ACEP
Alaska Center for Energy and Power

March 28, 2022

Chair Josh Revak
Senate Resources Committee
Via Email

Response to questions from the Senate Resources Committee Hearing (3-21-22) related to SB 177

1. *Senator Sevens asked whether a microreactor could be targeted by a hostile nation? What would happen if a missile hit a microreactor facility?*

A direct missile attack on a microreactor would not be expected to result in a release of nuclear material to the local environment due to the design of the reactor as well as the design of the fuel within the reactor. Nuclear facilities are some of the most well-protected industrial facilities in the nation. Microreactors, like all reactors, will be designed to withstand significant external events – both natural (e.g., tornados, high winds, flooding, earthquakes) and from humans (e.g., terrorist attack). Reactors are designed to protect against multiple reasonably foreseeable threats to ensure that there are no significant impacts to health and the environment.

Potential design options that are expected to be used in microreactors include physical protection, protective shielding (such as is done for large nuclear power plants), locating below grade, and using strong and robust structures for the reactor. Many of these features are similar to those used for other energy and industrial infrastructure.

Further protection is provided by the characteristics of advanced fuels and the passive safety and control systems that are part of many of the advanced microreactor designs. These features are designed to allow a reactor to "turn off" without human or mechanical intervention should an incident occur. In the event that in a worst-case scenario multiple integrated safety barriers between the reactor core and the environment fail, a common characteristic of advanced fuels such as TRISO is that any fission products are retained within the fuel kernel itself. In other words, each individual fuel particle – about the size of a poppy seed - acts as its own miniature containment system as a result of multiple layers of advanced materials that fully encapsulate the uranium fuel. This also is the reason that the emergency planning zone for an advanced reactor is very small, often the footprint of the facility itself, because it is defined by the distance a solid can travel compared to a gas or a liquid that could more easily spread within the environment.

2. *Senator Kiehl asked for the statutory citation for language that would give the Legislature siting authority for a proposed site within an unorganized borough.*

AS 18.45.025(c)(2) states "the municipality with jurisdiction over the proposed facility site has approved the permit". Local siting approval requirements will be established in the regulations developed by DEC, as required by the existing statute.

Specific to the siting requirements for unorganized boroughs, that is and will continue to be delegated to the legislature if this bill passes. Under 18 AAC Constitution, Article X, Section 6: "The legislature shall provide for the performance of services it deems necessary or advisable in unorganized boroughs, allowing for maximum local participation and responsibility. It may exercise any power or function in an unorganized borough which the assembly may exercise in an organized borough."

In addition to the questions for which the Committee asked for follow up responses, there were issues raised during the discussion for which ACEP and the Department of Environmental Conservation would like to provide information. The two agencies believe this additional information will be helpful to the Committee members as they deliberate on the issue.

1. *(Senator Kiehl) In addition to the definition of a microreactor, how is an advanced nuclear reactor defined under federal statutes?*

According to 42 USC § 16271(b)(1) (1) Advanced nuclear reactor The term "advanced nuclear reactor" means— (A) a nuclear fission reactor, including a prototype plant (as defined in sections 50.2 and 52.1 of title 10, Code of Federal Regulations (or successor regulations)), with significant improvements compared to reactors operating on December 27, 2020 , including improvements such as

- (i) additional inherent safety features
- (ii) lower waste yields
- (iii) improved fuel and material performance
- (iv) increased tolerance to loss of fuel cooling
- (v) enhanced reliability or improved resilience
- (vi) increased proliferation resistance
- (vii) increased thermal efficiency
- (viii) reduced consumption of cooling water and other environmental impacts
- (ix) the ability to integrate into electric applications and nonelectric applications
- (x) modular sizes to allow for deployment that corresponds with the demand for electricity or process heat
- (xi) operational flexibility to respond to changes in demand for electricity or process heat and to complement integration with intermittent renewable energy or energy storage;

2. *(Senator Von Imhof) What are potential vectors for environmental contamination from a microreactor?*

Microreactors are self-contained systems with multiple engineered barriers and will be well monitored to ensure there is no external release of radioactive materials. Microreactors generally do not use cooling water and would not have water that could come in contact with reactor fuel material.

In addition, the U.S. Environmental Protection Agency (EPA) sets environmental standards that plants must meet and both the NRC and the EPA regulate radioactive effluents. Operators are required to have environmental monitoring and reporting programs and to produce periodic monitoring reports that are publicly available. NRC has more information here: https://www.nrc.gov/reactors/operating/ops-experience/grndwtr-contam-tritium.html

3. *(Senator Von Imhof) Related to testimony from Alaskan Community Actions on Toxins: Was there an incident that occurred in conjunction with the Fort Greely SMA-1 Reactor installed and operated from 1962-72?*

On the following page is an excerpted section from ACEP's 2011 report related to the Fort Greely project. There have been persistent rumors in Alaska that the SM-1A reactor ended its useful lifetime in some kind of accident. ACEP completed an extensive review of publicly available documentation, and we were unable to find any information that would support this claim.

Sincerely,

Gwen Holdmann, Director
Alaska Center for Energy and Power
University of Alaska Fairbanks
(907) 590-4577
gwen.holdmann@alaska.edu

Fort Greely Reactor

Excerpted from page 17-20: **Holdmann, G.**, Fay, G., Witmer, D., Williams, F., Schwoerer, T., Pride, D. and Stevens, R., 2011, Small-Scale Modular Nuclear Power: An Option for Alaska?. 127 pages. *Technical report prepared for the Alaska Energy Authority at the request of the Alaska State Legislature.* Available at: https://acep.uaf.edu/media/147559/Small-Scale-Modular-Nuclear-Power-an-option-for-Alaska-2011-ACEP-and-ISER.pdf

Nuclear power has been used in Alaska at the Fort Greely Army Base, as part of the Army Reactor Program, active in the 1960s and 70s. The Fort Greely SM-1A Reactor was installed and operated near Delta, Alaska from March 13, 1962 until sometime in 1972. The Wikipedia page for the Army reactor program lists a total of 8 reactors that were built as part of the Army Nuclear program[1]. The reactor used highly enriched uranium (93% U-235) which is not available for use in civilian reactors due to safety and non-proliferation concerns.

The fact that this reactor operated for only ten years as compared to the 30 years operation expected from naval propulsion reactors raises the question, what happened? One problem that appears to have occurred is cracking associated with "stress corrosion" of the stainless steels used in construction of the reactor. The fuel was "clad in stainless steel" (from the Environmental Plan for the SM-1A Reactor)[2]. Given this material selection for construction of the reactor, cracking and subsequent failure (either catastrophic or non-catastrophic) would be expected. Solution to the problem would be to replace all chromium containing alloys in the plant with other alloys, which most likely would require repairs so extensive and costly that the only sensible course of action would be to terminate the operation of the reactor. Industry practice after that time was to use high zirconium alloys (zircalloy) for these applications, an alloy much more expensive than stainless steel, but much more stable with respect to both neutron bombardment and corrosion. In addition, the nickel content in austenitic stainless steels is considered a problem because nickel transmutes to other elements under neutron bombardment.

A web page from Fort Belvior lists several reports that are apparently not available to the public, indicating that there were other technical issues[3]. Several indicate that the fourth (and last) core used in the reactor was somehow different than the ones that came before, as reports are written about physical measurements made on it. One abstract refers to "In-place Annealing" of the reactor pressure vessel. Another source indicates that this was done to anneal the reactor to relive stress caused by neutron induced embrittlement, indicating that materials susceptible to this form of damage were used in the reactor construction.

All of these indicate that while the reactor was intended to provide power to Fort Greely, it also was being used to assess new materials and techniques for use in nuclear power generation systems. The near simultaneous decommissioning of the SM-1A at Fort Greely and the PM-3A reactor at McMurdo may indicate some common issues with materials used in these reactors, given that both reactors were managed by the same Army Nuclear program.

One other issue raised by some environmental groups is the large amount of water removed and re-injected by the operation of the reactor. According to the Environmental Plan listed above, 1,440,000 gallons of water were pulled from a well, used as cooling for the condenser, and reinjected—a flow of approximately 1000 gallons per minute. If we assume that the 2MWe steam plant operated at 33% efficiency, this means that 4MW thermal energy needed to be rejected, which would result in a rise of about 28 F for the water, a reasonable amount. This would also prevent the creation of a steam plume from releasing warm water at the surface.

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[1] "Army Nuclear Power Program - Wikipedia, the free encyclopedia," n.d., http://en.wikipedia.org/wiki/Army_Nuclear_Power_Program.

[2] Environmental Plan for the SM-1A, "GetTRDoc," June 1971., http://www.dtic.mil/cgi-bin/GetTRDoc?AD=AD726323&Location=U2&doc=GetTRDoc.pdf.

[3] "ARMY ENGINEER REACTORS GROUP FORT BELVOIR VA ENGINEERING DIV - Storming Media," n.d., http://www.stormingmedia.us/corpauthors/ARMY_ENGINEER_REACTORS_GROUP_FORT_BELVOIR_VA_ENGINEERING_DIV.html.

There is more information publicly available about the PM-3A reactor built by the same Army Nuclear Power program for use at McMurdo station in Antarctica. A web source titled "The Antarctic Environmental Awareness Pages" was found, which is a page attached to a site dedicated to the South Pole station. There is no author listed, but the account appears to be a first-person account based an individual who traveled to McMurdo in the 1970's. It contains the following paragraph:

> "This plant [the PM-3A] was shut down in September, 1972, three months before my visit, after wet insulation was observed around the reactor pressure vessel, presumably due to leakage in the shield coolant water piping. A team from the Navy nuclear power unit came down on my flight to evaluate the repair needs; at the time everyone assumed it would be back on line quickly. Meanwhile, McM was rather short on power, because the normal summer demand was 1000-1200 KW, and the "standby" power plant (Penguin Power and Light) had 4 500 KW diesel generators of which only 2 were operational. Ah yes. As we now know, the plant was never operated again. Since chloride stress corrosion cracking was suspected, it would have been necessary to disassemble everything to inspect for cracks, and that was not practical."

This is a very interesting paragraph, as it indicates that the reason the McMurdo reactor was not restarted was because of "chloride stress corrosion cracking" was suspected. This issue has been well established as a problem in nuclear power plants, where stainless steels containing chromium (typical 304, 304L and 316 contain chromium) subject to long term exposure to moderate stress levels in the presence of chlorine ions experience the migration of these ions down grain boundaries leading to the formation of a chromium-chloride phase, and a chromium depleted zone next to the grain boundary susceptible to corrosion crack formation. This problem was studied extensively by Charles McMahon, a professor at the University of Pennsylvania Materials Science department. The solution to this issue is to use high nickel alloys rather than stainless steels in the reactor design, and zircalloy cladding for the fuel. In commercial nuclear power plants, this problem required the replacement of various components from the reactor pressure vessel. If plants were operational, the replacement required an extensive shutdown of several months.

Also found on the web is a report titled "Final Operating Report for the PM-3A Nuclear Power Station, McMurdo Station, Antarctica" apparently written and released shortly after the reactor was shut down on October 26, 1972[4]. This report lists every start-up and shut down by the reactor, and there were a lot of them. The availability of this reactor was given as 72%, which indicates that the plant was not highly reliable (current nuclear plants operate at 96% availability). The reactor was removed from McMurdo Station several years later.

Returning to the installation at Fort Greenly, there remains the issue of persistent rumors in Alaska that the SM-1A reactor ended its useful lifetime in some kind of accident. The most extensive attempt to document radiation release from an event of this type is in a report by the Alaskan Community Actions on Toxins Report on Fort Greely[5]. While this report stridently claims that a significant event occurred at the SM-1A reactor that affects the health of local residents, the accompanying data (and the struggle of the authors of the report with the complicated units of radiation measurements) are less convincing. The report implies that significant radiation was released during an event with the steam turbine on March 23, 1972, but the Army COE report they cite does not support this conclusion[6]. This report was written in 1992 when the reactor was decommissioned, and summarizes the operating records of the SM-1A reactor, by including "nuclear incident reports" (without sequencing numbers) and "malfunction reports" (sequentially numbered by year, indicating that these are associated only with the SM-1A reactor, and most likely complete). This report does not describe any incident that resulted overheating of the fuel, or any major release of radioactive materials to the environment. Malfunction report 67-5 (pdf page 56) describes a steam generator leak, allowing water from the primary loop to leak into the secondary loop, but this would result only in cross contamination of the secondary loop, and is a relatively common incident in nuclear power plants.

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[4] "FINAL OPERATING REPORT.pdf," n.d., http://foia.navy.mil/FINAL%20OPERATING%20REPORT.pdf.

[5] "Fort_Greely_report_May_2000.pdf," n.d., http://www.akaction.org/Publications/Military_Waste_in_Alaska/Fort_Greely_report_May_2000.pdf.

[6] "ar008_sm1a_summary_dec1992.pdf," n.d., http://www.smdcen.us/rabfga/docs/adminrecord/ar008_sm1a_summary_dec1992.pdf.