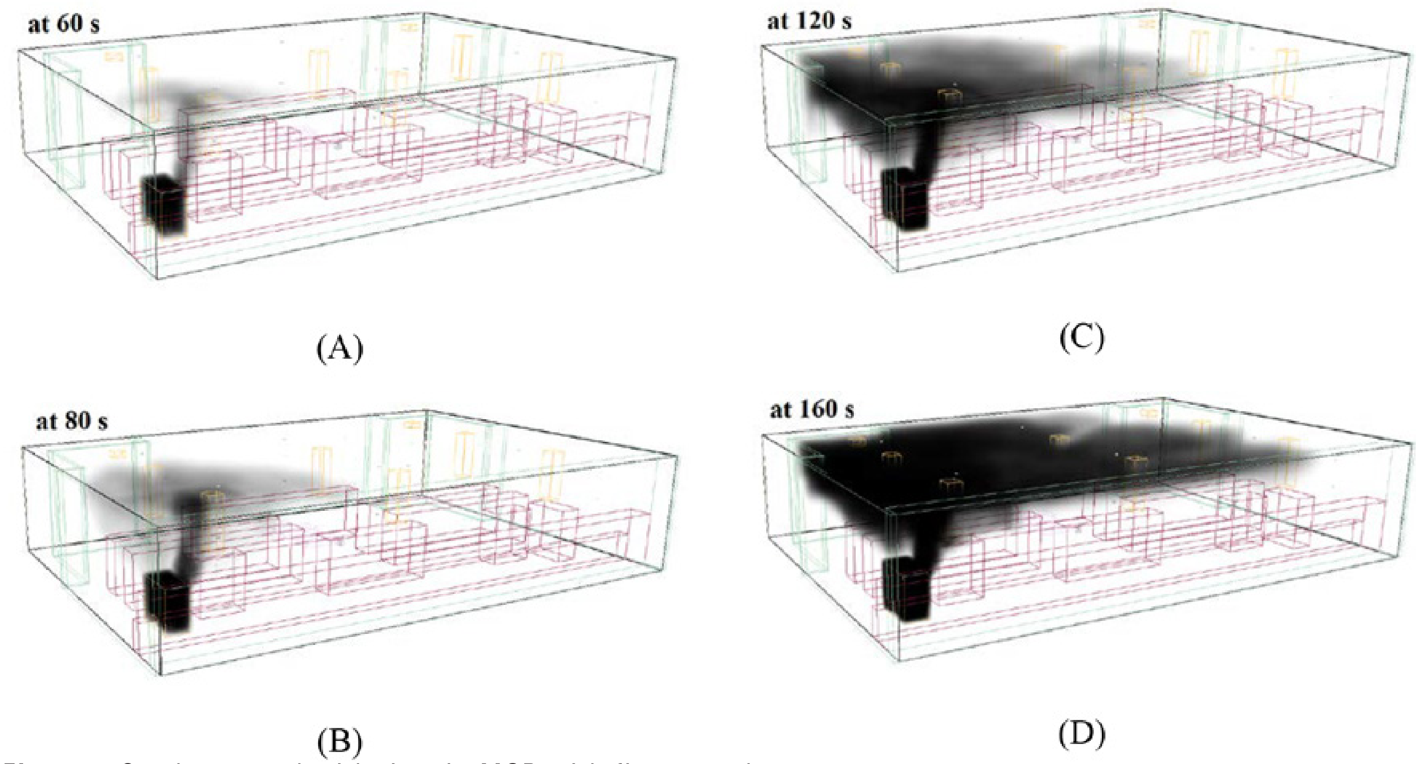


Figure 4 Smoke spread with time in MCR with fire growth.

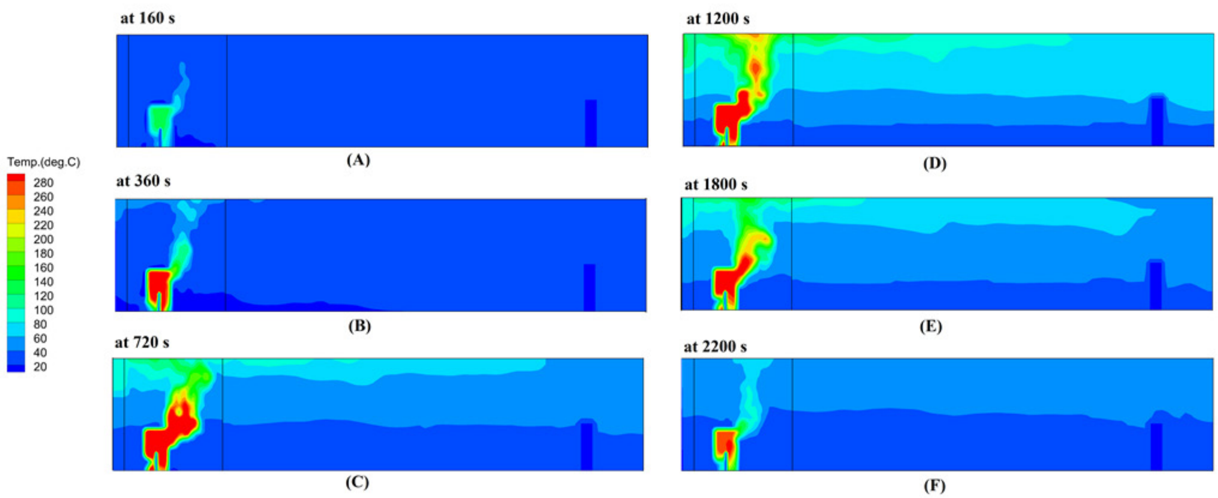


Figure 5 Instantaneous temperature contours on a cross-section across fire origin cabinet

was used to accurately capture the details of fire growth and propagation, as shown in Figure 3. The overall cell aspect ratio was maintained at 1:1 to avoid stretching of the cells. An initial time step size is of 0.07 s based on the cell size of 0.13 m, which was adjusted during the calculation to satisfy the CFL condition for numerical stability. Based on the pre-cursor runs for a wide range of test conditions, the mesh used in this study was found to be satisfactory for the current analyses.

The conservation equations for the fire-driven fluid flow are solved by FDS using finite difference method. The solution was updated in time on the 3D, rectilinear grid. The convergence of the solution was checked for errors in mass conservation, flow reversal over the time step, and the magnitude of change in the velocity solution. An explicit predictor-corrector scheme with second-order discretization accuracy in space and time was used for solving the equations. The flow obstructions in the computational domain were treated using a simple immersed-boundary method. The reaction rate was incorporated using a lumped-species model, and in the non-premixed, fast chemistry limit, the reaction model reduces to a simple "mixed in burnt" approximation, called the eddy dissipation concept. The gray gas radiation was modelled using finite volume solution to solve the radiation transport equation [17].

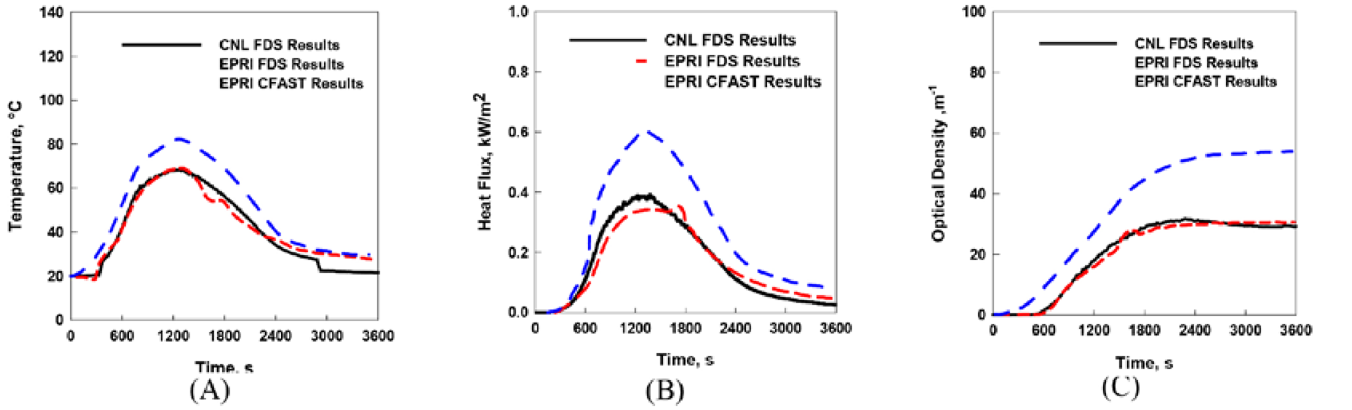


Figure 6 Temperature, heat flux and optical density near operator (at the height of 1.8 m above the floor).

Accurate prediction of the gas temperature surrounding a target and the heat flux to the target is essential for the evaluation of the environmental conditions under a fire in an MCR. The no-vent case predictions of CFAST and FDS reported in [1] were selected for code-to-code comparisons. All the comparisons were made at a location near the operator (in Figure 1).

4. Results and Discussion

The purpose of the current CFD simulations was to determine the length of time that the MCR remains habitable after the start of a fire in a low-voltage control cabinet. The simulations closely followed the guidance provided in [16]. To include all of the fire development stages, a total time of 3600 s was simulated in this study. Note that in general, MCR fire scenarios are treated differently than fires in other compartments, mainly because it is necessary to consider and evaluate forced abandonment in addition to equipment damage. The habitability criterion of the MCR depends on the temperature, heat flux, and smoke concentration to which the operators would be exposed. According to [16], abandonment of the MCR occurs if one of the following conditions is met:

- Gas temperature (at the height of 1.8 m above the floor) exceeds 95°C,
- Heat flux exceeds 1.0 kW/m^2, or,
- Optical density exceeds 0.3 m^{-1}.

For the no-vent case simulations, it was observed that the initial stage of fire/smoke generation and propagation started at ~10 s. As the buoyant hot gas moved upwards, smoke quickly filled up the small space of the cabinet. At ~60 s, smoke started to exhaust from an upper air vent located at the side of the cabinet (Figure 4A), then it was seen to gradually rise and spread laterally across the ceiling as a thin jet (Figure 4B). As the plume of the hot gases grew to the ceiling, it entrained colder air that resulted in the decrease of the plume temperature and concentration of the combustion products, while increasing the volume of smoke (Figure 4C). With further time elapse, the smoke, after impinged upon the ceiling, continued to expand laterally until it was confined by the enclosure boundaries (Figure 4D).

During the initial stage of fire growth (0-160 s), the predicted temperature did not change significantly because of dominant effects of turbulent mixing and cold air entrainment (Figure 5A). After the growth phase, the temperature started to increase slowly in the MCR at ~360s (Figure 5 B). The increase in the temperature intensified as the HRR reached the peak value shown in Figure 2 and the fire became fully developed (Figure 5 C). Near the end of the fully-developed phase (~1200 s), the temperature reached its maximum on the ceiling above the source of the fire (Figure 5 D). As the HRR decayed linearly with time, the fire power reduced to zero and the temperature decreased as shown in Figure 5 E and F.

Predictions of the key parameters, i.e., the HGL temperature, heat flux and optical density condition to which the operator would be exposed, are presented in Figure 6A-C. To assess the predictions obtained by CNL, a code-to-code comparison was made, as summarized in Table 2. It was observed that the CNL predictions agree well with the FDS (no-vent case) results reported in [1]. The predicted trends for all the three parameters are qualitatively similar; however, significant differences exist between the FDS and CFAST results from [1]. These differences are due mainly to the ability of CFD (FDS) to better predict turbulent mixing of hot

Table 2 Summary of the model predictions of MCR scenario

Parameters	Critical Value	***CNL FDS***	EPRI CFAST	EPRI FDS
HGL Temperature (°C)	95	***68***	82	70
Heat Flux (kW/m2)	1	***0.4***	0.6	0.4
Optical Density (m-1)	0.3	***31***	54	31

gas with ambient air, compared to the zonal methods (CFAST). Although the predicted trends by CNL are in line with EPRI's results, a step change in temperature was observed during the decay stage (at ~3000 s in Figure 6A). The reason for this discrepancy is currently being investigated. Numerical instability due to the use of a relatively large time step may be one of the contributors to this unexpected behavior. Based on the FDS results, the temperature and heat flux tenability limit would not be exceeded by a fire of this type. However, the FDS predictions clearly indicate that visibility would be impaired at the operator location in about 9 minutes, thereby triggering forced abandonment of the MCR.

5. Summary and Future Work

A fire model using FDS was developed based on the conditions outlined in [1] for a MCR fire scenario to assess the habitability of the MCR in the event of a fire in an isolated electrical cabinet. Based on the FDS results, at no-vent conditions, the operator would be forced to abandon the MCR as visibility criterion exceeds the critical value. The results from the code-to-code comparison (especially FDS simulations) show good agreement with some degrees of over- and under-prediction for certain key parameters, particularly those related with temperature and heat flux.

Future work will include the corresponding evacuation model with 3 to 5 operators in the MCR. The turbulence models of URANS and RNG k-Đ will be tested and compared with LES to assess accuracy and computational cost for CFD simulations of fire scenarios.

6. Acronyms

CFD	Computational Fluid Dynamics
CNL	Canadian Nuclear Laboratories
CFL	Courant, Friedrichs, Lewy
EPRI	Electric Power Research Institute
FDS	Fire Dynamics Simulator
HRR	Heat Release Rate
HGL	Hot Gas Layer
IPEEE	Individual Plant Examination of External Events
IRSN	Institut de Radioprotection et de Sûreté Nucléaire
LES	Large Eddy Simulation
MCR	Main Control Room
NEA	Nuclear Energy Agency
NIST	National Institute of Standards and Technology
NPP	Nuclear Power Plant
OECD	Organization for Economic Co-operation and Development
PIRT	Phenomena Identification and Ranking Table
PRISME	Propagation d'un Incendie pour des Scénarios Multi-locauxélémentaires (Fire propagation in elementary, multi-room scenarios)
RNG k-ε	Re-Normalisation Group, k - turbulence kinetic energy (m^2/s^2), ε - turbulence dissipation, (m^2/s^3)
STAR-CCM+	Commercial CFD code by Siemens CD-adapco
URANS	Unsteady RANS model
U.S. NRC	United States Nuclear Regulatory Commission
V&V	Verification and Validation
VTT	VTT Technical Research Centre of Finland Ltd.

7. Acknowledgments

This study has been funded by Atomic Energy of Canada Limited, under the auspices of the Federal Nuclear Science and Technology Program.

8. References

[1] U.S. NRC and EPRI, "Nuclear Power Plant Fire Modeling Application Guide (NPP FIRE MAG)", NUREG-1934 (EPRI 1019195), Final Report, November 2012.

[2] OECD and NEA, "Investigating Heat and Smoke Propagation Mechanisms in Multi- Compartment Fire Scenarios, Final Report of the PRISME Project", Nuclear Safety, NWA/CSNI/R(2017)14, January 2018.

[3] U.S. NRC and SNL, "A Phenomena Identification and Ranking Table (PIRT) Exercise for Nuclear Power Plant Fire Modeling Applications", NUREG/CR-6978, November 2008.

[4] IAEA, "International collaborative fire modeling project (ICFMP), Summary of benchmark", GRS 227, September 2008.

[5] VTT and NIST, "Fire Dynamics Simulator, User's Guide", NIST Special Publication 1019 6th Ed., National Institute of Standards and Technology, Gaithersburg, MA, October 2013.

[6] STAR CCM+ Version 13.02 User Guide, 2018.

[7] OpenFOAM Version 1712 Documentation, https://www.openfoam.com/documentation/cpp-guide/html/index.html (Last accessed on May 7, 2018).

[8] ANSYS CFX/FLUENT, Version 19.0, Documentation, 2017.

[9] ISIS Version 5.1.3 Documentation, http://www.irsn.fr/EN/Research/Scientific- tools/Computer-codes/Pages/ISIS-code-4576.aspx (Last accessed on May 22, 2018).

[10] P. Elder, "Opportunities for Canadian Nuclear

Laboratories in Support of Nuclear Safety and Regulation", Presentation at Canadian Nuclear Laboratories' "CNL Federal Lab Day", Ottawa, ON, February 15, 2018.

[11] X. Pan, "Computational Modeling of Human and Social Behaviors for Emergency Egress Analysis", Ph.D. Thesis, Department of Civil and Environmental Engineering, Stanford University, 2006.

[12] NIST, "A Review of Building Evacuation Models, 2nd edition", Technical Note 1680, November 2010.

[13] Pathfinder User Manual 2018, Thunderhead Engineering, 403 Poyntz Avenue, Suite B Manhattan, KS 66502, U.S.A.

[14] T. Korhonen, "Fire Dynamics Simulator with Evacuation: FDS+Evac, Technical Reference and User's Guide", VTT Technical Research Center of Finland, FDS 6.6.0, Evac 2.5.2, DRAFT, February 2018.

[15] U.S. NRC and EPRI, "Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications,"NUREG-1824 (EPRI 1011999) Volume 1 to 7, Washington, D.C., May 2007.

[16] U.S. NRC and EPRI, "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities", Volume 1 to 2, NUREG/CR-6850 (EPRI 1011989), 2005.

[17] VTT and NIST "Fire Dynamics Simulator, Technical Reference Guide, Volume 1: Mathematical Model", NIST Special Publication 1018 6th Ed., National Institute of Standards and Technology, Gaithersburg, MA, November, 2013.

[18] PyroSim 2018.1 User Manual, Thunderhead Engineering.

Commissioning the McMaster University CANS Hot Cells

by T. Marrone[1], Z.L. Peng[1], M. Al Aryan[1], J. Ballaro[1], J. Bennett[1], C. Heysel[1], J. Luxat[1]

[Ed. Note: The following paper was presented at the 38th Annual Conference of the Canadian Nuclear Society and 42nd Annual CNS/CNA Student Conference Sheraton Cavalier Hotel, Saskatoon, SK, Canada, 2018 June 3-6.]

Abstract

New post-irradiation examination (PIE) facility has been constructed at McMaster University's Center for Advanced Nuclear Systems (CANS). The CANS facility consists of a suite of 4 connected hot cells as well as an adjacent scanning electron microscope / focused ion beam instrument (SEM/FIB) for hot work. All facilities are designed to provide post-irradiation examination (PIE) research services to academic and nuclear industry users. The cells contain a variety of equipment including a Computer Numerical Control (CNC) milling machine, multiple sample preparation machines, a tensile testing rig, and an in-cell optical microscopy system. The facility can accommodate vertical and horizontal transfer flasks and samples of activity up to 150 Ci (Co-60). At the time of writing cold commissioning is well underway and it is anticipated that by the time of the conference hot commissioning and some hot work will have been completed. This paper describes the facility as well as commissioning and some initial operations results.

1. Introduction

The McMaster CANS facility is scheduled to be fully commissioned in 2018. The aim of the center is to help scientists research the behaviours exhibited by various materials when they are exposed to radiation and extremely high temperatures over long periods of time. This will aid with improvement of maintenance, safety, and continued operation of nuclear power plants. The facility includes four hot cells: receiving, CNC machining, preparation, and a canyon cell containing mechanical and optical testing. Each cell consists of a thick lead-infused shielded glass window, an in-cell crane for lifting equipment, and a pair of remote manipulators for handling material. The materials received can be processed through a sophisticated assembly line that logs samples, machines coupons for metallurgical testing with MTS equipment, polishes and etches, and views the microstructure evolution on each machining step. If required low total activity/high specific activity samples can be transferred out of the hot cells to an adjacent 3D FIB/SEM dual beam system for characterization and Transmission Electron Microscopy (TEM) sample preparation.

1. Center for Advanced Nuclear Systems (CANS), McMaster University, Hamilton, Ontario, Canada

Figure 1 CANS hot cells looking toward SEM/FIB

2. Receiving Hot Cell

CANS has a cell specifically dedicated to receipt of high activity samples. Samples can be received in either horizontal or vertical transfer flasks. As built the facility can handle horizontal flasks of up to 7,000 kg and vertical flasks up to 2,000 kg. The horizontal flasks are delivered to the facility via truck and unloaded using a large capacity forklift. After removal of transport over-pack, the flask is positioned on a 10,000 kg scissor lift for alignment with a horizontal pass through into the receiving cell. Once on the scissor lift the flask can be enclosed in a HEPA filtered contamination containment tent if anticipated contamination levels require it. Vertical flasks are loaded into the receiving cell through the rear service door using a pallet truck. Inside the cell, the flask is emptied using manipulators and the in-cell 500 kg crane.

Once unpacked in the receiving cell the samples are catalogued, characterized and entered into the facility inventory system. The open space and cleanliness requirements of the receiving cell also make it an ideal area for ad hoc and "one-off work".

Figure 2 Flask Delivery During Cold Commissioning

At the time of writing (March 2018) cold commissioning of the receiving facilities and receiving hot cell have been completed. Cold commissioning consisted of receiving clean transfer flasks loaded with un-irradiated Al stand-ins for CANDU pressure tube segments. The tubes were unloaded from road transport, transferred to the receiving cell, unloaded and entered into the CANS inventory system. Receiving systems are presently awaiting other areas of the facility before commencing hot commissioning.

Figure 3 Vertical flask in receiving cell during cold commissioning

3. CNC machining hot cells

The machining cell is the next cell in line from the receiving cell. It contains a Tormach PCNC 770 CNC mill that has been extensively modified for in cell use. The mill's table is equipped with an in-house designed and produced pneumatic clamping rotary stage. The stage is optimized to accept CANDU pressure tube sections up to 46 cm long and can accommodate variations in circularity and dimensions within the expected range for long use tubes. CNC programs for the production of all expected test sample configurations have been developed and tested on Al samples before being commissioned on cold Zr and activated Al.

The machining cell has a number of design challenges related to contamination potential and Zr's unique characteristics. Like all CANS cells, it is equipped with a HEPA vacuum for clean up. It also has externally refillable Class A/B/C fire extinguishing media along with in-cell stores of Class D fire extinguishing media. Machining procedures are all optimized to reduce the possibility of fire starting in the kerf. The CNC

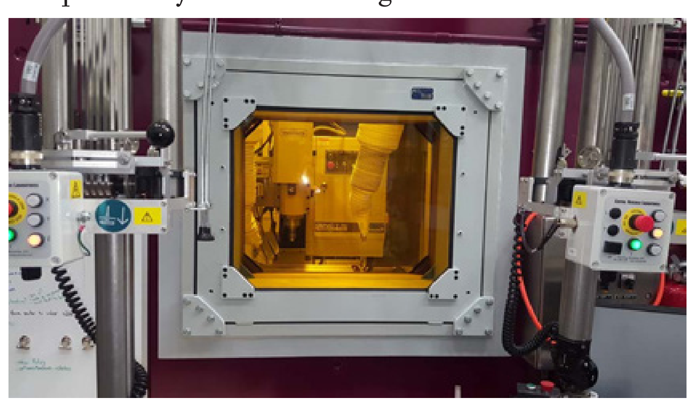


Figure 4 Tormach CNC mill in machining cell

machine is surrounded by stainless steel table tops that are sealed to prevent kerf from dropping to the cell floor and all machining is done "dry" (without lubrication) to minimize generation and distribution of liquid waste.

At time of writing, the machining cell has undergone extensive modification and cold machining of test samples out of Al has been achieved. Cold commissioning will commence once programming and final modifications to hardware are complete.

4. Sample Preparation Hot Cells

The Sample Preparation hot cell contains 3 Struers machines include the Secotom-10, CitoPress- 1 and TegraPol-11 for precision cutting, mounting/pressing, and grinding/polishing, respectively. These machines are adapted to allow remote operation and remote handling of specimens using hot cell manipulators. For example, zirconium alloy tubes used to contain fuel bundles in CANDU nuclear reactors are cut into 25mm x 6mm x 4mm samples. The Secotom-10 then performs precise and deformation-free cutting of these larger samples into 6mm x 4mm x 2.5mm specimens. The specimens are then placed in a hot mounting press, and the conductive PolyFast mounting resin is added. A temperature of around 180°C and a force of about 250 bar is applied during the embedding of the specimen. A TegraPol-11 is used for the grinding/polishing process. The basic process is material removal using abrasive particles in successively finer steps to remove cutting damage from the surface until the required result is reached. The specific requirement of the prepared surface is determined by the particular type of analysis or examination, the preparation can be stopped when the surface is acceptable for a specific examination. Fig. 5 shows a Zr specimen after mechanical polishing.

At the time of writing (Feb 2018) cold commissioning of the sample preparation hot cell have been completed. Cold commissioning consisted of processing numerous cold Al and Zr samples, preparing them for electron and optical microscopy. Sample preparation systems are presently awaiting other areas of the facility before commencing hot commissioning, initial work to be done with activated Al before progressing to activated Zr.

Figure 5 Zirconium specimen after polishing

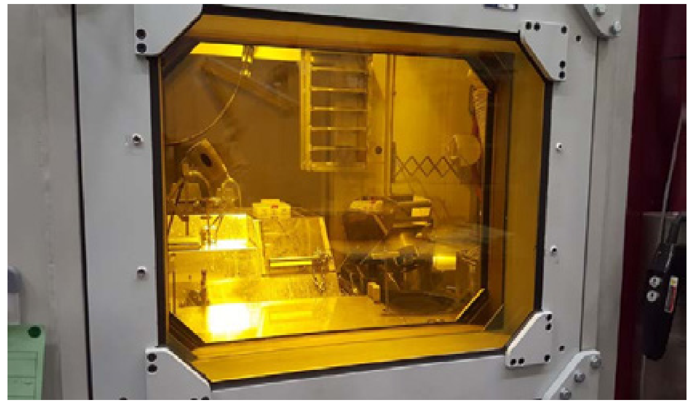


Figure 6: Sample preparation cell

5. Canyon Cell

The last cell in the CANS facility is called the canyon cell due to its length. It has 2 workstations in it, the first the MTS testing station, the second the optical microscopy station. Both stations have a window and 2 manipulators. The cell shares one crane hoist between the 2 stations.

Station 1 is home to an MTS Systems Corporation Model 370.10 Load Unit powered by an external 505.11 Hydraulic Power Unit. This system allows users to conduct tension, compression, fatigue and fracture testing remotely from outside the cells. Maximum force capacity is 100kN over a 100 mm dynamic stroke. The unit is also equipped with a 1400C furnace for high-temperature testing. The grips and in cell adjustments have been adapted to be operable by manipulator.

The second station in the canyon cell is occupied by an Olympus DSX-500 optical microscopy system mounted on a Kinetic Systems 2210 vibration isolator. This system provides for a maximum resolution of 10 nm and has a variety of functions including 3D and panoramic imaging. At the time of writing (Feb 2018) cold commissioning of the Canyon hot cell has been completed. Cold commissioning consisted of programming and testing the MTS load unit with numerous copper samples to ensure proper function of the unit and ability to process the samples remotely. Cold commissioning of the Olympus systems involved mock analysis runs on cold Al and Zr samples prepared in the Sample preparation cell. The Canyon Cell is awaiting completion of other areas of the facility before commencing hot commissioning, initial work to be done with activated Al before progressing to activated Zr.

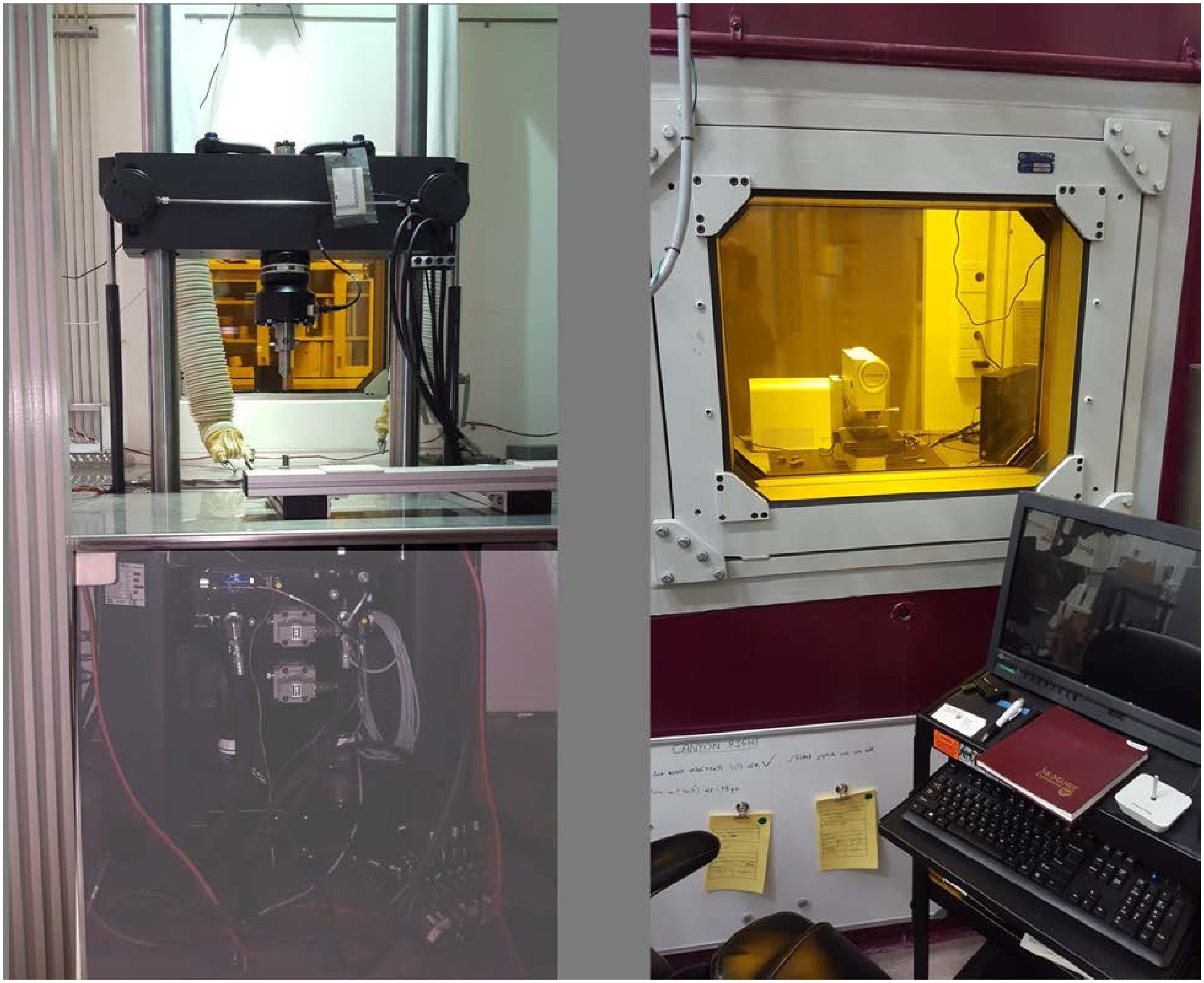


Figure 7 MTS load unit and adjacent Olympus microscopy cell

6. Scanning Electron Microscope and X-ray Micro-analysis

Adjacent to the canyon cell is the electron microscopy room. Material can be removed from the hot cell environment into this room via a shielded transfer port which empties into a fume hood containing an L block. Once out of the cells they can be loaded into the SEM/FIB system or transferred off-site as required.

The FEI Versa dual-beam system combines a Ga+ FIB column and a field-emission SEM column in one tool. It serves three basic functions: (1) imaging by e-beam / ion-beam. The SEM can reach a resolution of 1-2nm, while the FIB has a resolution of about 7-8nm; (2) at site- specific ion etching/polishing and cross-sectioning; (3) at site-specific metal deposition. Furthermore, the SEM with energy and wavelength dispersive x-ray spectroscopy (EDS, WDS) and electron backscatter diffraction (EBSD) is used for topographic features, elemental analysis, grain microstructure and their crystallographic orientations. The first research conducted at CANS was the preparation of radioactive TEM samples using the FIB. Typically, a 30 keV Ga+ ion beam is used for FIB to sputter materials in such a way as to leave a thin wedge of material at the desired sample site. The material must then be detached from the substrate and transferred using a micro-manipulator arm to a specialized TEM grid for further thinning. The final thickness is typically less than 100 nm for high-resolution TEM imaging.

The energy dispersive x-ray spectroscopy (EDS) and wavelength dispersive X-ray spectrometers (WDS) are additional features of the FEI dual beam system that allows in-situ chemical analysis on the surface or at the cross-section of a sample. The analysis of the characteristic x radiation can yield both qualitative identification and quantitative compositional information

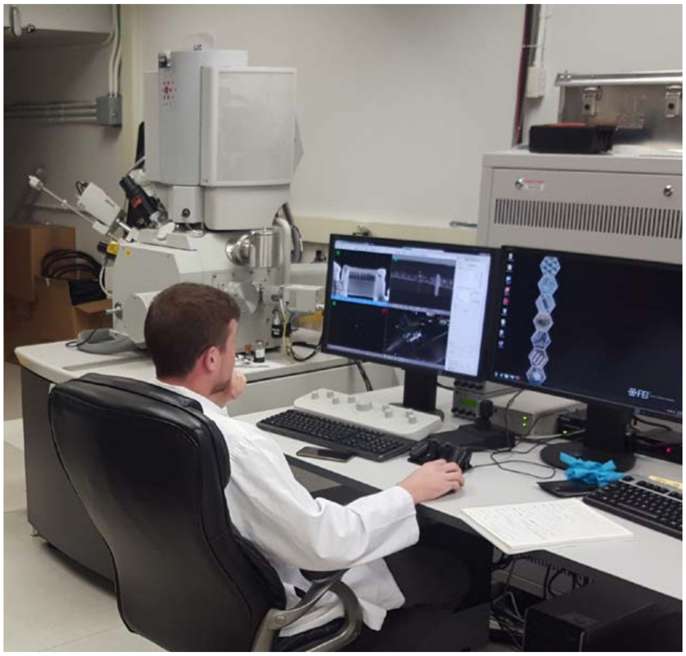


Figure 8 CANS SEM/FIB system

from regions of a specimen as small as a micrometer in diameter. Another important feature is the capability of obtaining compositional mapping with characteristic x-rays. The x-ray images show the elemental distribution in the area of interest.

Recently, FIB polishing has been developed to achieve a high-quality surface for EBSD measurement. In CANS, we use the lift-out technique with a micro-manipulator inside the FIB/SEM chamber for the preparation of EBSD samples. The procedure is similar to the preparation of TEM samples. The specimen from the substrate is removed and mounted to a Cu grid. The FIB polishing starts using 30kV Ga+ with 2nA current for coarse polishing, then 30pA current for fine polishing, and ends up at 5 kV or 2 kV with a low beam current ~16pA for final polishing to minimize the ion-induced damage. EBSD orientation mapping is then conducted with an EDAX Technology EBSD system on FEI dual beam system. Fig. 10 shows the EBSD sample prepared by FIB and its electron backscatter diffraction pattern.

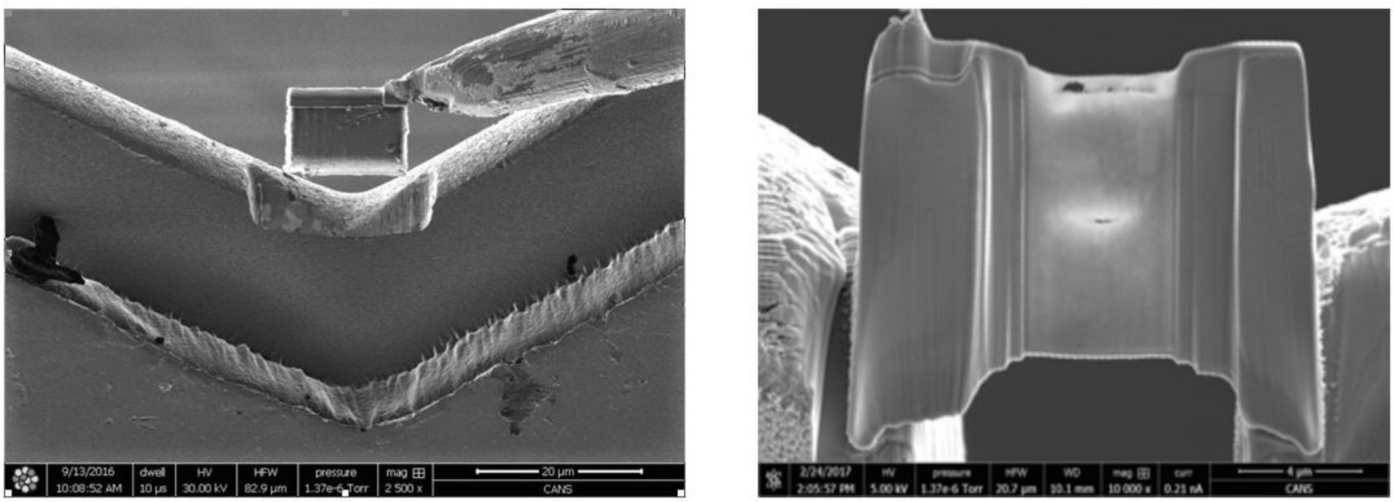


Figure 9 Preparation of Zirconium TEM sample by FIB

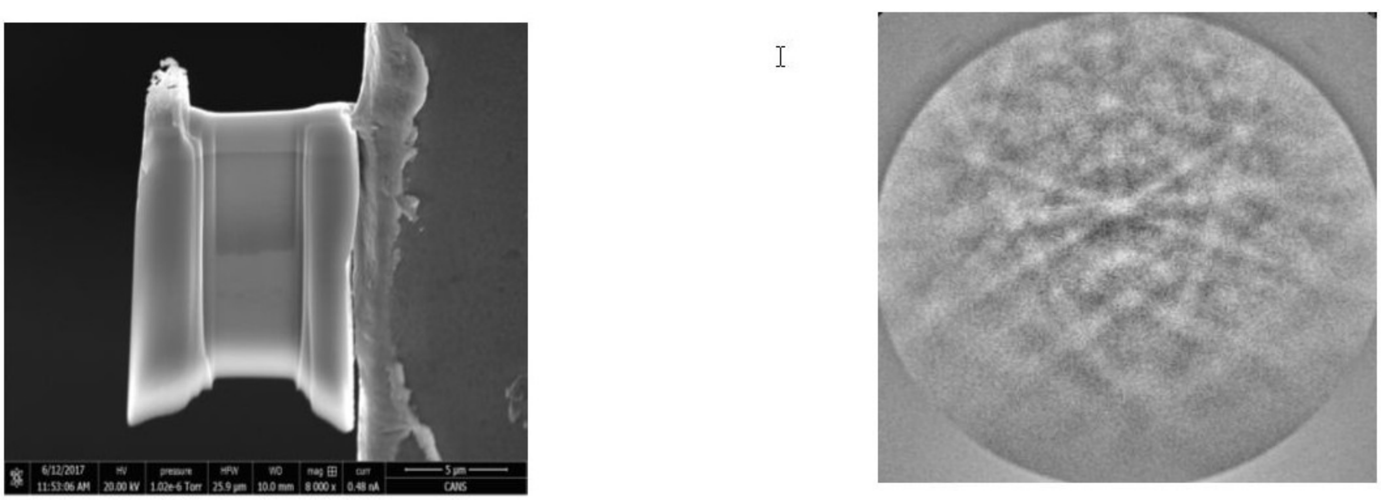


Figure 10 a) Zirconium EBSD sample prepared by FIB (b) electron backscatter diffraction pattern

Commissioning of the SEM/FIB is considered complete at this time. Research and commercial hot work has been completed in the facility including FIB work on Inconel X750 garter spring samples that had spent time in the core of a power reactor.

7. Other facilities in CANS

In addition to the facilities associated directly with the hot cells, CANS also includes:

- A Nuclear Materials Characterization Facility, featuring a Three Dimensional Atom Probe, located in the Brockhouse Institute for Materials Research at McMaster University;
- A nuclear safety thermal hydraulics facility that includes a heated water flow loop, an upgraded 256 kW power supply, cooling heat exchangers, a new heat transfer test section and 3-D Tomography and High-Speed Video instrumentation for state-of-the-art flow visualization, located in the Nuclear Research Building (NRB) at McMaster University.

These facilities are not described in this paper.

8. Summary

This paper presents an overview of the facilities available at the Center for Advanced Nuclear Systems (CANS), McMaster University.

The facility is in the final phases of cold commissioning before moving onto hot commissioning and further onto full hot work. When operational the CANS facility will provide full PIE capabilities for use on reactor core components with total activity less then 150 Ci (Co-60). This capability is unique in a Canadian university, and we believe is unique in any university facility in the world.

Acknowledgment

This new facility is funded through the Canadian Foundation for Innovation (CFI), the Ministry of Research and Innovation, McMaster University and private donations.

View of the McMaster Nuclear Reactor Building in Hamilton, Ontario. Photo courtesy of McMaster University.

Hundreds of Students Attend the 2018 Student Job Fair for the Nuclear Industry

by COLIN HUNT

Approximately 300 students participated in the 2018 Canadian Nuclear Society (CNS) Job Fair for the Nuclear Industry on October 16, 2018. As in 2017, this event was held at Durham College/UOIT in Oshawa.

They were at the Job Fair to meet with Canada's leading nuclear companies seeking information regarding employment opportunities. Nearly all of Canada's largest nuclear institutions were in attendance to meet with students. A total of 37 employers and exhibitors were present for the Job Fair. Jacques Plourde, Durham Branch Chair, was supported by 23 volunteers, primarily from the Durham and Toronto CNS Branches.

Just like the first Job Fair in 2017, employers were impressed by the number of students who came out to the Fair looking for opportunities. A high proportion of students coming to the Job Fair were in their final years of various engineering disciplines. Particularly noteable were the number of mechanical and electrical engineering graduates.

Many students visited the CNS booth during the four-hour event. They were interested in the opportunities that the CNS has to offer in networking among companies and among other individuals within the Canadian nuclear industry.

The Job Fair was a local initiative of the CNS Durham Branch held during Nuclear Science Week. Nuclear Science Week was developed in 2009 by the National Museum of Nuclear Science and History, affiliated with the Smithsonian Institute. Each year during the third week in October, the Museum helps to sponsor nuclear-related events across North America.

CNS 2019 SNC OTTAWA
Nuclear Energy's Value
Aligned with community expectations

39th Annual CNS Conference & 43rd Annual CNS/CNA Student Conference

2019 CNS Annual Conference | Call for Papers

The Canadian Nuclear Society (CNS) will host its 39th Annual Conference at the Westin Hotel in Ottawa, Ontario, Canada from June 23 to 26, 2019. To be successful, any project, initiative or on-going operation must deliver what the Community expects with respect to environmental impact, public consultation, economics and reliability. This year's conference will explore these expectations and will show Nuclear Energy's Value – aligned with community expectations.

The CNS 39th Annual Conference will feature:

- Plenary sessions with invited speakers to address such topics as large scale refurbishment projects, options for future new-build, etc;
- Technical sessions with subject-matter experts from utilities, suppliers, the regulator, academia, federal laboratories and agencies to present the latest advancements in nuclear science and technology;
- Exhibits with industrial leaders showcasing their latest nuclear products and technology;
- A Student Conference with student posters;
- Social events (such as opening reception, lunches, conference banquet, wine-&-cheese reception, coffee breaks and conference banquet) that facilitate discussions and networking on subjects of common interests.

The 43rd Annual CNS/CNA Student Conference will be held in parallel at the same venue, which facilitates interaction between experts and the future generation of nuclear scientists, engineers, and specialists. The Student Conference will feature a poster session, at which university students will showcase their latest research findings and advancements. A Call for Students' Extended Abstracts will be issued separately.

Important Dates:
Abstract submission: **January 31, 2019**
Full paper submitted for review: **February 28, 2019**
Final paper submission: **April 15, 2019**

Submission Guidelines:

- Papers must present original material or state-of-the-art review of a significant areas.
- Abstract should be a maximum of 150 words in length.
- Full papers should be no longer than 12 pages.
- The required format of submission is electronic (Word or PDF).
- By submitting a paper, you agree to it being published in the Conference Proceedings.
- Templates for abstracts & full papers are available on the Conference website: www.cns-annual-conference.org
- Submission should be made via: http://www.softconf.com/h/CNS2019Technical
- At least one of the authors must register for the Conference by the early-bird registration date (**May 1, 2019**) for the paper to be included in the Conference Proceedings.

General Enquiries: Benjamin Rouben
E-mail: annualconference@cns-snc.ca
Tel: 416-977-7620

39th Annual CNS Conference & 43rd Annual CNS/CNA Student Conference

CNS 2019 SNC OTTAWA
Nuclear Energy's Value
Aligned with community expectations

2019 CNS Annual Conference | Technical Topics

NEW BUILD & LIFE EXTENSION
New build programs; International collaborations; Regulatory policy and risk assessment; Life extension and license renewal; Design and construction; New-site licensing; Advanced systems and components; Passive safety

NEW TECHNOLOGY, RESEARCH & DEVELOPMENT
Advanced reactor physics, radiation physics; thermal hydraulics; Fusion; Hydrogen production; Materials Science for new and existing designs; Efficiency enhancements; Space, Mining and other novel applications; New nuclear codes and standards

SMALL MODULAR REACTORS
Deployment opportunities, design, licensing and deployment challenges. SMR concepts and designs; on-grid and off-grid applications in mining and remote locations

OPERATIONS & AGING MANAGEMENT
Operating Experience; Maintenance; Operational risk assessment; Outage management; Fuel and equipment performance; Equipment Reliability enhancement; On-line Condition Monitoring; Obsolescence; Component replacement; Supply chain

FACILITATING ENERGY POLICY & GLOBAL CONSENSUS
Policy development; International and regional cooperation; Energy mix; Safeguards; Sustainability; Climate change; Addressing public acceptance; Education; Communications; Outreach

ENHANCING SAFETY & SECURITY
Severe accidents; Accident management and analysis; Emergency planning; Plant security; Safety culture; Stress-testing; Criticality Safety Analysis; Probabilistic Risk assessment; Regulatory perspective; Nuclear security; Non-proliferation

ENVIRONMENTAL PROTECTION & WASTE MANAGEMENT
Designing for environmental protection; Assessment of environmental effects; Decommissioning and environmental remediation; Waste stream management and reduction; Progress in repository development; Interim used fuel storage strategies; Waste treatment, packaging and transportation

FUEL CYCLES
Uranium and thorium mining, milling, refining, conversion and enrichment; Uranium and Thorium fuel manufacturing; Fault-tolerant fuel designs; Open and closed fuel cycles; Proliferation-resistant fuels

COMPETITIVE CHALLENGES & COST REDUCTION
Design and construction; Manufacturing and modularity; Economics and financing; Supply chain assurance; Market and competitive challenges

MEDICAL & BIOLOGICAL BENEFITS
Medical and biological systems; Treatments and protocols; New isotope manufacture; Novel accelerators and target development; Supply assurance; Handling waste streams; Economics; International trends; Isotope production and use; Agricultural applications

The IAEA is pleased to announce the publications of:

Feasibility Study Preparation for New Research Reactor Programmes

IAEA Nuclear Energy Series No. NG-T-3.18

This publication describes the various elements to be included in a comprehensive, robust and logically structured feasibility study report for a new research reactor project. It provides guidance for the main supporting organization or team of a new research reactor to enable them to undertake an authoritative and comprehensive feasibility study that could be submitted to decision makers for their review in order to support proposals and endorse an action plan for construction of such a facility. It includes considerations of justification for a new research reactor, associated key nuclear infrastructure issues, cost-benefit analysis and risk management that would have to be addressed prior to authorizations for the establishment of a new research reactor. Addressing these issues will help Member States to develop a comprehensive understanding of all the roles, obligations and commitments involved in establishing and operating a research reactor and ensure that these are met during all phases of the project life cycle. The publication also includes a generic template for preparing a feasibility study report and provides some examples and lessons learned from individual Member States in preparing such studies.

STI/PUB/1816, 33 pp.; 5 figs.; 2018; ISBN: 978-92-0-104518-8, English, 30.00 Euro

Electronic version can be found: https://www-pub.iaea.org/books/iaeabooks/12306/Feasibility-Study-Preparation-for-New-Research-Reactor-Programmes

Approaches for Overall Instrumentation and Control Architectures of Nuclear Power Plants

IAEA Nuclear Energy Series No. NP-T-2.11

This publication concerns approaches for establishing the overall instrumentation and control (I&C) architecture of a nuclear power plant. It describes the characteristics and content of general I&C architectures, presents architectural principles and addresses the limitation of the potential effects of postulated common cause failures. It introduces an architectural development process and discusses technical considerations for the design. The publication emphasizes safety aspects, addresses the defence in depth concept, but also includes consideration of plant availability, operability and security. It recognizes the potential for adverse effects of I&C failures on plant availability and operability that may arise from increased architectural complexity, and also describes the optimization of I&C functionality and features that are required to be implemented.

STI/PUB/1821, 55 pp.; 9 figs., 2018; ISBN: 978-92-0-102718-4, English, 30.00 Euro

Electronic version can be found: https://www-pub.iaea.org/books/IAEABooks/12292/Approaches-for-Overall-Instrumentation-and-Control-Architectures-of-Nuclear-Power-Plants

Organization, Management and Staffing of the Regulatory Body for Safety

IAEA Safety Standards Series No. GSG-12

This publication provides recommendations on meeting the requirements of IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), Governmental, Legal and Regulatory Framework for Safety, in respect of the organizational structure, management and staffing of the regulatory body. It addresses the arrangements and processes regulatory bodies need to consider in carrying out their responsibilities and functions efficiently and effectively and in an independent manner. It also provides guidance on how an integrated management system should be established and implemented in order to have in place both the core processes that help the regulatory body to perform its core functions, and the management and support processes that are necessary to run the regulatory body. The publication is intended for use by all regulatory bodies, irrespective of the size and type of facilities and activities they regulate.

STI/PUB/1801, 124 pp.; 0 figs.; 2018; ISBN: 978-92-0-100218-1, English, 50.00 Euro

Electronic version can be found: https://www-pub.iaea.org/books/iaeabooks/12272/Organization-Management-and-Staffing-of-the-Regulatory-Body-for-Safety

Functions and Processes of the Regulatory Body for Safety

IAEA Safety Standards Series No. GSG-13

This Safety Guide provides recommendations on meeting the requirements of IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), Governmental, Legal and Regulatory Framework for Safety, on the regulatory body's core functions and associated regulatory processes. This guidance is particularly important for regulatory bodies having responsibilities covering a range of facilities and activities that give rise to radiation risks and the important organizational interfaces between various regulatory authorities, which require effective coordination and cooperation. It promotes a consistent approach to regulation and specifically addresses the release of facilities and activities from regulatory control including sites, buildings, equipment and material. The publication is intended to be used mainly by regulatory bodies but will also be useful for governments that are developing a regulatory framework for safety. It will also assist authorized parties and others dealing with radiation sources in understanding regulatory procedures, processes and expectations.

STI/PUB/1804, 137 pp.; 2 figs., 2018; ISBN: 978-92-0-100718-6, English, 52.00 Euro

Electronic version can be found: https://www-pub.iaea.org/books/IAEABooks/12271/Functions-and-Processes-of-the-Regulatory-Body-for-Safety

Prospective Radiological Environmental Impact Assessment for Facilities and Activities

IAEA Safety Standards Series No. GSG-10

This Safety Guide provides recommendations and guidance on a general framework for performing prospective radiological impact assessments for facilities and activities, to estimate and control the radiological effects on the public and on the environment. This radiological environmental impact assessment is intended for planned exposure situations as part of the authorization process and, when applicable, as part of a governmental decision making process for facilities and activities. The situations covered in the assessment include both exposures expected to occur in normal operation as well as potential exposures. The assessment of the radiological impacts includes consideration of the risk of radiation effects for humans and for populations of non-human biota. Guidance is provided on the assumptions and input data to be used, the necessary models for environmental transfer and radiation dose assessment and the definition and use of criteria for informing decisions.

STI/PUB/1819, 82 pp.; 5 figs., 2018; ISBN: 978-92-0-102518-0, English, 42.00 Euro

Electronic version can be found: https://www-pub.iaea.org/books/IAEABooks/12198/Prospective-Radiological-Environmental-Impact-Assessment-for-Facilities-and-Activities

Accelerator Simulation and Theoretical Modelling of Radiation Effects in Structural Materials

IAEA Nuclear Energy Series No. NF-T-2.2

This publication summarizes the findings and conclusions of the IAEA coordinated research project (CRP) on accelerator simulation and theoretical modelling of radiation effects, aimed at supporting Member States in the development of advanced radiation resistant structural materials for implementation in innovative nuclear systems. This aim can be achieved through enhancement of both experimental neutron-emulation capabilities of ion accelerators and improvement of the predictive efficiency of theoretical models and computer codes. This dual approach is challenging but necessary, because outputs of accelerator simulation experiments need adequate theoretical interpretation, and theoretical models and codes need high dose experimental data for their verification. Both ion irradiation investigations and computer modelling have been the specific subjects of the CRP, and the results of these studies are presented in this publication which also includes state-of-the-art reviews of four major aspects of the project: challenges and trends of structural materials development for present and future reactor designs, accelerator methodologies for material testing, multiscale modelling tools, and advanced examination techniques.

STI/PUB/1732, 116 pp.; 0 figs.; 2018; ISBN: 978-92-0-107415-7, English, 39.00 Euro

Electronic version can be found: https://www-pub.iaea.org/books/iaeabooks/10871/Accelerator-Simulation-and-Theoretical-Modelling-of-Radiation-Effects-in-Structural-Materials

International Conference on Physical Protection of Nuclear Material and Nuclear Facilities

Summary of an International Conference Held in Vienna, 13–17 November 2017

Proceedings Series

This publication presents the proceedings of an international conference in the field of nuclear security. The conference was convened to foster the exchange of practices and experiences related to the security of radioactive material under regulatory control in use, transport and storage, and the detection of nuclear and other radioactive material out of regulatory control. The conference provided a forum for Member States to share their experiences, difficulties, and lessons learned during the implementation of IAEA Nuclear Security Series No. 13, Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Rev.5). The publication contains the President's summary of the conference, statements from the opening and closing sessions, and an outline of the conference programme. The attached CD-ROM contains the full conference programme, the list of conference participants, and a selection of papers and presentations from the conference.

STI/PUB/1831, 36 pp.; 0 figs., 2018; ISBN: 978-92-0-106918-4, English, 40.00 Euro

Electronic version can be found: https://www-pub.iaea.org/books/iaeabooks/13396/International-Conference-on-Physical-Protection-of-Nuclear-Material-and-Nuclear-Facilities

Country Nuclear Power Profiles

2018 Edition

The Country Nuclear Power Profiles (CNPP) publication compiles background information on the status and development of nuclear power programmes across participating International Atomic Energy Agency (IAEA) Member States. The publication summarizes organizational and industrial aspects of nuclear power programmes and provides information about the relevant legislative, regulatory and international framework in each participating State. The descriptive and statistical overview of the economic, energy and electricity situation in each State and its nuclear power framework is intended to serve as an integrated source of key background information about nuclear power programmes throughout the world. This 2018 edition contains updated country information for 37 out of 50 participating Member States.

IAEA-CNPP/2018/CD, 2018; ISBN: 978-92-0-157718-4, English, 95.00 Euro

Electronic version can be found: https://www-pub.iaea.org/books/IAEABooks/13448/Country-Nuclear-Power-Profiles

Preparation, Conduct and Evaluation of Exercises for Security of Nuclear and Other Radioactive Material in Transport

Non-serial Publication

This publication provides practical advice for planners to prepare, conduct and evaluate nuclear material transport security exercises. Nuclear material transport security exercises are part of a comprehensive nuclear security regime. Exercises vary in scope and in scale, ranging from small drills, which focus on training, to large scale exercises, which aim at testing the overall command, control, coordination and communications arrangements. The purpose of exercises is not to 'demonstrate' the quality of the arrangements, but rather, to identify weaknesses and areas where improvements can be made. Hence, exercises are an integral part of a sustainable and continuous improvement programme for nuclear transport security. Exercises can also be a tool to assess and validate existing transport security arrangements prior to gaining regulatory approval for actual transport operations or transport campaigns. The material provided in this publication is intended as an example of a logical process for the preparation, undertaking and evaluation of exercises, which needs to be adapted to suit national systems, local circumstances and the specific aim of each exercise. It constitutes a starting point for organizations that have not previously organized or managed exercise programmes, as well as a reference for organizations that wish to validate or improve their existing exercise programmes.

IAEA-TDL-007, 120 pp.; 2 figs.; 2018; ISBN: 978-92-0-107018-0, English, 18.00 Euro

Electronic version can be found: https://www-pub.iaea.org/books/iaeabooks/12372/Preparation-Conduct-and-Evaluation-of-Exercises-for-Security-of-Nuclear-and-Other-Radioactive-Material-in-Transport

4th Canadian Conference on Nuclear Waste Management, Decommissioning and Environmental Restoration

SEPTEMBER 8-11, 2019
OTTAWA, ON

Moving Forward Together Toward Sustainable Solutions

Marriott Hotel, Ottawa, Canada

Sustainable solutions for nuclear waste management, decommissioning, and environmental restoration require a collaborative approach at the technical, regulatory, environmental, social, political, and economic levels. The Canadian Nuclear Society invites you to join this discussion.

Topics include

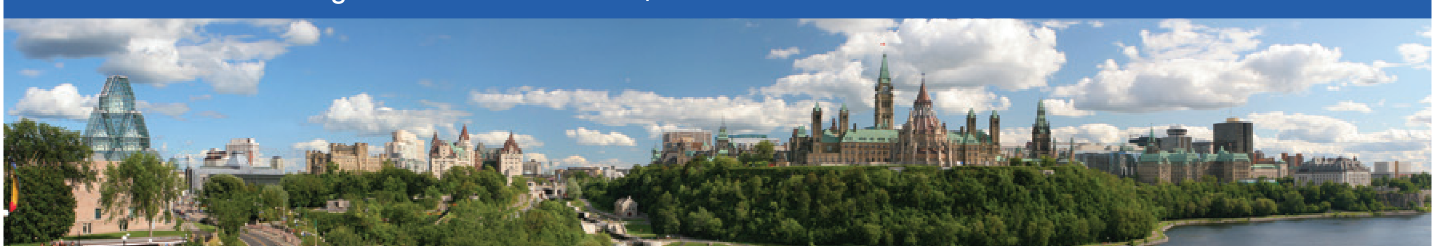
- Government Policies, Programs & Oversight
- Stakeholder Engagement
- Indigenous Participation in the Nuclear Industry
- Uranium Mining & Milling Waste Management
- Low Level, Intermediate Level & Mixed Waste Management
- Used Nuclear Fuel & High Level Waste Management
- Waste Characterization, Processing, Packaging & Waste Minimization
- Waste Transportation
- SMR Waste
- Environmental Remediation
- Decommissioning Strategies & Projects
- Other Potential Topics
  - Safety & Safeguards,
  - Information Management,
  - Quality Assurance,
  - Preservation of Knowledge,
  - Succession Planning.

Contact us

Conference Organizing Chair
Ms. Parva ALAVI
EWM Consulting
Tel: (905) 599 9534
Parva.alavi@ewmconsulting.net

Conference Sponsorship Chair
Ms. Ruth BURANY
Kinectrics
Tel: (647) 328 2422
Ruth.Burany@cns-snc.ca

For registration and other info, visit **cns-snc.ca/events/nwmder2019/**



2019 Canadian Nuclear Achievement Awards
Call for Nominations

We are announcing the Call for Nominations for the 2019 Canadian Nuclear Achievement Awards, jointly sponsored by the Canadian Nuclear Society (CNS) and the Canadian Nuclear Association (CNA). These Awards represent an opportunity to recognize individuals who have made significant contributions, technical and non-technical, to various aspects of nuclear science and technology in Canada.

Nominations may be submitted for any of the following Awards:

- W. B. Lewis Medal
- Ian McRae Award
- Harold A. Smith Outstanding Contribution Award
- Innovative Achievement Award
- John S. Hewitt Team Achievement Award
- Education and Communication Award
- George C. Laurence Award for Nuclear Safety
- Fellow of the Canadian Nuclear Society
- R. E. Jervis Award

The deadline to submit nominations is **January 12, 2019.** The Awards will be officially presented during the CNS Annual Conference held June 23 – 26, 2019 in Ottawa, ON, Canada.

For detailed information on the nomination package, Awards criteria, and how to submit the nomination please visit: http://cns-snc.ca/cns/awards.

If you have any questions, please contact Ruxandra Dranga, Chair – CNS/CNA Honours and Awards Committee by email at awards@cns-snc.ca, or by phone at (613) 717 – 2338.

GENERAL news

(Compiled by Colin Hunt from open sources)

Canada to Build Advanced Medical Isotope Centre

Canada is to invest more than $50 million on a new centre for advanced medical isotope research and development. The centre will be on the campus of Triumf, the national laboratory for particle physics, at the University of British Columbia.

Canadian Prime Minister Justin Trudeau announced federal funding for the Institute for Advanced Medical Isotopes (IAMI) during a visit to Triumf.

The 2500-square-metre state-of-the-art facility will house a new TR-24 medical cyclotron, a cyclotron control room and six laboratories. It will also have technical rooms, quality control laboratories, office space, and electrical control rooms.

The construction of the facility is valued at $31.8 million, Triumf said. "With additional equipment and philanthropic funding, the total value of the IAMI project will be more than $50 million," it added.

The government of Canada will contribute $10 million to the project through the Investing in Canada infrastructure plan. The Province of British Columbia has contributed $12 million Triumf is contributing $5 million and, through fundraising initiatives, BC Cancer and the University of British Columbia are each contributing $2 million.

UK, Canada Sign Nuclear Cooperation Agreement

The UK and Canada today signed a bilateral Nuclear Cooperation Agreement (NCA), the third such agreement signed by the UK this year in preparation for its exit from the European Union. It will allow the UK and Canada to continue their "mutually beneficial" civil nuclear cooperation when current European Atomic Energy Community (Euratom) arrangements cease to apply in the UK, Department of Business, Energy and Industrial Strategy (BEIS) said.

Announcing the agreement, BEIS said the UK has now concluded all replacement international agreements needed to ensure continuity of civil nuclear trade following Euratom exit.

"The signing of this NCA follows the recent signing of bilateral NCAs with Australia in August and the US in May. These NCAs will continue the effect of current arrangements provided for by UK membership of Euratom, which will cease to apply to the UK upon departure from the EU, ensuring a seamless transition for the nuclear sector in terms of its international relations," BEIS said.

"The UK-Canada NCA is the final NCA necessary to meet a legal requirement set in the Nuclear Safeguards Act 2018 to have in place all of the instruments required to ensure continuity of civil nuclear trade with international partners following the UK's withdrawal from Euratom," it added.

The NCA with Canada was signed in Ottawa by Mark Gwozdecky, Canadian assistant deputy minister, International Security & Political Affairs, and Susan le Jeune d'Allegeershecque, British high commissioner to Canada.

Ontario Leads Way on Air Quality

Other provinces and jurisdictions should follow Ontario's lead to improve the quality of life for people who live with asthma, allergies and other respiratory illnesses, according to a new joint report by Bruce Power and Asthma Canada. A separate report from the World Health Organisation (WHO) has called for decreasing global reliance on fossil fuels as a measure to combat polluted air, which it says caused 600,000 deaths in children under 15 in 2016.

Bruce Power and Asthma Canada's joint report, Clean Air Canada: Recognising the role of nuclear power sup-

porting coal phase-out to achieve long-term climate change goals, highlights nuclear power's integral role in helping Ontario transition away from burning coal for electricity.

Canada has committed to phasing out its coal-fired electricity power plants by 2030 and has reduced its coal consumption by 24% since 1990 and by 41% since 2000.

"Although Canada has already come a long way in reducing GHG [greenhouse gas] emissions in the electricity sector, in large part due to the leadership exemplified by Ontario, which closed its last coal plant in 2014, some provinces such as Alberta and Saskatchewan remain primarily fossil fuel-burning regions, which reflect opportunities for change," it says.

Much of Ontario's success at phasing out coal was made possible by the province's nuclear industry, the report notes. A major part of this commitment was achieved through the refurbishment and return to service of Bruce A's four units, which provided an additional 3000 MWe of carbon-free electricity to the provincial grid between 2003 and 2012.

Cameco Notes Market Improvements

The uranium market is showing a marked improvement compared with a year ago but there is still a long way to go, Cameco CEO Tim Gitzel said on 2 November.

The company has updated its outlook for 2018 and 2019, with changes in exchange rates, higher uranium prices and additional sales opportunities leading to increases in volumes, revenue and average realised uranium price for 2018, Gitzel said in the company's quarterly conference call.

Additional market demand has seen the company's delivery volumes for 2018 increase to 35-36 million pounds U3O8 (13,463-13,847 tU), up from the 34-35 million pounds given in the company's second quarter outlook, and 2019 sales commitments have increased to 27-29 million pounds (previously 25 million-27 million pounds).

Cameco remains on track to produce about 9 million pounds U3O8 this year, Gitzel said. The company expects it may need to purchase an additional 1-3 million pounds in 2018 and 10-12 million pounds in 2019, to meet its increased delivery commitments and maintain its inventory. This is in addition to committed purchases and material already secured in the spot market.

Gitzel said the Canadian company's results reflect the impact of its decision to extend the shutdown of its McArthur River and Key Lake operations, which it announced in July along with its half-yearly results.

CNL Launches Centre for Reactor Sustainability

Canadian Nuclear Laboratories (CNL) has launched the Centre for Reactor Sustainability (CRS), bringing together its broad research capabilities in support of the sustainable, long-term operations of the world's fleet of nuclear power reactors.

CNL describes the CRS as a "virtual centre with the mission to revolutionise nuclear power plants using technologies to sustain reliable and affordable nuclear reactors". The new centre, it said, will "help make nuclear power plants even more efficient and reliable, support reactor life extension and long-term operation, and enable plant modernisation through innovative technologies and inspection services".

The CRS will leverage CNL's specialised knowledge and experience to provide services to utilities and their suppliers in five key research areas. These are: ageing management, including post-irradiation examination; fuel characterisation; operational support and failure response; chemistry control, monitoring and optimisation; and, specialised inspection and maintenance tooling.

"CNL's Chalk River Laboratories is recognised around the world for its work to support the life extension and efficiency of nuclear power reactors," said CNL President and CEO Mark Lesinski. "CNL and the nuclear supply chain work together to deliver an integrated approach to reactor sustainability, leading to major costs savings and efficiency improvements for safe nuclear operations."

Reprocessing Ceases at UK's Thorp Plant

Reprocessing operations have ended at the Thermal Oxide Reprocessing Plant (Thorp) at the Sellafield site in the UK after 24 years. The facility will now be used to store used nuclear fuel until the 2070s.

Built at a cost of GBP1.8 billion (USD2.3 billion), the Thorp facility opened in 1994 and has since processed 9331 tonnes of used nuclear fuel from 30 customers in nine countries around the world. In doing so, it has generated an estimated GBP9 billion in revenue. It is one of only two commercial nuclear fuel reprocessing plants in the world, the other being Orano's La Hague plant in France.

The decision to cease reprocessing at Thorp was taken in 2012 in response to "a significant downturn" in demand, said Sellafield Limited. "The international market for reprocessing has shifted significantly since Thorp's construction, with the majority of customers now opting to store rather than reprocess their fuel."

The last batch of fuel to be reprocessed began its journey through the plant at 11.32am on 9 November.

Sellafield Ltd said the Thorp plant - the largest structure on the Sellafield site - "will continue to serve the UK until the 2070s" as a storage facility for used fuel.

Poland Ready for Nuclear Energy, says Minister

In order to meet increasing energy demand while meeting climate targets, coal-dependent Poland needs to introduce new sources of energy. This, says the country's energy minister, Kryzstof Tchórzewski, opens the opportunity to introduce emissions-free nuclear energy.

Speaking at the *World Nuclear Spotlight Poland* conference in Warsaw November 20, Tchórzewski said that following the country's independence from the Soviet Union, Poland had an independent energy system based on coal. "What we needed to do was meet the demand linked to economic growth," he said. "That was our priority."

After Poland's accession to the European Union in 2004, the country had a lot of investments and upgrades, particularly in the energy sector, Tchórzewski said. The power sector as a result was able to satisfy the growing demand for energy.

"But then we started thinking about the energy mix and I started the discussions on nuclear energy as the deputy minister of economy in 2007. Since 2015, we have been facing a different dilemma. We are now facing the issue of [EU] climate policy. We need to secure clean air and we are facing a situation where Poland is developing very fast. The economy is growing. We need to satisfy sustainable growth."

Union of Concerned Scientists Calls for Policy to Preserve Nuclear

The Union of Concerned Scientists (UCS) has called for federal and state policies in the USA to help preserve safely operating nuclear power plants that are at risk of premature closure to ensure their low-carbon energy is not replaced by fossil fuels.

More than a third of the country's nuclear fleet faces the prospect of early closure over the next decade, before their operating licences expire and with their low-carbon electricity likely to be replaced primarily by natural gas and coal, the group's latest analysis notes. Early nuclear retirements will pose no threat to electricity reliability or resilience, but its potential replacement with fossil fuels raises serious concerns about the USA's ability to achieve the deep cuts in carbon emissions needed to limit the worst impacts of climate change, it says.

The UCS report, *The Nuclear Power Dilemma: Declining Profits, Plant Closures, and the Threat of Rising Carbon Emissions,* suggests the adoption of a national carbon price or low-carbon electricity standard could avoid the potential early closure of all the unprofitable and marginally economic plants identified in the analysis. This would help the USA meet its commitment under the Paris climate agreement, it says.

"The United States is facing a dilemma," Steve Clemmer, the report's co-author and director of energy research and analysis at UCS, said. "Nuclear power plants are being squeezed economically at a time when we need every source of low-carbon power we can get to replace retiring coal plants and prevent an overreliance on natural gas."

Saudi Arabia Lays Research Reactor Foundation Stone

A foundation stone for Saudi Arabia's first research reactor has been laid at King Abdulaziz City for Science and Technology (KACST).

The low-energy research reactor was one of seven strategic projects in renewable and atomic energy, water desalination, genetic medicine and aircraft manufacturing formally inaugurated yesterday by Crown Prince Mohammed bin Salman bin Abdulaziz, who is also vice president of Saudi Arabia's Council of Ministers and the country's minister of defence.

Saudi Arabia's official press agency did not give further details of the research reactor project. However, according to the *Riyadh Daily*, construction of the 100 KW reactor is already under way and the project is due to be completed by the end of 2019.

"[The] specifications and design of the reactor were developed by Saudi nuclear experts and with the participation of the King Abdullah City for Atomic and Renewable Energy and international expert houses with the highest international safety standards," it reported.

Saudi Arabia intends to add nuclear power to the country's energy mix with the objective of diversifying and boosting its production capacity. The King Abdullah City for Atomic and Renewable Energy (KA-CARE) last year announced that it was soliciting proposals for 2.9 GWe of nuclear capacity from China, Japan, Russia and South Korea. The country is also advancing plans for small reactors.

First Reactor on Russia's Floating Plant Starts Up

One of the two reactors aboard Russia's first floating nuclear power plant, Akademik Lomonosov, has achieved a sustained chain reaction for the first time. The second reactor will be started up and tests carried out before the plant is towed to Pevek next year.

"The physical launch of the reactor unit on the starboard side of the floating nuclear power plant *Akademik Lomonosov* happened on Friday,» a spokesperson for state nuclear corporation Rosatom told *Ria Novosti*. "The reactor unit reached the minimum controlled power level at 5.58pm Moscow time."

Comprehensive testing of the reactor is expected to start within a few days. The vessel's second reactor will be started in the near future. All the final technological operations at the facility are scheduled to be completed by the end of this year.

The keel of *Akademik Lomonosov* was laid in April 2007 at Sevmash in Severodvinsk, but in August 2008 Rosatom cancelled the contract - apparently due to the military workload at Sevmash - and transferred it to the Baltic Shipyard in Saint Petersburg, which has experience in building nuclear icebreakers. New keel-laying took place in May 2009 and the hull was launched at the end of June 2010. The two 35 MWe KLT-40S reactors were installed in October 2013.

Akademik Lomonosov - 144 metres in length, 30 metres wide and having a displacement of 21,000 tonnes - left the Baltiysky Zavod Shipyard on 28 April. It arrived in Murmansk on 17 May after having been towed over 4000 kilometres and travelling through four seas: the Baltic, Northern, Norwegian and Barents.

Tokai 2 Cleared for Extended Operation

Japan Atomic Power Company (JAPC) has received regulatory approval of an extension to the operating period of unit 2 at its Tokai nuclear power plant, enabling the reactor to operate for up to 60 years.

Under Japan's revised regulations, reactors have a nominal lifespan of 40 years. However, extensions can be granted once only and limited to a maximum of 20 years, contingent on exacting safety requirements.

JAPC applied to the Nuclear Regulation Authority (NRA) on 24 November 2017 to extend the operation of the unit - a 1060 MWe boiling water reactor that started commercial operation in 1978 - by 20 years.

The company announced today that the NRA had approved the extension. Tokai 2's current operating licence is due to expire on 28 November.

So far, three pressurised water reactors have been approved for extended operation under the revised regulations. These are Takahama units 1 and 2 and Mihama 3, all owned and operated by Kansai Electric Power Company.

Court Ruling Clears Way for Ikata 3 Restart

The Hiroshima District Court has rejected a call from residents to re-impose an injunction on the operation of unit 3 at the Ikata nuclear power plant in Japan's Ehime Prefecture. The move clears the way for owner Shikoku Electric Power Company to restart the reactor.

Ikata 3 - a 846 MWe pressurised water reactor - was given approval by the Nuclear Regulatory Authority to resume operation in April 2016, having been idle since being taken offline for a periodic inspection in April 2011. Shikoku declared the unit back in commercial operation on 7 September 2016.

Four residents from Matsuyama and Hiroshima filed a request for a temporary injunction against the unit's operation with the Hiroshima District Court on 11 March 2016, the fifth anniversary of the Fukushima Daiichi accident. The plaintiffs claimed that Shikoku had underestimated the potential size of an earthquake that could strike the plant and the risks posed by a volcano some 130km away. The operator has claimed there is a low possibility of Mount Aso experiencing a large-scale eruption while the reactor is in operation.

However, on 30 March 2017, the court ruled that Shikoku had used reliable measures in calculating the basic earthquake ground motion at the site and rejected the petition. The following month, the plaintiffs appealed the decision in the Hiroshima High Court.

Hurricane-Hit Puerto Rico to Consider Nuclear Power

The majority New Progressive Party in Puerto Rico's House of Representatives introduced a resolution instructing the chamber's Government Committee to investigate the possibility of building nuclear power plants on the island, Caribbean News has reported.

The party's spokesman, Gabriel Rodríguez, said that following Hurricane Maria's damaged to Puerto Rico's power grid it was "imperative to look for new, more efficient and less expensive sources" of energy generation.

Hurricane Maria was the strongest storm to make landfall in Puerto Rico in 85 years. It came ashore on 20 September last year, with sustained winds of 155 mph, knocking out power to the entire island.

"One of the most damaged areas and which took longer to restore service was the mountainside. In my representative district #13, there were sectors where electricity was restored a year after Hurricane Maria," the lawmaker reportedly said. Production of power from natural gas or renewable energy have been discussed publicly, but each has advantages and disadvantages, he added.

"The important thing is we do not rule out any of the options in advance, among them the production of nuclear energy," he said, adding that "a feasibility study for its incorporation for the benefit of our citizens" has not yet been conducted.

Indian Reactor Breaks Operating Record

Unit 1 of India's Kaiga nuclear power plant has completed its 895th day of continuous operation, a new world record for continuous operation of a pressurised heavy water reactor (PHWR) and the second-longest for a nuclear power reactor of any type.

The 220 MWe Indian-designed and domestically fuelled reactor has now operated without a break since 13 May 2016, Nuclear Power Corporation of India Ltd (NPCIL) announced today.

The previous operating record for a PHWR of 894 days was set in October 1994 by the Pickering 7 reactor in Canada. The current world record for continuous operation for a commercial nuclear power reactor of any type is held by unit 2 of the UK's Heysham II plant, an advanced gas-cooled reactor (AGR) which had completed an unbroken 940 days in service when it was taken offline for a scheduled maintenance outage in September 2016.

Canadian Nuclear Society
Société Nucléaire Canadienne
998 Bloor St. W. #501, Toronto, ON M6H 1L0
Tel: (416) 977-7620 E-mail/Courriel: cns_office@cns-snc.ca

Scholarships in Nuclear Science and Engineering at Canadian Universities

The Canadian Nuclear Society (CNS) is pleased to offer scholarships to promote Nuclear Science and Engineering to students at Canadian universities.

Two scholarships are offered in 2019: One graduate school entrance scholarship of $5,000 and two undergraduate summer research scholarships of $3,000 each.

Graduate School Entrance Scholarship: $5,000

This entrance scholarship is designed to encourage undergraduate students to enter a graduate program related to Nuclear Science and Engineering at a Canadian university.

Eligibility

You must be enrolled in a full-time undergraduate program at a Canadian University and be a member of the CNS.

The duration of the graduate program must be at least two years and is expected to lead to a Master's or a PhD degree.

Undergraduate Student Research Scholarship: $3,000

This scholarship is designed to encourage undergraduate students to participate in research in Nuclear Science and Engineering during the summer months.

Eligibility

You must be enrolled in a full-time undergraduate program at a Canadian University for at least two years and be a member of the CNS.

The scholarship is to be matched by $2,000 from the supervisor for a total of $5,000.

The recipients of the scholarships will be selected on the basis of their academic standing and other information to be supplied with the application.

The Scholarship Committee of the Canadian Nuclear Society will collect and review the submissions, and make the award decisions.

Details of the scholarships and the procedure for application can be found on the CNS website at

www.cns-snc.ca/Scholarships

The deadline for submission of the application is **February 18th, 2019**.

Canadian Nuclear Society
Société Nucléaire Canadienne
998 Bloor St. W. #501, Toronto, ON M6H 1L0
Tel: (416) 977-7620 E-mail/Courriel: cns_office@cns-snc.ca

Bourses en science et génie nucléaire dans les universités canadiennes

La Société Nucléaire Canadienne est heureuse d'offrir des bourses afin d'encourager les étudiants dans les universités canadiennes à étudier la science et le génie nucléaire.

Deux bourses sont offertes en 2019: une bourse de 5,000$ à l'entrée aux études supérieures, et deux bourses de recherche d'été (de 3,000$ chaque) pour étudiants poursuivant la licence.

Bourse d'entrée aux études supérieures : 5,000$

Le but de cette bourse est d'encourager les étudiants à s'inscrire aux études supérieures en science et génie nucléaire dans une université canadienne.

Éligibilité

L'étudiant(e) doit être présentement inscrit(e) plein-temps à un programme poursuivant la licence dans une université canadienne, et doit être membre de la SNC.

L'échéancier du programme en études supérieures doit couvrir une période minimale de deux ans, et devrait mener à une maîtrise ou à un doctorat.

Bourse de recherche pour étudiants poursuivant la licence : 3,000$

Le but de cette bourse est d'encourager les étudiants poursuivant la licence à participer en recherche en science et génie nucléaire pendant l'été.

Éligibilité

L'étudiant(e) doit être inscrit(e) plein-temps à un programme d'au moins 2 ans poursuivant la licence dans une université canadienne, et doit être membre de la SNC.

Cette bourse doit être complémentée par un montant de 2,000$ de la part du directeur de la recherche, pour un total de 5,000$.

Les gagnant(e)s des bourses seront sélectionné(e)s à partir de la qualité de leur dossier académique, ainsi que d'autres données à être fournies en même temps que la demande de bourse.

Le Comité des bourses de la Société Nucléaire Canadienne recevra et étudiera les candidatures, et attribuera les bourses.

Les détails des bourses et les procédures de demande sont disponibles sur le site web de la SNC à

www.cns-snc.ca/bourses

La date limite pour la soumission de demande de bourse est le **18 février 2019**.

1st International Conference of Materials, Chemistry and Fitness-For-Service Solutions for Nuclear Systems

Challenges and Innovative Solutions in Fitness-for-Service

MCFD-2019 Conference:

15 – 17 May 2019 – Hilton Toronto/Markham Conference Centre – Markham, ON Canada

Canadian Nuclear Society ®

CALL FOR ABSTRACTS

The focus for the MCFD-2019 Conference is on the approaches used to demonstrate the continued Fitness-for-Service (FFS) of components in Nuclear Power Plants. Ever increasing demands for FFS demonstrations often require innovative and multidisciplinary solutions that involve elements of engineering from: materials, chemistry, stress analysis, thermal-hydraulic analysis, probabilistic assessment methods, examination and inspection approaches, and operational strategies. This is the case for most major nuclear plant systems and components, regardless of reactor type.

Objectives of this conference are:

- to provide a forum for exchanging views, ideas, and information relating to innovative FFS demonstrations, and
- to share technical engineering in support of life extension and refurbishment of nuclear plant major components.

The conference will be of interest to representatives from various sectors of the Nuclear Industry including: material and equipment vendors, technical and engineering service providers, utility technical staff, regulators, designers, researchers, students, and academia.

Abstracts are sought in the following areas:

- OPEX and lessons learned from recent FFS activities
- FFS case studies
- FFS programs, plans, and achievements
- Materials factors in FFS demonstrations
- Chemistry factors in FFS demonstrations
- FFS methodologies for
    - Steam generator tubing
    - CANDU fuel channels
    - PWR reactor vessel and internals
    - BWR reactor vessel and internals
    - Piping systems
    - Major heat exchangers
- Regulatory issues surrounding FFS
- Application of codes and standards in FFS
- Developments in probabilistic assessments
- Analytical tools
- Novel or innovative solutions
- Meeting the challenges of emerging issues

Student participation is encouraged, in particular by means of a student poster session. The top three student submissions will be selected to present at the conference.

Submission guidelines

Abstracts should be a maximum of 250 words and are to be submitted through the conference website. It will be a requirement for all presenting authors to provide a full presentation for the conference proceedings. Students submitting poster abstracts are encouraged to provide a summary of the work suitable for inclusion in the proceedings, but this is not mandatory. *As well as the conference proceedings, authors are encouraged to prepare full papers for submission to a special issue of a Nuclear Journal for publication.*

Abstract deadline: 3 December 2018

Timeline:

Abstract submission:	3 December 2018
Author notification of acceptance:	20 December 2018
Draft presentations:	31 March 2019
Review notification:	15 April 2019
Final presentations:	30 April 2019
Conference:	15 – 17 May 2019

2019

February — **CNA Nuclear Industry Conference and Tradeshow**
Westin Hotel
Ottawa, Ontario
cna.ca/2019-conference

March 10-13 — **11th International Symposium on Supercritical Water Cooled Reactors (ISSCWR-11)**
Vancouver, BC
Organized by: CNS NS&E Division
Contact: Canadian Nuclear Society Office,
Tel: 416-977-7620
cns-snc@on.aibn.com
www.cns-snc.ca

March — **Nuclear 101 Ottawa**
Organized by: CNS Education and Communication Committee
Contact: Canadian Nuclear Society Office
Tel: 416-977-7620
cns-snc@on.aibn.com
www.cns-snc.ca

Spring — **Reactor Physics Course**
Contact: Canadian Nuclear Society Office,
Tel: 416-977-7620
cnssnc@on.aibn.com
www.cns-snc.ca

March — **CANDU Technology & Safety Course**
cns-snc.ca

May — **Nuclear 101**
cns-snc.ca

May-June — **1st Innovative Materials, Chemistry and Fitness-For Service Solutions for Nuclear Power Systems Conference**
Organized by: CNS MCF Division
Contact: Canadian Nuclear Society Office
Tel: 416-977-7620
cns-snc@on.aibn.com
www.cns-snc.ca June 9-13, 2019

ANS Annual Meeting
Minneapolis, MN
Organized by: ANS
www.ans.org/meetings

June 23-26 — **39th Annual CNS Conference & 43rd Annual CNS/CNA Student Conference**
Westin Hotel, Ottawa, Ont
Contact: Canadian Nuclear Society Office
Tel: 416-977-7620
cns-snc@on.aibn.com
www.cns-snc.ca

July 21-24 — **International Conference on CANDU Fuel**
Hilton Meadowvale Hotel, Mississauga, ON
Organized by: CNS FT Division
Contact: Canadian Nuclear Society Office,
Tel: 416-977-7620
cnssnc@on.aibn.com
www.cns-snc.ca

September 8-11 — **Waste Management, Decommissioning and Environment Restoration for Canada's Nuclear Activities**
Ottawa Marriott Hotel, Ottawa, ON
Organized by: CNS E&WM Division
Contact: Canadian Nuclear Society Office
Tel: 416-977-7620
cns-snc@on.aibn.com
www.cns-snc.ca

2018-2019 CNS Council • Conseil de la SNC

Executive / *Exécutif*

President / ***Président***	John Luxat. 905-525-9140 x24670
e-mail	luxat@mcmastr.ca
Past President / ***Président sortant***	Daniel Gammage 519-621-2130 x2166
e-mail	dgammage44@gmail.com
1st Vice-President / ***1ier Vice-Président***	Keith Stratton 506-343-4060
e-mail	kstratton@bellaliant.net
2nd Vice-President / ***2ième Vice-Président***	Aman Usmani 416-592-3667 x3667
e-mail	aman.usmani@kinectrics.com
Treasurer / ***Trésorier***	Mohamed Younis 905-829-0357
e-mail	mhyounis2018@gmail.com
Secretary / ***Secrétaire***	Colin G. Hunt. 613-742-8476
e-mail	colin.hunt@rogers.com
Financial Administrator / ***Administrateur financier***	Ken L. Smith. 905-828-8216
e-mail	unecan@rogers.com
Executive Director / ***Directeur exécutif***	Ben Rouben 416-663-3252
e-mail	roubenb@alum.mit.edu
Communications Director / ***Directeur des communications***	Peter Easton. 613-863-1027
e-mail	peter@petereaston.net
ECC Chair	John Roberts. 519-396-8843
e-mail	alchemy@tnt21.com

Members-at-Large / *Membres sans portefeuille*

Parva Alavi 905-599-9534
John Barrett. 613-237-4262
Ruth Burany . . . . 416.207.6000 x 6027
Chris Ciaravino 416-697-4170
Xinjian Duan . . . . 905 823 9040 x 36646
Romney Duffey 208-360-5218
Peter Easton 613-863-1027
Mohinder Grover. 416-499-5591
Jerry Hopwood . . . . 905-823-9060 x 37507
Ross Horgan. 506-659-7554
Doddy Kastanya. 416-592-1946
Wilson Lam 416-212-1116
Dorin Nichita 905-721-8668
Peter Ottensmeyer 416-444-4746
Chary Rangacharyulu 306-966-6412
Nick Sion 416-487-2740
Kamal Verma . . . . 905-823-9040 x 35947

CNS Committees / *Comités de la SNC*

Program / Programme
Ruth Burany 416-207-6000 x6027

Branch Affairs / Chapitres locaux
Ben Rouben . . . . 416-663-3252 roubenb@alum.mit.edu

Education and Communications / Éducation et communications
Ruxandra Dranga . . . . .613-584-3311 x46856 ruxandra.dranga@cnl.ca

Membership / Adhésion
Dan Gammage . . . . .519-621-2130 x2166 dgammage44@gmail.com

Finance / Finances
Mohamed Younis . . . . 905-829-0357 mhyounis2018@gmail.com

Bulletin
Colin Hunt . . . . 613-742-8476 colin.hunt@rogers.com

Past Presidents / Anciens présidents
Dan Gammage . . . . .591-621-2130 x2166 dgammage44@gmail.com

Honours and Awards / Prix et honneurs
Ruxandra Dranga . . . . .613-584-3311 x46856 ruxandra.dranga@cnl.ca

International Liaison Committee / Liaisons internationales
Chris Ciaravino. 416-697-4170

Internet / Internet
Andrew Prudil . . . . 613-483-0346 andrew.prudil@gmail.com

Inter-society Relations / Relations inter-sociétés
Peter Ozemoyah . . . . .289-288-0490 x249 pozemoyah@tyne-engineering.com

Strategic Planning
Jacques Plourde . . . . 905-441-2776 jap-performance@rogers.com

Scholarship / Bourses
Mohamed Younis . . . . 613-592-2256 mohamed.younis@amecfw.com
. . . . 416-592-6516

Technical Divisions / *Divisions techniques*

- Nuclear Science and Engineering (NSE) Division / Division des sciences et du génie nucléaires
  Wei Shen 289-400-7280 wei.shen@candu.org
- Fuel Technologies (FT) Division / Division des technologies du combustible
  Paul Chan 613-541-6000 x6145 paul.chan@rmc.ca
- Design & Materials Division Materials, Chemistry & Fitness-for-Service (MCF) Division / Division des matières, de la chimie, et de l'aptitude au service
  Mohammadreza Baghbanan 416-217-2100 m.baghbanan@utoronto.ca
- Division of Environment, Waste Management & Decommissioning (EWMD) Division / Division de l'environnement, de la gestion des déchets, et du déclassement
  Parva Alavi 905-599-9534 parva.alavi@ewmconsulting.net
- Nuclear Operations and Maintenance (NOM) Division/ Division de l'exploitation et de la maintenance
  Polad Zahedi 905-839-6746 x4029 polad.zahedi@opg.com
- Generation IV and Small Reactor Technology Division / Division de la technologie des Réacteurs de la Génération IV et des Petits Réacteurs
  Wilson Lam (416)-212-1116 wilsonlam.cns@gmail.com
- Fusion Science and Technology Fusion Energy (and Accelerator) Science and Technology (FEAST) Division / Division de la science et de la technologie de l'énergie nucléaire de fusion et des accélérateurs
  Blair Bromley 613-584-3311 x43676 blair.bromley@cnl.ca

CNA Liaison / ***Agent de liaison avec l'ANC***
John Barrett 613-237-4262 barrettj@cna.ca

CNS Bulletin Publisher / Éditeur du Bulletin SNC
Colin Hunt 613-220-7607 colin.hunt@rogers.com

CNS Bulletin Editor / Rédacteur du Bulletin SNC
Ric Fluke 416-592-4110 rfluke@sympatico.ca

CNS Office Manager / Bureau de la SNC
Bob O'Sullivan 416-977-7620 cns-snc@on.aibn.com

Branches / Chapitres locaux

Bruce	John Krane	519-361-4286 jck@bmts.com
Chalk River	Andrew Morreale	613-584-8811 x 42543 morreaac@mcmaster.ca
Durham Region	Jacques Plourde	905-441-2776 jap-performance@rogers.com
Golden Horseshoe	Michael Tucker	289-880-8696 tuckerm@mcmaster.ca
Manitoba	Jason Martino	204-753-2311 x62229 martinoj@cnl.ca
New Brunswick	Derek Mullin	506-650-3374 dmullin@nbpower.com
Ottawa	Ken Kirkhope	ken.kirkhope@cnsc-ccsn.gc.ca
Québec	Michel Saint-Denis	514-875-3452 michelstdenis@videotron.qc.ca
Sheridan Park	Raj Jain	raj.jain@candu.com
Toronto	Mohammad Fadaee	647-909-0816 moe.fadaee@cns-snc.ca
UOIT	Mohamed Saleh	289-221-0739 mohamad.saleh@uoit.net
Western	David Malcolm	867-446-7017 david.malcolm@mcri.ca

CNS WEB Page - Site internet de la SNC

For information on CNS activities and other links – Pour toutes informations sur les activités de la SNC

http://www.cns-snc.ca

Why the Nuclear Industry Cannot Bury Its Waste Problem

by NEIL ALEXANDER

Don't panic! I am not saying there is a technical problem!

It's a headline designed to attract the attention but the reader quickly finds that it is not the challenge of burying the waste to which I refer, but instead the problem of convincing the public that we know what we are doing.

The idea is to capture attention long enough to induce some critical thinking.

There is no nuclear subject where critical thinking is more needed than in dealing with the "waste" issue because the concepts are very challenging. As an example, many groups say that we should not have a repository close to a Great Lake because in 100,000 years time the repository may leak into that lake and yet the chances are that the Great Lakes won't be there in 100,000 years time. This, though obvious, is a hard thing for people to appreciate because people have only ever lived their own life and during that life the Great Lakes have always been there. So, they think they always will be. The concept of 100,000 years is something we are not equipped to understand because it has never been relevant to us.

This whole 100,000-year idea comes in because people think that because radioactive materials have a half-life, then they must be dangerous until they are completely non-radioactive. It sounds logical but it isn't.

Clearly, this premise is a nonsense. The world is covered with radioactive materials. Always has been. Always will be. So far as I can tell radioactive materials have not wiped all life off the face of the earth. In fact, in all probability, they have enabled the evolution that has led to the human race.

But then the whole concept that something must be kept out of the environment until it is no longer dangerous is also a complete nonsense. We use lots of materials that are "dangerous". The cadmium sometimes used in solar panels is very nasty stuff, as is the neodymium used in the magnets of industrial wind turbines. No one is saying they need to be isolated from the environment forever. Because they don't. Nature, well before mankind was around, had lots of dangerous materials. We call many of them ores and we dig them up.

As scientists and engineers, we think that we can always engineer our way to a solution. But you cannot engineer a way out of problems that can only exist in our imaginations.

Yes, of course, by showing people our plans we may instill confidence in many that those plans make sense. But we will never be able to show that we can keep these materials isolated for ever. And that is what people imagine that they need. But then if people imagined that we needed to keep used magnets out of the environment forever no one could ever show that was possible either.

But then in a massive irony, the real reason, I suspect, why it is so hard to get permission to implement our disposal plans, is that there is no driving need to do so. Thus, it is that everyone can wait. Wait until there is better technology. Wait until after the next election. Wait until another minister has to make the decision. Wait.

If this is the case then the secret to gaining approvals is not to demonstrate that our proposed disposal route is safe (although that must be done as well) but to show that there is good reason to do it and that the best time to do it is now.

Neil Alexander is presently running an ironic campaign to have all the world's Uranium dug up and buried properly in order to draw attention to some of the silly things that are written about nuclear wastes.

Nuclear Qualified, Certified *and* Energized

E.S. Fox Ltd. has been in business for eighty years, designing and building major power projects throughout Canada and around the world.

As a single source of industrial construction, fabrication and engineering solutions, our integrated mechanical, electrical and civil departments ensure we adhere to, control and execute all your design requirements.

E.S. Fox Fabrication has held ASME Nuclear N, NPT, NA and NS Certifications since 2010, one of a select few Canadian Nuclear suppliers to hold these qualifications. We are also a key supplier of EPC construction and maintenance services to major nuclear power producers in the country.

For the better part of a century, E.S. Fox has achieved and continues to foster a reputation for the highest quality workmanship, engineering excellence, timely project completion and operational efficiency. We strive to be your contractor of choice.

TO LEARN MORE, CALL US AT (905) 354-3700, OR VISIT US AT ESFOX.COM

E.S. FOX LTD. CONSTRUCTORS

80 Years Of Integrated Construction Solutions

THESE STAMPS ARE TRADEMARKS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS AND THE NATIONAL BOARD OF BOILER AND PRESSURE VESSEL INSPECTORS, RESPECTIVELY.

N NPT NA NS U U2 S PP NB R

Canadian Nuclear Laboratories | Laboratoires Nucléaires Canadiens

We're building a new Chalk River campus!

We invite you to learn more about our vision for the future at www.cnl.ca.

Canada's storied Chalk River Laboratories campus is being revitalized. Enabled by an investment of $1.2 billion from AECL and the Government of Canada, we have already cut the ribbon on a new materials science complex and a new tritium laboratory, and construction is underway on three new buildings. The cornerstone of the new campus will be the Advanced Nuclear Materials Research Centre, a truly world class facility set to open in the coming years.

Chalk River Laboratories; a proud history and a bright future.

www.cnl.ca