RECYCLING USED NUCLEAR FUEL FOR A SUSTAINABLE ENERGY FUTURE

Pyroprocessing Technologies
Nuclear power is the most environmentally friendly way of generating large amounts of electricity on demand. Through the development and application of advanced technologies for recycling “spent,” or used nuclear fuel, nuclear power could also become truly sustainable and essentially inexhaustible.
THE BASICS OF PYROPROCESSING

The electrorefining procedure is key to pyrochemical recycling of used nuclear fuel. This process removes the waste fission products from the uranium and other actinides (heavy radioactive elements) in the used fuel. The unfissioned uranium and actinides are then recycled to fast reactors.

Through pyroprocessing and the much more efficient fast reactor fuel cycle, vastly more of the energy in the uranium ore can be used to produce electricity.

OXIDE REDUCTION UNIT

The oxide fuel is first converted to metal through oxide reduction.

ELECTROREFINER

Electrorefining is very similar to electropolishing. Used fuel attached to an anode is suspended in a chemical bath; electric current then dissolves the used fuel and plates out the uranium and other actinides on the cathode.

CATHODE PROCESSOR

These extracted elements are then sent to the cathode processor where the residual salt from the refining process is removed and recycled back to the electrorefiner.

FUEL FABRICATION FURNACE

Finally, the remaining actinides and uranium are cast into fresh fuel rods and the salt is recycled back into the electrorefiner.

WHAT IS FISSION?

AND OTHER DEFINITIONS

Fission
The splitting of the nuclei of heavy-metal atoms (mainly uranium and other actinides) resulting in the release of large amounts of energy.

Fission products
The true waste of fission, a mixture of lighter elements created when the heavy atom splits.

Used fuel
Unfissioned uranium and other actinides (including plutonium and several other heavy radioactive elements). The actinides are the main source of today’s nuclear waste problem.

Actinides
Heavy radioactive elements, including neptunium, plutonium, americium, and curium, that are separated out during recycling, and remain with the unfissioned uranium as they are recycled back into new fuel. The actinides are then destroyed in fission, turning them into short-lived fission products.

If the reprocessing and refueling steps are repeated enough times, nearly all the actinides will have been fissioned, leaving only short-lived waste fission products containing very little actinides. This process not only reduces the amount of waste created, but also the time it must be isolated—from approximately 300,000 years to approximately 300 years.
TURNING NUCLEAR WASTE INTO A “WONDERFUEL”

Argonne’s pyrochemical process research is opening the doors to a sustainable nuclear energy future for the nation.

The Laboratory’s goals are to:
☐ Optimize energy production and use of resources
☐ Manage the fission waste in an environmentally responsible manner
☐ Provide advanced pyroprocessing technologies that are economical to use

Argonne scientists and engineers are developing commercially viable technologies with the following characteristics:
☐ Robust process chemistry and engineering
☐ High product quality
☐ Scalability
☐ Minimal secondary waste production
☐ In line with U.S. non-proliferation objectives

ABOUT ELECTROREFINING
Electrorefining is the key to pyrochemical processing: an electrometallurgical treatment of spent nuclear fuel that uses molten salt to recover the uranium and other actinides for recycling into new fuel.

Electrorefining enables:
☐ Fission product and actinide partitioning
☐ Electrodeposition of actinides for recycle
☐ Fission products to be recovered in a subsequent process and encapsulated in durable waste forms

CURRENT R&D AT ARGONNE
Argonne’s current electrorefining R&D focuses on process efficiency and scalability. Research activities include:
☐ Increasing throughput (i.e., batch size) to enable the treatment of used light water reactor fuel
☐ Incorporating automated product recovery to enhance and increase throughput
☐ Developing intermittent actinide removal from cathodes to enhance process efficiency
☐ Conceiving and evaluating prototype test electrorefining module designs to establish data essential to the design of commercial systems

CHEMICAL AND FUEL CYCLE TECHNOLOGIES

A VISION FOR A SUSTAINABLE NUCLEAR ENERGY SYSTEM

ARGONNE NATIONAL LABORATORY

Argonne’s comprehensive vision for an expanded, sustainable nuclear energy system.
Argonne researchers recently patented an innovative technology for depositing both the uranium and transuranic (other actinides such as neptunium, plutonium, and americium) metal product onto a solid cathode during electrorefining for recycling into fast reactor fuel. During their work, a more detailed understanding of the fundamental electrochemistry behind co-deposition is being gained. The technology:

☐ Features robust process chemistry that limits the impurities being carried over into the fuel. Fewer impurities in the fuel could increase fuel burn-up in the reactor, resulting in fewer recycle steps

☐ Reduces the complexity of the process when compared to older technologies

☐ Maintains the non-proliferation features critical to U.S. fuel cycles

IN SITU PROCESS MONITORING FOR PYROCHEMICAL SYSTEMS

A powerful process monitoring and safeguards technology for the electrorefining systems used in actinide recovery is being developed by Argonne’s research team, which includes experts in process research and nuclear safeguards. Reliable process monitoring and control technologies are essential for operating a commercial fuel treatment facility. A variety of electroanalytical methods including cyclic and square-wave voltammetry, and spectroscopic techniques are being developed and evaluated to determine the quantity of actinide in molten salt. This research includes developing:

☐ Methods that achieve representative and reproducible conditions at the sensing electrode/molten salt solution interface

☐ Methods to determine the sensing electrode’s effective area, which is vital to accurate concentration measurements

PYROCHEMICAL PROCESSING FACILITY CONCEPT

To further advance Argonne’s pyroprocessing work and the potential for recycling used nuclear fuel, researchers developed a conceptual 100 metric tonne per year pyroprocessing facility. This work includes the development of processes, equipment concepts, an operations model, and the identification of materials handling issues.
Argonne's groundbreaking pyroprocessing technologies enables 100 times more of the energy in uranium ore to be used, and by recycling all actinides it significantly reduces the amount of nuclear waste and the time it must be isolated.

See the video on Argonne’s pyroprocessing research: http://youtu.be/MlMDDhQ9-pE
ARGONNE NATIONAL LABORATORY
☐ U.S. Department of Energy research facility
☐ Operated by the University of Chicago
☐ Midwest’s largest federally funded R&D facility
☐ Located in Lemont, IL, about 25 miles (40 km) southwest of Chicago, IL (USA)
☐ Conducts basic and applied research in dozens of fields
☐ Unique suite of leading-edge and rare scientific user facilities

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