The Grainger College of Engineering

Nuclear, Plasma & Radiological Engineering

News from the Illinois Microreactor Demonstrator Project

Status of the Illinois Microreactor Demonstration Project

By Caleb Brooks and Tim Grunloh

The Illinois Microreactor Demonstration Project (IMDP) is rapidly progressing towards submitting a Construction Permit Application (CPA) in collaboration with technology partner NANO Nuclear Energy. Until recently, the focus of the effort has been project development and pre-licensing engagement with the Nuclear Regulatory Commission (NRC). The project development focus has included tasks like site development and research application development. Pre-application engagement is a formal process with the NRC where the applicant (in this case the University of Illinois) develops certain aspects of the projects, submits documents to the NRC, and receives formal feedback. Through this process, we received “Safety Evaluations” on five topical reports which varied from interpreting regulations to quality assurance plans to fuel qualification methodology. The content in these topical reports will then be included in applications with the NRC without any further review.

The next major planned engagement with the NRC is the CPA. Following a “Part 50” licensing pathway, the CPA is expected to be reviewed in 18 months. After issuance of the CPA, official construction of the nuclear facility can begin. However, operations cannot begin until an Operating License (OL) is issued – another 18 month review period. The next steps in developing the CPA are A) a great deal of writing to document the design and its key safety features and B) a geotechnical investigation of the site.

The geotechnical investigation consists of extracting soil samples from around the site - some from deeper than 100 feet – to characterize the layers of soil and other materials. One of the primary purposes of this is to understand the safety of the facility in the event of earthquakes. Longtime residents of Illinois might be surprised to hear about earthquakes – we simply don't feel a lot of them around here. This is a testament to the extreme priority placed on safety by IMDP, the University of Illinois, NANO, and the NRC. While earthquakes are rare, there are significant fault systems around that could theoretically produce large seismic events. Our facility is designed – and will be constructed – to be safe even in these once-in-a-century (or even less frequent) events. This level of scrutiny and consideration is applied to all aspects of the project.

A Site Characterization Investigation has begun for the NANO KRONOS Microreactor

By William Roy

A major step has been taken for bringing the NANO KRONOS MMR Research Microreactor to the campus of the University of Illinois. A Site Characterization Investigation has been launched at the site. AECOM Technical Services was hired by NANO Nuclear Energy Inc. AECOM has performed field studies to better understand the geology, hydrogeology, and geotechnical attributes of the subsurface materials for the suitability of siting the Microreactor. Geological cores were drilled and collected using a truck-mounted drill rig. Several cores have been collected—some as deep as 125 feet. These cores will be studied in detailed and saved by the Illinois State Geological Survey for additional studies and public engagement.

Although on-going, preliminary observations indicate that the first 4 or 5 feet of material is backfill resulting from the construction of numerous campus buildings near the Abbott Power Plant. Below that are layers of unconsolidated material that were deposited during the Wisconsin Glacial Episode. This episode—the last of several advances of glaciers—ended about 23,000 years ago in the Champaign County. The melting ice deposited glacial outwash in the form of sandy materials, and post-glacial lake sediments. Below the outwash is a thick layer of stiff glacial till that was deposited across the site by glacial ice. Samples of these materials have been collected for geotechnical measurements. Groundwater samples have also been collected.

During the second phase of the investigation, geophysical measurements will be made. Seismic Cone penetration tests with pore-pressure soundings will be performed by a subcontractor under AECOM. Downhole, shear-wave velocity will also be measured. This information will be essential for the safety analysis that will be included in the application for a Construction Permit that will be submitted to the Nuclear Regulatory Commission.

A part of our education and public outreach activities, local students have been visiting the site. A group of students from the Department of Civil and Environmental Engineering came to site for a drilling demonstration by AECOM. Students from the Department of Earth Science and Environmental Change also visited the site. The local chapter of Women in Nuclear will also be given a lecture at the site. These education-outreach activities should help fill the need to build a workforce for the coming Next-Generation, Advanced Nuclear Reactors.

What is a High-Temperature Gas-cooled Reactor (HTGR)?

Introduction

The Illinois Microreactor Demonstration Project (IMDP) is working to deploy a NANO Nuclear Energy KRONOS Micro Modular Reactor™ (MMR™) on the Urbana-Champaign campus. The MMR is one version of a class of nuclear reactors known as High-Temperature Gas-cooled Reactors, or HTGRs for short. The basic concepts behind HTGRs are not new. Several examples of this technology have operated safely around the world over the past few decades. China is currently operating HTGRs technologies at the HTR-10 and HTR-PM plants in Shandong Province. Japan hosts the High-Temperature Engineering Test Reactor (HTTR) research facility. Several major reactors have operated in Europe. The US has also licensed and operated HTGRs.

Technology

The specifics of HTGR technology vary from design-to-design. Two major sub-types are defined through the configuration of the reactor core: prismatic and pebble bed. Pebble bed fuel elements are typically billiard ball-sized spheres which move through the core over time. The MMR is a prismatic HTGR in that the core is a fixed geometry that is primarily built up with hexagonal blocks of graphite that are around a foot or two tall. Inside these blocks are stacks of cylinders that are each an inch or two tall. Inside these cylinders are lots of small poppyseed-sized fuel particles. The fuel blocks also have open channels through which the coolant flows to remove the nuclear fission energy.

U.S. History

The United States has significant, real-world experience building and operating HTGRs This history is centered on two key demonstration plants that provided the foundation for today's designs.

The first large-scale HTGR in the US was Peach Bottom Unit 1 in Pennsylvania. Operating from 1966 to 1974, this 40-MWe (megawatts-electric) plant was a successful technology demonstrator. It proved the fundamental concept: a graphite-moderated, helium-cooled reactor could operate safely at high temperatures. Most importantly, it validated the revolutionary "TRISO" coated-particle fuel, which demonstrated its incredible ability to trap fission products directly within the fuel particle, ensuring system cleanliness.

Building on this success, the industry scaled up to the Fort St. Vrain (FSV) Generating Station in Colorado, a larger 330 MWe plant that operated from 1976 to 1989. While the reactor core and fuel performed well, the plant was challenged by “first-of-a-kind” engineering issues in its non-nuclear components, particularly its complex helium circulators. Issues like this impacted the plant's economic reliability and led to significant downtime.

However, the lessons learned from FSV were crucial. The operational challenges were not the result of core nuclear technology, but rather they were from the supporting mechanical systems—engineering hurdles that were complex for the 1970s. Critically, the plant did not experience a safety failure related to the reactor concept. This history provides an

The coolant of an HTGR is another crucial choice. As suggested by the name, the coolant is a gas, which helps reach high process temperatures. Most currently proposed designs use helium as the coolant. Helium is inert (it does not undergo chemical reactions that drive corrosion or cause explosions), it has large heat capacity and has a very small probability of absorbing neutrons.

Graphite

HTGRs usually utilize large amounts of very high-quality graphite. Nuclear-grade graphite is very high purity in carbon, which is an exceptional moderator of neutrons. Graphite is also extremely robust to hot temperatures: it does not melt or burn even at temperatures hotter than 2700° F.

Fuels

Theoretically, HTGRs can use a variety of fuel types. However, most of the currently proposed designs (at least in the US) use a fuel form known as TRISO (TRIstructural ISOtropic). The name refers to the complex engineered system of materials that make up the poppy-seed sized TRISO particles. A small grain of uranium in a ceramic form with oxygen and carbon lies at the center. This grain, or kernel, is surrounded by a layer of porous graphite that is designed to allow size changes and provides a space for gaseous fission products to accumulate. Next is an inner layer of pyrolytic carbon, followed by a layer of silicon carbide (SiC), then an outer layer of pyrolytic carbon. Thousands of these particles are then held fixed in a matrix of graphite or similar material. The combination of these layers provides for very strong barriers that are resistant to thermal changes and radiation damage even over decades. The SiC in particular is remarkably impermeable for essentially every type of material, including the radioactive fission products. Practically, this means that radioactive materials do not move from where they are created. This retention of radiological material, combined with stability under reactor conditions, is what makes TRISO fuel among the safest forms of fuel available today.

invaluable foundation. The behavior of reactors at scale is well known, and today's advanced designs leverage 40 years of progress in materials science, digital instrumentation and controls, and advanced manufacturing to solve the specific integration challenges that FSV faced. Further, the experience gained from this, as well as growing interest from the private sector, have led to a great deal of regulator experience with this technology, which can reasonably be expected to streamline future applications.

Unlocking the Opportunity of HTGRs

There are several reasons developers are pursuing HTGR technologies. One is that their configuration and enhanced margins of safety make them exemplars of passive safety, meaning that rigorous safety regulations can be met with minimal complexity and reduced cost. Another major benefit is the high temperatures that can be reached. The use of TRISO fuel and graphite structure elements allow for HTGRs to potentially reach process temperatures of 1000° C (or 1832° F). This attribute can dramatically improve the efficiency with which electricity can be produced. It also enables a wide range of industrial applications where high temperatures are needed (e.g., think melting metals). This capability makes HTGRs potential game changers for industries which use not just electricity, but heat. The IMDP will provide a facility to study and optimize a variety of these applications such as district heating, hydrogen production, and more.

Public Perception of Nuclear Energy in Illinois

By William Roy

The perception of the public about nuclear energy has been measured throughout time by conducting polls and surveys. These polls have varied in design and scope, but generally have been applied to study the demographic characteristics of the population that participated in the poll. These polls provide a snapshot of public perception at various periods in time. Depending on the goals and design of the poll, demographic trends have been observed in the U.S. and internationally. For example, numerous surveys have shown that men are more likely to favor nuclear energy than women. Poll data have also suggested that people who identify themselves as relatively conservative favor nuclear energy as a means of generating electricity. People who identify themselves as liberal tend not to be as receptive. There are very few such polls that *specifically* asked the residents of Illinois about their opinions and attitudes concerning nuclear energy. However, it appears that the long-term perception of nuclear energy in Illinois has mirrored that of the nation.

There was a nuclear research reactor that operated on the campus from 1960 to 1998. The University of Illinois Nuclear Research Laboratory was the home of a TRIGA research reactor (Training, Research, Isotopes, General Atomics). TRIGA reactors are in use internationally. The TRIGA reactor on campus was used for 38 years by students, faculty, and staff. The TRIGA reactor first became operational in 1960, and at that time, there was little—if any—public opposition to sighting of a reactor on campus. The public perception of the TRIGA reactor in the 1960s was both positive and enthusiastic. Professor James Stubbins recalled that "In 1980, the TRIGA reactor was the most popular tour given at the Engineering Open House." Public perception of nuclear energy in the U.S. was positive, and the TRIGA reactor benefited from that enthusiasm. As the old saying goes, "*When the tide rises, so do the ships."* The reverse of this generalization is also true. The TRIGA reactor operated for three decades without a major incidence. However, events *outside* of Illinois would erode some of that enthusiasm.

The historical perception of nuclear energy in the U.S. has been impacted by major nuclear accidents. The Three Mile Island accident in 1979 was the result of mechanical failures coupled with a lack of training available to resolve the failures. Already in decline, public support for nuclear energy decreased at that time (Fig.1). The Three Mile Island accident proved to have a sizable and persistent impact, decreasing public support over a 9- to 10-year span (Gupta et al., 2019). The Chernobyl Nuclear Accident occurred in 1986. The accident was the result of operator error that led to a sequence of reactor failures. The Russian-designed Reactor 4 was destroyed by explosions and a meltdown of the core. The Chernobyl accident resulted in a very pronounced initial impact that faded after about six years (Gupta et al., 2019). The post-Chenobyl gain in nuclear confidence was put to the test by the Fukushima Nuclear Incident in 2011. A major earthquake created a tsunami that flooded the Fukushima Daiichi Nuclear Power Plant. Radioactive contaminants were released into the local area. Gupta et al. (2019) concluded that the Fukushima accident had only a modest effect on public perception, but that it persisted in eroding public support for nuclear energy for the seven years after the earthquake.

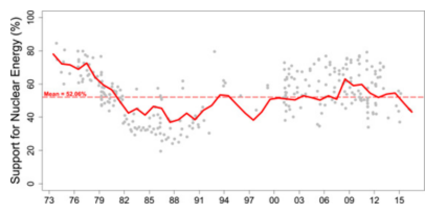

Figure 1. Estimated distribution of public support for nuclear energy in the U.S. up to about 2015 (modified from Gupta et al., 2019).

Since 2015 to the present, public support for nuclear energy has increased (Fig. 2). Various polls have documented greater support for nuclear energy—and by inference—in Illinois (Bisconti Research, Inc., 2023; Pew Research Center, (2025); Radiant Energy Group, 2023). The recent emergence of small modular reactors nationally and internationally has bolstered a new era of public support for nuclear energy. It seems likely that—with continuing public education and outreach combined with transparent siting and construction of small modular reactors—public perception of nuclear energy in Illinois will continue to increase to unprecedented levels.

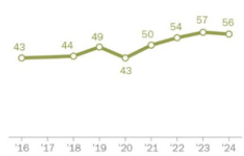

Figure 2. Percentage of adults who favor more nuclear power plants in the U.S. to

generate electricity (Pew Research Center, 2025)

Additional information is available at:

Bisconti Research, Inc. (2023). 2023 National Nuclear Energy Public Opinion Survey: Public Support for Nuclear Energy Stays at Record Level For Third Year in a Row (accessed at https://www.bisconti.com/blog/public-opinion-2023).

Gupta, K. M. C. Nowlin, J.T. Ripberger, H. C. Jenkins-Smith, and C. L. Silva. 2019. Tracking the nuclear 'mood' in the United States: Introducing a long-term measure of public opinion about nuclear energy using aggregate survey data. **Energy Policy**, *133*, 110888.

Pew Research Center. 2025. Majority of Americans continue to support more nuclear power in the U.S. (accessed at https://www.pewresearch.org/).

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