Chemical Engineering 512

Nuclear Reactor Transient Modeling

Lecture 2

Reactor Concepts

RELAP5-3D Introduction

Export Control Laws

Spiritual Thought

"I went and my very fist day I went to Café Rio. I'm standing right in the middle of everyone, holding a church book, just like this, it's a biography on one of the prophets… You know how it feels when people are looking at you? That's how I felt… I remember feeling tense, and finally the guy next to me gets me attention and he goes 'Pretty ironic looking the way you do holding that book!'

My heart broke. I wanted to turn and I wanted to scream at him: 'Do you know what I just went through? Do you know how hard this is? Do you know what and who I had to give up to be here?'"

-Al Carraway

Generations I-IV

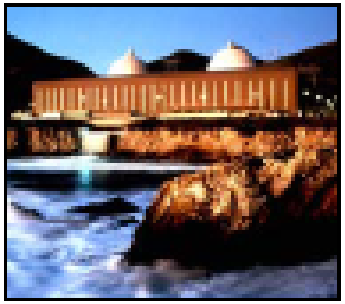
Generation I

Early Prototype Reactors

- Shippingport
- Dresden, Fermi I
- Magnox

Generation II

Commercial Power Reactors



- LWR-PWR, BWR
- CANDU
- AGR

Generation III

Advanced LWRs

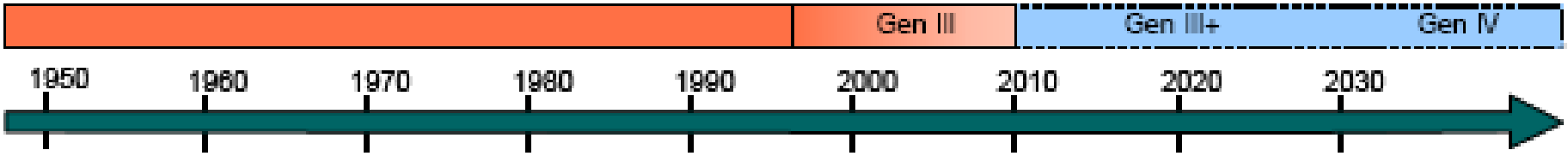
- ABWR
- System 80+

Generation III +

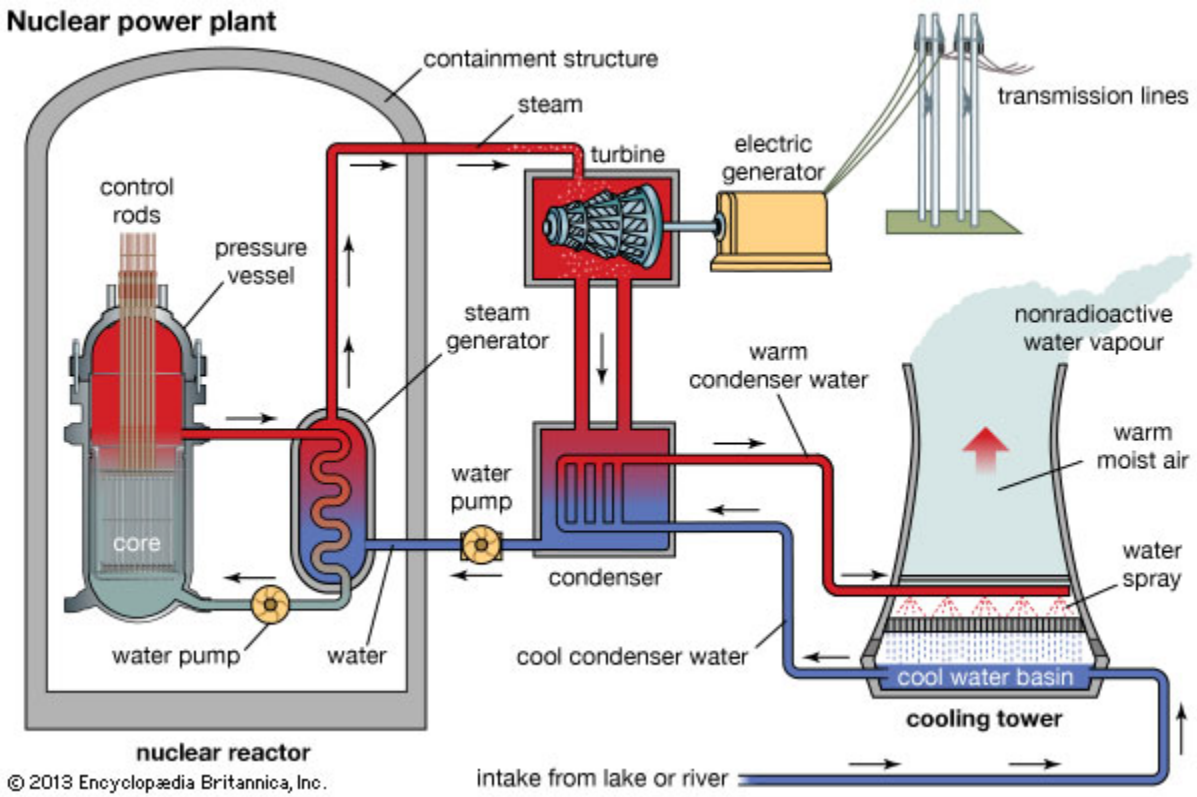
Evolutionary Designs Offering Improved Economics for Near-Term Deployment

Generation IV

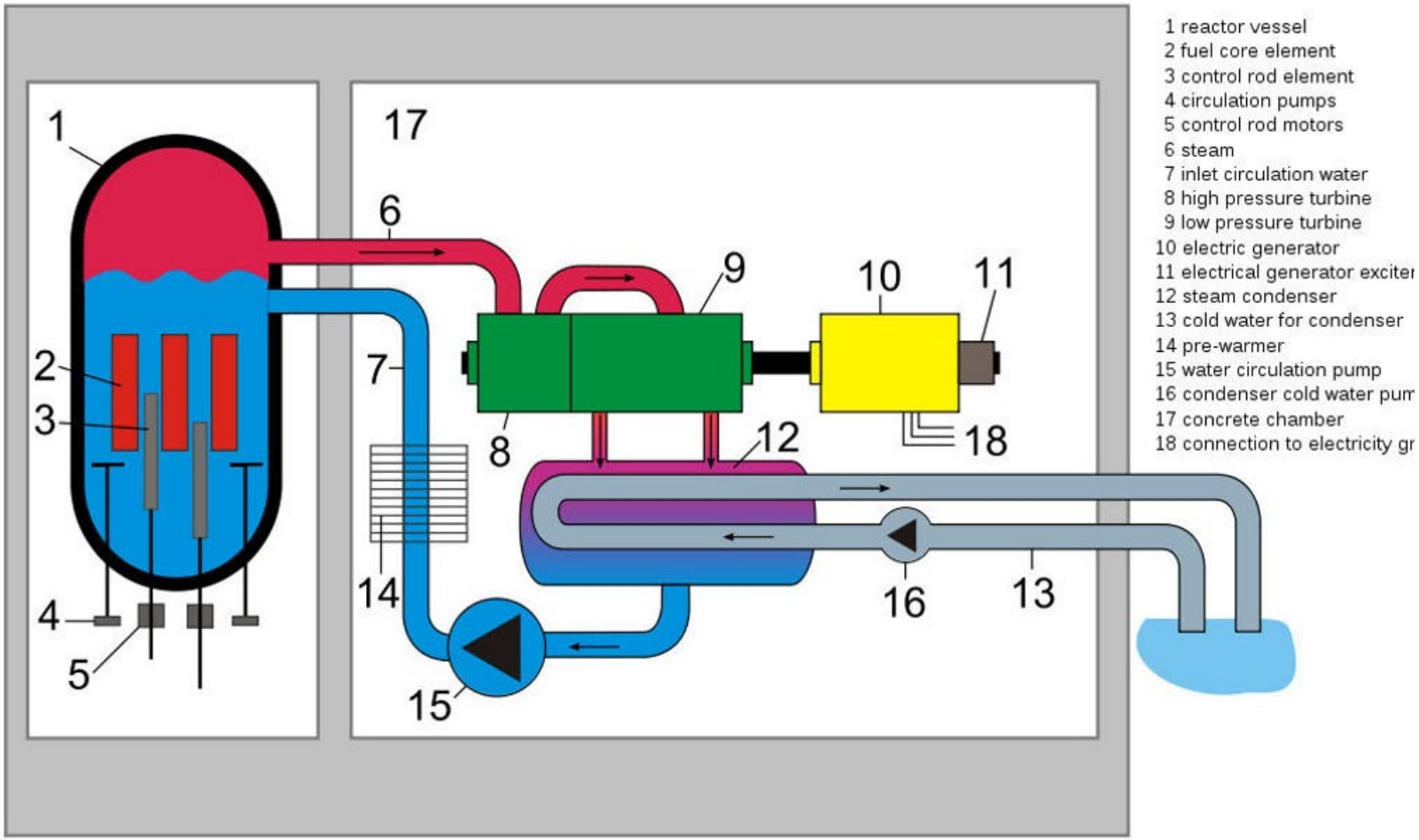
- Highly Economical
- Enhanced Safety
- Minimal Waste
- Proliferation Resistant



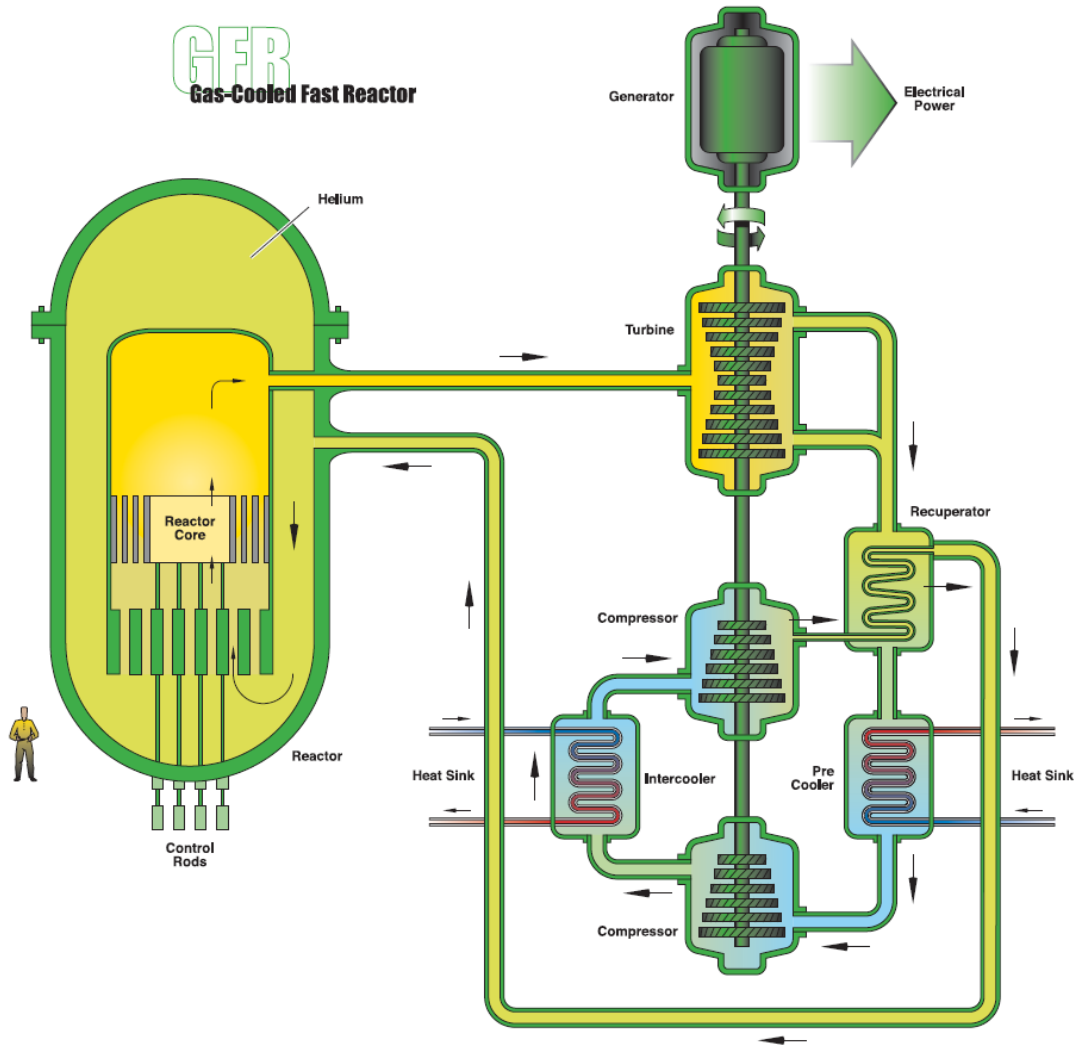
PWR (Currently Operating)



BWR (Currently Operating)

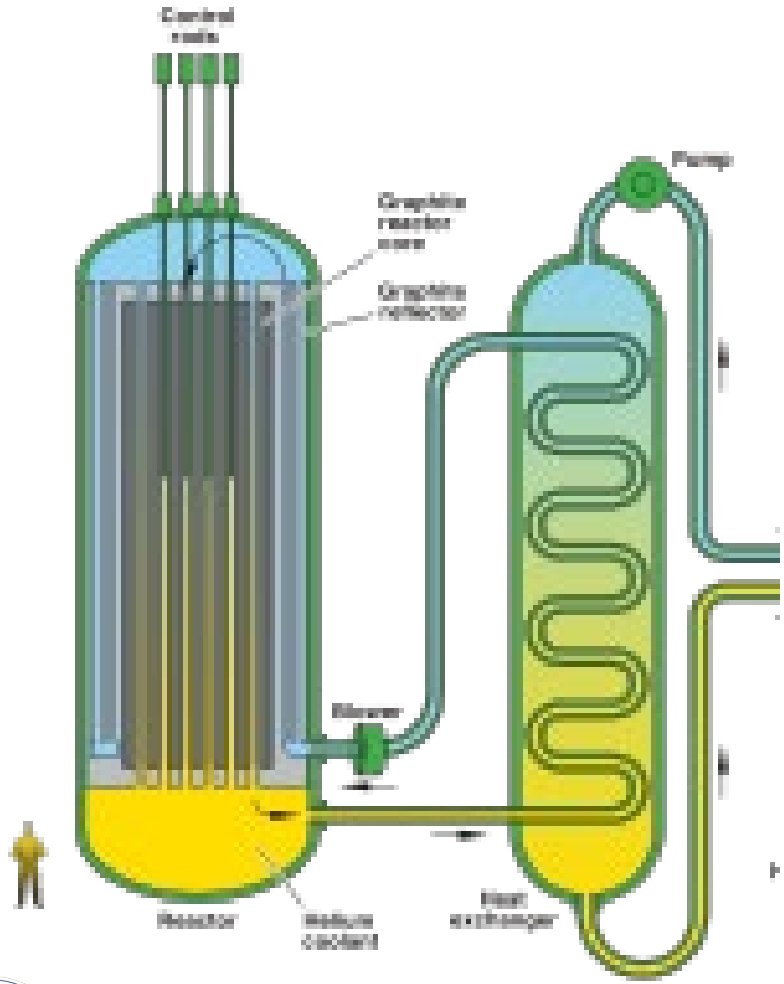


Gas-cooled Fast Reactor

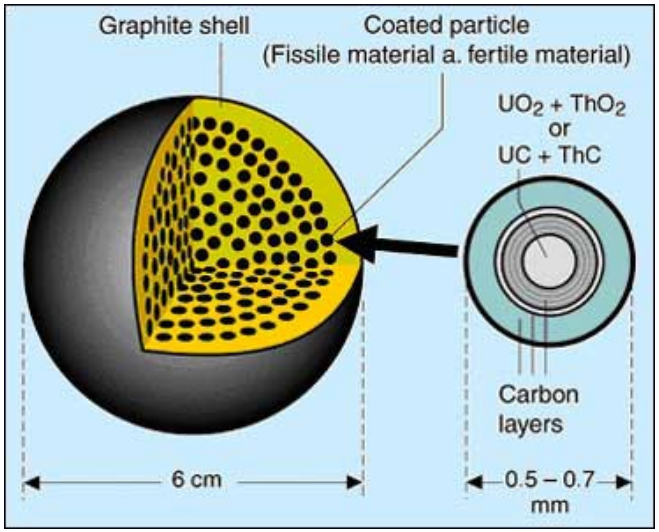


- He cooled with direct Brayton cycle for high efficiency
- Closed fuel cycle
- Low Power Density
- Fuel Rods, ^{239}Pu

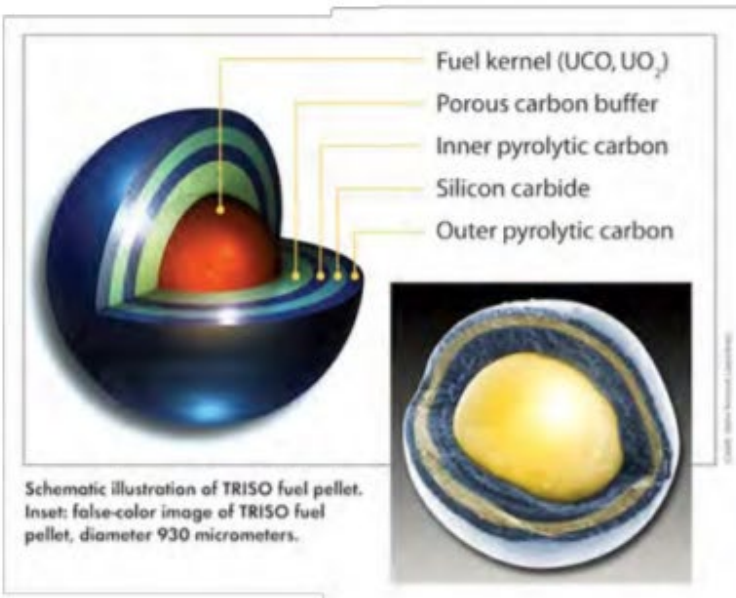
Very High Temperature Reactor



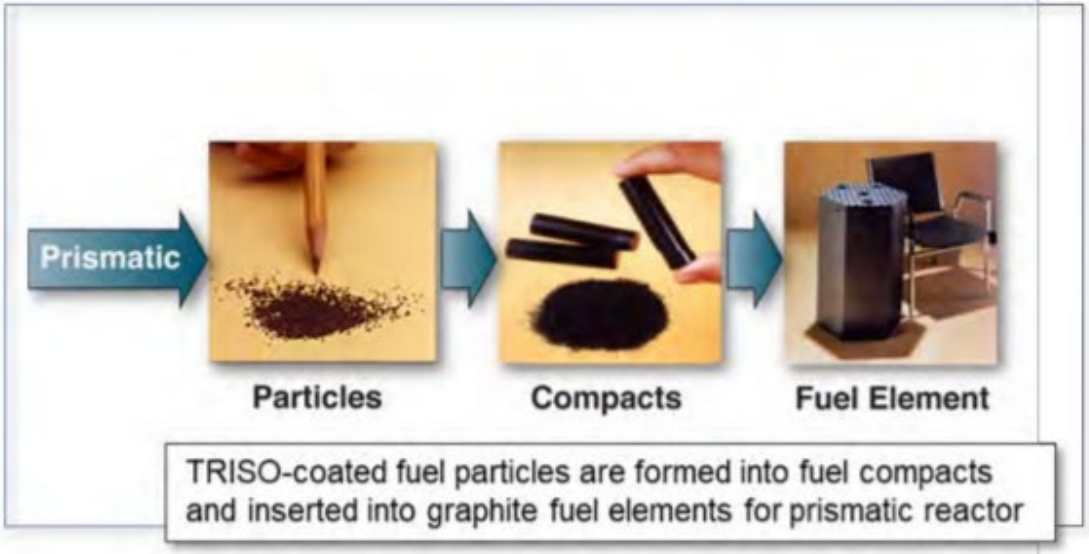
- T_{out} = 1000° C
- Gas cooled (He)
- Inherently safe
- Low Power Density
- Brayton Cycle



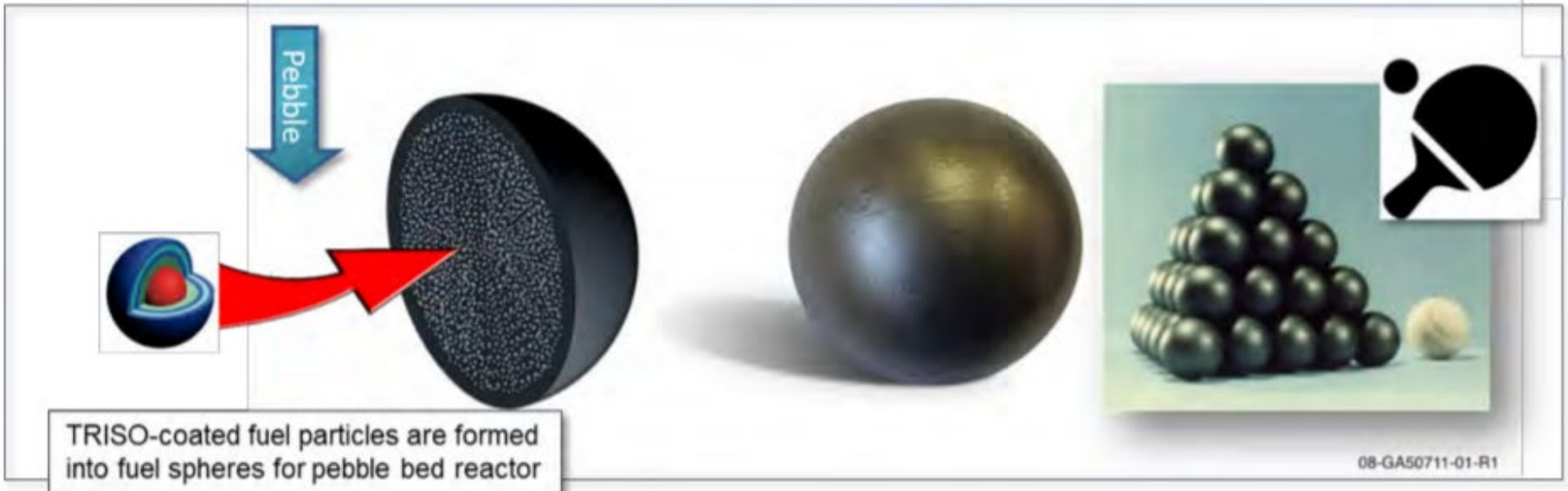
New fuel form - TRISO



Schematic illustration of TRISO fuel pellet. Inset: false-color image of TRISO fuel pellet, diameter 930 micrometers.

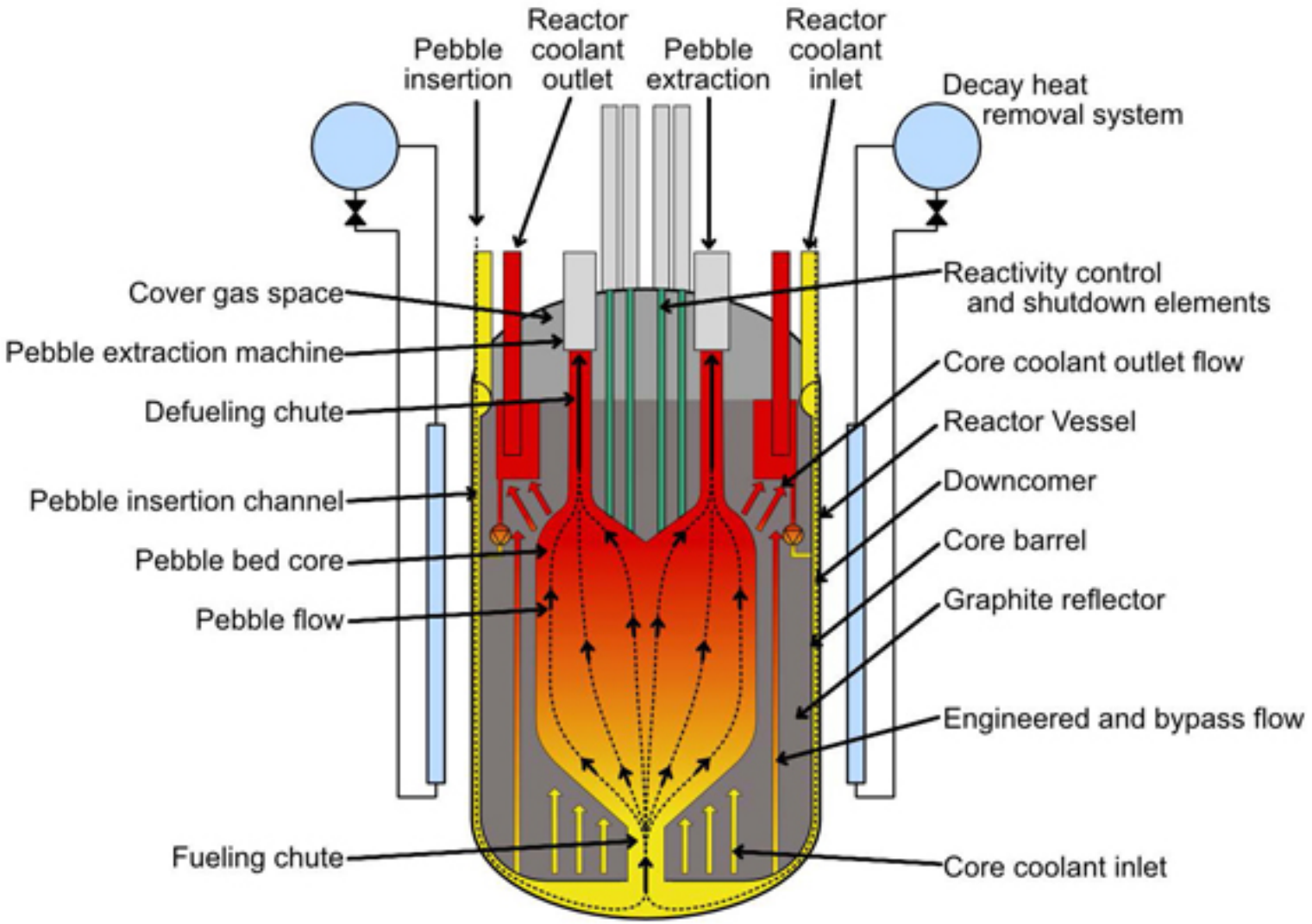


TRISO-coated fuel particles are formed into fuel compacts and inserted into graphite fuel elements for prismatic reactor

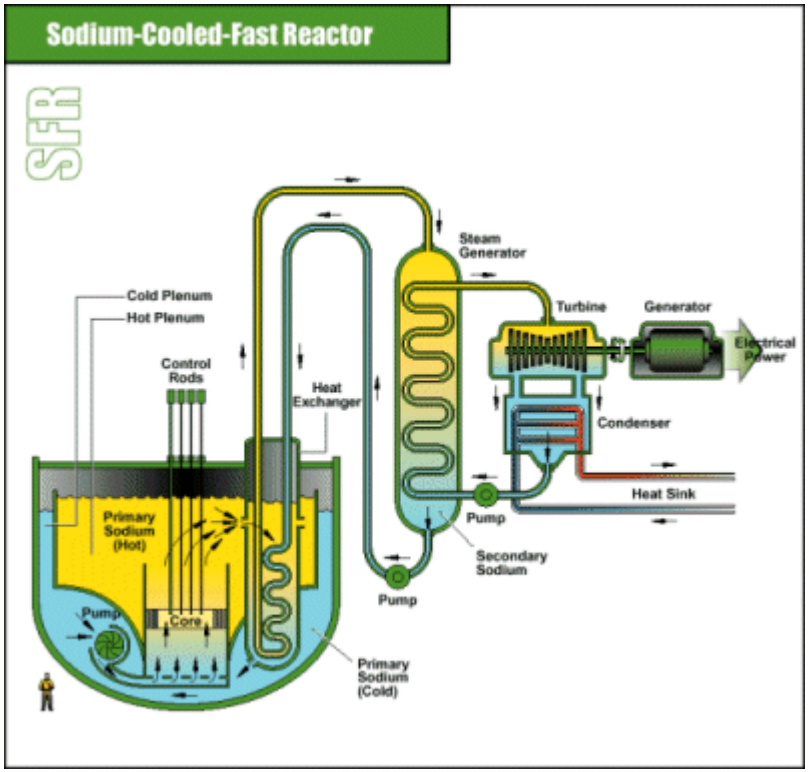


TRISO-coated fuel particles are formed into fuel spheres for pebble bed reactor

Fluoride-salt High-temperature Reactor (FHR)

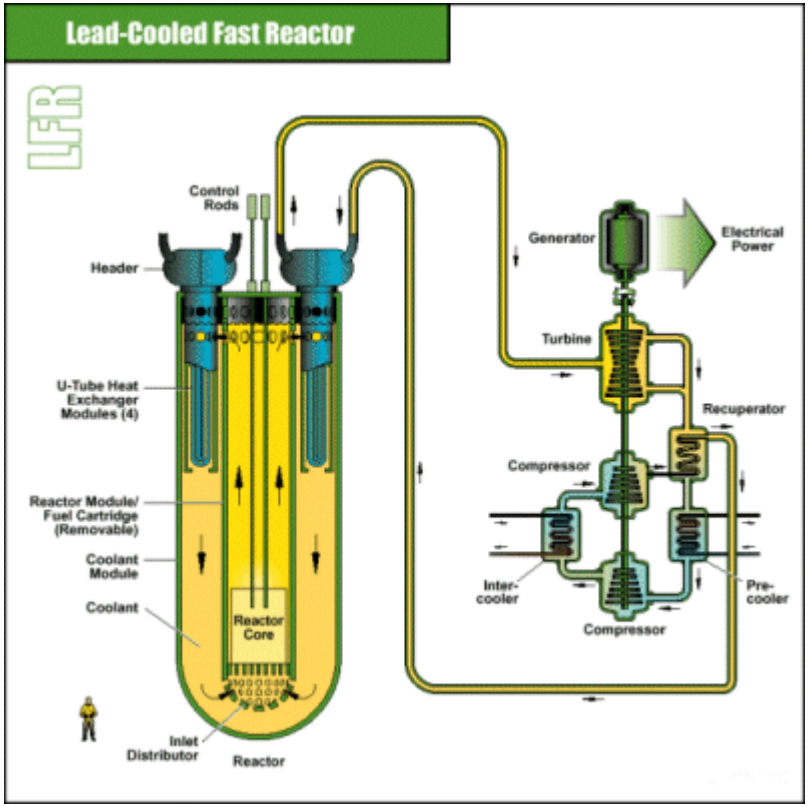


Sodium-Cooled Fast Reactor



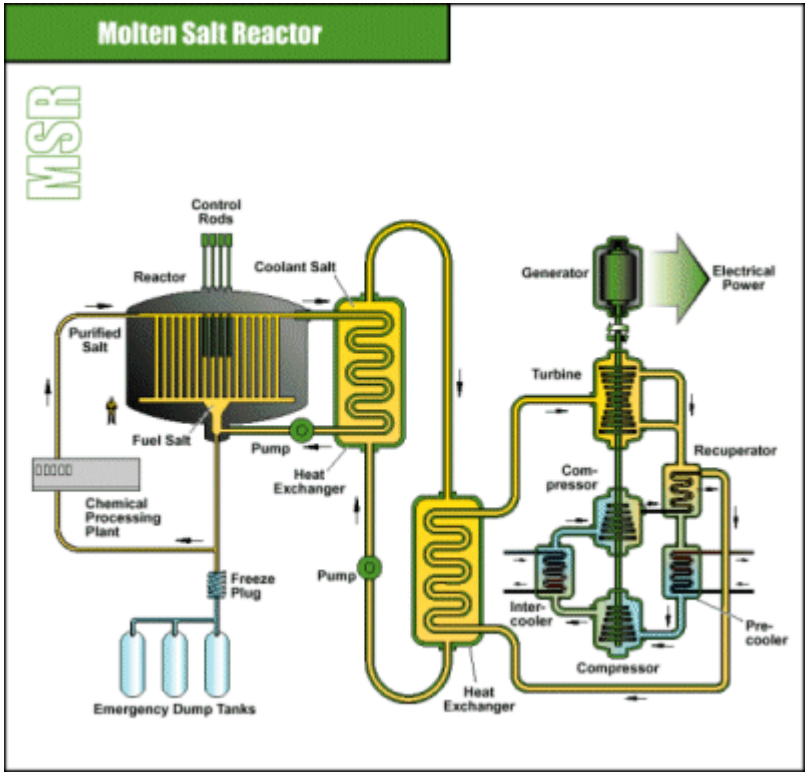
- Eliminates the need for transuranic (Pu) isotopes from leaving site (by breeding and consuming Pu)
- Liquid sodium cooled reactor
- Fueled by U/Pu alloy
- Fuel Rods (Zr-Pu-U metallic fuel), ^{239}Pu

Lead-cooled Fast Reactor



- Molten lead or lead-eutectic as core coolant
- Heat exchanged to gas-driven turbine
- Natural convection core cooling (cannot fail unless gravity fails)
- WEC Choice
- Fuel Rods (Zr-Pu-U metallic fuel), ^{239}Pu

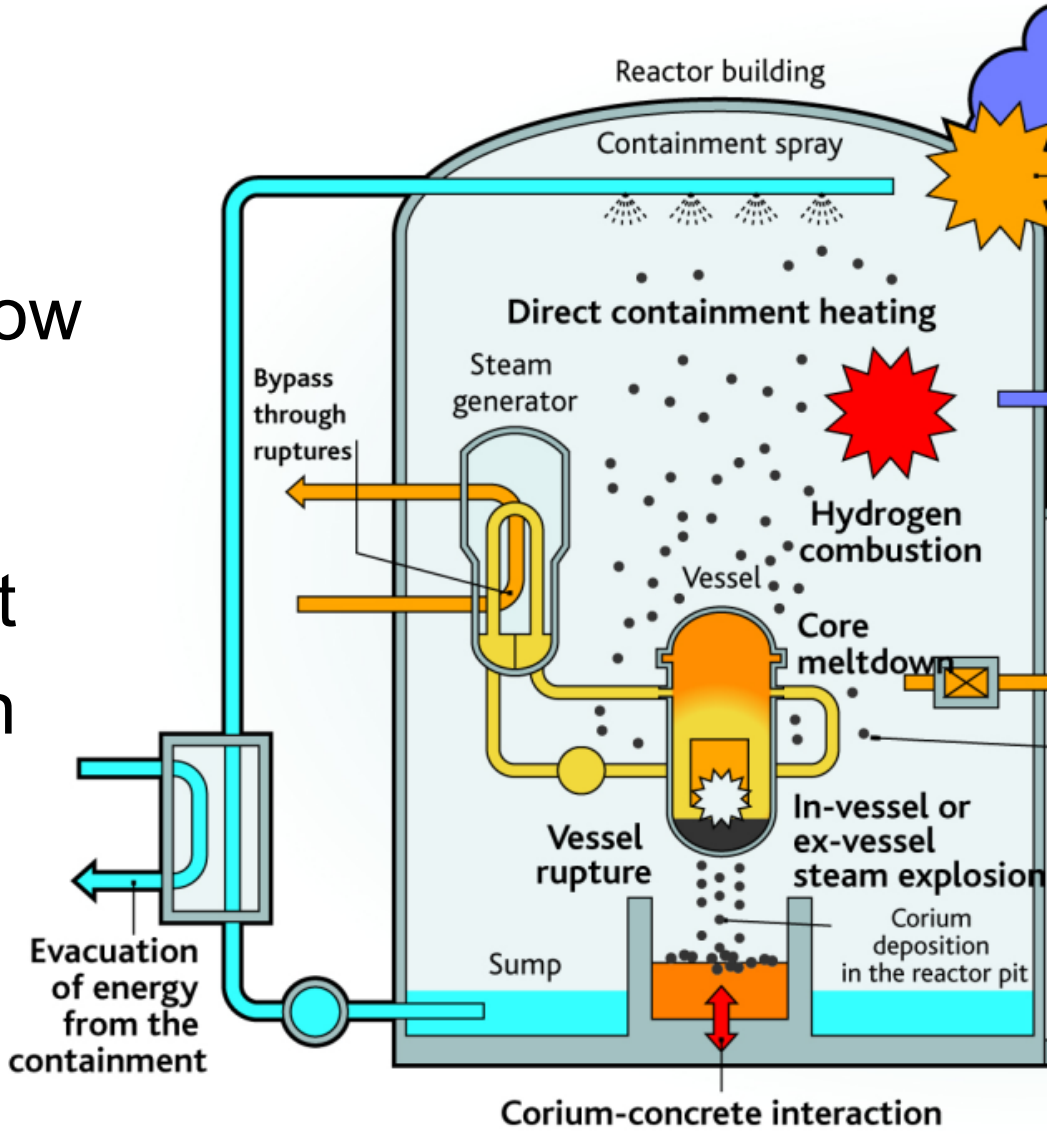
Molten Salt Reactor



- Low-pressure, high-temperature core cooling fluid
- Fuel either dissolved in salt (typically as UF_4) or dispersed in graphite moderator.
- Perhaps gas-driven (S-CO2) turbine.
- Liquid Fuel, ^{235}U or ^{233}U

Typical Design Basis Transients

- LOCA – loss of coolant accident
- LOFA – Loss of Flow accident
- LOHSA – Loss of Heat Sink Accident
- Reactivity Insertion Accident
- *Station Blackout*



Your Project

- Pick a reactor type
  - Use existing data, reports, hand calcs, design documents
  - Model a steady state version (no safety systems)
  - Demonstrate steady state operation at specified parameters
- Pick a transient type from previous slide
  - Implement the transient into a RELAP5-3D deck
  - Run the transient, assess performance

- BONUS- implement a safety system to mitigate your transient, if needed (or justify no need)

RELAP 5

- “A simulation tool that allows users to model the coupled behavior of the reactor coolant system and the core for various operational transients and postulated accidents that might occur in a nuclear reactor.” (relap53d.inl.gov)
- Designed for use with Pressurized Water Reactors
- Developed in the 1980s → Fortran

RELAP 5

- Thermal hydraulic transient modeling code

- Transient: A change in the reactor coolant system temperature, pressure, or both, attributed to a change in the reactor's power output. Transients can be caused by (1) adding or removing neutron poisons, (2) increasing or decreasing electrical load on the turbine generator, or (3) accident conditions (nrc.gov)

RELAP5-3D

- Capability of modeling 3 dimensional systems (CFD light)
- Ability to create and input custom fluid files
- Not as restricted as RELAP 5 Mod3
  - Mod3 is used to license reactors with the NRC, RELAP5-3D is “experimental version”

Running RELAP

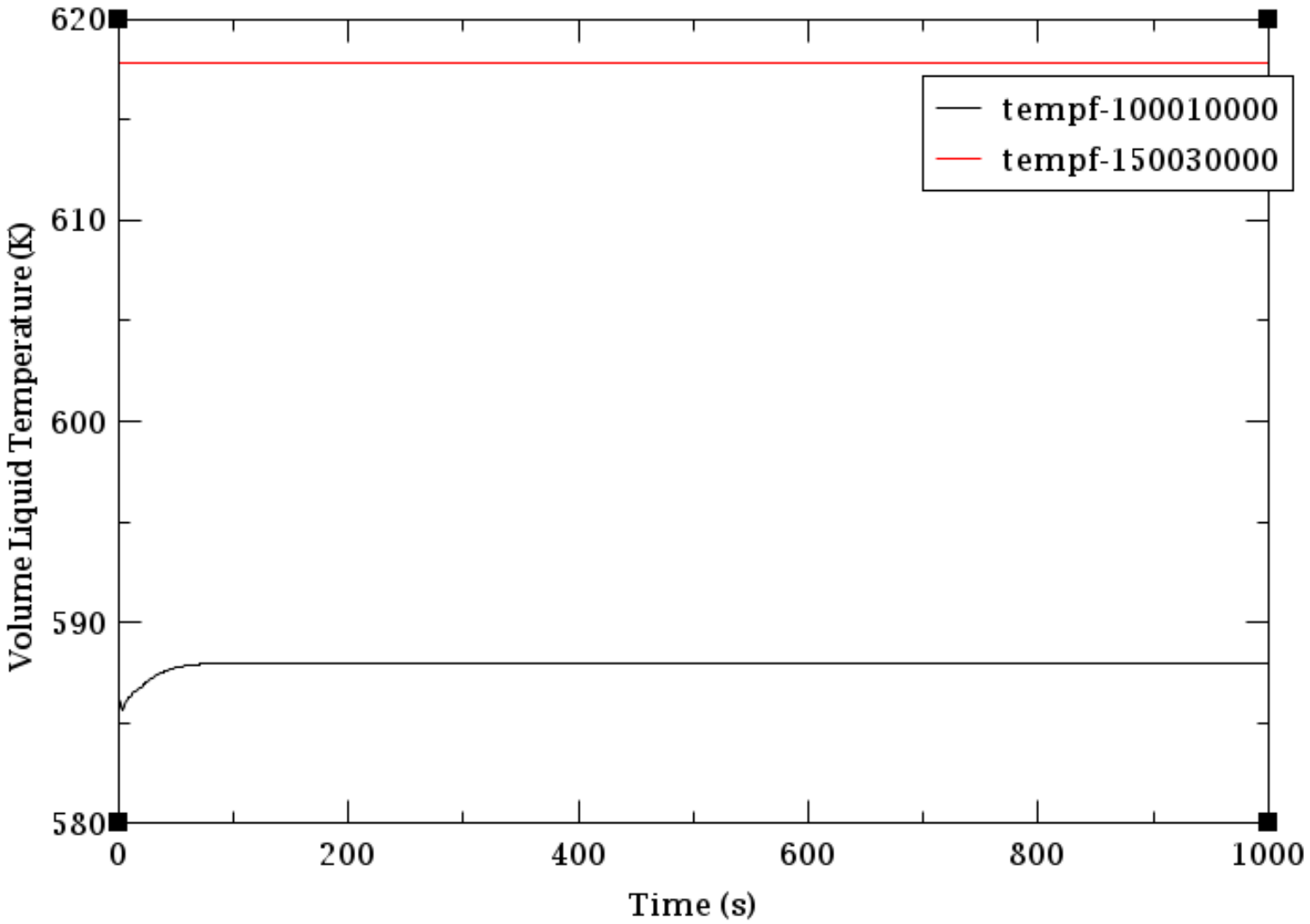
- Open up a command prompt, and navigate to RELAP5-3D folder
- Ensure several files are present:
  - tpfh2o
  - Input file (*.i) (must not have output (*.o) or restart plot (*.r) files present
- Type in the command prompt:

  relap5 –i *.i, -o *.o, -r *.r >*.txt

  Where * is the name of your file/run

Plotting Results

- Open APT Plot
- File>Read>RELAP5 data
- Navigate to location of completed run
- Open plot file of interest
- In “Select RELAP Channels Box” expand channel of interest
  - Found under Window>Select RELAP Channels
- Click item to plot then click plot


620
610
600
590
580
0
200
400
600
800
1000
Volume Liquid Temperature (K)
Time (s)
tempf-100010000
tempf-150030000

Export Control

- RELAP5-3D usage and information falls under 10 CFR Part 10
- Knowledge of nuclear technology generally falls under this same export control law

- The following slides are a training on Part 810 done by NNSA

Assignment

- Before Tuesday's class, watch sections 5 and 6 on DVDs
- Homework 1 is due Tuesday (9/12)

Continuing Obligations Under 10 CFR Part 810:

Awareness Training for Individuals with Knowledge of Nuclear Technology

Disclaimer: This is guidance provided by NPAC pursuant to 10 CFR 810.5 and subject to the limitation in 10 CFR 810.5. This information is subject to change. Unless authorized by the Secretary in writing, no interpretation of the regulations in 10 CFR 810 other than a written interpretation by the DOE General Counsel is binding upon DOE.

5/18/2018

Introduction

- Employees who leave a company are often subject to continuing contractual obligations, such as Non-Disclosure Agreements and Non-Competition Agreements.
- Individuals with knowledge of nuclear technology have additional, enduring legal obligations, including continued compliance with Part 810 of Title 10 of the Code of Federal Regulations (Part 810).
- The purpose of this training is to highlight and explain continuing obligations related to Part 810, especially as they relate to post-employment activities such as independent consulting or employment by a nuclear related company.
- Individuals also should be mindful of their obligations under other federal export control regulations, which are not addressed in this presentation.

Training Objectives

Even if you had prior Part 810 training, this training will help you to:

- Understand the purpose and content of the Part 810 regulation.
- Understand the penalties for noncompliance with Part 810 and where you can go for additional information.

Atomic Energy Act (AEA) of 1954 and Part 810

- Section 57. b.(2) of the Atomic Energy Act (AEA) of 1954, as amended prohibits all direct or indirect assistance in the development or production of special nuclear material (SNM) outside the United States, unless authorized by the Secretary of Energy following a “non-inimicality” determination.
- This requirement, as implemented by DOE through the Part 810 regulation, applies to technology transfers and assistance related to certain nuclear fuel-cycle activities, commercial nuclear power plants, and research and test reactors.

Determining Coverage – Is the Activity Within the Scope of Part 810?

Part 810 applies to the transfer of technology or assistance that involves any of the following activities:

1) Chemical conversion and purification of uranium and thorium;
2) Chemical conversion and purification of plutonium and neptunium;
3) Nuclear fuel fabrication;
4) Uranium and plutonium isotope separation (as well as separation of other isotopes in certain cases);
5) Nuclear reactor development, production or use of the components within or attached to the reactor vessel, equipment that controls the power level of the core and the equipment or components that contain, come in direct contact with or control the primary coolant of the reactor core;
6) Production accelerator-driven subcritical assembly systems;
7) Heavy water production and hydrogen isotope separation;
8) Reprocessing of irradiated nuclear fuel or targets, and post-irradiation examination if it is part of a reprocessing program; and
9) The transfer of technology for the development, production, or use of equipment or material especially designed or prepared for any of the above listed activities.

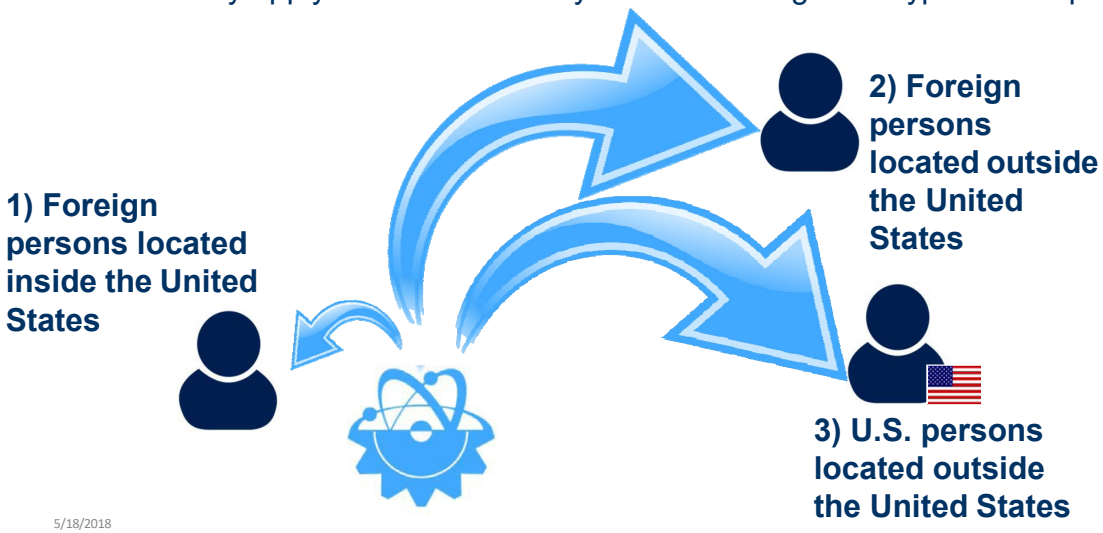
Determining Coverage – Is the Activity Within the Scope of Part 810? (Continued)

Part 810 does *not* apply to:

1) Exports authorized by the Nuclear Regulatory Commission, Department of State, or Department of Commerce;
2) Transfer of publicly available information, publicly available technology, or the results of fundamental research;
3) Uranium and thorium mining and milling;
4) Nuclear fusion reactors per se, except for supporting systems involving certain hydrogen isotope separation technologies; and
5) Production or extraction of radiopharmaceutical isotopes when the process does not involve special nuclear material.

Determining Coverage – Where is Technology Going?

- Whether Part 810 applies to a given transfer of technology or assistance also depends on the type of recipient, including who they are and where they are located.
- Part 810 may apply to transfers to any of the following three types of recipients:



Common Misunderstandings about Part 810 Authorizations

The Misunderstanding

The Reality

- Verbal transfers of information, even in the context of informal conversations, can still constitute "assistance" that is controlled by Part 810.
- Anytime you are meeting with employees or individuals connected with non-U.S. entities or foreign citizens, be aware of falling into conversations about nuclear technology.
- Pay particular attention to questions that are not "on topic" during conferences or training sessions.

Common Misunderstandings about Part 810 Authorizations (Continued)

The Misunderstanding

The Reality

- Teaching someone how to use equipment or software or interpret the results of tests or calculations is considered assistance and may be covered by the rule.
- This holds true regardless of whether the recipient already has manuals or other instructional materials.

Common Misunderstandings about Part 810 Authorizations (Continued)

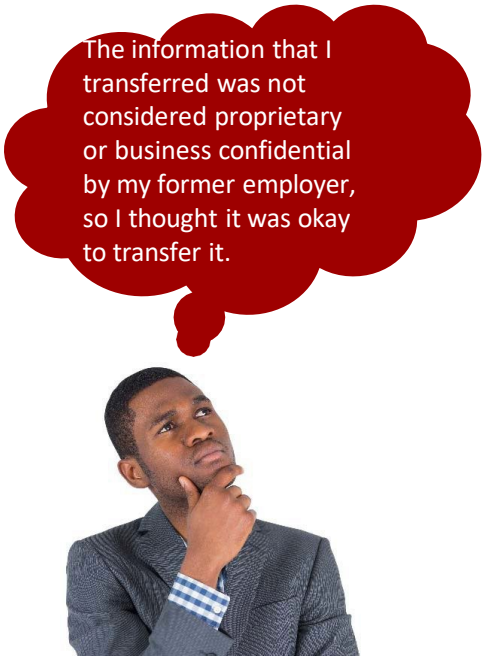
The Misunderstanding

The Reality

- If a company is paying you for information, then it is unlikely that the information is already publicly available.
- DOE/NNSA also does not consider information available only through search engines or Wikipedia to be "public" for the purposes of Part 810. Few people would base any significant work on information from unknown sources.
- Training on industry standards, or other common knowledge may be considered publicly available, but consult with DOE/NNSA to make sure your planned activity/assistance is not covered.

Common Misunderstandings about Part 810 Authorizations (Continued)

The Misunderstanding



The Reality

- Proprietary information is an issue between you and the owner of such information. DOE/NNSA is only concerned with transfer of, or assistance with, nuclear technology.
- While proprietary information is more likely to be covered under the rule, material developed in private consulting may also by covered.

Common Misunderstandings about Part 810 Authorizations (Continued)

The Misunderstanding

The Reality

- Specific authorizations must be requested by the exporter. Foreign entities seeking to receive U.S. nuclear technology or assistance cannot request or obtain specific authorizations.
- If a foreign client claims to have requested and received a specific authorization, contact DOE/NNSA.

Common Misunderstandings about Part 810 Authorizations (Continued)

The Misunderstanding

Isn't my private consulting work with this foreign company covered by the existing authority that a U.S. company already has with the same foreign company?

The Reality

- Specific authorizations are exclusive to the company, the end user, and the technology. They do not extend to other contracts between the end user and other companies.
- Unless the work is being done under the auspices of the authorized U.S. company and it has confirmed that your work is within its scope, you should assume that you are required to obtain a separate authorization for the scope of work.

Common Misunderstandings about Part 810 Authorizations (Continued)

The Misunderstanding

I wasn't technically working for a foreign company…I was working through a U.S. company, which was providing consulting work to the foreign company

- The Reality

- Consultants are responsible for ensuring that any technology or assistance they provide to a U.S. company is not ultimately being passed to a foreign end user, unless that foreign end user is duly authorized to receive it under Part 810.
- When working through a U.S. company to provide assistance to a foreign entity, ask about the authorization, get a copy of it and make sure your scope is included. Also, make sure you understand who is responsible to report your activities.
- If in doubt, ask DOE/NNSA for a determination.

- Section 222 of the Atomic Energy Act of 1954, as amended, establishes criminal penalties, including terms or imprisonment and fines, that apply to willful violations of Part 810 (or attempts or conspiracies to commit such violations).
- Penalties are higher for violators who intended to injure the United States or secure an advantage to a foreign nation, but all willful violators are potentially subject to criminal prosecution, including imprisonment.
- The Secretary of Energy may also revoke, suspend, or modify a general or specific authorization for several reasons, including any material false statement in an application for specific authorization, any material false statement in a report, and failing to provide required reports.

- Contact DOE/NNSA team:
  - Part810@nnsa.doe.gov
  - (202) 586-1007
- Include in request:
  - Requestor Information
  - Proposed Activity
  - Type of Guidance sought
    - Request for Determination (binding determination made by DOE/GC)
    - Technical Assistance (non-binding advice and consent from DOE/NNSA staff)
- Part 810 website: https://www.energy.gov/nnsa/10-cfr-part-810