Introduction to the OSU Research Reactor (OSURR)
OSURR Tour

• Introduction in foyer
• Rotation in reactor bay
  – Reactor pool top
  – Control room
  – Rabbit workbench (activation demo)
• Please ask questions!
OSURR History

• Origin
  – Facility built in 1960; reactor first critical in 1961
  – 10 kW training reactor with HEU MTR-type fuel

• Conversion
  – Analysis for LEU fuel at 500 kW in 1980s
  – Fuel conversion to LEU in 1988
  – Power uprate in 1992

• Present
  – 500 kW reactor with multiple vertical dry-tubes
    – fluxes ~ $10^{12} - 10^{13}$ nv
    – Beam facility (flux ~ $10^6$ nv)
  – Gamma irradiators
    – In-pool, benchtop, spot
  – Gamma counting lab
OSURR Power Level

• Only about 2 dozen university-based research reactors remaining in the U.S.
• U.S. research reactors cover large power range
  – Lowest power: 1 \( W_{\text{th}} \)
  – Most in US in range 100 kW – 2 MW
  – OSU-NRL: 0.5 MW\(_{\text{th}}\) (500 kW\(_{\text{th}}\))
  – Highest power at university: 10 MW\(_{\text{th}}\)
  – Highest power: 250 MW\(_{\text{th}}\)
• Power reactors ~ 3000 MW\(_{\text{th}}\)
  – About 1000 MW\(_{\text{elec}}\)
OSURR Purpose

• No electricity produced
  – No capability to produce electricity
    • Low power, low exit temperatures
    • No steam generators, turbines, generators, etc.
  – Not our mission

• Produce neutrons and radiation
  – Support research
  – Industry service
  – Education: reactor dynamics experiments and demos; educational tours
OSURR Purpose

- Largely serve State of Ohio and the surrounding area
- Only research reactor in Ohio and within a 6-hr drive from Columbus
- Serve nuclear industry in Cleveland area
- Serve customers outside area too

(distance to nearest research reactors shown)
Fission Reaction

- $^{235}_{92}U$ absorbs a neutron $\rightarrow$ becomes unstable and splits into 2 smaller atoms (fission fragments)
- 2 or 3 neutrons are released (avg = 2.5)
- After slowing down, these neutrons can then cause more fissions $\rightarrow$ fission chain reaction
- In nuclear power plants, thermal energy used to make steam $\rightarrow$ electricity

$$ ^1_0 n + ^{235}_{92}U \rightarrow FF_1 + FF_2 + 2.5n + \beta + \gamma + \bar{\nu} + 220 \text{ MeV} $$

Fission fragments, radiation, energy

Same U-235 fission process used in all US power and research reactors
Fission Reaction Control

• To control fission chain reaction, must absorb some of the neutrons that would otherwise cause fissions.

• Neutron absorbers
  – Can use solid absorber rods called control rods.
  – Can use absorbers dissolved in the coolant called chemical shim (power plants use boric acid dissolved in the water).

• OSURR
  – Stainless steel control rods; 3 with 1.5% natural boron.
  – No chemical shim.
OSU Research Reactor

- Fuel: elements composed of thin plates with Al cladding
  - Fuel elements sit in 5 x 6 grid plate
  - 4 elements have slots for control rods
- Dry tubes: used for irradiating experiments and samples
  - 3 vertical dry tubes in core; multiple moveable large dry tubes that can be positioned next to core
    - Capability for instrumented experiments for in-situ monitoring
    - *Unique capability of high-temp expts*
  - 2 beam ports
    - BP1 used as horizontal dry tube
    - BP2 used to bring thermal beam out of the reactor
  - 1 pneumatic “rabbit” tube
Reactor Monitoring

• Reactor power not directly measured
• Signals from neutron-sensitive chambers used to monitor reactor power
  – Some neutrons escape from the core, making the core a source of neutrons
  – Of neutron emission is proportional to power
  – Chambers placed in pool near core
  – Different designs to cover full range of operation
  – Electric signal proportional to reactor power from ion chambers
  – Redundant channels for safety
OSURR Research, Testing

- Radiation sensor studies, radiation sensor testing
  - Test prototypes for next-gen reactors (fiber-based)
  - Test fission chambers for use in existing power reactors
  - Unique capability for high-temperature testing
- Neutron activation analysis (NAA)
  - Very sensitive means to determine elemental analysis
  - Measure energy of γs from reactor-activated samples
  - Trace element studies (ppb sensitivity for some)
OSURR Research, Testing

- Neutron depth profiling
  - Measure distribution of certain elements
  - Useful for optimizing batteries by studying Li distribution

- Neutron imaging
  - Like taking X-ray images, but sensitive to different elements

- Neutron transmission testing
  - Test neutron absorbing capability of material by measuring percentage of neutrons that pass through
OSURR Research, Testing

- Electronics damage studies
  - Characterize response of electronics to radiation to determine usefulness for use in nuclear industry, spacecraft

- Source production
  - Effluent monitor testing
  - Radioactive tracers
  - Medical studies (not humans for OSURR)
  - Physics studies
Supporting Ohio Industry

- GE (Measurement & Control Solutions, OH): fission-chamber testing
- Holtec (Orvillon division, OH): Testing neutron absorbing materials
- Fluke Biomedical (Victoreen division, OH)
- UDRI (OH): components for NASA spacecraft missions
- L3 Cincinnati Electronics (OH)
- University of Cincinnati
- Saint Gobain (world largest radiation scintillation detection manufacturer, Ohio)
- Lithium Innovations Company (SBIR, Ohio)
Why do we use nuclear power for generating electricity?
Energy density

Energy density of U-235 is about a million times greater than coal, so significantly less must be mined and used.
Lifecyle Emissions

Coal: 820 g CO₂/kW·hr

Natural gas: 490 g CO₂/kW·hr

Median values for lifecycle emissions data for various sources are from 2014 IPCC, Global warming potential of selected electricity sources.
Lifecycle Emissions

Biomass (dedicated): 230 g CO$_2$/kW∙hr

Solar: 48 g CO$_2$/kW∙hr

Median values for lifecycle emissions data for various sources are from 2014 IPCC, *Global warming potential of selected electricity sources*
Lifecycle Emissions

Hydroelectric: 24 g CO$_2$/kW∙hr

Wind: 11 g CO$_2$/kW∙hr

Median values for lifecycle emissions data for various sources are from 2014 IPCC, Global warming potential of selected electricity sources
Lifecycle Emissions

Nuclear: 12 g CO₂/kW·hr

Median values for lifecycle emissions data for various sources are from 2014 IPCC, *Global warming potential of selected electricity sources*
Emissions

• In 2017, the average annual electricity consumption for a U.S. residential utility customer was 10,399 kilowatt-hours (kWh); therefore average tons of CO$_2$ per year per per household per type is:
  – Coal: 9.4 tons
  – Gas: 5.6 tons; biomass: 2.6 tons
  – Solar: 0.5 tons; hydro: 0.3 tons
  – Nuclear, wind: ~ 0.1 tons
Emissions: pollution

- Forbes - How Deadly Is Your Kilowatt?
  - **Energy Source Mortality Rate (deaths/trillion kWhr)**
  - Coal – global average 170,000 (50% global electricity)
  - Coal – China 280,000 (75% China’s electricity)
  - Coal – U.S. 15,000 (44% U.S. electricity)
  - Oil 36,000 (36% of energy, 8% elec)
  - Natural Gas 4,000 (20% global electricity)
  - Biofuel/Biomass 24,000 (21% global energy)
  - Solar (rooftop) 440 (< 1% global electricity)
  - Wind 150 (~ 1% global electricity)
  - Hydro – global avg 1,400 (15% global electricity)
  - Nuclear – global avg 90 (17% global electricity)

(w/Chern&Fukush worst-case predictions; LNT assumed)
Impact of Different Energy Sources

Nuclear: The Safest Energy Source of All

Deaths per terawatt hour by energy source

The nuclear bar should be 
\(-0.0013\), not 0.04.

The 2008 UNSCEAR update on their 
Chernobyl Report changed the 
"4000" future deaths from cancer to 
undetectable future deaths. With that 
reduction, the deaths per TWh drop 
accordingly.

Source: nextbigfuture.com
NRL Rules for Touring Visitors

• **Backpacks and bags must be left in the classroom.** The Nuclear Reactor Lab takes no responsibility for items lost or stolen at the facility, but the classroom door will be locked during the tour.

• **Photography is not allowed** in the Reactor Building; cameras must be left in the classroom. In addition, cell phones, pagers, and two-way radios should be left in the classroom.

• **Consumption of food, beverages or gum is not permitted** while in the Reactor Building.