Environmental Defense Institute

News on Environmental Health and Safety Issues

June 2023 **Volume 34** **Number 6**

The Department of Energy is promoting a plethora of proposed new nuclear reactors, none of which will be deployed in time to matter in the fight against climate change

According to The Idaho Falls Post Register, the Department of Energy's Idaho National Laboratory is working on two very small reactors, the 100 kw MARVEL reactor and mobile Department of Defense, TRISO-fueled Pele reactors. Idaho Falls is part of UAMPS that have signed on the build small pressurized water reactors, the small modular NuScale reactors that uses zirconium clad fuel and is similar to existing light-water reactors, to be built on the INL site west of Idaho Falls. [1] The INL is also planning to conduct research on a 200-kW molten-salt reactor that put the nuclear fuel in the coolant (see the April 2023 EDI newsletter and draft DOE/EA-2209), although this research is decades aways from any useful application.

However, the main three new nuclear reactors are Bill Gates' TerraPower Natrium, the NuScale small modular reactors, and X-energy's high-temperature gas-cooled reactors, which are discussed below.

What is a stake with these new nuclear reactors? First of all, the Department of Energy is giving away taxpayer money like it's nothing. The companies like NuScale plan to pass off their construction cost overruns to the ratepayers and taxpayers — even if the reactors startup is delayed or the reactors never run for the years needed to recoup the expense. What happens when a reactor is prematurely shutdown due to problems too expensive to fix? The ratepayers are still likely to be on the hook for paying for construction and now will still be on the hook for paying for decommissioning. Then the rate payers will still be on the hook for paying for dry fuel storage. And because the U.S. Nuclear Regulatory Commission knows there is no repository, it assumes that the dry storage cannisters for the fuel will be replaced as needed — **all by costs for managing the waste, the spent nuclear fuel, are borne by either the ratepayers or the taxpayers, far into the future.**

Because there is no place for the spent nuclear fuel to go, the spent nuclear fuel will be staying onsite indefinitely. Yet, there is no safety assessment of the long-term risks of dry storage. Each new reactor type requires different research for interim and permanent storage.

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[1] David Pace, *The Idaho Falls Post Register*, "LINE Commission returns to Idaho Falls," May 5, 2023.

The spent nuclear fuel holds an enormous radionuclide inventory. For conventional commercial nuclear reactors, inside each thin-walled canister susceptible to chloride-induced stress corrosion cracking, is a human catastrophe, should it be released.

A study of a variety of small modular reactors concluded that the spent fuel would exacerbate disposal problems and require far more space in a repository by factors of 2 to 30 compared to existing large reactors. [2] With existing and projected spent nuclear fuel from existing reactor, the U.S. already needs two deep geologic repositories the size designated for Yucca Mountain, but does not have even one repository. [3]

All uranium fueled nuclear reactors make plutonium. They all fission (or burn) plutonium to some degree, as well. Thorium cycle reactors make uranium-233, with is also a weapons-usable fissile material. While plutonium is indeed an important component of nuclear waste, burning plutonium in the Natrium reactor creates more nuclear waste. As nuclear reactors are operated, they all generate radionuclides and some of these gaseous radionuclides are very difficult to confine, such as tritium, iodine-129, technetium-99, krypton and xenon and carbon-14. Fissioning either uranium or plutonium, in a nuclear reactor or in a nuclear weapon, also creates many radioactive fission products including cesium-137 and strontium-90, that contaminate air, water and food, for over 300 years.

TerraPower's Natrium Sodium-Cooled Reactor

The Department of Energy is giving money to Bill Gates' backed TerraPower, that is planning to build a 345-MWe sodium-cooled fast reactor, called "Natrium," in Kemmerer, Wyoming, that scales up the INL's former 20 MWe EBR II sodium-cooled reactor. The Natrium reactor will be accompanied by a molten salt-based energy system. [4] TerraPower claims Natrium can be running by 2030 – which appears unrealistic. INL is collaborating with the nuclear fuel design, despite the news that the fuel material will be imported from Russia, rather than INL's HALEU from EBR-II from its Materials and Fuels Complex. [5] [6]

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[2] Lindsay M. Krall, Allison M. Macfarlane, and Rodney C. Ewing, *PNAS*, "Nuclear waste from small modular reactors," Received June 26, 2021, Published May 31, 2022, https://doi.org/10.1073/pnas.2111833119.

[3] United States Government Accountability Office, Report to Congressional Requesters, COMMERCIAL NUCLEAR WASTE – Resuming Licensing of the Yucca Mountain Repository Would Require Rebuilding Capacity at DOE and NRC, Among Other Key Steps, GAO-17-340, April 2017. https://www.gao.gov/assets/690/684327.pdf This 2017 GAO report stated that "nearly 80,000 metric tons of spent nuclear fuel are being stored at 75 reactor sites in 33 states. The Nuclear Waste Policy Act of 1982 limited the amount of SNF/HLW in the first repository to 70,000 metric tons heavy metal of which commercial SNF is limited to 63,000 MT and DOE waste is limited to 7 MT. Commercial nuclear power plants in the U.S. produce roughly 2,000 MT per year.

[4] David Pace, *The Idaho Falls Post Register*, "INL director joins Bill Gates at future Natrium reactor site," May 5, 2023.

[5] Dustin Bleizeffer, *WyoFile*, *The Idaho Falls Post Register*, "TerraPower boost nuclear fuel effort amid calls for import ban," March 23, 2022.

[6] Environmental Defense Institute, April 2022 newsletter article, "HALEU Fuel for the TerraPower's Proposed Sodium-Cooled Natrium Nuclear Plant Could be Impacted by Ban on Russian Imports of Low-Enriched Uranium."

Despite billions of dollars spent world-wide on this type of reactor, sodium-cooled fast reactors have a long legacy of poor reliability and premature shutdown. Experience with the U.S. Fermi nuclear plant, France's Super Phoenix, and Japan's Monju and others have proven sodium-cooled reactors to be costly and prone to frequent outages. Sodium-cooled reactors are considered the most difficult to operate due to sodium fires and prone to sudden catastrophic failure.

The sodium-cooled fast neutron reactor, Natrium, slated for Kemmerer, Wyoming is facing at least two years of delays because of difficulty getting its nuclear fuel from Russia. [7] I would agree that plutonium is a waste, while the Department of Energy prefers to called it a "resource." While it is true and has been known for decades that plutonium can be bred in a nuclear reactor and can also fission in a nuclear reactor, the Department of Energy's claims that a sodium-cooled fast reactor can burn "nuclear waste" are misleading. **The Natrium will produce more nuclear waste than it can burn and cannot use but a tiny fraction of the existing nuclear waste for its fuel.**

Furthermore, the Natrium reactor will not be deployed in time to help combat climate change, and its high cost will take resources away from more timely, affordable and effective solutions.

Construction has not yet started on the 325 mega-watt-electric (MWe) Natrium sodium-cooled fast reactor nuclear plant. Sodium-cooled fast reactors are the least safe to operate, create the comparatively far more radioactive waste disposal problems and will require costly conditioning to remove the salt before disposal.

The Natrium reactor is to use high-assay low-enriched uranium (HALEU) that is enriched to nearly 20 percent in uranium-235. Conventional light-water reactors use fuel enrichment below 5 percent. The invasion of the Ukraine by Russia has made it more difficult to obtain the HALEU fuel from Russia. So much for the claim that this type of reactor "burns" the waste.

When used in the reactor, the HALEU (up to 20 percent enriched in uranium-235) will create more plutonium and that plutonium will be a weapons proliferation risk as well as a spent fuel disposal problem.

The higher the fissile content in the spent fuel, the greater the criticality hazard for transportation, storage and disposal. The criticality risk may not peak until 25,000 years after removed from a reactor, despite the lack of regulations for criticality beyond 10,000 years by the U.S. Environmental Protection Agency.

About half of the money to build the $ 4 billion Natrium reactor is coming from the Department of Energy. And now Natrium backers are seeking lawmakers to provide another $2.1 billion to support HALEU fuel production. A vast amount of misinformation is coming directly from the Department of Energy, like misleading claims that a sodium-cooled fast reactor can burn spent nuclear fuel, see https://www.energy.gov/ne/articles/3-advanced-reactor-systems-

[7] Catherine Clifford, CNBC, "Bill Gates-backed nuclear demonstration project in Wyoming delayed because Russia was the only fuel source," December 16, 2022. https://www.cnbc.com/2022/12/16/bill-gates-backed-nuclear-demonstration-delayed-by-at-least-2-years.html

watch-2030 where DOE states that sodium-cooled fast reactors "can burn spent nuclear fuel from current reactors." With the vast amounts of spent nuclear fuel from US commercial nuclear reactors, then the inability to get HALEU fuel from Russia would not be much of a problem, would it?

HALEU fuel production releases airborne radiological contamination and is expensive. It's relatively high uranium-235 enrichment is being aided by existing highly enriched uranium-235 material already accumulated by the U.S. Department of Energy, such as from the EBR-II reactor research. The pyroprocessing of EBR-II fuel in Idaho is causing excessively high airborne radiological releases and is being paid for by taxpayers. Nevertheless, Natrium is seeking its high enriched uranium fuel (HALEU) from Russia.

The Natrium sodium-cooled fast reactor is seeking approval from the U.S. Nuclear Regulatory Commission. [8] If the proposed reactor design wasn't already bad enough, TerraPower is seeking to allow the significant **release of radionuclides** during operating transients rather than meet fuel design limits (See ML23024A281) during plant upsets.

NuScale Small Modular Reactor

The NuScale small modular reactor is seeking to sound affordable and low accident consequence by being called "small," and yet 6 or 12 reactor modules of 60 MWe to 77 MWe (in the latest proposed change), mean a nuclear facility with total spent nuclear fuel risks in the storage pool and dry storage, are like a full-sized commercial nuclear reactor. The zirconium-clad fuel generates hydrogen if overheated, and many novel aspects of the NuScale reactor facility may increase accident risk, like lifting the modules over the shared pool while other reactor modules are operating. The risk assessment isn't being disclosed. And also, the novel, never-before built or used anywhere, steam generators with steam on the tube side, will be prone to causing accidental radiological releases to the environment, frequent operational shutdowns, and replacement or repair costs that are result in premature reactor end of life.

X-energy High Temperature Gas-Cooled, TRISO Fueled Reactors

The Department of Energy is generously giving away taxpayer money to high temperature gas-cooled reactor designer X-energy. [9] The Xe-100 was initially to be 80 MW electric (MWe), and scalable to a 320 MWe four-pack. The Xe-100 would use TRISO fuel somewhat like the troubled Fort St. Vrain nuclear reactor.

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[8] U.S. Nuclear Regulatory Commission website at nrc.gov and NRC's ADAMS database. https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/natrium.html See also flow blockage issues at https://www.nrc.gov/pmns/mtg?do=details&Code=20220791 NRC Adams ML22227A058.pdf gives link to NATD-LIC-PRSNT-0026 which leads to NRC Adams ML222078814.pdf, a 2022 Gap analysis, including various safety exceptions for emergency planning and others. In ML23024A281.pdf TerraPower, January 24, 2023, Submittal of TerraPower Topical Report, "Principal Design Criteria for the Natrium Advanced Reactor" allowing radiological releases is being sought, rather than meeting fuel design limits in order to prevent radiological releases.

[9] X-energy, X-energy awarded $80 Million for the Department of Energy's Advanced Demonstration Program (ARDP), October 14, 2020. https://x-energy.com/media/news-releases/x-energy-awarded-80-million-department-of-energy-advanced-reactor-demonstration-program-ardp

X-energy is also making TRISO fuel for the Department of Defense's Project Pele mobile reactor as well as for X-energy by its fuel fabrication company, TRISO-X, in Tennessee. [10] Now X-energy is aggressively seeking partners that want the long-term, forever costs, of its spent nuclear fuel storage.

The company that created the largest default in history on nuclear power costs, Washington Public Power Supply System (WPPSS), that later changed their name to Northwest Energy, is now aggressively seeking to partner with X-energy and to put rate payers on the hook for research as well as spent nuclear fuel storage and disposal costs.

Another company, Kairos Power, is seeking to build a different reactor called Hermes, a fluoride-cooled reactor, that would use TRISO fuel reactor. It has different TRISO fuel production facility in New Mexico. [11]

The Fort St. Vrain reactor was a gas-cooled reactor that never ran reliably. It used a very highly enriched in uranium-235 fuel fuel similar to TRISO fuel. Taxpayers are paying for continued storage of the Fort St. Vrain fuel in both Colorado and in Idaho. There is no place for this fuel to go – there is only "forever" storage and costs associated with this TRISO-like fuel.

There have been several gas-cooled reactors built. Germany operated the THTR, a 750 MW-thermal pebble-bed reactor (FRG) from 1985 to 1991. [12] In the U.S., the Department of Energy research included the Peach Bottom high temperature gas-cooled reactor (40 MWe) and the Fort St. Vrain (330 MWe) high-temperature gas-cooled reactor. [13] Fort St. Vrain was based on the Peach Bottom reactor design and used a fuel that was a mixture of carbides of uranium and thorium with TRISO coatings.

The Fort St. Vrain reactor was high-temperature gas-cooled reactor. It was helium-cooled, graphite-moderated, and *operated between unplanned repairs* between 1979 and 1989. The Fort St. Vrain reactor used TRISO fueled, using high enriched in uranium-235 and thorium-uranium carbide particles. The Fort St. Vrain reactor was plagued with problems. [14]

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[10] X-energy, webpage, TRISO-X Announces Relocation and Expansion of its Oak Ridge Offices Ahead of Construction for New Headquarters and Fuel Fabrication Facility, February 21, 2023. https://x-energy.com/media/news-releases/triso-x-announces-relocation-and-expansion-of-its-oak-ridge-offices-ahead-of-construction-for-new-headquarters-and-fuel-fabrication-facility

[11] Kairos Power, webpage, Kairos Power Signs Agreement to Product Fuel for Hermes at Los Alamos National Laboratory, December 8, 2022. https://kairospower.com/external_updates/kairos-power-signs-agreement-to-produce-fuel-for-hermes-at-los-alamos-national-laboratory/

[12] J. M. Beck and L. F. Pincock, Idaho National Laboratory, High Temperature Gas-cooled Reactors Lessons Learned Applicable to the next Generation Nuclear Plant, INL/EXT-10-19329, Revision 1, April 2011. https://inldigitallibrary.inl.gov/sites/sti/sti/5026001.pdf

[13] J. M. Beck and L. F. Pincock, Idaho National Laboratory, High Temperature Gas-cooled Reactors Lessons Learned Applicable to the next Generation Nuclear Plant, INL/EXT-10-19329, Revision 1, April 2011. https://inldigitallibrary.inl.gov/sites/sti/sti/5026001.pdf

[14] U.S. Nuclear Waste Technical Review Board (NWTRB, Factsheet Fort St. Vrain. https://www.nwtrb.gov/docs/default-source/facts-sheets/doe-snf-fact-sheet---fort-st-vrain-rev-1.pdf?sfvrsn=14

The high-temperature gas-cooled reactor Fort St. Vrain nuclear reactor suffered cost overruns in construction and operation, continuous breakdowns and was a huge financial failure. It had corrosion problems and it was shut down for repairs most of the time, with average capacity of only 14 percent. [15] Moisture in-leakage into the helium-cooled reactor degraded the control rod drives and reserve shutdown systems. [16] Six control rod pairs failed to scram during an event on June 23, 1984. This represented a significant safety hazard for the nuclear plant despite some claims to the contrary. Helium leaks were a challenge. Moisture in the helium coolant also degraded the nuclear fuel, caused by hydrolysis of the fuel particle coating of the TRISO fuel. [17]

Regarding waste disposal, something the Department of Energy is actively ignoring, according to the 2017 U.S. Nuclear Waste Technical Review Board report, [18] "Chemical reactivity of DOE SNF affects how some SNF is stored. For example, SNF from helium-cooled reactors that contains coated carbide fuel particles — such as that from the Peach Bottom Unit 1 Core at INL and FSV [Fort St. Vrain] SNF, which is at both INL and FSV — is stored in a gas environment (helium or nitrogen) within containers … because if the coatings on the carbide particles are damaged, the carbide will react with water to produce flammable gases."

The NWTRB factsheet, however, says that Fort St. Vrain spent nuclear fuel does not require a storage with an inert gas (e.g., helium). [19] The Department of Energy never completed the design of proposed "standardized canister" and associated neutron absorbers required for the spent nuclear fuel stored at the Idaho National Laboratory to be repackaged. But DOE has estimated that all Fort St. Vrain spent nuclear fuel stored at the INL and in Colorado would require approximately 500 DOE canisters, **disproportionately high relative to the metric tons of the fuel because of the high enrichment of the fuel**, according to the NWTRB factsheet. The reason is the high enrichment, 93.5 percent uranium-235 and the breeding of uranium-233.

Just one year of storage of the spent nuclear fuel from the unsuccessful decade between 1979 and 1989 of Fort St. Vrain reactor operation costs the U.S. taxpayer about $11 million dollars for dry storage in Colorado, according to recent Department of Energy budget estimates. Repackaging of the Fort St. Vrain spent nuclear fuel in Colorado is expected to require shipment to the Idaho National Laboratory, if and when a repackaging facility is built. The canisters that the spent nuclear fuel would be loaded into at the INL repackaging facility are the DOE "standardized" canisters which currently have not been designed or licensed.

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[15] Cathy Proctor, *Business Journal*, "Fort St. Vrain power plant reborn after checkered past," June 10, 2001. https://www.bizjournals.com/denver/stories/2001/06/11/story3.html (converted from nuclear to fossil fuel)

[16] D. A. Copinger and D. L. Moses, ORNL Prepared for U.S. NRC, "Fort Saint Vrain Gas Cooled Reactor Operational Experience," NUREG/CR-6839, September 2003. https://www.nrc.gov/docs/ML0403/ML040340070.pdf

[17] D. A. Copinger and D. L. Moses, ORNL Prepared for U.S. NRC, "Fort Saint Vrain Gas Cooled Reactor Operational Experience," NUREG/CR-6839, September 2003. https://www.nrc.gov/docs/ML0403/ML040340070.pdf

[18] U.S. Nuclear Waste Technical Review Board (NWTRB), Management and Disposal of U.S. Department of Energy Spent Nuclear Fuel. Arlington, December 2017.

[19] U.S. Nuclear Waste Technical Review Board (NWTRB, Factsheet Fort St. Vrain. https://www.nwtrb.gov/docs/default-source/facts-sheets/doe-snf-fact-sheet---fort-st-vrain-rev-1.pdf?sfvrsn=14

Gas-cooled reactors are prone to problems including air-ingress and material corrosion issues. But even if the X-energy nuclear accident risk is less (and anything would be safer than a sodium-cooled fast reactor), ***there remains the gaseous radiological releases during operation, radiological releases from accidents or sabotage and the so far unsolved and exorbitant cost of spent nuclear fuel disposal.***

There is no process developed for reprocessing TRISO fuel. See how the Germans had wanted to import their TRISO fuel to the U.S., as reported by Savannah River Watch, [20] explained further in an article below.

Summary

It is important to know that each new design requires money to be spent not only design and construction innovation, and not only on regulatory oversight, it also requires additional design work for spent nuclear fuel management and disposal. Spent fuel repackaging technology for existing light-water reactor spent fuel is already needed but has not been developed. It is assumed that taxpayers will fund this, eventually, so that stranded spent nuclear fuel already at 75 commercial nuclear sites around the country, when needed, and perhaps repeatedly, can be repackaged, until a repository is available. [21]

Maximized tax money giveaways appear to be the main product of the Department of Energy's research spending on nuclear – **all while DOE is not doing the research to address the large, looming and growing existing spent nuclear fuel waste disposal problem**. Finally, to make a dent in gas and oil use would require so many nuclear reactors generating more spent nuclear fuel that a new Yucca Mountain repository would be needed every year [22] …. which alone is reason enough to stop this madness.

With the Department of Energy throwing taxpayer money at a plethora of proposed reactors, a summary, though incomplete, is provided in Table 1.

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[20] SRS Watch, "DOE Breaks 6 Years of Unexplained Silence, Finally Complies with Environmental Commitment Concerning Now-Terminated German Spent Fuel Import Scheme," May 18, 2023. https://srswatch.org/doe-breaks-6-years-of-unexplained-silence-finally-complies-with-environmental-commitment-concerning-now-terminated-german-spent-fuel-import-scheme/

[21] Nuclear Regulatory Commission, 10 CFR 51, Waste Confidence-Continued Storage of Spent Nuclear Fuel, Federal Register, Vol. 78, No. 178, September 13, 2013.

[22] Edited by Allison M. Macfarlane and Rodney C. Ewing, *Uncertainty Underground Yucca Mountain and the Nation's High-Level Nuclear Waste*, The MIT Press, 2006. Page 4.

Table 1. Partial list of nuclear reactors currently receiving U.S. research dollars, including the Versatile Test Reactor, Natrium, X-energy's Xe-100, NuScale and other reactors.

Reactor Category ***Reactor name***	**Reactor type/ Fuel type**	**MW-thermal**	**MW-electric**	**Fissile Material**	**Special notes**
Materials Testing					
Versatile Test Reactor (DOE/EIS-0542)	Fast neutron, sodium-cooled, U-Pu-Zr	300 MWth	None	Uranium-plutonium-zirconium metal	Uses but does not generate electricity. Very high accident consequences.
Commercial electrical power					
TerraPower & GE Hitachi *Natrium*	Fast neutron, sodium-cooled, U-Zr	840 MWth	345 MWe	Uranium-zirconium-hydride using HALEU	High project risk. High accident risk. High risk of frequent repairs. High risk of premature shutdown like other similar reactors.
GE Hitachi BWRX-300	Fast neutron, sodium-cooled, U-Zr ?	?	300 MWe	?	Clinch River site proposed
X-energy's *Xe-100*	High-temperature gas cooled, TRISO "pebble bed"	200 MWth times 4	Xe-100, 80 MWe; 4-pack is 320 MWe	TRISO (tristructural isotropic) uranium fuel from HALEU DOE Advanced Reactor Demonstration Program, 2020, promised up to $ 1.2 Billion.	High risk of frequent repairs. TRISO fuel used in Fort St. Vrain reactor. No containment. No existing technology for reprocessing.
	Hermes, Kairos Power Fluoride salt cooled high-temperature reactor	320 MWth or reduced scale	140 MWe, Or reduced scale	TRISO fuel	Received DOE Advanced Reactor Demonstration Program money.

Reactor Category *Reactor name*	Reactor type/ Fuel type	MW-thermal	MW-electric	Fissile Material	Special notes
(Small Modular Reactor) *NuScale*	Light-water pressurized reactor, standard PWR fuel with MOX and other fuels envisioned The reactor modules are submerged in a common pool and lifted modules pose a risk to entire facility.	?	NuScale 50 MWe Various uprating to 60 MWe and even higher. For 60 MW per module, a 12-pack plant is 720 MWe	<4.95 percent enriched standard PWR fuel, hope to use plutonium mixed oxide fuel (MOX) and/or higher enrichment fuels. Zirconium-clad fuel poses hydrogen generation when overheated, like all PWRs.	High risk of frequent and costly repairs. Hot risk of premature shutdown due to materials reliability and novel design. Accident risks not better than conventional PWRs.
Mobile reactors	Variety Generally sized for cargo container shipment.	?	< 20 MWe	variety	Wide range of sizes and accident consequences.
	Project Pele, BWXT Advanced Technologies, LLC, X-energy, LLC, high temperature gas cooled		1 to 5 MWe	TRISO fuel	Department of Defense High target risk at deployed at military bases. Likely to become permanent stranded fuel site where ever deployed.
	Oklo, a $25-million startup company (Aurora Powerhouse)	4 MWth	1.5 MWe	HALEU	Creates spent nuclear fuel problems without any significant benefit
	Ultra Safe Nuclear Corporation (USNC), gas-cooled reactor		5 MWe		Canada at Ontario’s Chalk River site

Reactor Category *Reactor name*	Reactor type/ Fuel type	MW-thermal	MW-electric	Fissile Material	Special notes
	demonstration project				
	Westinghouse Canada eVinci Micro Reactor		1 MWe to 5 MWe		
Micro *MARVEL*	Sodium-potassium-cooled, HALEU	100 kWth	"less than 100 kWe" Expect 20 kWe (0.02 MWe)	150 kg of 20 percent enriched U-235 (U-Zr-Hydride fuel in stainless-steel cladding	Testing planned at INL's TREAT facility
Molten Salt or Chloride Reactor	Molten Chloride Reactor Experiment (MCRE) DOE/EA-2209.	200 kWth	None for the research experiment	Not enough information. Note that the fuel is in the reactor coolant. Any significantly scaled-up reactor would be many decades away.	Preliminary research with no reprocessing capability and hold up of gaseous radiological releases.

Table notes: MWth is megawatts-thermal energy, MWe or simply MW is megawatts-electric energy. HALEU is high assay low-enriched uranium, produced by the Idaho National Laboratory in a highly environmentally airborne polluting pyroprocessing operation. Note regarding past, current or under construction reactors: the nominally 1000 MWe Westinghouse AP1000 under construction is a light-water pressurized reactor, 1000 MWe, fuel of uranium oxide of 4.55 percent uranium-235 enrichment; existing Advanced Test Reactor, 250 MW-thermal, 93 percent enriched uranium-235; formerly operated Fort St. Vrain high-temperature gas-cooled reactor, 330 MWe, used TRISO fuel; formerly operated Peach Bottom reactor, 40 MWe; formerly operated Hanford's Fast Flux Test Facility reactor was a 400 MW-thermal fast neutron sodium-cooled reactor; formerly operated INL's Experimental Breeder Reactor II (EBR-II) was a fast neutron sodium-cooled pool-type reactor of 62.5 MW-thermal (19 MWe), see Perry et al., Seventeen Years of LMFBR Experience: Experimental Breeder Reactor II (EBR-II), CONF-820465—2, April 1982 at https://www.osti.gov/servlets/purl/6534205 . Some MWth information added from Edwin Lyman, Union of Concerned Scientists, *"Advanced" isn't always better – Assessing the Safety, Security, and Environmental Impacts of Non-Light-Water Nuclear Reactors*, March 2021.

Idaho LINE Commission eager to give nuclear promotors big tax breaks, guts laws that protect the public, and press for reduced safety regulatory oversight

The Idaho Leadership in Nuclear Energy (LINE) Commission met on May 3 in Idaho Falls. Lt. Gov. Scott Bedke and Idaho National Laboratory Director John Wagner co-chaired the meeting. [23] Most members of the commission responded eagerly to the request to irresponsible seek tax breaks for nuclear projects, eliminate any laws that might impede nuclear energy projects, and to promote the reduction of nuclear regulatory oversight.

It was painful to watch and reminded me of watching children playing with matches. **The unbalanced presentations to the LINE Commission omitted mention of any of nuclear energy's many downsides, such as extremely high cost, high risk of being deployed too late to help climate change, high risk of premature project termination for cost or safety reasons, the high cost of managing the spent fuel, and the lack of a permanent solution for the spent nuclear fuel.** And then there are the radioactive releases from normal operations and the accident radiological releases that citizens may never be compensated for, as they are forced to evacuate their homes and land.

The LINE Commission was briefed by the Department of Energy on the cleanup of legacy transuranic waste and the recent startup of the Integrated Waste Treatment Unit to treat radioactive liquid high-level waste. The work is difficult and expensive and after more than a decade late, progress has been made.

However, the problem areas were not discussed, such as there is no place to ship the waste treated by the IWTU. Nor is there a plan to repackage the radioactive and high-soluble high-level waste called calcine stored at the INL, mainly from research reactor and naval spent fuel reprocessing. There is no plan yet for repackaging DOE's wide variety of spent nuclear fuel at the INL. Not being discussed is that the milestone from removing the high-level waste and spent nuclear fuel from the state will be missed and will be missed by decades, if ever met. The reality of the DOE's lack of a repository for HLW and spent nuclear fuel was not discussed. This is just one way that deliberate omissions of information are blind-folding the LINE Commission.

A legislator from Wyoming, Rep. Don Burkhart, spoke in favor in his state's continued mining of coal and uranium and the promotion of the Bill Gates' Natrium reactor, the TerraPower sodium-cooled fast reactor slated for Kemmerer, Wyoming. Wyoming is cash-rich and Burkhart advocated for working to promote nuclear energy with money behind the scenes and outside of public scrutiny — doing it the Wyoming way — to get things done.

Nuclear Energy Institute's John Kotek gave a presentation claiming that the problems of the recent cost overruns at the two U.S. reactors being built in Georgia, the AP1000 reactors at the Vogtle plant, had been studied and he claimed that now the industry knows how to avoid cost

[23] David Pace, *The Idaho Falls Post Register*, "LINE Commission returns to Idaho Falls," May 5, 2023.

overruns on new nuclear reactor construction. His presentation is available on the LINE Commission website. [24] Given the range of new, novel reactor designs and the lack of operating and construction experience that will be needed, it is highly speculative to claim that the study of what went wrong with the rather conventional AP1000 nuclear reactors will assure no more construction cost overruns. Existing operating experience for sodium-cooled fast reactors and gas-cooled reactors indicates there are likely to be serious operational problems as well as construction cost overruns.

Kotek's presentation expressed how the cost of nuclear reactors will be somewhat offset by other more affordable energy sources, but he pressed for giving big tax breaks for only nuclear projects. The nuclear industry always seeks to address climate change but only if the answer is nuclear power — and even if there is no realistic way for nuclear reactors to be deployed in time.

I remember when the four AP1000 nuclear reactors were planned about 20 years ago and the industry was claiming then, that it knew how to control construction costs. Two of the AP1000 reactors were cancelled after billions of dollars had been spent. The cost overruns continued to increase for the other two. Westinghouse Nuclear Division declared bankruptcy over the AP1000 reactor problems — and the AP1000 reactors were very close in design to conventional light-water reactors. [25]

It is no wonder Kotek was making such remarkable claims. The Nuclear Energy Institute has a history of promoting unvetted claims and it ran radio ads for a now defunction nuclear company, Transatomic Power, whose inflated claims were shown to be wrong by an MIT study. [26] [27]

The Department of Energy is giving millions of dollars to every conceivable reactor design, from sodium-cooled fast reactors, to gas-cooled reactors, to molten salt reactors. The technical challenges of building and operating these reactors is far greater than the challenges of the AP1000 pressurized water reactors and the cost overruns for this wide variety of new reactors will only increase the costs.

DOE's seeking such a wide variety of reactor designs creates a large workload for the U.S. Nuclear Regulatory Commission that reviews and licenses nuclear reactors. At the May 2023

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[24] John Kotek, Nuclear Energy Institute, *Presentation to the LINE Commission, NEI Demand Survey and DOE Pathways Report Overview*, May 2023.

[25] Patty Durand, *UtilityDive*, "Georgia's Plant Vogtle is a $35B boondoggle. We need new and better solutions for a carbon-free grid," May 18, 2023. https://www.utilitydive.com/news/georgia-power-plant-vogtle-boondoggle-small-modular-reactor-carbon-free-grid/650456/?utm_source=Sailthru&utm_medium=email&utm_campaign=Issue:%202023-05-18%20Utility%20Dive%20Newsletter%20[issue:50602]&utm_term=Utility%20Dive

[26] James Temple, *MIT Technology Review*, "Nuclear Energy Startup Transatomic Backtracks on Key Promises," February 24, 2017. https://www.technologyreview.com/2017/02/24/68882/nuclear-energy-startup-transatomic-backtracks-on-key-promises

[27] Edwin Lyman, Union of Concerned Scientists, *"Advanced" isn't always better – Assessing the Safety, Security, and Environmental Impacts of Non-Light-Water Nuclear Reactors*, March 2021.

LINE meeting, the Nuclear Energy Institute's Kotek irresponsibly pressed in his presentation for reduced regulatory oversight by the U.S. Nuclear Regulatory Commission.

Is Pressing for Reduced Regulatory Rigor for New Nuclear Reactors Wise?

At the May 2023 LINE meeting, [28] the Nuclear Energy Institute's John Kotek, among other things, irresponsibly pressed for reduced regulatory oversight by the U.S. Nuclear Regulatory Commission.

Important insights can be gained by past nuclear reactor accidents — and no one who understands the regulatory failures that contributed to these accidents would be pressing for reduced nuclear regulatory oversight.

The nuclear industry likes to say a tsunami like the one the occurred in the 2011 Fukushima accident won't happen in Idaho. And the industry likes to claim that operator error was the cause of the 1979 Three Mile Island nuclear accident and the 1986 Chernobyl accident. **But if you study these accidents, all three accidents were due in large part to lax regulatory oversight coupled with the overriding desire to help the profitability of the reactors.**

In the case of the Fukushima nuclear disaster where three reactors melted down, the inadequate height of the tsunami wall to protect the plant was known, and the risk was known to be unacceptably high. Yet, the regulator in Japan did not want to burden the utility will the cost of modifications to protect the plant from the natural hazard that was well known.

In the case of Three Mile Island, the nuclear regulators had been made aware of several serious problems regarding the tendency and training of reactor operators, particularly at B&W reactors, to rely on pressurizer level as an indication of water in the reactor vessel (which is not reliable in off-normal conditions) and also the tendency to switch off emergency core cooling before knowing it was not needed. The NRC actually conducted a sham investigation into the issues at B&W plants without actually conducting a technical investigation, so that it could conclude the NRC inspector raising the concerns simply had a communication problem. [29]

After the Three Mile Island accident, the NRC found many problems including inadequate emergency procedures and inadequate understanding of small loss of coolant accidents at all of its licensed plants. Operator training was found inadequate, yet the U.S. NRC had licensed the reactor operators as well as the plant designs and control room interfaces that left operators "flying blind."

In the case of the Chernobyl accident in the Ukraine, the RBMK reactor type had, on paper, a way to remain electrically powered, to insert safety rods and cool the reactor, during a station

[28] David Pace, *The Idaho Falls Post Register*, "LINE Commission returns to Idaho Falls," May 5, 2023.
[29] Mike Gray and Ira Rosen, *The Warning – Accident at Three Mile Island*, W. W. Norton and Company, 1982. ISBN: 978-0-393-32469-3

blackout. [30] But this actually relied on using the rundown energy of the electrical generator — which in fact, those licensing the reactor knew did not work. The regulatory failure allowed a known defect that put all RBMK reactors at risk in a wide-spread power outage.

This serious design flaw at Chernobyl was allowed by the regulators and it increased the urgency of performing the special test that led to the accident. The regulatory agency was required to approve the flawed and casually modified test procedure, but it had not been approved by the regulatory agency nor had it received adequate nuclear safety expert review.

The supervisors at Chernobyl were accustomed to breaking operating rules especially when schedule pressure demanded it and the regulatory oversight was permitting this. People who were willing to break rules and not be cautious tended to be promoted. When the reactor operators initially refused to continue to conduct the poorly planned test, they were berated and they knew their jobs were in jeopardy. These young operators, one with less than 4 months experience, had not even been briefed on the test plan. These operators knew that they were struggling to increase reactor power because of xenon poisoning, having fallen from a higher reactor power. But these young operators were being required to follow instructions of a superior that broke the safety rules of the plant and they were following the flawed test plan that put the plant's operation far outside safe parameters and had disabled various safety systems.

The accident at Chernobyl was indeed a failure of the regulatory oversight of the design of the RBMK reactor and of failure to perform rigorous test plan development to assure the safety of the plant.

In the U.S., it has taken decades to develop safety design standards and an understanding of the systems. It only became apparent after the Three Mile Island accident in 1979 that in the U.S., nuclear power plants were licensed without adequate and comprehensive accident analyses and the plants were operated with loosely written inadequate operating and emergency procedures. It has taken years of effort to address safety deficiencies at U.S. nuclear plants that are the pressurized water reactors (PWRs) and boiling water reactors (BWRs) that are both considered light-water reactors.

Despite continuing efforts by the U.S. NRC to improve regulations, the agency has all too often failed to recognize and take proper actions particularly due to materials aging issues at U.S. nuclear power plants. The corrosion of the reactor head at Davis-Besse is one example. The plant experts argued that inspections were not needed and when the plant was finally shut down and inspected, the metal was nearly corroded through by boric acid.

Steam Generator Tube Failures in Pressurized Water Reactors

Another example would be the NRC approval of operation with cracked steam generator tubes, arguing that the cracks would leak before rupture, thus allowing the plant to be shutdown safely. The problem was that cracked steam generator tubes would be more vulnerable to a steam

[30] Zhores Medvedev, *The Legacy of Chernobyl*, W.W. Norton & Company, 1990. ISBN 0-393-30814-6

line break or perhaps to seismic events. The NRC has been all too willing to bet on contrived arguments that operating with a large number of cracked steam generator tubes was adequately safe. Radioactive primary coolant can escape to the environment via broken steam generator tubes, thus posing a radiological release to the environment that bypasses the reactor containment. Ultimately, the high cost of steam generator tube replacements has led to the shutdown of nuclear reactors in the U.S., including the Trojan plant in Oregon [31] and the San Onofre plant. The rapid failure of steam generator tubes at the last operating San Onofre unit occurred despite the recent replacement with new steam generators (see SanOnofreSafety.org).

The steam generator design was altered at the San Onofre reactor, without the utility even admitting to the U.S. NRC that the design had been altered. The design was understood to have been modified, but the utility sought to avoid the increased review and licensing scrutiny that would accompany admitting that the steam generator design had been modified. The flow and vibration changes resulted in high numbers of failed tubes within a few years of the replacement and created a very unsafe condition despite the fact that the U.S. NRC was willing to approve continuing operation with the ever-increasing number of tube failures, even in the earthquake-prone area.

For the proposed small modular reactor, NuScale, the U.S. Nuclear Regulatory Commission gave its conditional stamp of approval despite the untested and novel steam generator design.

The transcript of the publicly available portion of the February 4, 2020 Advisory Committee on Reactor Safeguards (ACRS) meeting discusses problems with the unique helical steam generator design — and that part of the problem is that the NuScale Final Safety Analysis is full of unproven statements. [32] For a multitude of systems and components, the design details don't exist and won't exist when the US NRC and the ACRS rubberstamp their approval of the NuScale design. The technical requirements for analyzing the various components are not even delineated and may not even exist because of the unique design.

The unique steam generators will have steam flowing in the tube-side, rather than the typical U-tube steam generators in other pressurized water reactors which have the steam on the shell-side. NuScale's unique, untested components, like its unique helical steam generators, can be expected to result in unforeseen problems. [ML20043D049] Read more in the EDI September 2020 newsletter.

The NuScale design that incorporates the steam generators into the same space as the reactor core requires compact and sometimes novel geometries, such as helical coils. According to Edwin Lyman of Union for Concerned Scientists: [33]

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[31] Gregory Nipper, Portland State University, Dissertations and Theses, *Progress and economy: the clash of values over Oregon's Trojan Nuclear Plant*, January 2005. https://doi.org.10.15760/etd.249

[32] Official Transcript of Proceedings, Nuclear Regulatory Commission, Advisory Committee on Reactor Safeguards, NuScale Subcommittee. Open Session, February 4, 2020. NRC.gov Adams accession number ML20043D049.

[33] Edwin Lyman, Union of Concerned Scientists, *Small Isn't Always Beautiful – Safety, Security, and Cost Concerns about Small Modular Reactors*, September 2013.

> "That increases the intensity of the radioactive environment in which the generators must operate, and could affect such issues as corrosion and also make the generators much more difficult to inspect and repair. In lights of the problems experienced at the San Onofre Nuclear Generating Station in California — shut down for good as a result of the faulty design of new steam generators that led to premature wear — one should not underestimate the potential operating difficulties that could be caused by unexpected problems in novel designs of steam generators and other components. A faulty steam generator in a small, modular iPWR [NuScale] would most likely result in the permanent shutdown of the plant."

The NuScale design continues to be developed and modified. Licensing of the partially completed design is reviewed and then rubber-stamped with U.S. NRC approval, with caveats or unresolved issues that will be left to a few NRC staffers who will face mounting pressure to approve anything NuScale wishes. [34] It should also be noted that obtaining NRC licensing approval does not mean the design is workable, reliable or affordable, let alone safe.

Furthermore, it bears repeating that the NuScale spent nuclear fuel will require at least double the space in a repository due to characteristics of small reactors. The U.S. Nuclear Regulatory Commission does not bother itself with continuing storage or disposal problems or costs. A study of a variety of small modular reactors concluded that the spent fuel would exacerbate disposal problems and require far more space in a repository by factors of 2 to 30 compared to existing large reactors. [35]

With Loosening of Reactor Siting Regulations and Safety Oversight, the Public Should Be Reminded That Their Homes, Property and Lives Are at Stake

Small, micro, mini — various sizes of proposed new reactors are being tossed about. While some of the reactors being researched at this time are indeed very small, most are not so small — especially when deployed in groups, like a 12-pack NuScale reactor plant. NuScale's rated electrical power level is not determined yet, but even at 60 MWe, a twelve-reactor module plant at 720 MWe is nearly the size of a large conventional light-water reactor. The power rating of each module is being sought to be 77 MWe. The spent fuel pool, dry storage risk and the reactor module pool risks and costs are anything but small.

Of course, if an accident occurs, the nuclear entrepreneurs won't be on the hook, And neither will the utility that makes cost cutting shortcuts on safety.

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[34] See more NuScale documents at Federal Register, NuScale Small Modular Reactor Design Certification at https://www.federalregister.gov/documents/2023/01/19/2023-00729/nuscale-small-modular-reactor-design-certification and NuScale slides for 3/21/2023 PreApplication meeting for a new reactor design https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML23076A124

[35] Lindsay M. Krall, Allison M. Macfarlane, and Rodney C. Ewing, *PNAS*, "Nuclear waste from small modular reactors," Received June 26, 2021, Published May 31, 2022, https://doi.org/10.1073/pnas.2111833119.

That is because the U.S. has the Price-Anderson Act that protects these nuclear folks when they bungle it. The Price-Anderson Act governs federal and state liability in the event of nuclear accidents, by commercial nuclear power plants, transportation of spent fuel, and government-owned nuclear reactors.

In 1985, the State of Washington recognized that the Price-Anderson Act likely would not going to cover the full costs of an accident sought that DOE accept complete liability for any nuclear accident, but DOE said that the cap on liability is limited to the Price-Anderson Act, [36]despite that $500 million cap not being large enough to fully compensate people for the loss of their homes, vehicles, and land, not to mention lives and health.

Some people do not realize that their home owners and vehicle insurance policies exclude nuclear accidents or any sort of radiological event from coverage.

DOE contractor sought to import spent fuel from Germany, but never developed a reprocessing method for the gas-cooled reactor fuel

SRS Watch, "DOE Breaks 6 Years of Unexplained Silence, Finally Complies with Environmental Commitment Concerning Now-Terminated German Spent Fuel Import Scheme," May 18, 2023. https://srswatch.org/doe-breaks-6-years-of-unexplained-silence-finally-complies-with-environmental-commitment-concerning-now-terminated-german-spent-fuel-import-scheme/ and link to "Auf Wiedersehen to DOE Nuclear Waste Dumping Scheme," that points out how Department of Energy Contractor for the Savannah River Site wanted to divert priorities from cleanup and increase the environmental radiological releases of tritium, krypton-85, carbon-14 and perhaps other radionuclides that are difficult or impossible to capture in filters from spent fuel reprocessing they hoped to profit from at the Savannah River Site. The high-enriched uranium in the fuel had come from the U.S.

The effort to import the German demonstration gas-cooled reactor fuel began in 2012 and has been terminated by September 2022. The Department of Energy committed to transparency regarding the project but failed to provide updated information.

"It is of great concern that no DOE office has assessed the international nuclear proliferation risks of developing graphite spent fuel reprocessing techniques, to removed HEU [high enriched uranium] and/or LEU [low enriched uranium], at SRS [Savannah River Site operated by Battelle Savannah River Alliance].

The actual reason may have been profit-motivated as developing the ability to reprocess graphite pebble fuel for gas-cooled reactors. This could have aided the gas-cooled reactor promoters in the U.S. The Department of Energy was seeking to develop reprocessing techniques

[36] Richard Burleson Stewart and Jane Bloom Stewart, *Fuel Cycle to Nowhere – U.S. Law and Policy on Nuclear Waste*, Vanderbilt University Press, 2011.

for the gas-cooled reactor fuel with partial funding from Germany. The Department of Energy did not develop this reprocessing technology and the German spent nuclear fuel and its associated fission and neutron-absorption radionuclides will now, not be imported to the U.S.

It should be noted that the Department of Energy is responsible for the never-profitable Fort St. Vrain spent fuel and taxpayers pay millions of dollars annually for continued storage of Fort St. Vrain spent fuel in Colorado and Idaho.

X-energy is promoting a gas-cooled reactor, the Xe-100, that if built and operated, will also require forever storage of the spent fuel. X-energy is seeking to put Washington State on the hook for forever storage of its spent fuel, should Washington State legislators be so foolish as to invite this costly boondoggle into their state.

Workers, Families harmed by Idaho National Laboratory exposures testify at meeting

On May 17, an Office of Workers Compensation Programs meeting of the Energy Advisory Board at the Department of Labor held a meeting in Idaho Falls. This is the Board on Toxic Substances and Worker Health under the Energy Employee Occupational Illness Compensation Program Act (EEOICPA).

Public comment was given by workers and their families and others concerned about fraudulent exposure records provided by Department of Energy contractors, such as Battelle Energy Alliance.

I testified on the issue of radiation exposure dose fraud at the Idaho National Laboratory. The summary below, is not verbatim, but is what I tried to explain in my public comment.

I had studied the radiation exposure records from the 2011 plutonium inhalation event at the Idaho National Laboratory's Materials and Fuels Complex. I had studied the lung count results of Ralph Stanton, the worker who had the highest lung count result on the first day and who had been closest to the radiological airborne release in the Zero Power Research Reactor (ZPPR). Because the INL did not have a procedure to translate the lung count results into a radiation dose, the lung count results were given to the Oak Ridge National Laboratory for them to translate the lung counts into a dose. Workers, it appears by an oversight, were sent the Oak Ridge lung count report. That report excluded Stanton's first day lung count, which would have yielded a dose estimate exceeding the 5 rem annual whole body dose and the 50 rem bone dose. It would have predicted about 6 rem whole-body dose. Battelle Energy Alliance's final estimate dose for Stanton was 100 millirem (or 0.1 rem) whole-body dose.

While Battelle Energy Alliance claimed that there was essentially no intake, Stanton's urine and fecal bioassay yielded positive detections 226 days after the accident, and no further bioassay was conducted. Stanton should not have been allowed to return to radiation work at that point, but was released for radiation work and also not told that his bioassay was still high.

There are reasons to suspect that even the lung count results had underestimated his dose. Stanton's lung count reports had numerous error messages and various abnormal results. The reason for the drop in americium-241 detected on the second day was suggested as clearance of the material in his lungs; but actually, his gross counts were the same on Day 1 as the first lung count on Day 2 — and the difference was entirely due to the problem the software had in determining the background counts on Day 1.

The fact is, at the Department of Energy contractor's lung counting, the lung counting software allows a lung count operator perform undocumented manipulations to the lung count reports with the input of gain settings and the use of other manipulations such as gamma spectrum peak delete operations.

Another worker harmed in the 2011 accident, Brian Simmons, was killed by a swat team in Maricopa, Arizona August 29, 2022. Ralph Stanton wrote an open letter to Maricopa that is available online. [37]

More information about the 2011 plutonium inhalation event can be found on the Environmental Defense Institute website, including the INL accidents page at https:// http://www.environmental-defense-institute.org/inlrisk.html

Three Mile Island, a Look at the Inadequate Worker Radiation Records for the 1979 TMI accident

This is Part 2 of a series about the 1979 Three Mile Island Accident. See Part 1 in the May 2023 Environmental Defense Institute newsletter.

Few reports for the 1979 Three Mile Island accident review the inadequate worker radiation protection and missing radiation dose records for workers during the days and weeks of the accident.

Various official reports typically summarize the worker exposures at the TMI-2 accident as follows, all based on the utility's radiation monitoring at the plant: [38]

> "During the period from March 28 to June 30, three TMI workers received radiation doses of about 3 to 4 rems; these levels exceeded the NRC maximum permissible quarterly dose of 3 rems." [The annual dose limit in the U.S. is 5 rem per years.] [39]

It was also stated in the Kemeny report that:

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[37] *InMaricopa.com*, "Ex-colleague: Brian Simmons you knew – mentally ill after workplace radiation exposure – not real Brian Simmons," Letter to the Editor from Ralph Stanton, December 6, 2022. https://www.inmaricopa.com/maricopa-brian-simmons-you-knew-mentally-ill-after-workplace-radiation-exposure-not-real-brian-simmons/

[38] John G. Kemeny, Chairman, *Report of The President's Commission on the Accident at Three Mile Island*, October 1979.

[39] Note that some people use the writing style of "rems" while others, including myself, accept the use of "rem."

“Met Ed experienced several radiation protection problems during the accident: a) the emergency control center for health physics operations and the analytical laboratory to be used in emergencies was located in an area that became uninhabitable in the early hours of the accident; b) there was a shortage of respirators; and c) there was an inadequate supply of uncontaminated air.”

Part (a) of the above statement is correct. However, the other statements, (b) and (c) as well as other parts of the Kemeny report reveal that its review of radiation worker protection was superficial and unreliable. There are two types of respiratory protection: respirators and self-contained breathing apparatus, which are more effective in limiting airborne intakes of radioactive particles. The respirators may be better than nothing, but these lacked iodine filters and would perhaps filter some radioactive particulates but not radioactive gases. During the accident at TMI, with contaminated air everywhere, there indeed was a wide spread lack of uncontaminated air, and this included the lack of uncontaminated air to refill air bottles for self-contained breathing apparatus. The Kemeny report and other reports appear to echo conclusions that rely on Med Ed’s information that worker doses did not exceed quarterly limits **without examination** of the many problems in radiological monitoring of workers during the accident for several days.

One report gives some insights of the unprecedented radiological problems faced during the Three Mile Island Unit 2 accident: NUREG-0600 by the Office of Inspection and Enforcement. [40] My review is limited, and I am only able to give the reader some idea of why the conclusions that the TMI worker doses largely did not exceed quarterly doses, is suspect.

Before the accident, radiation surveys in most areas of the auxiliary building were generally less than 1 milliR/hr, except for higher values in valve rooms, cubicles containing demineralizers, filters and waste tanks. (NUREG-0600, 549th page.)

By early morning of the accident, around two hours after the upset conditions began at 4 am on March 28, 1979, areas of the auxiliary building were exceeding 5 R/hr, 100 R/hr and even 1000 R/hr, for external radiation in Roentgen per hour, without assessing the airborne contamination. The R/hr would likely underestimate the “rem/hr” dose because it expresses an absorbed dose in air from gamma external radiation reading not specific to the particular radionuclides present. The R/hr readings would represent gamma radiation emitted from inside piping, tanks or cubicles, but would neglect the additional dose from an airborne release of radiation that could be inhaled or absorbed through the skin, whether alpha, beta or gamma radiation upon entry to the area.

Radiation worker entries made into contaminated areas that lacked planning, appropriate protective gear and even when resulting in contamination, no record of the entries was made.

[40] U.S. Nuclear Regulatory Commission, Office of Inspection and Enforcement, *Investigation into the March 28, 1979 Three Mile Island Accident by Office of Inspection and Enforcement*, NUREG-0600, Date Completed: July 1979, Published: August 1979. Findings of the investigation are signed by Victor Stello, Jr., 821 pages with many details not discussed elsewhere.

During many worker radiation exposures at the TMI-2 accident, radiation instruments often went off-scale, no air samples were taken or if taken were not evaluated, no extremity monitoring was worn, no records of area surveys were made, nor were records of personnel clothing or skin contamination made. (NUREG-0600, 553rd and 584th page.)

In the late evening of March 28, radiation levels on the TMI grounds were 365 milliR/hr beta-gamma and 50 milliR/hr gamma on the island. (NUREG-0600, 682th page.) At this level of 365 mR/hr, neglecting inhalation, the quarterly dose would be exceeded in nearly 8 hours.

The very high amount of beta dose relative to gamma dose also brings into question arguments made that public doses could neglect the beta radiation. The beta radiation can be shielded by skin and cause a skin beta dose; however, the beta particles can also be inhaled and taken into the blood stream.

All radiation workers at TMI were issued thermoluminescent dosimeters (TLDs). The TLD data are incomplete and unreliable, however. Prior to and during the TMI-2 accident, the utility conducted the onsite personnel dosimetry program. (See the 37th page of NUREG-0600.) No one had been assigned the specific responsibility for reading the film badge or TLD dosimetry. (NUREG-0600, 483rd page.) Typically, the TLDs were only read twice a year. When one worker, a technician who had received two hours of on-the-job training two years prior, worked to process the TLDs, he worked 48 hours straight, and did not have a procedure for either operation or documentation of the TLD results. Two hundred TLDs were processed and at least 10 TLD results were called out as obviously in error and reporting too low of a dose exposure. (NUREG-0600, 579rd page.) TLD reports are generally calibrated to expected routine radiation exposure and TLD reports generally subtract what is measured as expected background, based on a TLD not used to make entries into radiological areas. With wide-spread radioactivity, there is no telling what elevated background was subtracted from the TLDs. The TLDs would be seeing the elevated levels of radiation, that normally would be subtracted from workers TLDs when processed.

The absence of a procedure for assessing the dose from TLDs especially in this very abnormally high and wide-spread radioactivity is not a trivial matter. The opportunities for error in reading the TLDs as well as the possible pressure to provide low doses on the TLDs from the technician's employer should not be lightly dismissed. In addition to external doses, skin and extremity doses were sometimes high and had been neglected by Med Ed. (NUREG-0600, 713th page)

Self-reading pocket dosimeters of various ranges were available. However, the higher range pocket dosimeters were in short supply. There were only fifteen 0-20 R dosimeters available the day of the accident. And even though there were fifty 0-5 R dosimeters available, their short supply contributed to a worker exceeding the quarterly dose limit. The more widely available pocket dosimeters with the range from 0-200 milliR were used; however, these quickly went off-scale. (NUREG-0600, 484th and 573rd page.)

Teletectors (a radiation meter on a long stick), high-range survey meters, and self-contained breathing apparatus or air packs were all in short supply during the TMI-2 accident. (NUREG-0600, 487th page)

Many radiation monitors at TMI-2 went off-scale high the day of the accident, but many were in inaccessible areas such as the reactor containment building. There were instances of radiation workers the day the accident began, who had their radiation survey instruments fail or go to full scale. This meant that they had no idea what high radiation exposure they were receiving. (See the 36th page of NUREG-0600.)

Air samples were not analyzed to identify the radionuclides present. This was due to the loss of the lab and equipment in the building due to airborne radiation contamination. The equipment for analyzing the samples was in an area that was extensively contaminated from the efforts to obtain primary coolant samples. A mobile laboratory for sample evaluation was set up, but until 0030 on March 30, 1979. (NUREG-0600, 578th page.)

Extremity monitoring was available but only by taping a TLD badge to the extremity, which would have limited the ability of the person to conduct needed work and was apparently not done during the accident.

Urine samples provided by workers the day after the March 28 accident were not analyzed "as of May 24, 1979." (NUREG-0600, 583rd page.) The radioactive decay of the samples for iodine-131 is limited and it is likely that the adverse findings could be unwelcome by the utility operating TMI-2, Met Ed.

Worker radiation doses at the TMI-2 accident are likely gross underestimates of the actual radiation doses. TLDs were not processed using any known or identified procedure. The TLD exposure data indicated several errors, including missing dose records and doses recorded that appeared inconsistent with information from interviews. For similar entries, some TLD's indicated both beta and gamma dose, yet other indicated only gamma dose and did not measure beta radiation. (NUREG-0600, 579 and 580th page.) Inadequate bioassay was conducted to determine inhalation dose. Inadequate extremity and skin dose estimates were made.

Even the control room at TMI-2 was contaminated and respirators were worn for 6 hours the day of the accident. (See the 562nd page of NUREG-0600.) Exposure rates in the control room were measured as high as 10 mR/hr, with beta-gamma survey instruments. (NUREG-0600, 568th page.)

Respirators are not as effective as self-contained breathing apparatus. The available respirators did not have iodine absorbing cartridges, something that was needed during the TMI accident. (See the 485th page of NUREG-0600.) There was a breathing air compressor to refill air supply bottles, but the high airborne radioactivity limited its quality of air. (See the 485th page of NUREG-0600.) There were radiation workers wearing self-contained breathing apparatus that ran out of air while still in radiologically contaminated areas. (NUREG-0600, 369th page.)

The inhalation doses would not be known by evaluating the TLDs. Inhalation doses could not be estimated because air monitoring was not conducted and evaluated in order to estimate the inhalation doses prior to radiological entries or from simply being onsite at TMI-2. Urine samples would be an indication of inhalation and were collected but not evaluated.

The NRC found that the method for evaluating skin dose from March 28 to March 30 appeared to be in error. (NUREG-0600, 579th page.)

It would not be surprising if TMI workers had subsequent malfunctioning thyroids and later thyroid abnormalities including thyroid cancer that can take away one's health and energy. Furthermore, the other radionuclide exposure and intakes that were encountered would have also increased their cancer risk and shortened their life spans.

It wasn't known in 1979, but later epidemiology of nuclear workers in general would find that annual radiation doses for workers averaging about 400 millirem per year showed increased rates of cancer. [41]

Emergency planning approved by the U.S. Nuclear Regulatory Commission for TMI had not addressed sustained radiation hazards from a reactor accident. (NUREG-0600, 37th page.)

An Overview of the In-plant TMI-2 Accident Releases

The primary coolant system water had become highly radioactive when the zirconium cladding was overheated and damaged, releasing hydrogen and gaseous radionuclides held in the fuel pin by the cladding. In addition, overheating the fuel pellets would release other radionuclides.

Radioactive primary coolant escaping the primary system from the pressure-operated relief valve, ultimately was pumped from the containment building sump to the auxiliary building. The primary coolant, when depressurized releases entrained and dissolved radioactive and non-radioactive gases. As the tanks in the auxiliary building were overfilled, the radioactive liquid and gases were pushed up through open drain lines to the floor drains in the auxiliary building and the fuel handling building. Gaseous paths from the tanks and the building areas also escaped via ventilation ducts or any opening.

Radioactive pump seal water systems were lost at the time of the hydrogen burn in the reactor containment building at about 1:50 pm March 28. Additional leaks of radioactivity occurred from leaks and gaseous releases from primary coolant system letdown and makeup systems.

Airborne radiation was escaping from numerous vents and building areas. The condenser off gas monitor also indicated that a primary to secondary leak had developed via steam generator

[41] Richardson, David B., et al., "Risk of cancer from occupational exposure to ionizing radiation: retrospective cohort study of workers in France, the United Kingdom, and the United States (INWORKS), BMJ, v. 351 (October 15, 2015), at http://www.bmj.com/content/351/bmj.h5359 Richardson et al 2015 This cohort study included 308,297 workers in the nuclear industry.

"B" tube breaks. (NUREG-0600, 135th and 548th.) Later investigation of steam generator contamination would also reveal that the sample lines for the steam generator's A and B were incorrectly mislabeled. (NUREG-0600, 525th page.) **Steam generator "B" was in fact, contaminated from radioactivity from the primary coolant system. Boiling the steam generators dry early in the transient had ruptured the steam generator tubes in SG "B" and it was fortunate that the SG "A" tubes had not ruptured.** Heat removal via steam generator "A" was re-established later on March 28 and was vital to cooling the reactor because pressure could not be lowered enough for core flood tanks to empty into the reactor and borated water storage tank inventory via the high-pressure injection pumps was limited.

"Although liquid volume release rates appear to be small, the specific activity of the reactor coolant was so high that any leakage was significant...Gases evolved from reactor coolant released into the fuel handling and auxiliary buildings contributed to airborne radioactivity inside these buildings." (NUREG-0600)

Hot Primary Coolant Water Samples Collected

The radiation worker who took a sample of the primary coolant water on March 28 was exposed to gamma radiation from the small 100 milliliter liquid sample that read 1000 R/hr on contact and was also exposed to unmonitored levels of airborne radiation. The 100-milliliter sample was poured from the full one-liter sample bottle with unshielded gloved hands. (NUREG-0600, 582th page.)

Workers were not adequately trained to cope with the hazards of taking even a small primary coolant system sample. The job planning was inadequate, no air samples were taken, and no one was assigned to time their exposure. Inadequate tools were available to handle the highly radioactive primary coolant samples. A 300 milliliter (ml) sample was collected and a 100 ml gave a radiation exposure rate of 400 R/hr at a distance of 1 foot. (NUREG-0600, 36th page.)

Decontamination of workers involved with primary coolant sampling were found to be contaminated and despite efforts to decontaminate the workers, residual contamination remained on one worker's skin for over 30 days.

What was contained inside the container holding the liquid sample is not what contaminated his skin and could not be scrubbed off — it was unmonitored airborne radionuclides. A chemistry foreman was sent home with gloves on and a plastic cap taped to his head, to limit his contaminating his home and bed, shared with his wife, perhaps from exposure to airborne radioactive iodine. [42] The iodine can emit gamma and beta radiation; however, the beta radiation from the iodine for example, was not consistently monitored.

Collecting the primary coolant sample contaminated various rooms and required evacuation of the emergency command area that had just been set up.

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[42] Mike Gray and Ira Rosen, *The Warning – Accident at Three Mile Island*, W. W. Norton and Company, 1982. ISBN: 978-0-393-32469-3 See page 187 and 197.

The TMI-2 primary coolant, after fuel damage had occurred early in the morning of March 28 included radioactive iodine, cesium and strontium radionuclides. The specific radionuclides of the alpha emitters, such as plutonium, were not estimated, but are harmful released even in small amounts. The amount of gross alpha in the primary coolant exceeded the amount of iodine-131 in the primary coolant and was significant, despite rarely being mentioned. (NUREG-0600, 534th page.) The radioactive half-life and the high radioactive dose contribution from the plutonium, curium, and americium appear to have been unmonitored and not included in the worker radiation dose estimates.

Radiation Worker Assess to the Auxiliary Building and Other TMI Buildings

For emergency actions and assessment of plant conditions, workers needed to access the auxiliary building and other plant areas. Although significant fuel damage had already occurred, actions were still needed to re-establish core cooling. These plant areas now had gamma exposure rates from 5 to 100 R/hr, and even exceeded 1000 R/hr. (NUREG-0600, 569th and 577th page.) The resin area receiving primary coolant indicated survey values approaching the 1000 R/hr scale by 0734 on March 28 (NUREG-0600, 659th page).

Limiting the time that workers needed to perform an action was then critical. The stay time of 5 minutes in a 100 R/hr field would be over 8 R, and this would be at least 8 rem, neglecting any inhalation, skin contamination, etc. Also, note that respirators did not have iodine cartridges.

A radiation dose of 400 rem would be lethal within a few weeks, to half of those exposed to such a dose. The external dose would be the R/hr field multiplied by the duration of the exposure.

The TMI data would not include inhalation dose, but let's assume that the dose in R or Roentgen is the lower bound for the radiation dose in rem. It is known that the LD-50/60 for whole body radiation is about 400 rem, meaning that 50 percent of adults exposed to 400 rem would die within 60 days. The "R/hr" dose rate available from the TMI data is absorbed dose in air from the gamma dose and would not reflect the airborne contamination from alpha or beta (or airborne gamma) emitters that contacted skin or were inhaled. Workers at TMI were being sent into situations that posed life-threatening radiation exposures from gamma shine. The airborne radioactivity nor its composition of specific radionuclides was being monitored or included in the dose estimates.

While no TMI-2 workers were reported to have been hospitalized nor were there acute radiation fatalities reported, there are many signs that the radiation exposures of many TMI workers are likely to be significantly higher than reported by the electric utility.

The families of workers who died of cancer (or other illnesses) would have not have been eligible for any compensation for radiation-related illnesses, for their lost ability to provide for their families or for their shortened lives. There is no compensation program for radiation workers at U.S. NRC licensed commercial nuclear power plants.

Also of note, a new movie is being released, *Radioactive – The Women of Three Mile Island*, by Three Mile Island Productions, 2023 trailer at **https://radioactivethefilm.com/ It Wins the Audience Award for Best Feature Documentary at Dances with Films Festival – NYC.**

Articles by Tami Thatcher for June 2023. On May 26, I corrected my mistake in stating R/hr when I meant the total dose in R or Roentgen. The use of R/hr rather the rem/hr is due to the older conventions used in NUREG-0600 published in 1979.