CHALLENGES AND INITIATIVES

1.0 Stockpiles of <u>used nuclear fuel</u> (UNF) and high-level waste (HLW)

2.O Enhancing accident tolerance fuel of the existing reactor fleet (re; March 2011 events at the Fukushima Daiichi nuclear power plant)

3.0 Establishment of the Fuel Cycle Technologies (FCT) program; Managing Research & Development

- Five R&D campaigns
  - Fuel Cycle Options
  - Advanced Fuels
  - Separations and Waste Forms
  - Used Fuel Disposition
  - Material Protection, Control, and Accountability Technologies
- ESTABLISHING OBJECTIVES
  - Advanced Modeling & Simulation
  - Develop and apply M&S tools focused on Light Water Reactor (LWR) technologies for improved understanding of critical operational and safety issues in existing reactors.
  - To enable industry to address reactor performance issues relative to safe operations and maintenance.

History of Nuclear Power Development

Recall from 1st Presentation

Key Points to Operational Safety, Quality and Reliability,

Navy Captain Hyman G. Rickover received nuclear power training at Oak Ridge in 1947
Director Naval Reactors Branch in the Bureau of Ships, joint activity with AEC in 1949
Submarine Nautilus commissioned 1954; 1st commercial reactor (Shippingport,PA) 1957
https://en.wikipedia.org/wiki/Naval_Reactors#History

Management and Personal Principles:
Attention to detail and adherence to rigidly-defined standards and specifications
Attitude change to large American commercial manufacturer's and CEOs
DoD and NASA compliance requirements. {Recall large variable spacing between U. S. car doors to main frame (1/8-5/8 inch) during the 50s & 60s.}

Brief History of Quality Assurance and Reliability

William Edwards Deming; https://en.wikipedia.org/wiki/W._Edwards_Demin
"Statistical Product Quality Administration" Recall the Japanese recovery after WWII 1950s

Joseph Moses Juran; https://en.wikipedia.org/wiki/Joseph_M._Juran
Known for adding the human dimension to quality management

Recall from 1st Presentation

William Edwards Deming (October 14, 1900 – December 20, 1993)
Walter Andrew Shewhart (March 18, 1891 – March 11, 1967)

Deming is best known for his work in Japan after WWII, particularly his work with the leaders of Japanese industry. That work began in July and August 1950, in Tokyo and at the Hakone Convention Center[4], when Deming delivered speeches on what he called **"Statistical Product Quality Administration".** Many in Japan credit Deming as one of the inspirations for what has become known as the Japanese post-war economic miracle of 1950 to 1960, when Japan rose from the ashes of war on the road to becoming the second-largest economy in the world through processes partially influenced by the ideas Deming taught.

Dr. Walter A. Shewhart pronounced like "shoe-heart", was an American physicist, engineer and statistician, sometimes known as the father of Statistical Quality Control and also related to the Shewhart cycle.

Invented the control chart working for Bell Labs in the 1920s while seeking to improve the reliability of their telephony transmission systems. Because some equipment had to be buried underground, there was a strong business need to reduce the frequency of failures and repairs.

Shewhart's work pointed out: the importance of reducing variation in a manufacturing process; understanding continual process-adjustment; bringing production processes into a state of statistical control to improve Reliability.

Recall from 1st Presentation

Significant Points of Interest/Discussion of Nuclear Power Plant Construction

Available Resources of the 1970s

Limited availability of trained professionals in the many technical areas and management fields

Pioneering explorers. Just as challenging and dangerous as space exploration in early 60s.

Innovative thinking and New Capabilities Design Required
(i.e. Why not design & build it RIGHT the first time)

Design & Development, Quality, Reliability, Safety; Life Sciences, Environmental Impact, Operational Maintenance; Security, Fuel Storage, and Decommissioning; Cost effectiveness.

However, in my opinion, Federal Government NUCLEAR SAFETY Requirements was Priority #1 at the very beginning.

Rickover's management philosophy was applied to Commercial Nuclear Power Generation.
Convincing power corporation CEOs was another matter. However, the Design & Development Engineers used redundant safety systems which really paid off.

The U.S. lacked a scientific facility to provide fast neutron testing, required for rapid and accurate new material and nuclear fuel research and development.
Many U.S. companies are working on technologies to make the next generation of reactors and the existing reactors more economically competitive and reliable.
New reactors and support of existing reactors require continuing research and development of new materials and nuclear fuels.
The next few slides illustrate significant DOE progress.
This problem is not as severe today; as the DOE has been diligent in creating both facility and technical personnel.

Things You Should Know About Accident Tolerant Fuels

1. Accident tolerant fuels beat the heat and perform better

Withstand extreme heat and steam for longer than the current fuel system of uranium dioxide fuel and zircaloy cladding.

2. Accident tolerant fuels last longer

Could potentially use roughly 30% less fuel

3. Accident Tolerant fuels improve plant performance

Could possibly run with less downtime—leading to higher profit

Recall monthly fossil plants down time and how reduced (re DoD)

4. Accident tolerant fuels are industry-led

Three US Companies, DOE, and the National Labs are currently testing

5. Accident tolerant fuels could debut by 2025

6. Check out this video on YouTube: https://youtu.be/BmHbbar_s8M

Nuclear Energy Enabling Technologies (NEET)

Collectively, NEET-sponsored activities support the goals, objectives, and activities of the Gateway for Accelerated Innovation in Nuclear (GAIN) initiative to make these technology advancements accessible to U.S. industry through private-public partnerships.

Program Elements

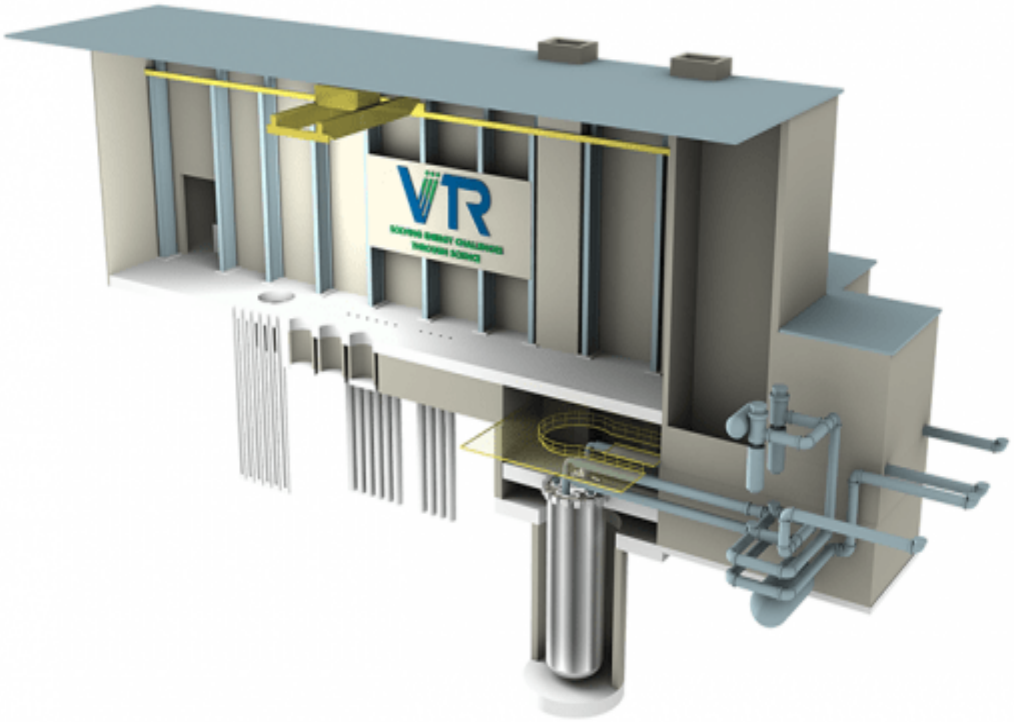
- Crosscutting Technology Development:
  - Advanced Sensors and Instrumentation
  - Advanced Methods for Manufacturing
  - Hybrid Energy Systems
  - Cybersecurity
- Advanced Modeling and Simulation
- Nuclear Science User Facilities
- Glove Boxes (large and small) nuclear material handling & processing
- Transformational Challenge Reactor

https://youtu.be/MlMDDhQ9-pE Recycling spent fuel.

Why don’t we use pyroprocessing already?

- **Lack of financial incentive.** Raw uranium is cheap. At the moment, it’s cheapest to run the fuel through once and then store it, mostly because other methods would have to be researched and tested. Light-water reactors are cheaper to build, because both utilities and the U.S. Nuclear Regulatory Committee are familiar with the technology. Since the process for approving a new reactor design takes years, there’s not much incentive to build different types of reactors, including fast reactors.

DOE's Versatile Test Reactor.



What is a Nuclear Microreactor?

1. **Factory fabricated:** All components of a microreactor would be fully assembled in a factory and shipped out to location. This eliminates difficulties associated with large-scale construction, reduces capital costs and would help get the reactor up and running quickly.
2. **Transportable:** Smaller unit designs will make microreactors very transportable. This would make it easy for vendors to ship the entire reactor by truck, shipping vessel, airplane or railcar.
3. **Self-adjusting:** Simple and responsive design concepts will allow microreactors to self-adjust. They won’t require a large number of specialized operators and would utilize passive safety systems that prevent any potential for overheating or reactor meltdown.

Idaho National Laboratory Image of a Nuclear Microreactor

The National Reactor Innovation Center (NRIC)

We build advanced nuclear reactors for this century

NRIC is a national Department of Energy program led by Idaho National Laboratory, allowing collaborators to harness the world-class capabilities of the U.S. National Laboratory System. We are charged with and committed to demonstrating advanced reactors by the end of 2025.

The National Reactor Innovation Center (NRIC)

Innovative designs for cutting-edge applications:

Advanced nuclear technologies will serve new sectors of the economy by providing more than just clean electricity.

This includes decarbonized heat generation, water desalination, and hydrogen production.

Hybrid energy systems will benefit from the flexible output of advanced fission plants that can balance renewables and deliver low-carbon electricity in all conditions.

Innovative applications for maritime propulsion and space technologies will provide unmatched reliability on new frontiers.

Memorandum of Understanding Between DOE and NRC on Nuclear Energy Innovation

NUCLEAR ENERGY in the FUTURE

The **U.S. Department of Energy** (DOE) and U.S. **Nuclear Regulatory Commission** (NRC) signed a Memorandum of Understanding (MOU) to share technical expertise and computing resources to speed up the deployment of advanced nuclear technologies. The MOU centers on DOE's new National Reactor Innovation Center initiative which was authorized by the Nuclear Energy Innovation Capabilities Act of 2017.

Authorized by the Nuclear Energy Innovation Capabilities Act of 2017.

DOE url: **https://www.energy.gov/ne/nuclear-reactor-technologies**

Next Generation Nuclear Plant

High temperature gas-cooled reactor (HTGR) technology to provide both electricity and high-temperature process heat for a a variety of industrial uses

Collaborative efforts with universities, industry, and the U.S. Nuclear Regulatory Commission (NRC)

Focus is on efficiency and cost-effectiveness to ensure maximum usefulness and applicability of results

Advanced Reactor Concepts

ARC key benefits:

•Research on innovative technologies that: resolve key feasibility and performance challenges, and reduce fabrication, construction and operating costs.

•Exploration and development of supercritical CO_2 Brayton thermal cycle for diverse reactor applications that couple nuclear reactors to power generation with much improved conversion efficiency and reduced plant size.

•Enable, through research, additional long-term nuclear energy options that have the potential to provide significant safety, economic improvements and lower fabrication, construction and operations costs.

•Utilize international collaborations to leverage and expand R&D investments.

Supercritical CO_2 Brayton thermal cycle

When carbon dioxide (CO2) is held above its critical temperature and pressure, it acts like a gas yet has the density of a liquid. In this supercritical state, small changes in temperature or pressure cause dramatic shifts in density - making sCO2 a highly efficient working fluid to generate power.

Three DOE Offices (Nuclear Energy, Fossil Energy, and Energy Efficiency and Renewable Energy) are working together to reduce the technical hurdles and support foundational research and development of sCO2 power cycles.

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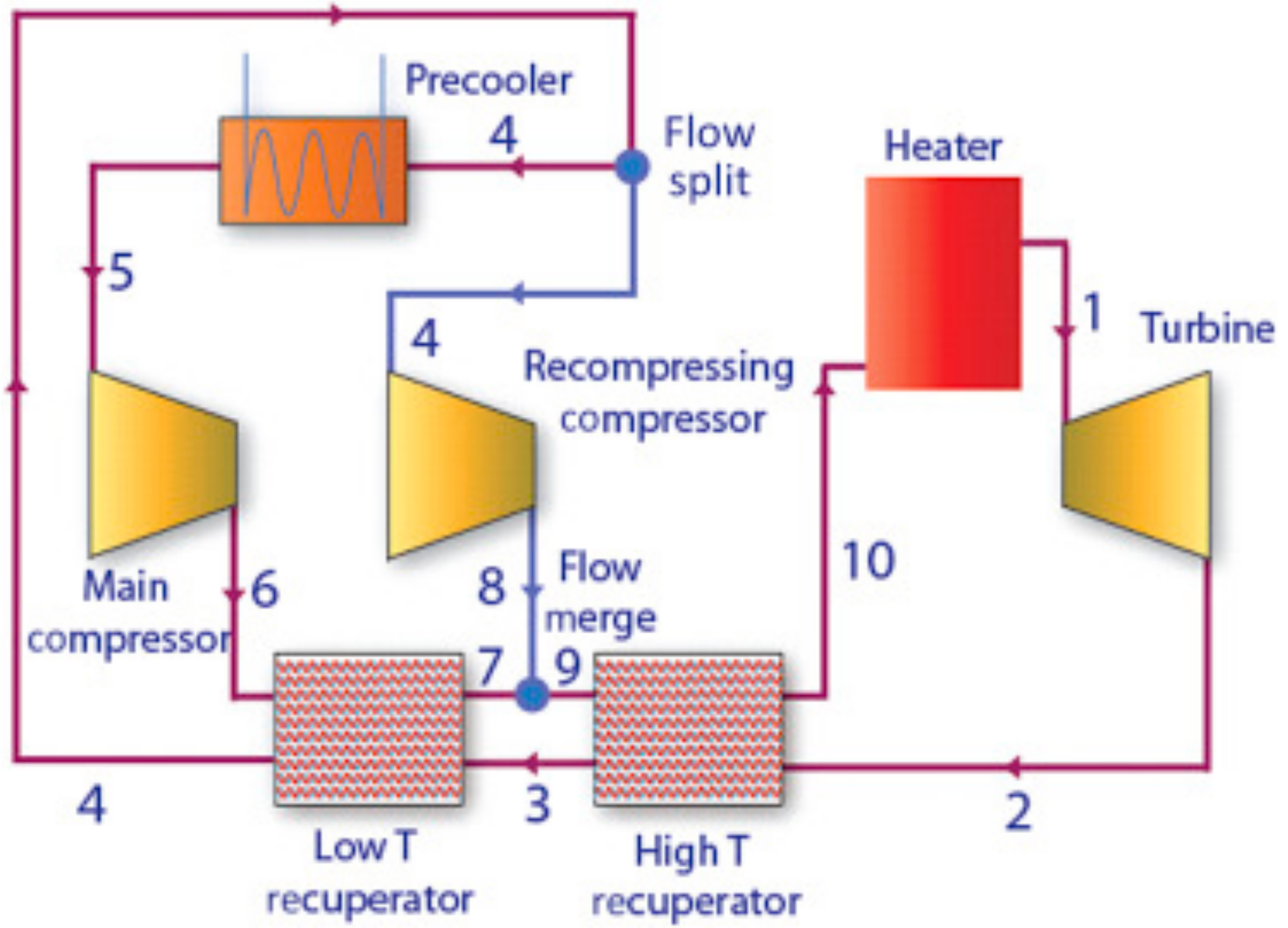
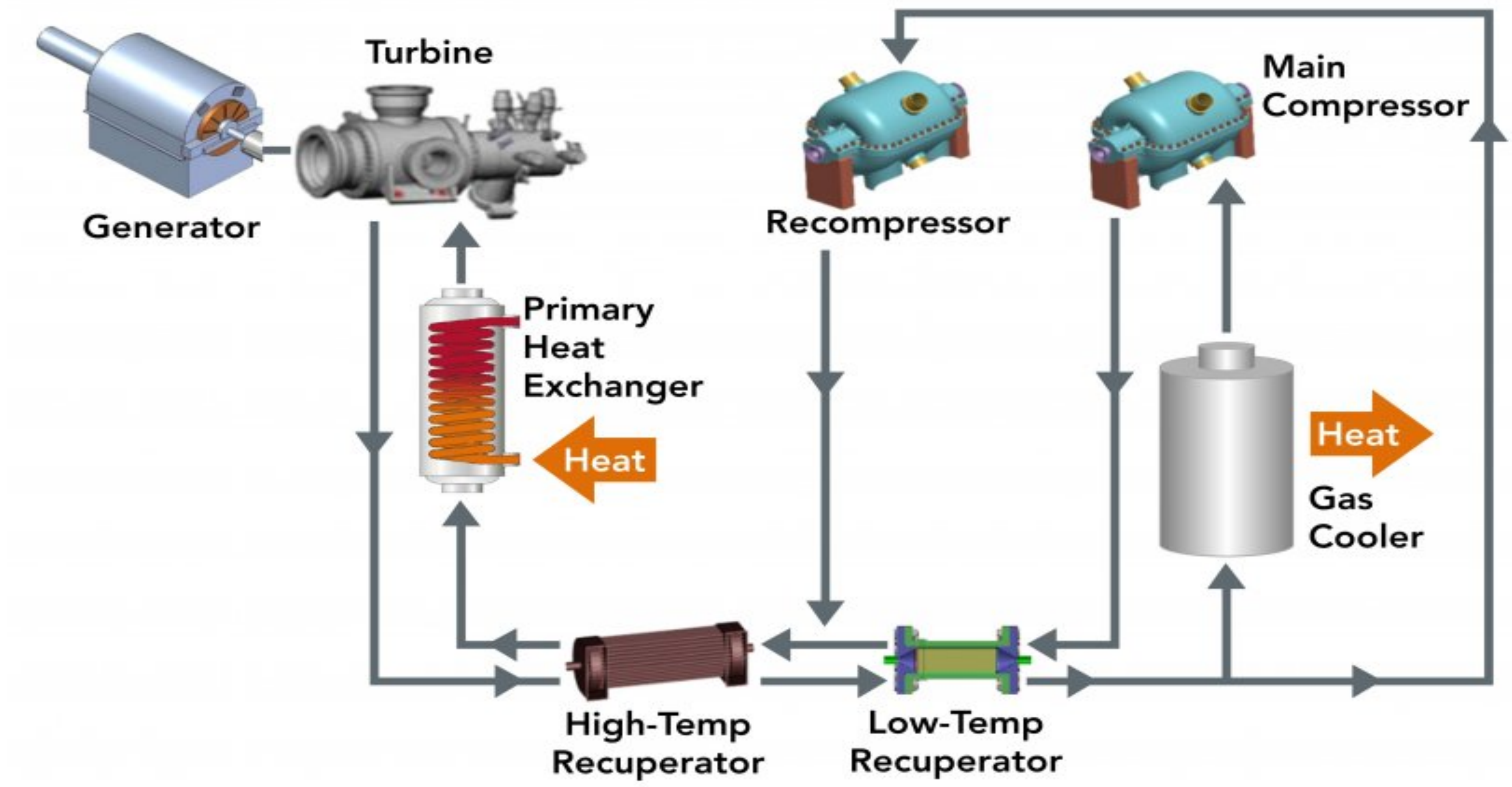
Three DOE Offices (Nuclear Energy, Fossil Energy, and Energy Efficiency and Renewable Energy) are working together to reduce the technical hurdles and support foundational research and development of sCO_2 power cycles.

Simple Closed-Loop Brayton Cycle.

In a simple closed-loop Brayton cycle, the working fluid (CO_2) is heated indirectly from a heat source through a heat exchanger (as steam would be heated in a conventional boiler); energy is extracted from the CO_2 as it is expanded in the turbine; the CO_2 exiting the turbine is then cooled in a heat exchanger to the desired compressor inlet temperature; and after compression to the required pressure, the CO_2 is sent back to the heater to complete the cycle. At a turbine inlet temperature (TIT) of 700C and a turbine exit pressure of 8.27 MPa, maximum cycle efficiency is an estimated 34.5%.



Review of SCO2 Power Cycle



SCO2 Power Cycles for Nuclear

The National Reactor Innovation Center (NRIC)

Radioisotope thermoelectric generators (RTGs), and small heat sources called radioisotope heater units (RHUs) that keep spacecraft components warm in harsh environments. DOE also maintains responsibility for nuclear safety throughout.

A Versatile Test Reactor, or VTR. Due to the very high neutron flux provided by VTR, the irradiation time for testing materials can be reduced by a significant order of n order of magnitude

Multi-Mission Radioisotope Thermoelectric Generator

What is a Radioisotope Power System?

Radioisotope power systems (RPS) convert heat generated by the natural decay of **plutonium-238**—a radioactive isotope—into electrical power. They have powered more than two dozen U.S. space missions and are capable of producing heat and electricity under the harsh conditions in deep space for decades without any maintenance.

Two types:

- Small devices that provide heat
- Devices that provide power and heat

What is a nuclear glovebox?

In a nuclear laboratory, a glove box is **a windowed, sealed container equipped with two flexible gloves that allow the user to manipulate nuclear materials from the outside in an ostensibly safe environment**.

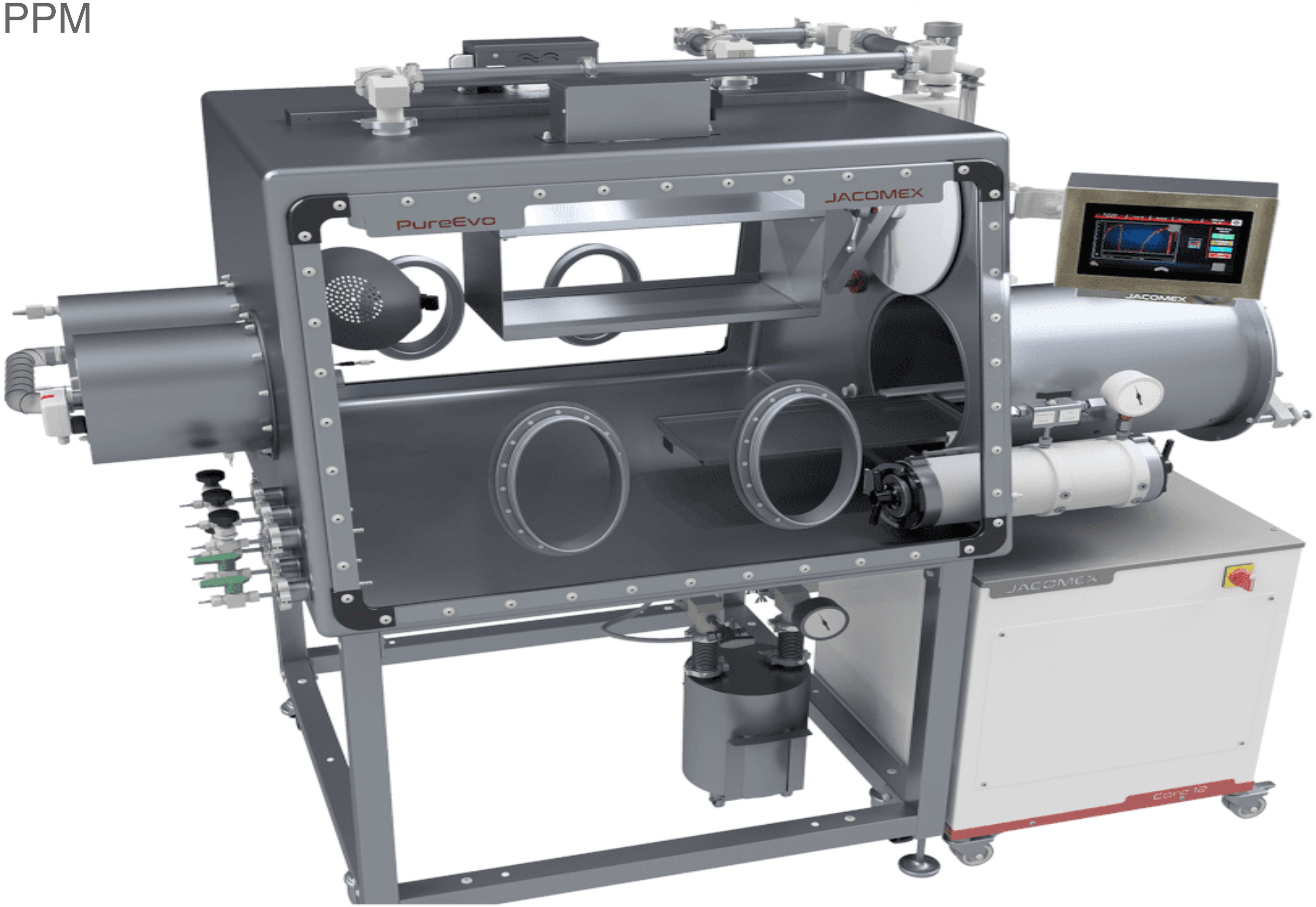
https://www.energy.gov/ne/initiatives/fuel-cycle-technologies

URL to the Future through Innovation!

PureEvo

GLOVE BOX

Glove box designed for research and industry for all applications < 1PPM H_2O – O_2



3 Early-Stage R&D Programs Transforming the Nuclear Industry

Dozens of U.S. companies are working on a fourth generation of reactor designs that will soon come in a variety of sizes. The **Advanced Research Projects Agency-Energy (ARPA-E)** is a uniquely positioned office at DOE that focuses specifically on supporting early-stage technologies. Here are three ARPA-E programs helping to make advanced nuclear a reality. READ MORE

DOE Releases Final Environmental Impact Statement for Versatile Test Reactor

DOE released the Final Environmental Impact Statement for the construction of the Versatile Test Reactor (VTR). The proposed VTR will be a sodium-cooled fast-neutron-spectrum test reactor that will enhance and accelerate research, development, and demonstration of innovative nuclear technologies. READ MORE

Argonne Adds New Testing Capability for Liquid Metal Fast Reactors

Argonne National Laboratory recently added the Thermal Hydraulic Experimental Test Article (THETA) to provide high-resolution and high-quality data that can be used to develop computer codes to support the licensing of liquid-metal fast reactor designs. THETA is currently running its first test with Oklo Inc. as the company seeks to better understand the behavior of its fast reactor designs. READ MORE

Facts to Know About Three Mile Island

A combination of equipment failure and operator error led to the partial meltdown of Three Mile Island nuclear station's Unit 2 reactor that resulted in the release of a small amount of radioactive material. Here are 5 facts you should know about the accident at Three Mile Island. READ MORE