PennState
College of Engineering

NucE 497: Reactor Fuel Performance

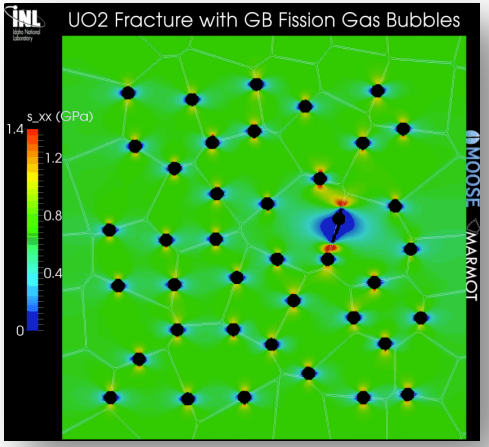
Lecture 1: Course Overview and Fuel Performance Summary

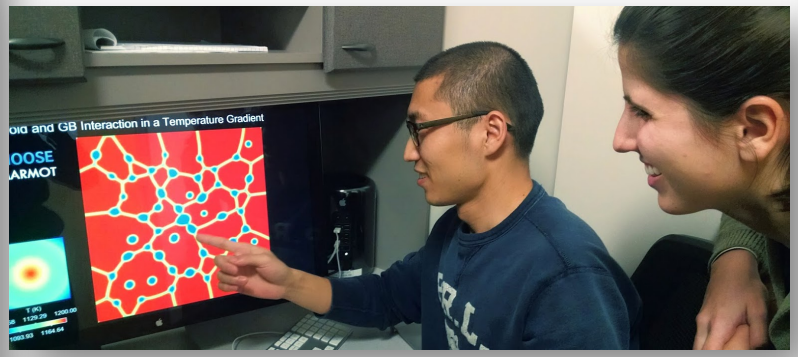
January 9, 2017

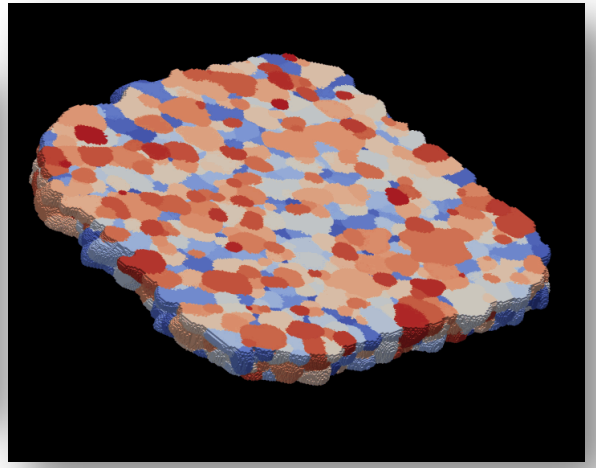
Michael R Tonks
Mechanical and Nuclear Engineering

I am a computational scientist in my second year at Penn State

My focus area is to investigate the impact of microstructure evolution on material properties







- Learn more about the **Microstructure Science and Engineering Laboratory** at msel.mne.psu.edu
- My research has a strong focus on understanding the impact of material behavior on fuel performance

Review syllabus

Course Syllabus

Jump to Today | Edit

Professor:

Professor Michael Tonks
Mechanical and Nuclear Engineering
233 Reber
814-863-1323
michael.tonks@psu.edu
Office hours: M 2:30 - 4:00
Th 10:30 - 12:00

TA:

Muhammet Ayanoglu
Nuclear Engineering
mua214@psu.edu
Office hours: TBD

Technical help:

Michael Sechrist
Continuing & Distance Education
College of Engineering
814-863-3494
mss32@psu.edu

January 2017

25	26	27	28	29	30	31
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	1	2	3	4

Spring 2016, M W F 11:15 - 12:05 PM, 265 Willard

In a nuclear reactor, the fuel generates heat through fission that is used to generate electricity. Thus, the performance of the nuclear fuel directly impacts the efficiency of the reactor. In addition, nuclear fuel operates in an extreme environment that induces complex multiphysics phenomena that degrade the fuel performance and reduce reactor safety. Because of its pivotal impact on the reactor safety and efficiency, understanding fuel performance is a critical part of nuclear reactor engineering.

In this course we will study the basic role of the fuel in reactor operation and understand how the fuel impacts heat generation and transport to the coolant. We will also study various fuel types and geometries, with a focus on light water reactor fuel and cladding. We then will study changes in the fuel and cladding material that degrade the performance of the fuel, with a focus on how these changes are modeled in fuel performance codes.

Assignments are weighted by group:

Group	Weight
Homework	25.0%
Quizzes	10.0%
Exams	40.0%
Final project	25.0%
Total	100%

Primary topics

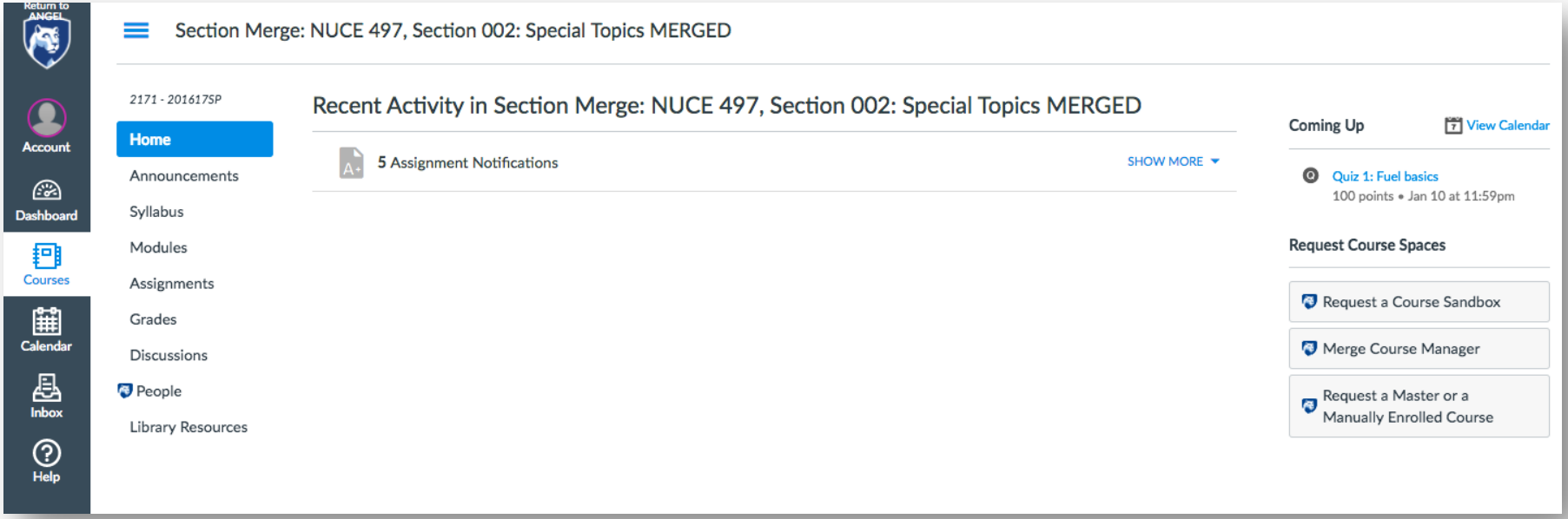
1. Heat generation and transport
2. Thermomechanical behavior of the fuel
3. Microstructure evolution in the fuel and cladding
4. Fuel performance codes
5. Current issues in fuel performance

Course objectives

Students completing this course should be able to

- Calculate the rate at which heat is transport to the coolant from the fuel
- Quantitatively describe the thermomechanical behavior of the fuel and set up the equations used to model it
- List the most important microstructure changes that take place within the fuel and cladding and describe how they impact the fuel performance
- Describe the basic structure of a fuel performance code and use an existing fuel performance code

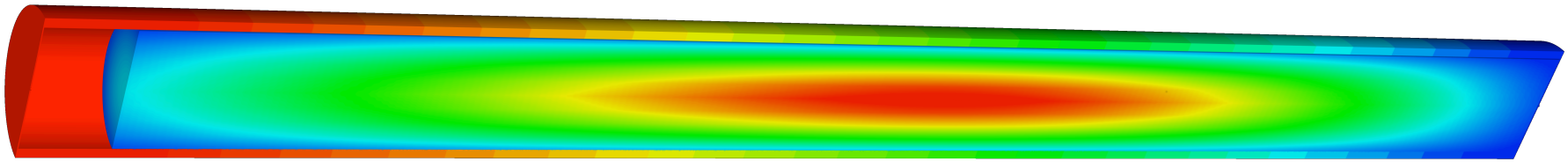
My primary tool for communication to you during the course is Canvas



- General announcements will be done through the Announcements section
- Most homework questions should be asked through the Discussions section
- For direct communication to me, you can use the Canvas Inbox or send me an email directly

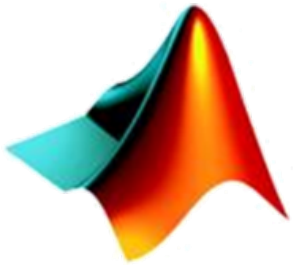
In this course we will study the role of the fuel in reactor operation

- Students completing this course should be able to
  - Calculate the rate at which heat is transported to the coolant from the fuel
  - Quantitatively describe the thermomechanical behavior of the fuel and set up the equations used to model it
  - List the most important microstructure changes that take place within the fuel and cladding and describe how they impact the fuel performance
  - Describe the basic structure of a fuel performance code and use a simple code that they develop



You will use MATLAB on many of the homework assignments and possibly on the project

- You will need access to MATLAB
- If you cannot find a way to get access to MATLAB, let me know



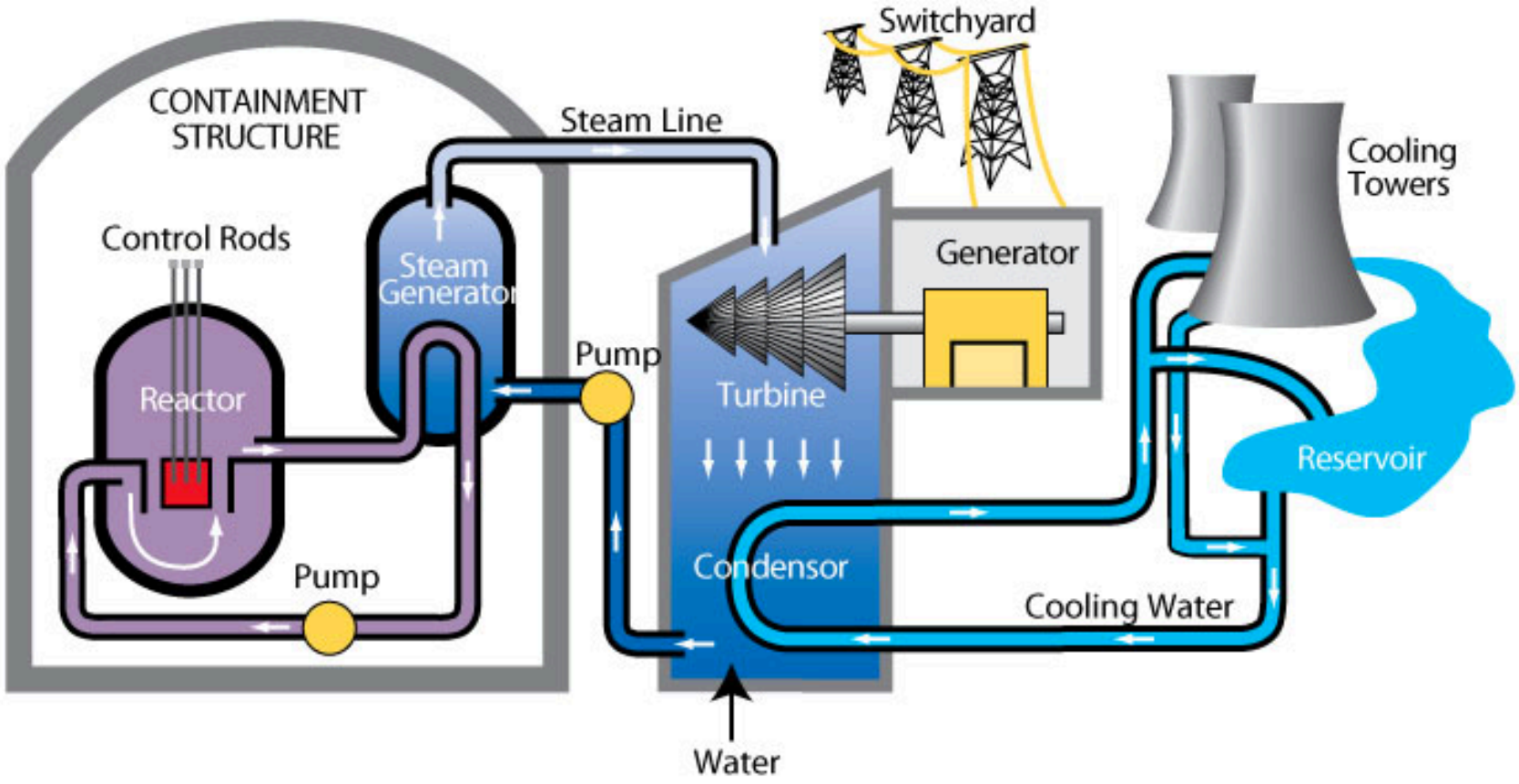
MATLAB®

The performance of a reactor is measured by how much power it safely generates

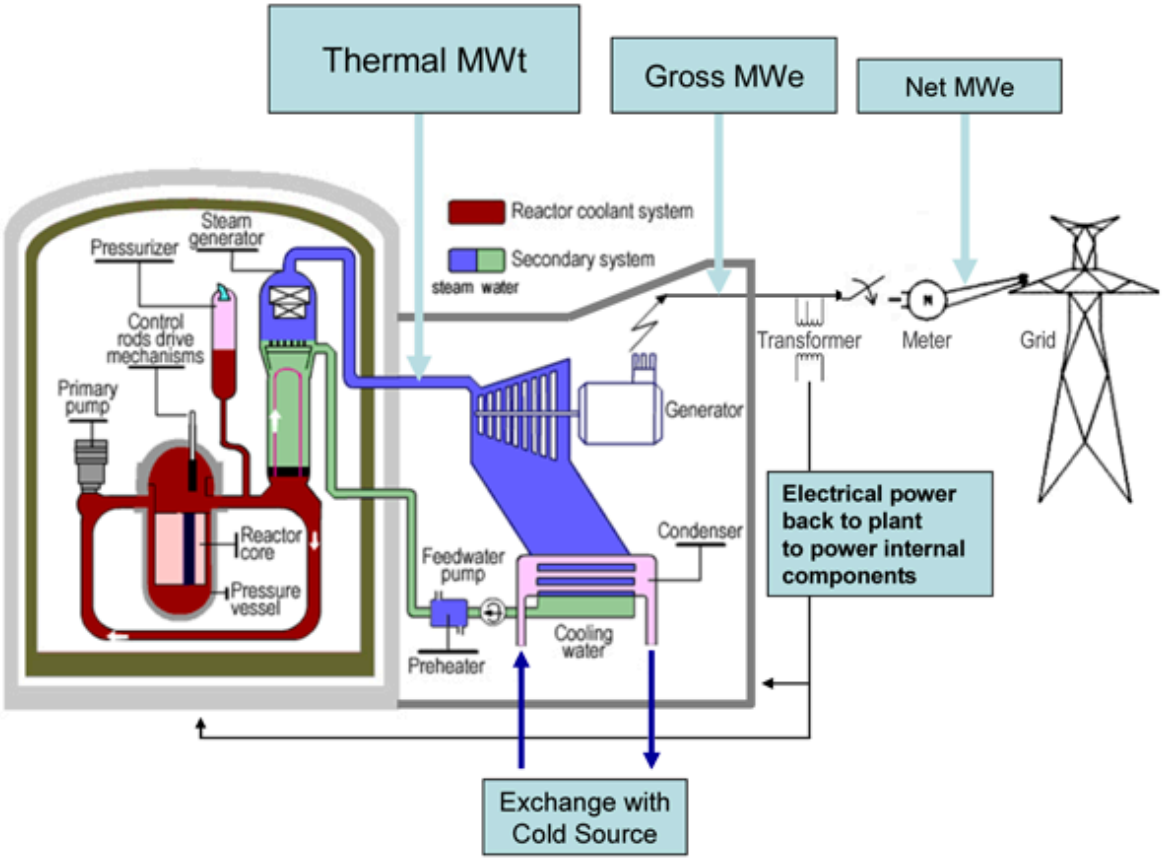
The performance of the fuel is measured by

- How much heats the coolant
- The length of time it operates without any problems
- How well it performs during an accident

Though the fuel is only a small part of the reactor, it has a huge impact on its performance

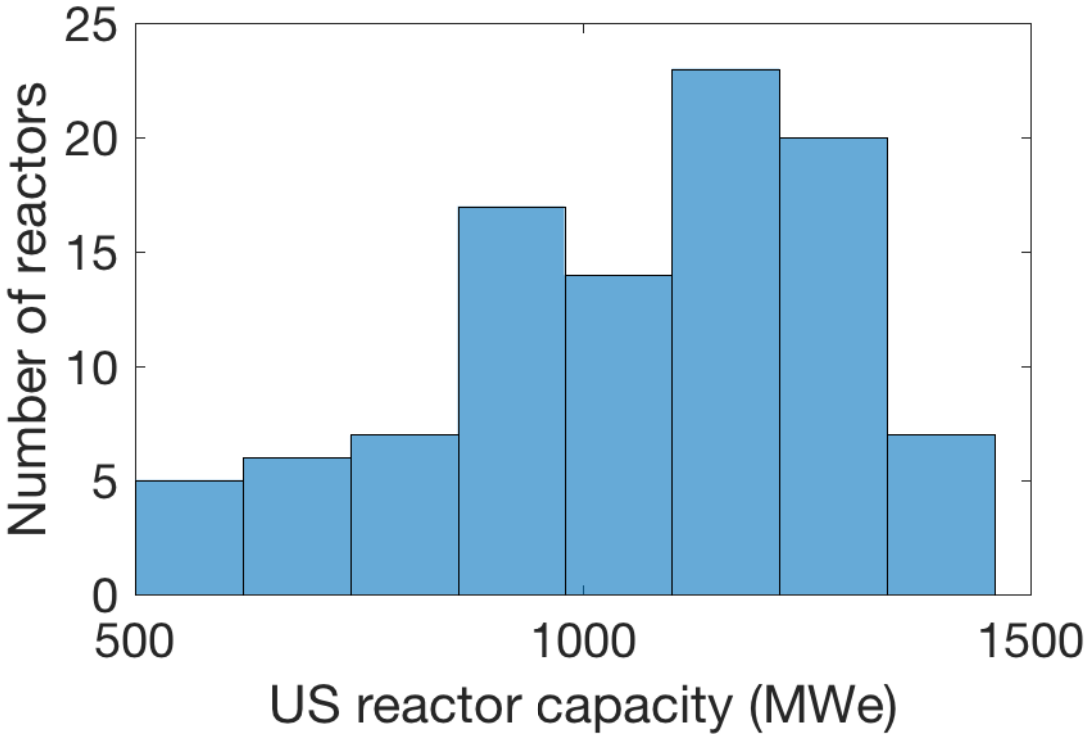


The power generation capacity of the steam generated by the reactor is dictated by the fuel

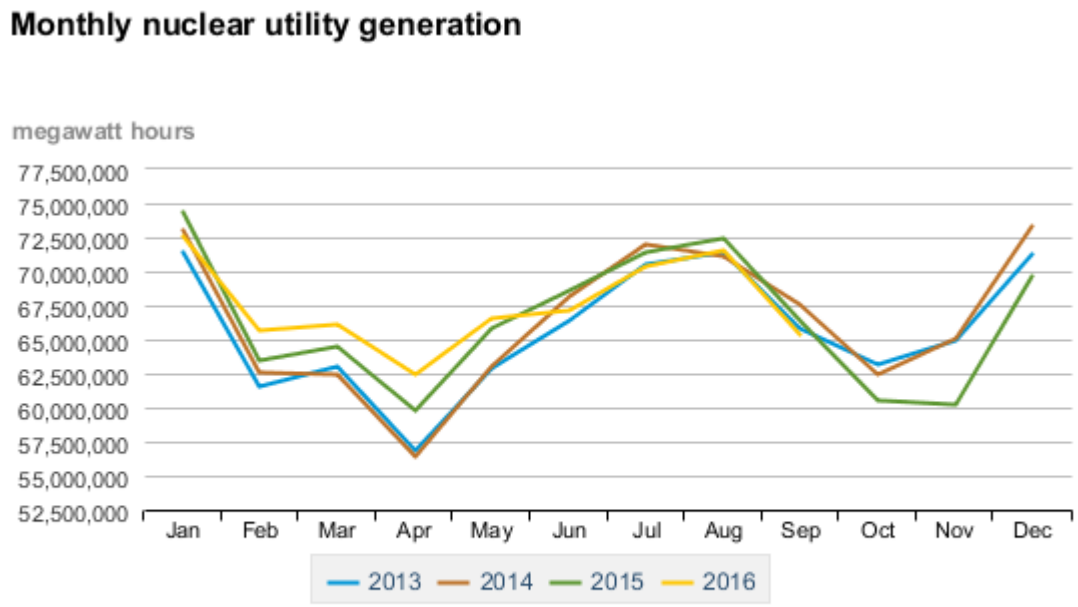


The base power generation capacity of a reactor depends on its design

Nameplate capacity of all reactors in the US in 2015



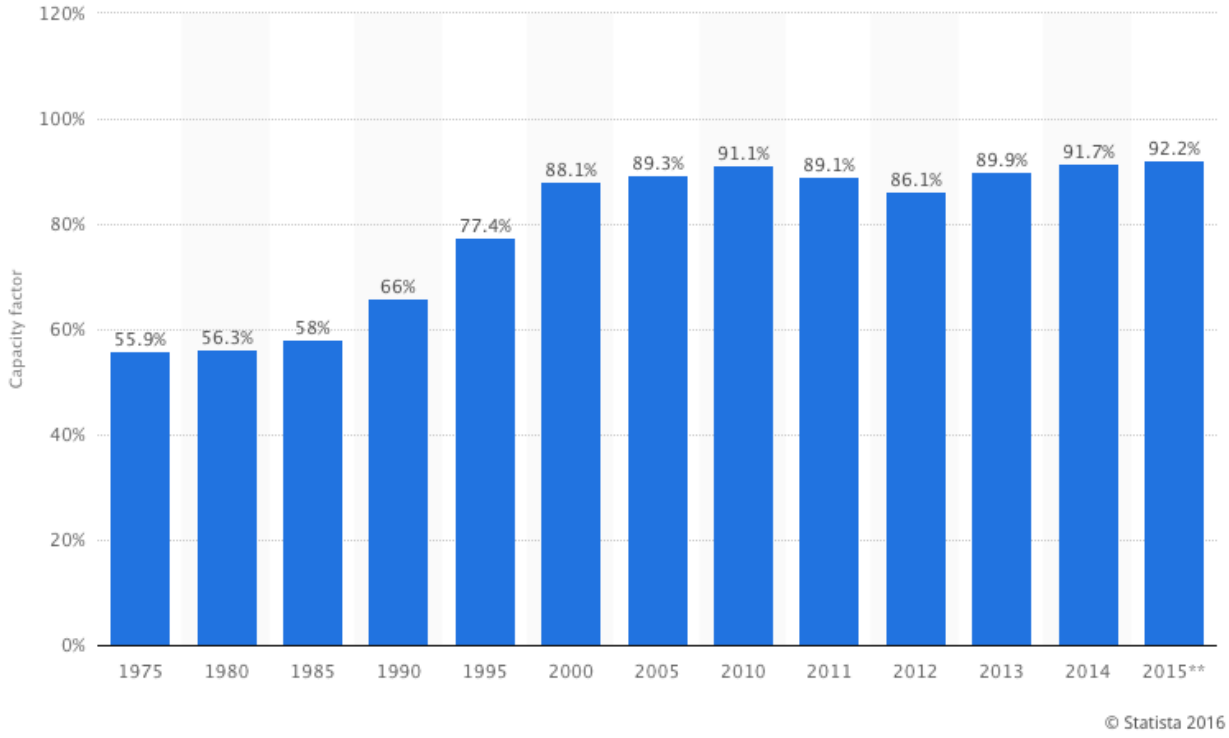
No matter the generation capacity, the actual generation depends on hours of operation



eia Source: U. S. Energy Information Administration

The capacity factor is the ratio of actual power generated to the possible power generated

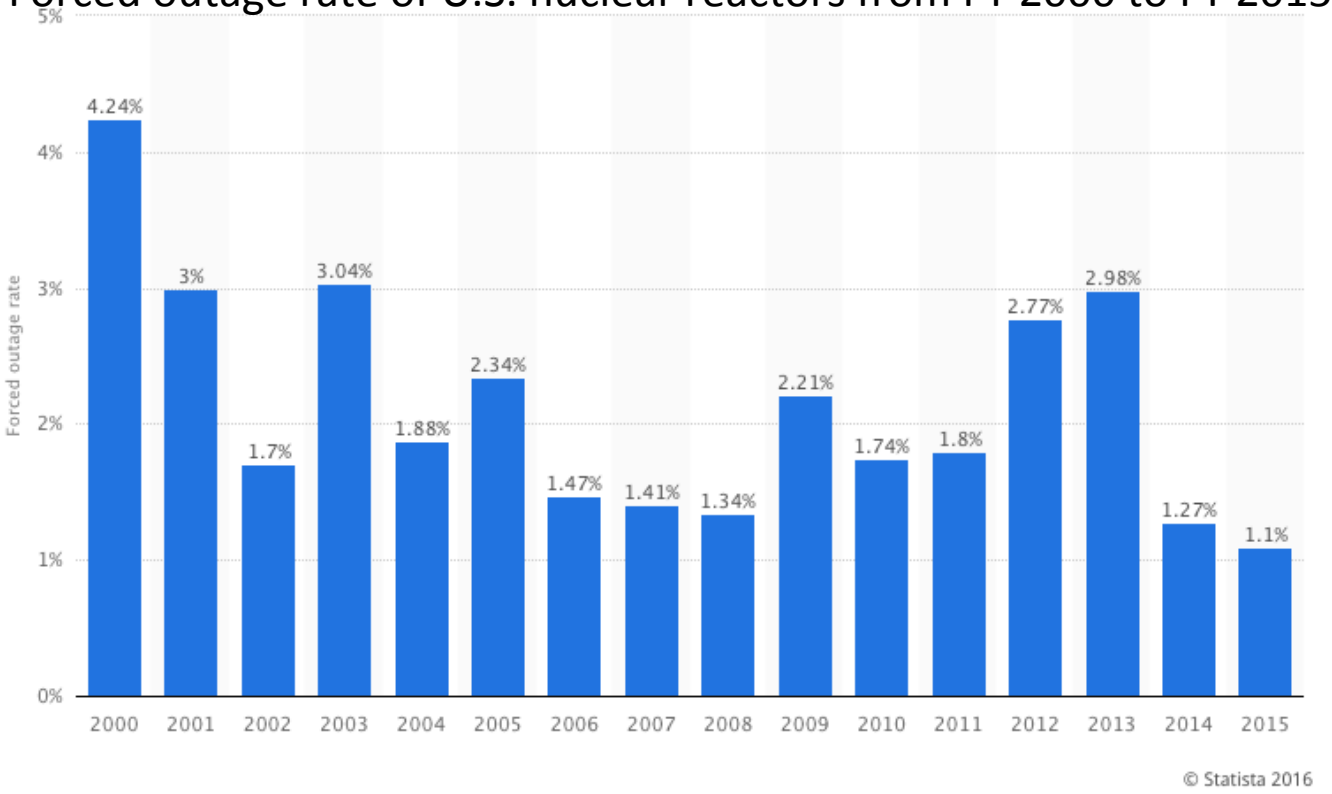
Capacity factor of nuclear power plants in the U.S. from 1975 to 2015



- Capacity factor increases due to
  - Reducing number of refuelings (increasing fuel burn-up)
  - Reducing maintenance outages (increasing reactor reliability
  - Decreasing number of forced outages

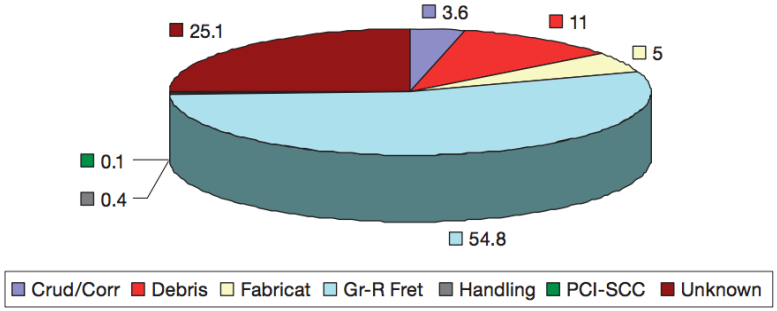
Outages can be scheduled (maintenance, refueling, inspection) or forced due to problems

Forced outage rate of U.S. nuclear reactors from FY 2000 to FY 2015

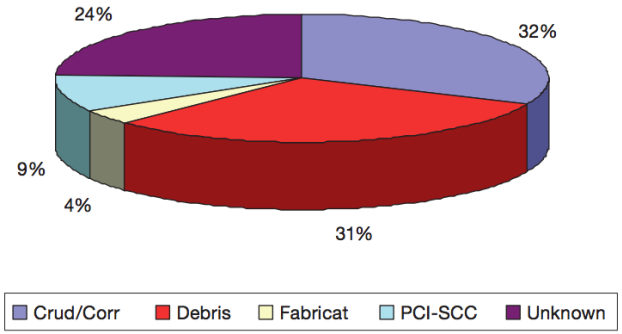


Leaking fuel rods are a common cause for forced reactor outages

- Leaking fuel rods force reactor outages

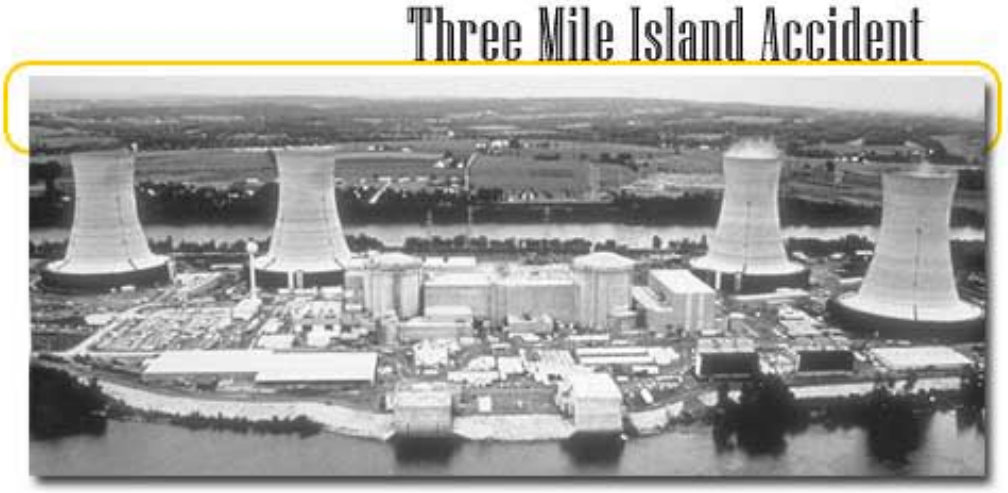


PWR fuel leak causes worldwide in 1994–2006.

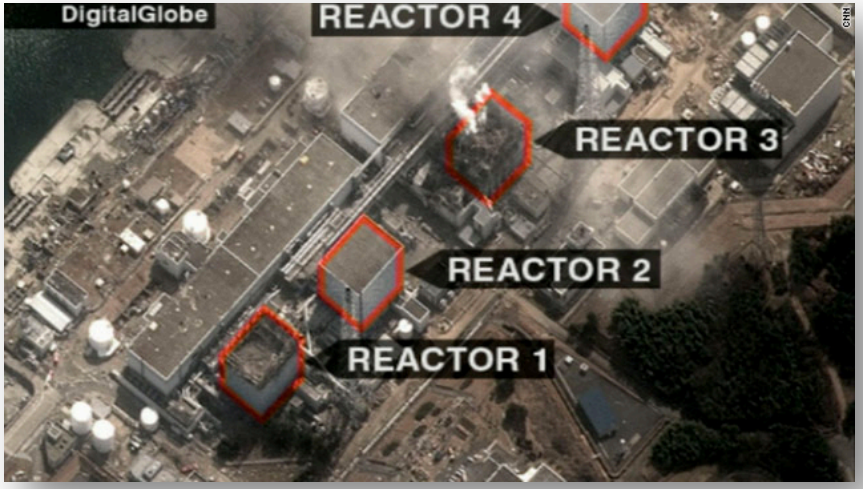


Estimated world distribution of BWR fuel failure causes

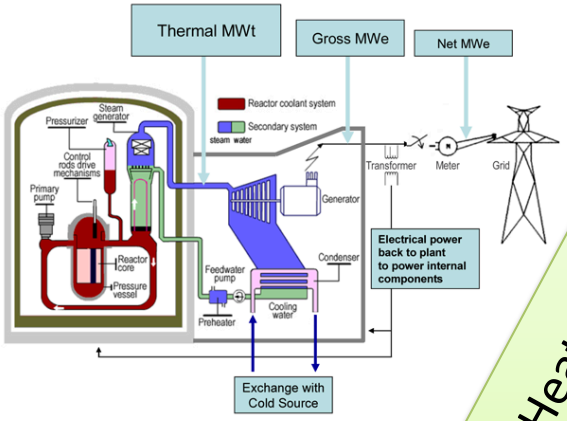
Reactor fuel is a huge safety concern during accidents

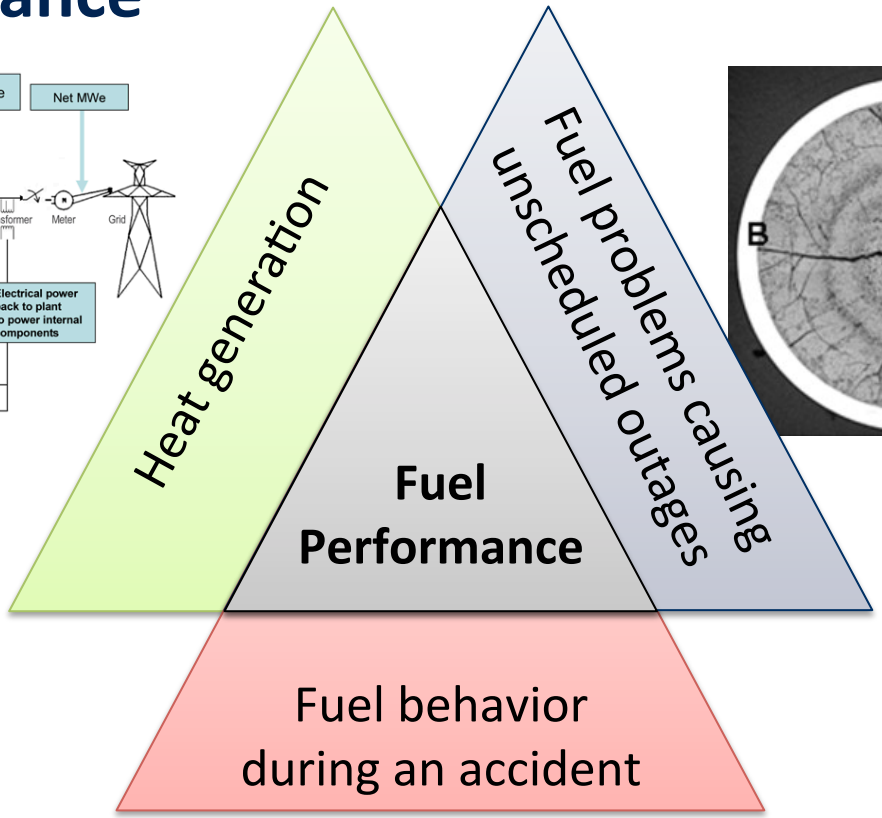


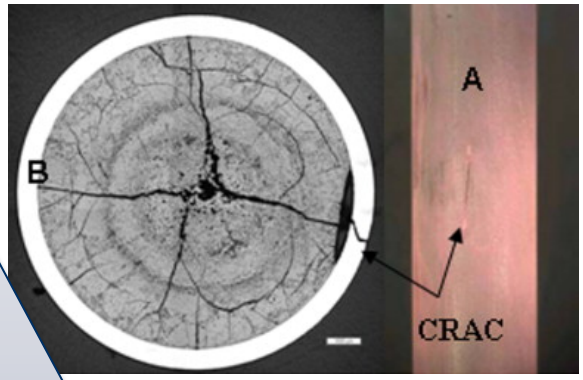
Fukushima Daiichi Accident

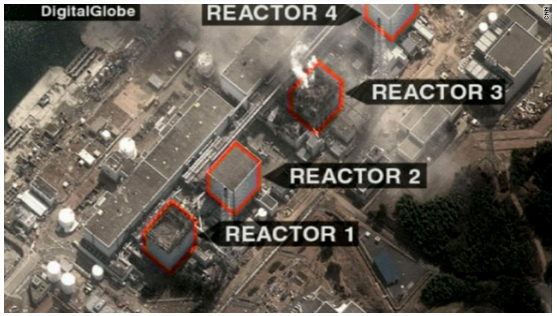


All of these factors together represent what we call "fuel performance"









This semester we will discuss various details of reactor fuel performance

- Modules:
  1. Fuel Basics
  2. Heat transport
  3. Mechanical behavior
  4. Materials issues in the fuel
  5. Materials issues in the cladding
  6. Used fuel disposition, fuel cycle, and accidents

Summary

- Reactor fuel performance is a measure of its
  - Power generation
  - Safety
- Power generation is a function of the
  - Reactor power capacity
  - Capacity factor
- Reactor operation is interrupted by
  - Planned outages (refueling, maintenance, inspections)
  - Forced outages
- REMINDER: Take the first quiz!