Characterization of a University TRIGA Reactor

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Overview

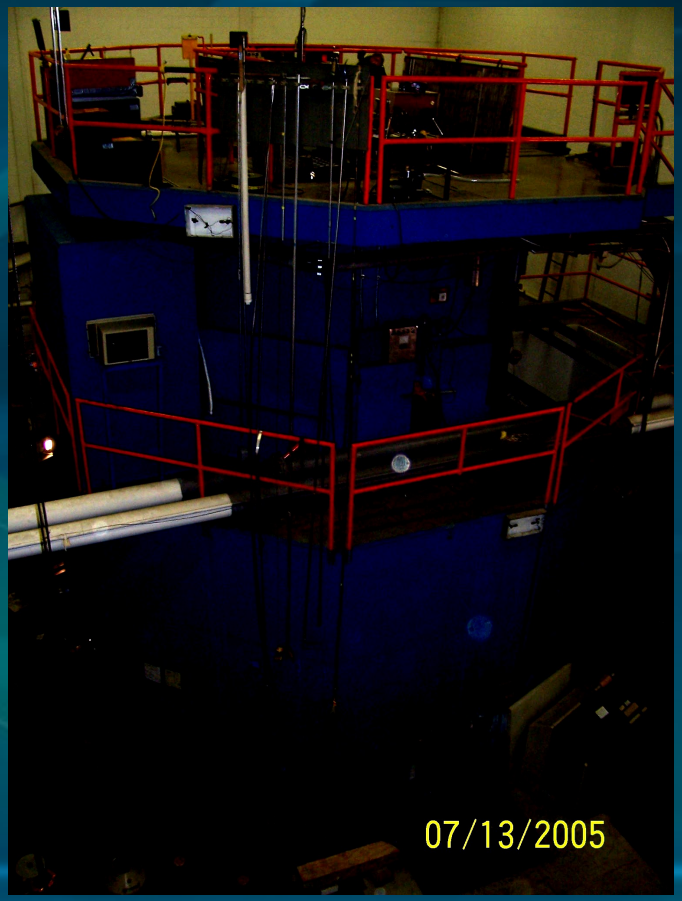
- Reactor Facility – University of Illinois
- Characterization "Toolbox"
  - Surveys
  - Sampling
  - On-site Analysis
  - Off-site Analysis
  - Modeling
- Characterization Results

Reactor History

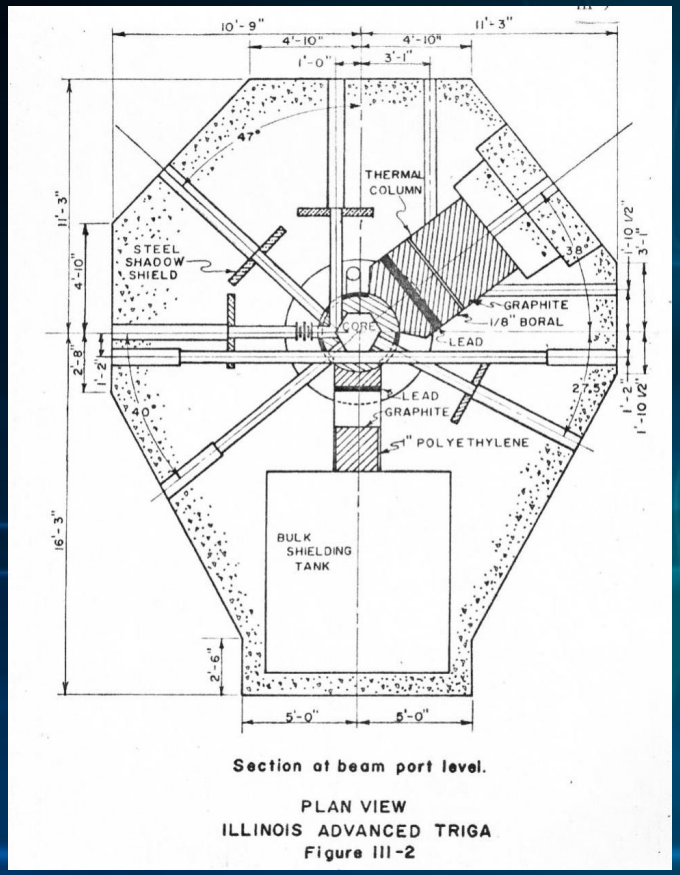
- Initial criticality in 1960 (100 kW)
- Upgraded to forced circulation cooling in 1969 (250 kW)
- Shut down in 1998
- Fuel shipment in 2004
- Demolition in 2008

Reactor Components

- High-density concrete bioshield
  - Magnetite aggregate
- 6.5’ x 22’ aluminum tank
- Reactor assembly
- Experimental systems
  - Beam ports
  - Thermal columns
  - Lazy Susan
- Bulk Shielding Tank



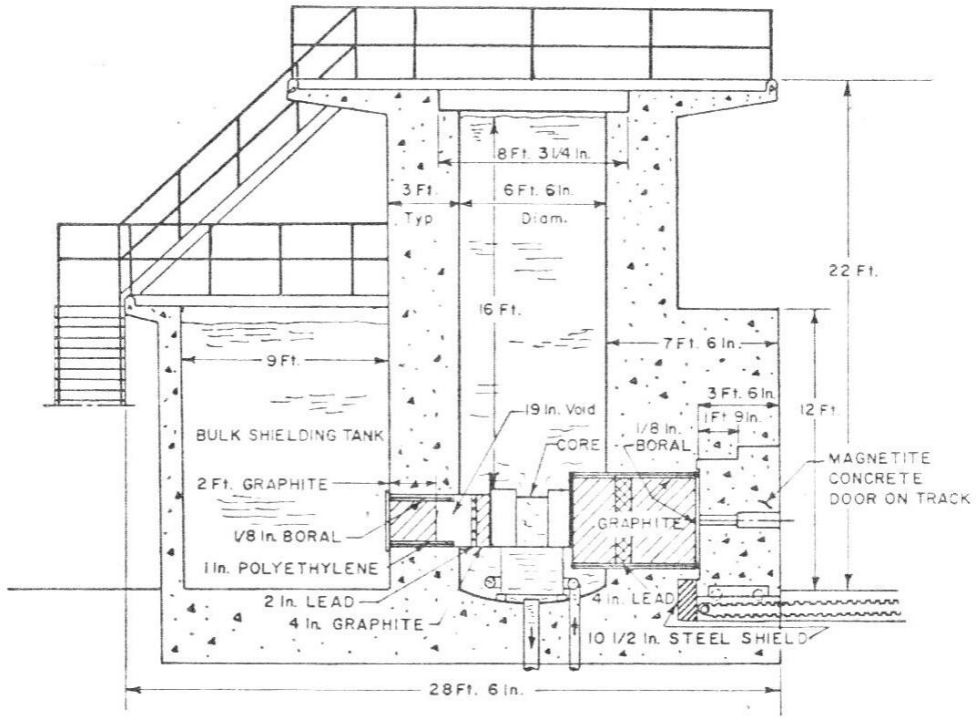
Reactor Components



Section at beam port level.

PLAN VIEW
ILLINOIS ADVANCED TRIGA
Figure III-2

VERTICAL SECTION
ILLINOIS ADVANCED TRIGA
Figure III-1



Section through bulk shielding tank and thermal column.

Reactor Components

- N-16 decay tanks
  - 5,000 gallon
  - 3,000 gallon
- Heat exchanger
- Primary and secondary pumps
- Cooling towers
- Liquid waste tank
  - 500 gallon

Characterization Toolbox

- Surveys
  - Direct measurements, scanning, removable contamination
- Sampling
  - Concrete, soil, graphite, metals
- On-site Analysis
  - Liquid scintillation counting, gamma spectroscopy
- Off-site Analysis
  - Tritium, Iron-55, Nickel-63
- Modeling
  - MicroShield

Structure Surveys

- Direct measurements, scans, and smears
  - Gas flow proportional detector (floor monitor)
  - α/β phoswich detectors
  - Beckman LS-6500 liquid scintillation counter (LSC)
- Floors and walls of reactor room, control room, offices, and storage areas
- Systematic grid and judgmental surveys
  - Horizontal surfaces, floor drains, beam catchers
- High % of rejected direct beta measurements due to high gamma background

Structure Surveys

Equipment Surveys

- Direct and removable contamination surveys
  - LSC and α/β proportional counting
  - Verified contaminated equipment
    - Large glove box
    - Reactor bridge
- Gamma radiation surveys
  - 2x2 NaI gamma scintillation detector and ion chamber
  - Identified unknown contamination/activation
    - N-16 tanks (5,000 gal and 3,000 gal)
    - Primary coolant pipes under reactor
    - Beam port and thermal column plugs

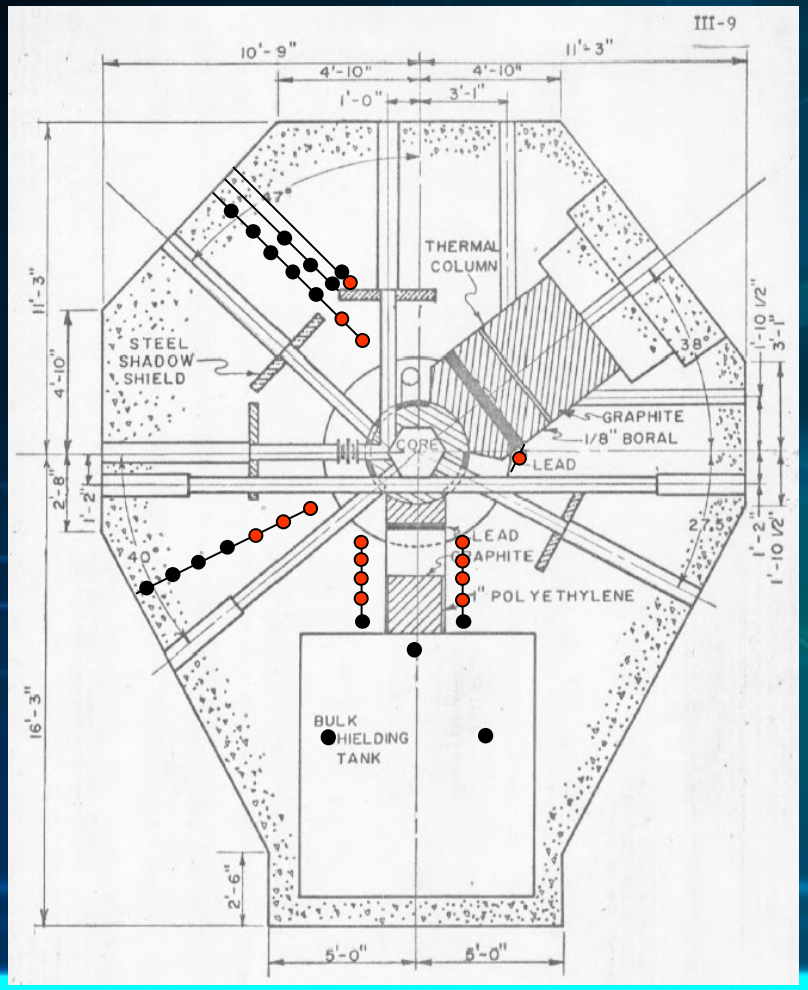
Equipment Surveys

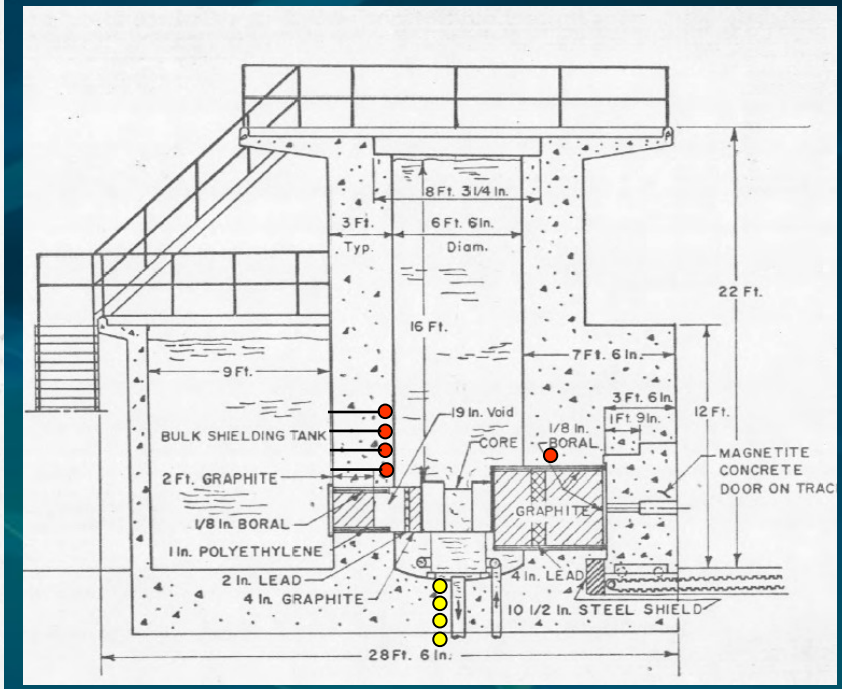
Concrete Sampling

- ***TruPro***® sampling technology from New Millennium Nuclear Technologies, LLC
  - Hammer drill with hollow bit
  - Vacuum pump
  - Sample filters
- Replaced traditional core boring
- Fast (52 samples in 2.5 days): no sample preparation, no water to control, no airborne contamination issues
- On-site sample analysis

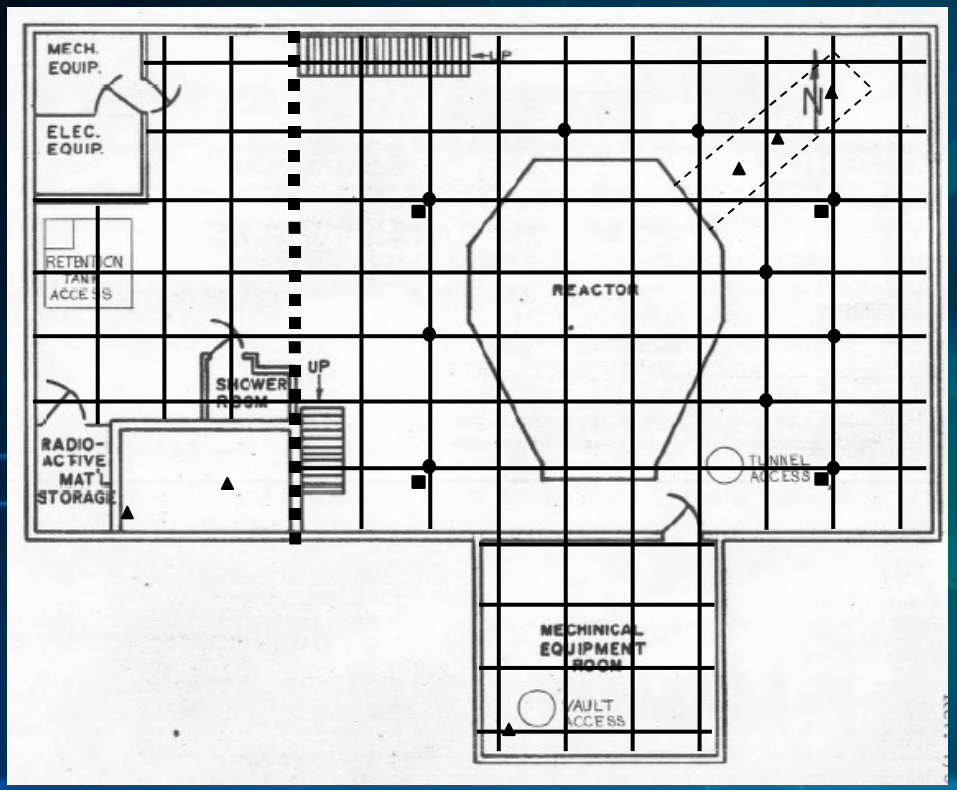
Concrete Sampling

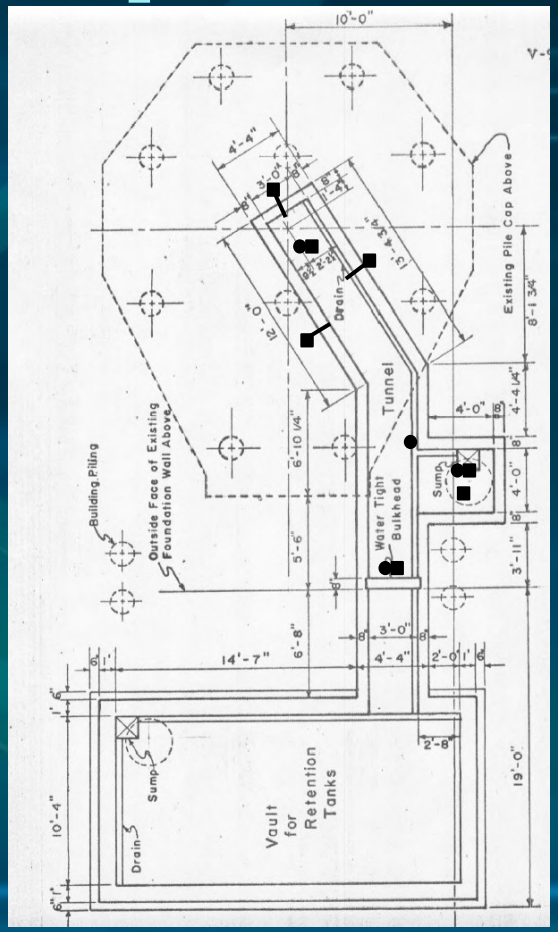
Concrete Sampling





Concrete Samples





Soil Samples

- Below concrete floor
  - 4 locations with ***TruPro®*** and a ***GeoProbe®***
  - 0”-3”, 0’-1’, 3’-4’, 6’-7’, 9’-10’, 12’-13’
- In the pipe chase tunnel under the reactor
  - Through tunnel wall
  - Through the floor
  - Through the sump to 13’
- Around the perimeter of the building
  - 12 locations with a ***GeoProbe®***
  - 4’-5’, 8’-9’, and 12’-13’

Soil Sampling

Graphite and Metal Sampling

- ***TruPro***® used to collect samples
- Aluminum pipe from emergency spray (4)
- Top grid plate (2)
- Stainless steel screw (1)
- Graphite from the large thermal column (4)

Graphite and Metal Sampling

On-site Sample Analysis

- Portable Beta Scout® LSC for tritium and gross beta analysis of concrete, soil, and graphite samples
  - Used 0.1 gm in 2 ml of LiquiGel® scintillation fluid and 2 ml of water
- Gamma spectroscopy of concrete, soil, graphite, and metal samples
  - High-purity Germanium detector
  - Shielded counting well
  - Canberra Genie2000 software

On-site Sample Analysis

- Gamma spectroscopy and *In-Situ* Object Counting System (ISOCS) also used to:
  - Analyze contaminated filter resins
  - Bulk analysis of graphite block stacks
  - Verify the presence of a radium-beryllium neutron source
  - Identify the isotopes present in contaminated lead bricks
  - Identify Co-60 as the primary contaminate in the N-16 decay tanks (NaI spectroscopy)

On-site Sample analysis

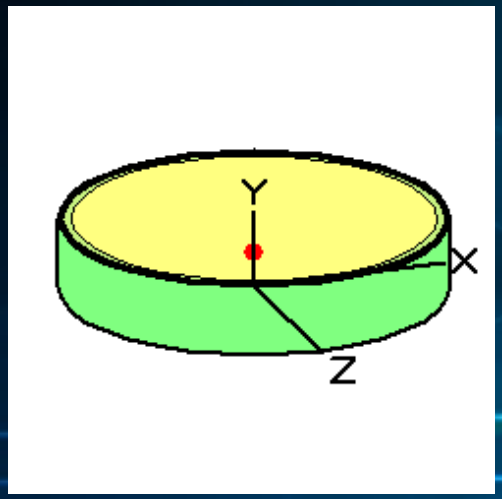
Off-site Sample Analysis

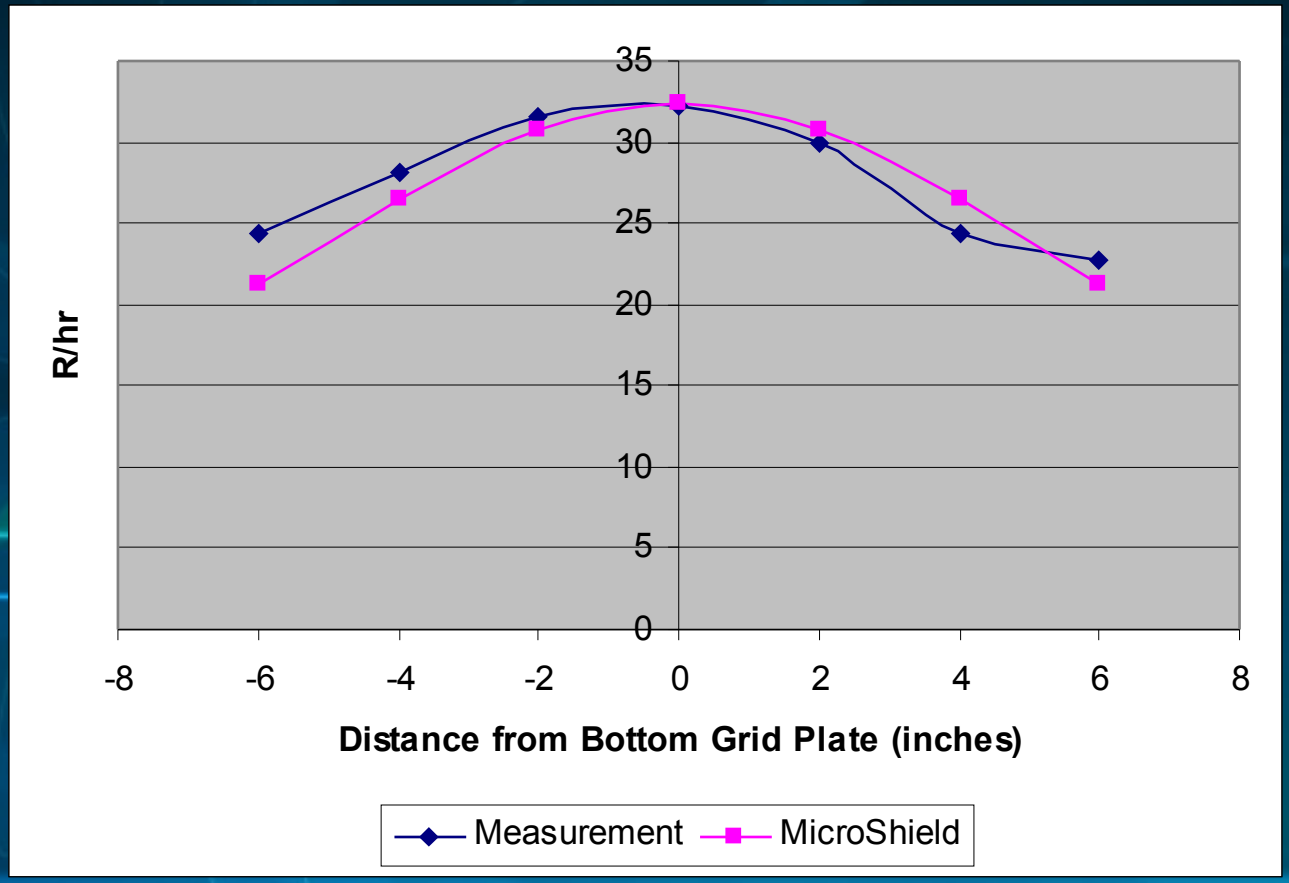
- Severn Trent Laboratories, St. Louis, MO
  - Tritium in 60 subsurface soil samples
    - More samples than originally planned because of variability in the on-site analysis
  - Fe-55 and Ni-63 in 13 concrete samples
    - Complete range of on-site gross beta results
  - Tritium in concrete (planned)
    - Samples from the reactor room floor slab

Modeling

- The Lazy Susan was believed to be the most activated reactor component but was inaccessible for sampling
  - Lazy Susan contains stelite bearings
  - Unactivated Stelite contains 60% stable cobalt
- Collected dose rate measurements in the reactor tank with an ion chamber (Eberline RO-7 in an underwater housing)
- Vertical dose rate profile obtained with center section of the top grid plate removed
- MicroShield used to estimate the amount of Co-60 in geometry similar to the Lazy Susan assuming all gamma activity is from Co-60.

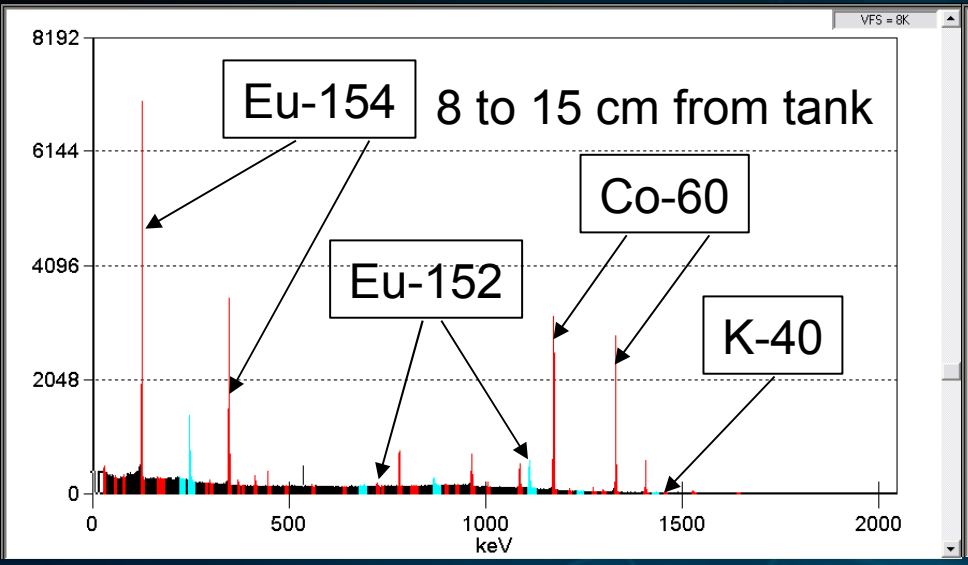
Modeling

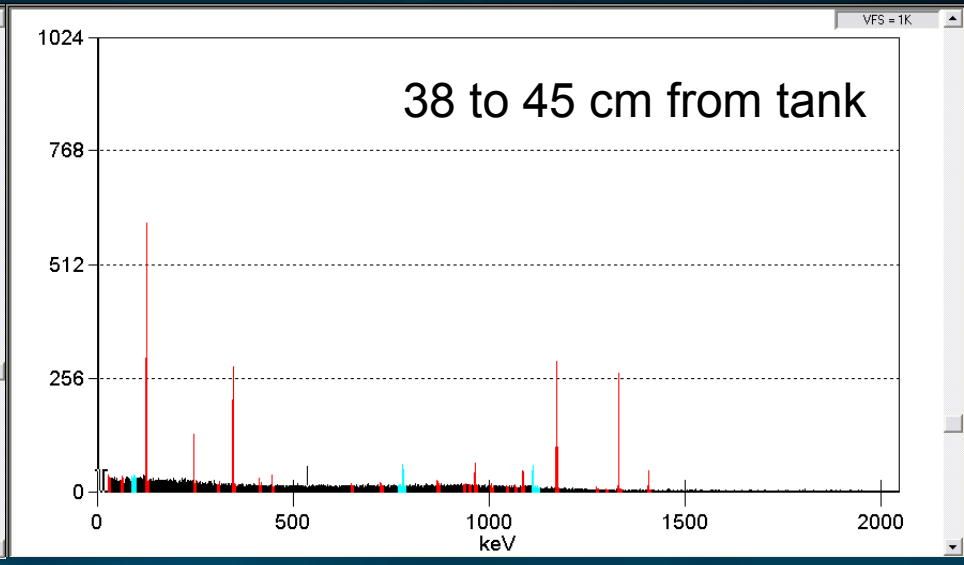

Y
X
Z

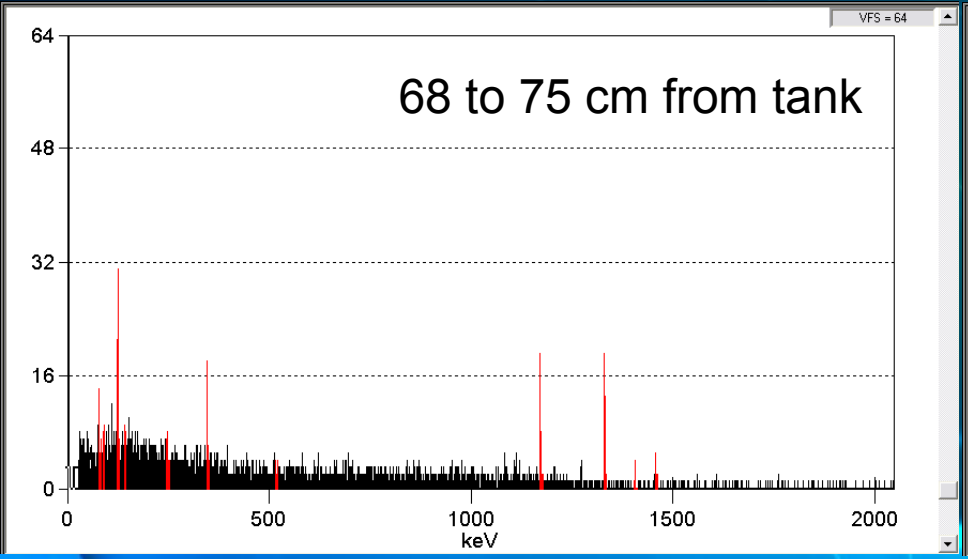

35
30
25
20
15
10
5
0
R/hr
-8
-6
-4
-2
0
2
4
6
8
Distance from Bottom Grid Plate (inches)
Measurement
MicroShield

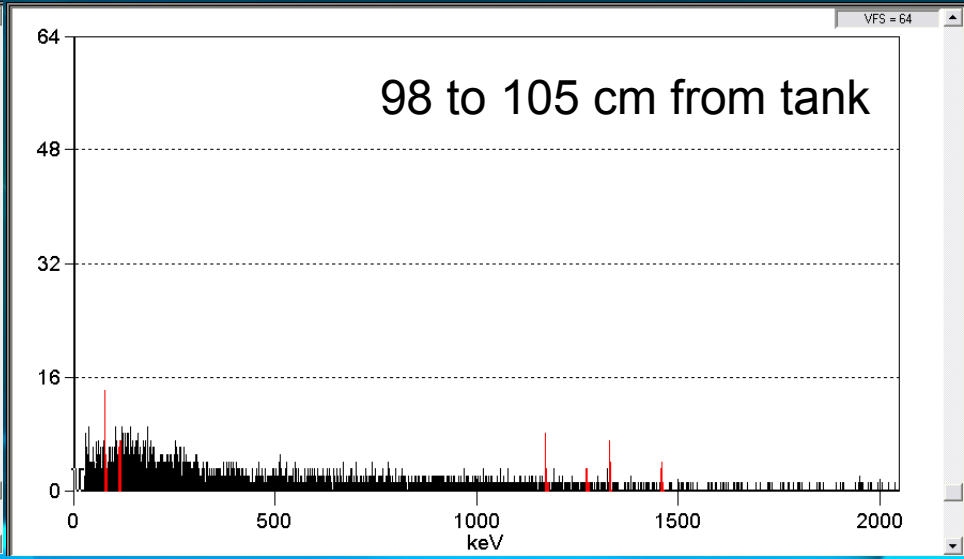
Characterization Results

- Activation Analysis (Concrete)
  - Radius of bioshield activation is about 0.75m from the tank wall (Co-60 and Eu-152 from gamma spec.)
    - Radius of activation varies because of embedded objects (beam ports, shadow shields, thermal columns)
  - Co-60 and Eu-152 in approximately equal concentrations in activated high-density concrete (mangetite aggregate)
  - Maximum measured activities at tank wall at the reactor centerline:
    - Co-60: 311 Bq/g (8,400 pCi/g)
    - Eu-152: 333 Bq/g (9,000 pCi/g)
    - Eu-154: 21 Bq/g (580 pCi/g)


VFS = 8K
8192
6144
4096
2048
0
Eu-154
8 to 15 cm from tank
Co-60
Eu-152
K-40
0
500
1000
1500
2000
keV


VFS = 1K
1024
768
512
256
0
38 to 45 cm from tank
0
500
1000
1500
2000
keV


VFS = 64
64
48
32
16
0
68 to 75 cm from tank
0
500
1000
1500
2000
keV


VFS = 64
64
48
32
16
0
98 to 105 cm from tank
0
500
1000
1500
2000
keV

Characterization Results

- Activation Analysis (Other materials)
  - Aluminum tank activated to a height of about 2m from the reactor core (Co-60 from gamma spec. of aluminum pipe samples)
  - Activation of aluminum reactor components > 3,700 Bq/g (0.1 uCi/g) Co-60 (gamma spec. of top grid plate)
  - Activation of stainless steel bolt from grid plate > 2.22 MBq/g (60 uCi/g) Co-60
  - All graphite is activated (Eu-152 from gamma spec.)
    - Eu-152 ranged from 0.6 Bq/g (0.15 pCi/g) to 630 Bq/g (1,700 pCi/g) in large thermal column)
  - Eu-154 present at 5 to 15% of Eu-152
  - Lazy Susan Co-60 activity estimated to be ~ 0.15 TBq (4 Ci)

Characterization Results

- Contamination Analysis
  - Removable H-3 (up to 1,200 dpm/100cm^2) and fixed H-3 contamination [up to 44 Bq/g (1,200 pCi/g)]
  - H-3 in concrete bioshield highest very near the tank wall [200 Bq/g (5,400 pCi/g)] and under reactor
  - H-3 in leak residue ~ 30 Bq/g (800 pCi/g)
  - Highest tritium concentrations in soil were ~ 1 pCi/g
  - Fe-55 contamination near metal components may have traveled through concrete with water
  - Co-60 contamination in the N-16 tanks
  - Many contaminated pieces of equipment

Successful Toolbox Approach