Update on the Rapid Sample Transfer System for the National Criticality Experiments Research Center

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Outline

- Introduction
- Motivation
- Key Requirements
- Design
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- Control
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Introduction

- **Programmatic need to perform measurements on short-lived isotopes in irradiated samples**
- **Samples irradiated at the National Criticality Experiments Research Center (NCERC) in the Device Assembly Facility (DAF) at the Nevada National Security Site (NNSS)**
  - Comet, Flattop, Godiva, Planet
- **Ingress/egress times do not allow for measurement of short-lived isotopes**
- **Pneumatic sample transfer system (rabbit system) is being designed to meet programmatic needs**
  - Rapidly transfer and position samples to and from critical assembly machines and detectors

Motivation

- **Scientific:**
  - Measure short-lived activation products that have not been measured before
  - Half lives from seconds to a few hours
- **Nuclear Forensics:**
  - Develop major gamma ray spectrum signatures for rapid post-detonation analysis
  - Signatures provide data on intensity of gamma ray emission
  - Samples signatures collected post-detonation can be compared with laboratory data to help determine fuel and estimate isotopic ratios and composition

Motivation

- **Net count rates for the top 15 post-fission signatures 4 hours following irradiation:**

Natural Uranium

Isotope	Energy (keV)	Net CPS
^{134}I	846.77	94.82
^{134}I	883.81	62.68
^{92}Sr	1383.66	37.34
^{142}La	641.07	34.16
^{97}Zr	743.03	32.85
^{133}I	529.82	31.78
^{97}Nb	657.91	29.91
^{135}Xe	249.76	28.73
^{239}Np	277.766	26.82
^{105}Ru	723.97	24.71
$^{132}Te/^{239}Np$	228.22	23.27
^{91}Sr	555.47	22.41
^{139}Ba	165.96	19.85
^{134}Te	210.76	18.62
^{105}Ru	676.63	18.40

Highly Enriched Uranium

Isotope	Energy (keV)	Net CPS
^{134}I	847.49	172.44
^{134}I	884.56	112.75
^{92}Sr	1384.2	94.51
^{142}La	641.73	74.81
^{97}Zr	743.76	68.41
^{91}Sr	556.1	58.62
^{97}Nb	658.6	58.47
^{133}I	530.4	58.28
^{135}Xe	250.23	52.99
Annih.	511.48	38.95
^{139}Ba	166.27	36.19
^{87}Kr	403.14	35.46
^{135}I	1260.75	28.24
^{88}Kr	196.73	27.96
^{85m}Kr	151.4	27.27

Key Requirements - Design

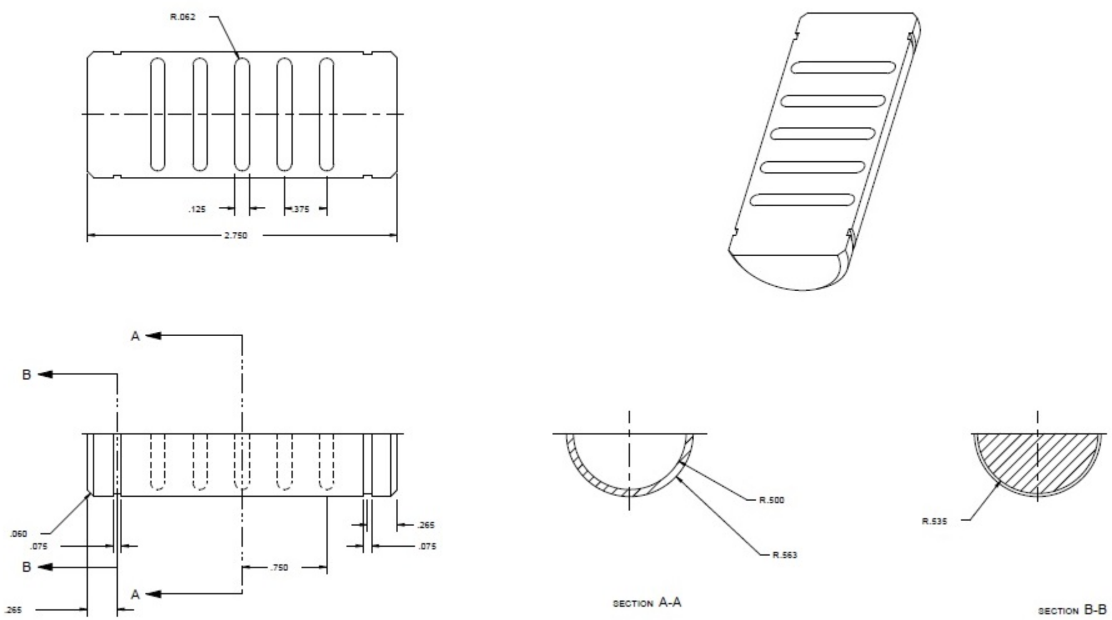
- Transfer capsule must hold samples internally
- Minimize potential for activation of transfer capsule
- Samples must transfer in less than 3 seconds
- Samples can transfer between irradiation point and detector repeatedly
- Mechanically adjustable to accommodate any distance from critical assemblies and any detector
- Tests must be repeatable
- Remote operation from the critical assemblies control room

Key Requirements – Compressed Air

- **DAF house air is compressed air, dried and stored at a nominal 115 psig**
- **Maximum allowable working pressure is 150 psig (DAF design limits)**
  - Rabbit system pressure will be limited to 150 psig by pressure relief valves
- **Rabbit system components will be pressure tested and/or manufacturer certified to operate up to 225 psig**
- **System pressure and transfer capsule speed controlled by a regulator between house air connection and accumulators**

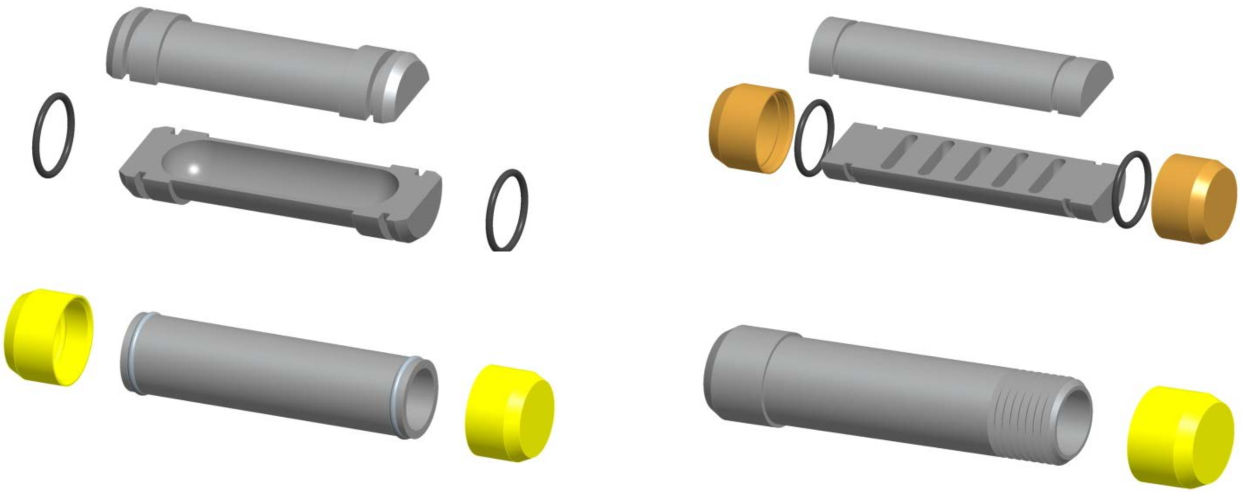
Design

- **Size of the transfer capsule will dictate the minimum bend radius of the tubing**
- **Size of tubing determines the size of the transfer capsule**
- **Settled on tubing 1.5 in OD x 1.37 in ID and 1.25 in OD x 3 in length transfer capsule**



Design – Transfer Capsule

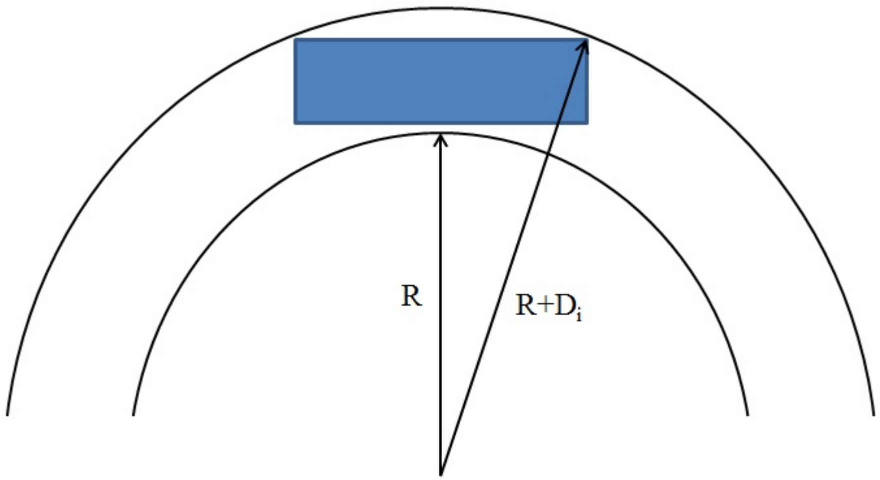
- **4 designs:**

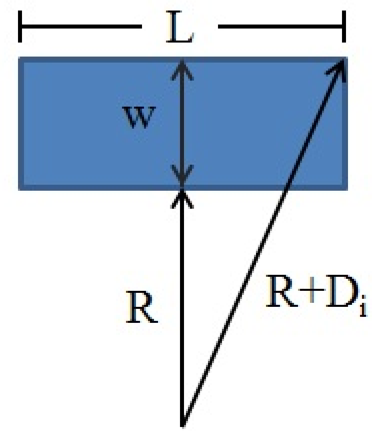


- **Materials will be either high purity polyethylene (PE) or reactor grade graphite**
- **Must build prototypes (smooth and dimpled) to test ease and cost of machining, physical flaws in design, potential catch points, and other unexpected defects**

Design – Minimum Bend Radius

- **Minimum bend radius determined by the dimensions (OD and length) of transfer capsule**

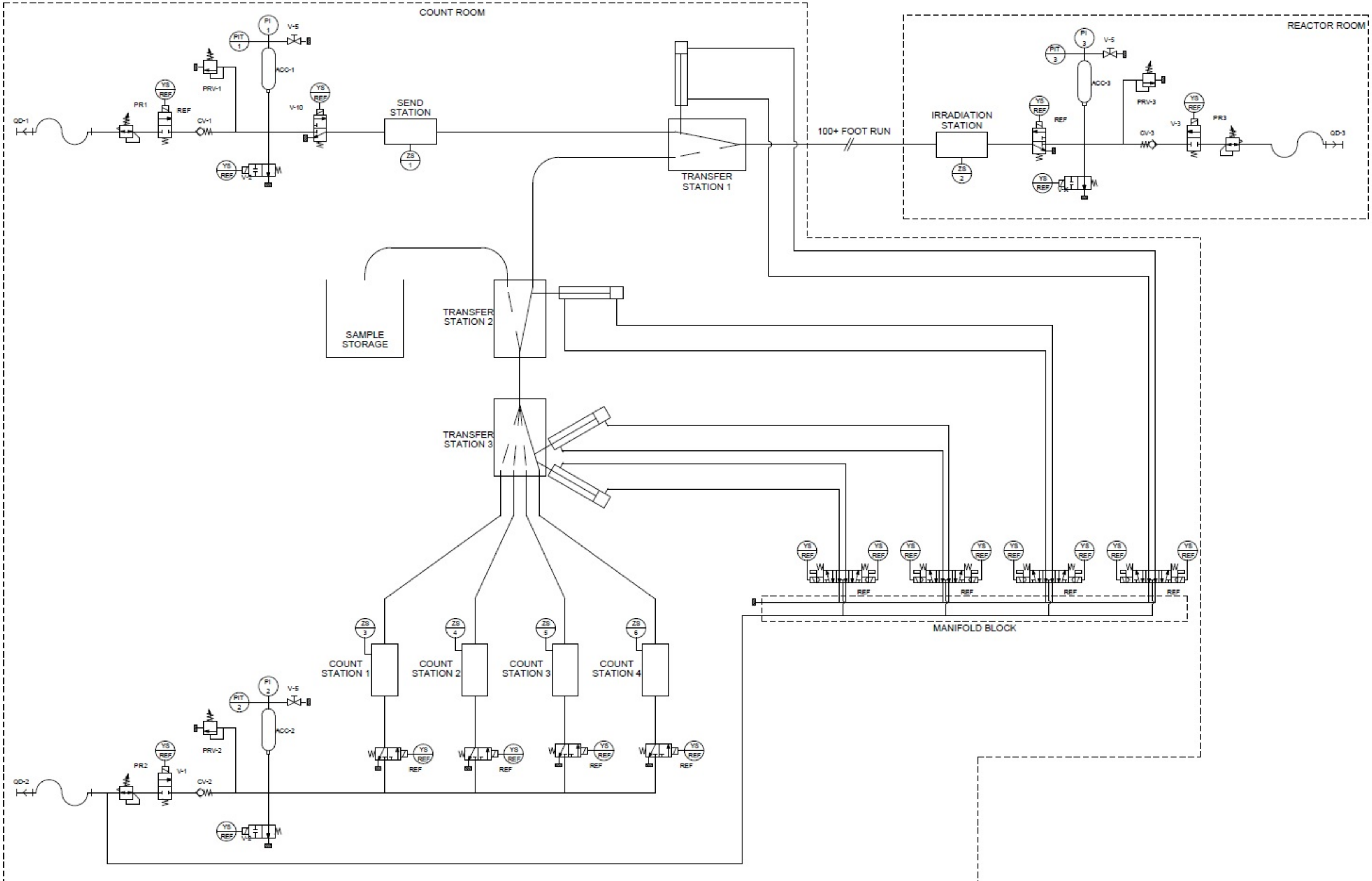




$$(R + w)^2 + \left(\frac{L}{2}\right)^2 = (R + D_i)^2$$

- **Adding a safety factor of 2 → minimum safe bend radius for nominal dimensions of the transfer capsule = 16.1 in.**

Rabbit System Schematic Diagram



Component Selection

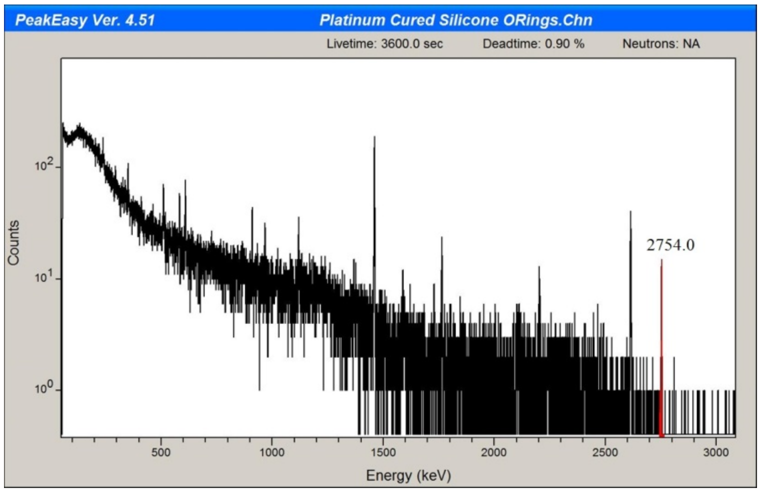
- **Tubing:**
  - 1.5 in OD x 1.37 in ID tubing chosen
  - Swagelok® sanitary flanges for quick connect/disconnect of sections
  - Flanges welded to section ends by Swagelok Southwest Co.
- **Valves:**
  - Solenoid operated, check, pressure relief
- **Accumulators**
  - Large enough to push transfer capsule ~150 ft in ~1 s
- **Pneumatic linear actuators**
  - Adjust transfer station positions
- **Pressure transducers**
- **Position sensors**
  - Optical or mechanical

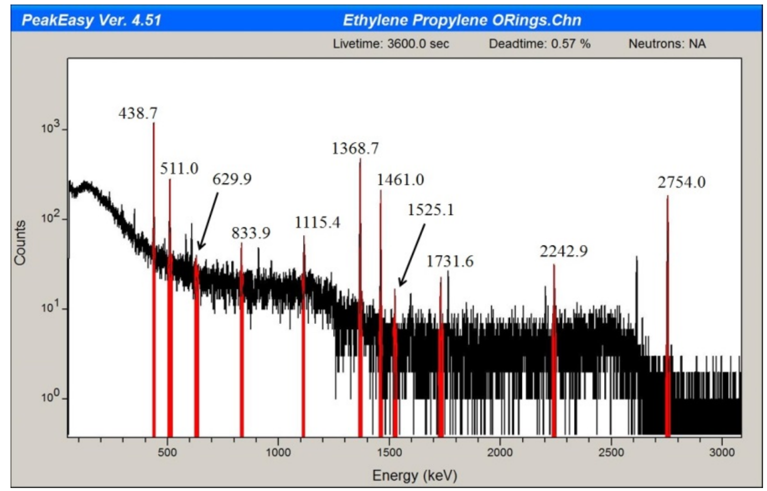
Component Selection – O-Rings

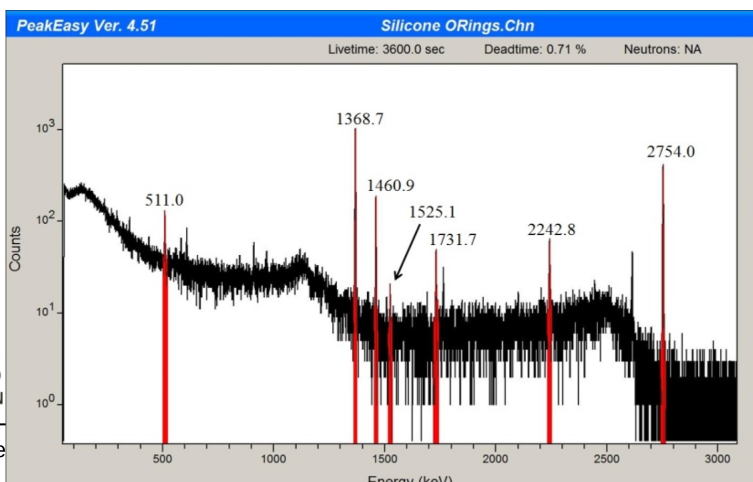
- **2 transfer capsule designs employ o-rings to seal capsule when closed**
- **O-ring materials must have a negligible probability for activation**
  - Many gasket materials have high amounts of F and Cl, both of which have a high σ_c
- **Three materials met the requisite mechanical properties and did not contain F or Cl:**
  - Ethylene propylene diene monomer (EPDM)
  - Silicone
  - Medical grade, platinum cured silicone
- **Once received, o-rings were only handled with gloves**
  - The only contamination on the o-rings would be from manufacturer or distributor

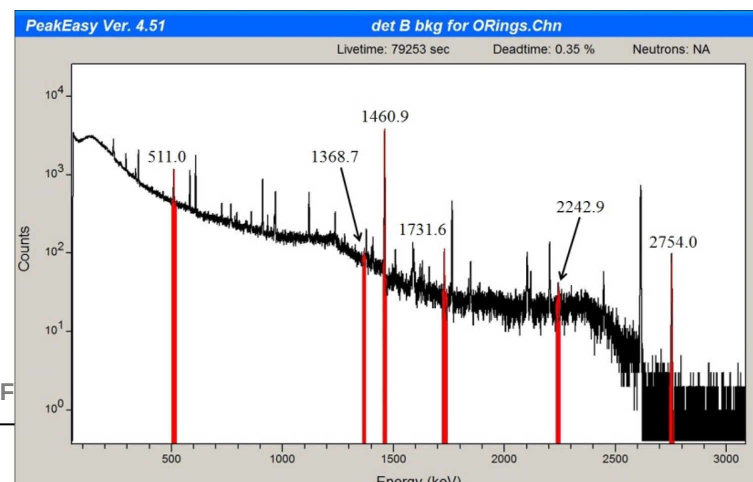
O-Ring Irradiation Experiment

- **An irradiation experiment was conducted using Comet on 12 August 2013 to determine the activation probability of each material**









O-Ring Irradiation Experiment

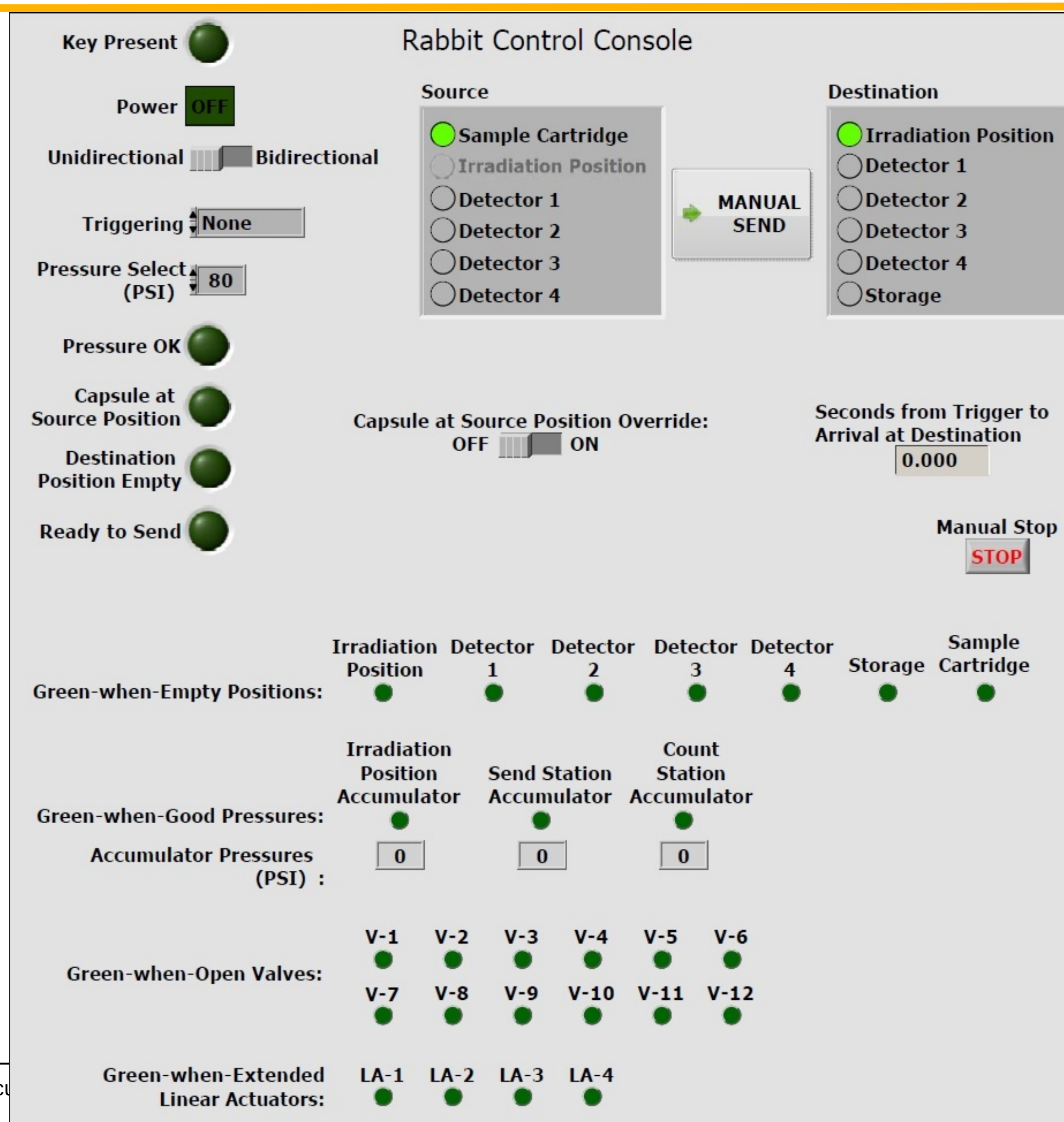
Peak (keV)	Net Count Rate Above Background (cps)	Isotope	Reaction
EPDM			
438.7	1.991 ± 0.026	^{69}Zn	$^{68}Zn(n,\gamma)^{69}Zn$
511.0	0.536 ± 0.018	Annih.	
629.9	0.0313 ± 0.0080	^{72}Ga	$^{71}Ga(n,\gamma)^{72}Ga$
833.9	0.0667 ± 0.0076	^{72}Ga	$^{71}Ga(n,\gamma)^{72}Ga$
1115.4	0.123 ± 0.008	^{65}Zn	$^{64}Zn(n,\gamma)^{65}Zn$
1368.7	0.947 ± 0.018	^{24}Na	$^{23}Na(n,\gamma)^{24}Na$
1461.0	0.0148 ± 0.0133	^{40}K	$^{39}K(n,\gamma)\ ^{40}K$
1525.1	0.0200 ± 0.0037	^{42}K	$^{41}K(n,\gamma)^{42}K$
1731.6	0.0358 ± 0.0054	^{24}Na	Double Escape
2242.9	0.0716 ± 0.0063	^{24}Na	Single Escape
2754.0	0.514 ± 0.013	^{24}Na	$^{23}Na(n,\gamma)^{24}Na$
Silicone			
511.0	0.149 ± 0.015	Annih.	
1368.7	2.18 ± 0.03	^{24}Na	$^{23}Na(n,\gamma)^{24}Na$
1460.9	0.0185 ± 0.0134	^{40}K	$^{39}K(n.\gamma)^{40}K$
1525.1	0.0257 ± 0.0045	^{42}K	$^{41}K(n,\gamma)^{42}K$
1731.7	0.0936 ± 0.0073	^{24}Na	Double Escape
2242.8	0.172 ± 0.009	^{24}Na	Single Escape
2754.0	1.14 ± 0.02	^{24}Na	$^{23}Na(n,\gamma)^{24}Na$
Silicone (Platinum Cured)			
2754.0	0.0181 ± 0.0032	^{24}Na	$^{23}Na(n,\gamma)^{24}Na$

- **Inadequately shielded irradiated Al sample holder determined to be in the line-of-sight of the detector (^{24}Na)**

System Control

- **NI CompactRIO will hold modules required for control**
- **Operators will be able to control the system using a LabVIEW interface**

LabVIEW Control Panel



Next Steps

- Fabricate transfer capsule prototypes
  - No need for high purity PE or reactor grade graphite yet
- Procure components
- Conduct testing in NISC machine shop
  - Prove that we can move the transfer capsule 150 ft in ~1 s
  - Minimum safe bend radius
  - Determine the minimum pressure required to operate
  - Repeatability
- Once the concept has been proven, build the system at DAF

Acknowledgements

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