

**Roldan, Lizette**

---

**From:** Brian Oyadomari [boyado@queens.org]  
**Sent:** Wednesday, February 16, 2011 12:58 AM  
**To:** Roldan, Lizette  
**Subject:** Re: REQUEST FOR ADDITIONAL INFORMATION  
**Attachments:** Cyclotron Decomm Analysis 02152011.pdf; MCA Spectrum Report.pdf

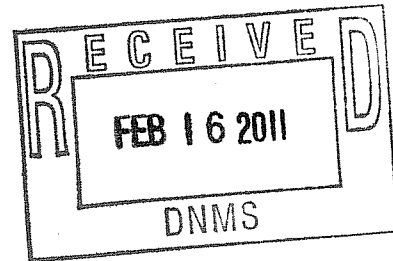
Dr. Roldan-Otero,

I'm sending my response to your letter dated February 8, 2011 requesting additional information concerning our Decommissioning FA analysis.

Please let me know if I can provide any additional information.

Thank you,

Brian Oyadomari  
RSO  
The Queen's Medical Center  
(808)547-4884



>>> "Roldan, Lizette" <[Lizette.Roldan@nrc.gov](mailto:Lizette.Roldan@nrc.gov)> 02/10/11 10:37 AM >>>

Hi Brian,

The letter is attached. I have also mailed it.

Thanks,

*Lizette Roldán-Otero, Ph.D.*

Health Physicist

Nuclear Regulatory Commission

612 E. Lamar Blvd., Suite 400

Arlington, TX 76011

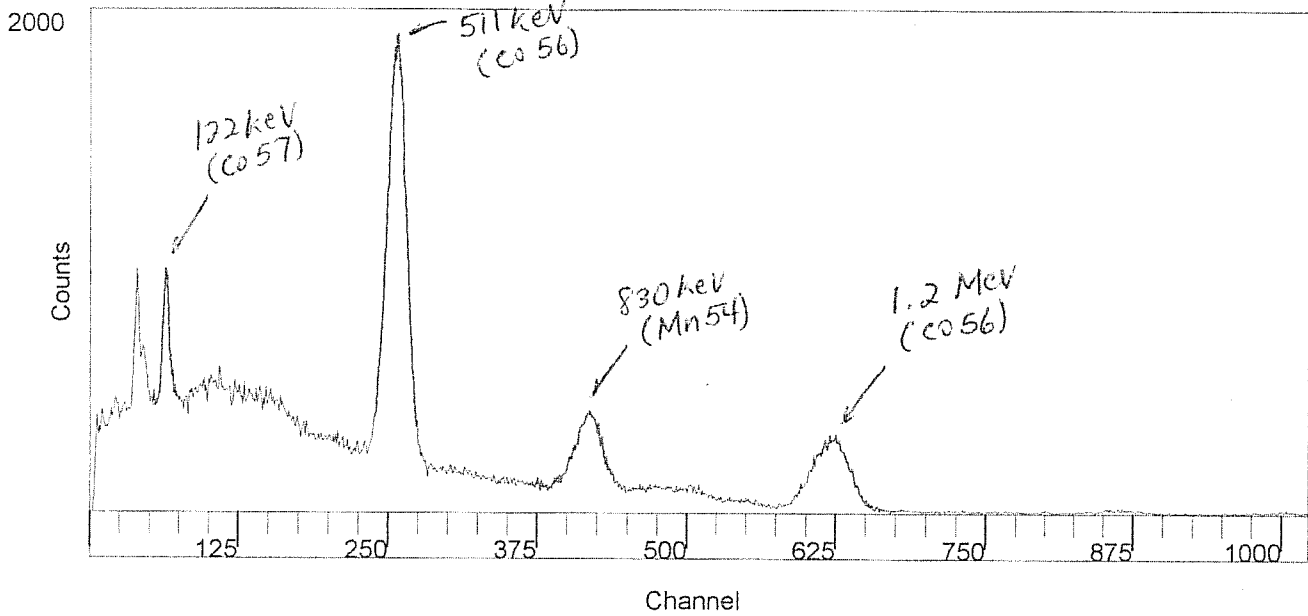
Office: 817-276-6596

Fax: 817-860-8263

Window # 1

The Queen's Medical Center  
 Nuclear Medicine  
 1301 Punchbowl Street  
 Honolulu, Hawaii 96813  
 CAPTUS 3000 S/N: CNV-545

MCA Spectrum Report



ID: 0.8 mR/hr

Spectrum Data

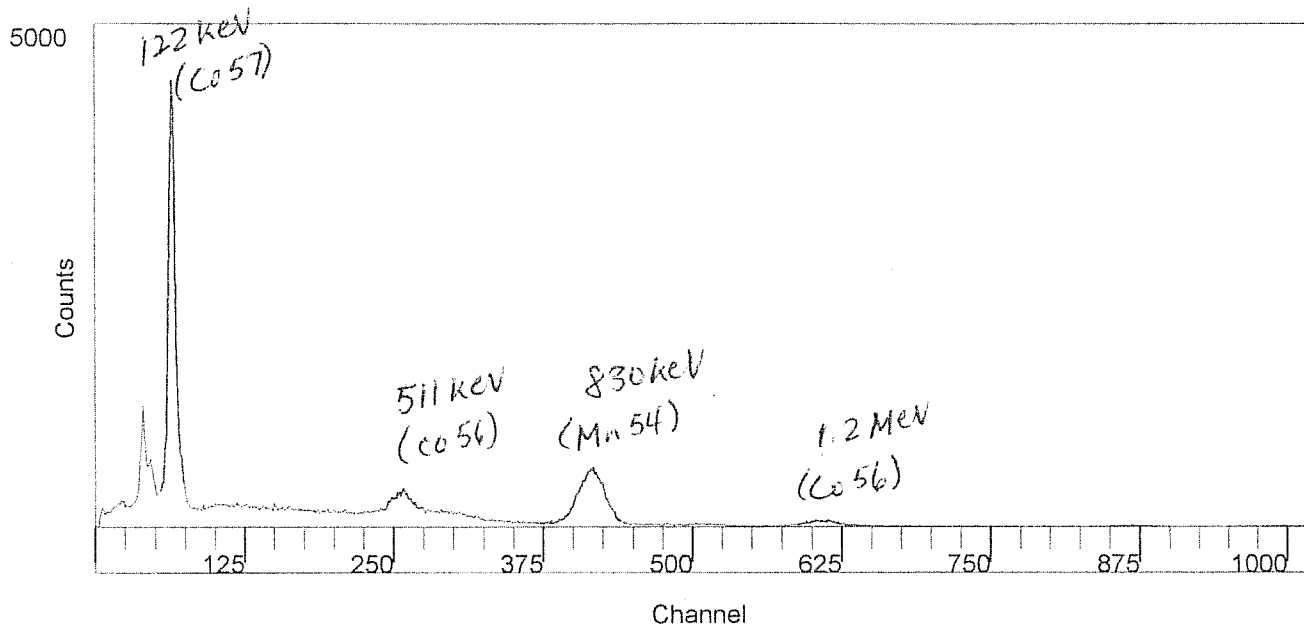
Acquisition Date	01/21/2011
Acquisition Time	13:24
Real Time	300.59 Sec
Live Time	300.00 Sec
Measured In	Probe
High Voltage	1000 V
Gain	12.09
Zero Offset	-0.67 %
Threshold	0.80 %
FWHM	6.5 %
Total Counts	196537
Total Spectrum Counting Rate	39307 cpm

ROI #	Start Chan	End Chan	Integral	Centroid	$\times 2 \frac{\text{kev}}{\text{ch}}$	cpm	
1	56	74	11890	64.9	130 keV	2378	Co 57
2	240	274	39378	256.7	513	7876	annihilation from Co 56
3	370	440	15137	410.9	822	3027	Mn 54, Co 56
4	610	665	8978	627.5	1255	1796	Co 56

Window # 2

The Queen's Medical Center  
 Nuclear Medicine  
 1301 Punchbowl Street  
 Honolulu, Hawaii 96813  
 CAPTUS 3000 S/N: CNV-545

MCA Spectrum Report



ID: 0.4 mR/hr

Spectrum Data

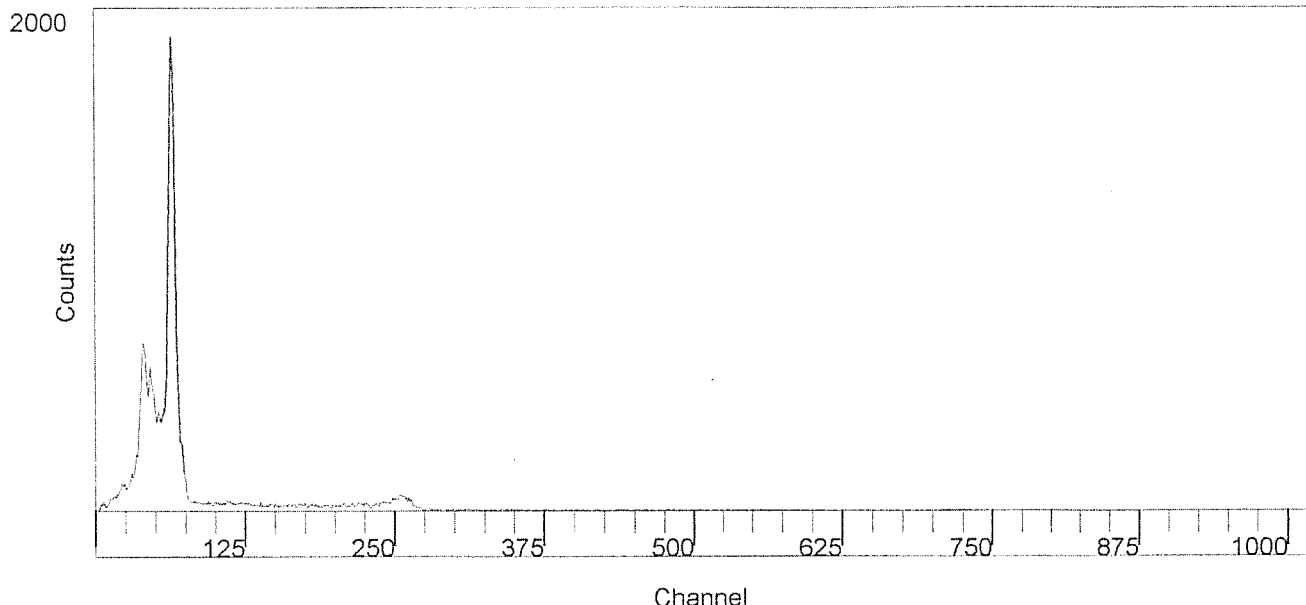
Acquisition Date	01/21/2011
Acquisition Time	17:37
Real Time	300.38 Sec
Live Time	300.00 Sec
Measured In	Probe
High Voltage	1000 V
Gain	12.09
Zero Offset	-0.67 %
Threshold	0.80 %
FWHM	6.5 %
Total Counts	126271
Total Spectrum Counting Rate	25254 cpm

ROI #	Start Chan	End Chan	Integral	Centroid	$\times 2 \frac{\text{keV}}{\text{Ch}}$ ↓ cpm	
1	56	74	34712	64.5	129	6942 Co 57
2	240	274	9174	256.9	514	1835 annihilation from Co 56
3	370	440	16624	413.3	827	3325 Mn 54, Co 56
4	590	660	2099	613.3	1227	420 Co 56

Co-57 reference source

The Queen's Medical Center  
Nuclear Medicine  
1301 Punchbowl Street  
Honolulu, Hawaii 96813  
CAPTUS 3000 S/N: CNV-545

### MCA Spectrum Report



ID: Co-57

#### Spectrum Data

Acquisition Date	01/21/2011
Acquisition Time	10:34
Real Time	500.10 Sec
Live Time	500.00 Sec
Measured In	Probe
High Voltage	1000 V
Gain	12.09
Zero Offset	-0.67 %
Threshold	0.80 %
FWHM	6.5 %
Total Counts	34756
Total Spectrum Counting Rate	4171 cpm

ROI #	Start Chan	End Chan	Integral	Centroid	$\downarrow$ cpm	$\frac{\text{cpm}}{\mu\text{Ci}}$
1	56	74	15398	64.1	$\frac{128 \text{ keV}}{1848}$	6160
2	2	9	154	6.3	18	

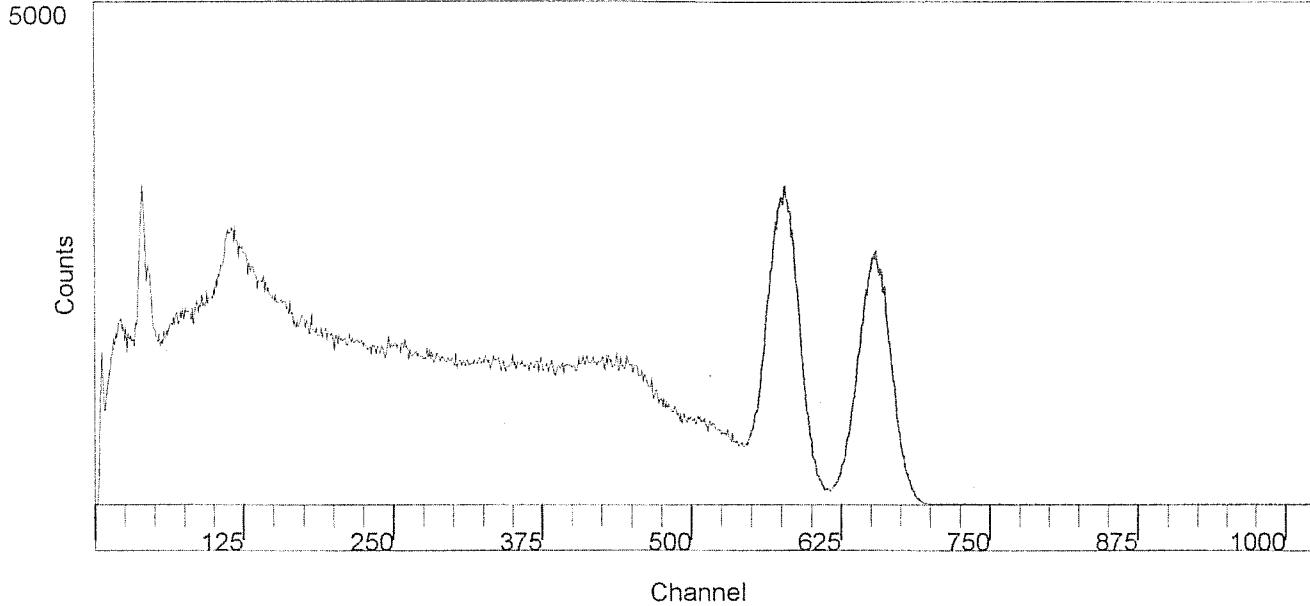
Co-57 check source  
 Cal. Date: May 18, 2000  
 Activity: 5.5 mCi  
 Current: 0.3  $\mu\text{Ci}$  ✓

Measurement Date: 1/21/11  
 Decay factor:  $5.2 \times 10^{-5}$   
 Current activity: 0.3  $\mu\text{Ci}$  ✓

Co-60 reference source

The Queen's Medical Center  
Nuclear Medicine  
1301 Punchbowl Street  
Honolulu, Hawaii 96813  
CAPTUS 3000 S/N: CNV-545

### MCA Spectrum Report



ID: Co-60

#### Spectrum Data

Acquisition Date	01/21/2011
Acquisition Time	18:18
Real Time	503.13 Sec
Live Time	500.00 Sec
Measured In	Probe
High Voltage	1000 V
Gain	12.09
Zero Offset	-0.67 %
Threshold	0.80 %
FWHM	6.5 %
Total Counts	1032934
Total Spectrum Counting Rate	123952 cpm

ROI #	Start Chan	End Chan	Integral	Centroid	cpm	cpm/uci
1	550	613	103014	576.6	12362	19166
2	620	694	83663	653.1	10040	15566

Co-60 Check Source  
cal. date = 5-6-1997  
cal. activity = 55 uCi  
current = 0.645 uCi

Arnavar™ (UNS #R30007) is a corrosion-resistant, nonmagnetic age-hardening alloy with good hot and cold working properties. A cobalt-base high-strength alloy, it is characterized principally by its high fatigue resistance, high tensile strength and torque values. Arnavar is vacuum melted to ensure uniformity of composition and cleanliness of the metal.

**Forms Available**

Arnold can provide this material in strip and foil forms.

**Applications**

Flapper valves, power springs, watch springs, electronic components, drive bands, and motion straps.

**General Characteristics**

**Magnetic Qualities:** After exposure to a field of 5000 oersteds, no residual magnetism can be detected with a search coil of 50 gauss sensitivity. Arnavar also has an exceptional combination of high-strength and fatigue-endurance limits and excellent corrosion resistance. It is generally resistant to pitting, stress and crevice corrosion cracking.

**Mechanical Properties:** Mechanical properties, especially spring properties, are retained to a satisfactory limit at sub-zero temperatures and up to about 750°F. The alloy is hard and tough but capable of cold forming. It is non-magnetic, age hardenable under controlled conditions, and has a corrosion resistance in the age hardened condition that is slightly better than in the untreated state. This alloy possesses exceptionally high resistance to permanent deformation, permitting a more constant delivery of torque over extended periods.

**Physical Properties**

	As Rolled	Aged
Tensile Strength (psi)	260,000-290,000	330,000-360,000
Yield Strength (psi)	230,000-260,000	225,000-280,000
Rockwell Hardness (C)	46-50	54-60
Specific Gravity (g/cc)		8.300
Density (lb/cu in)		0.300
Coefficient Linear Expansion (°C, 0-50°)		0.0000125
Electrical Resistivity (ohms/cir mil ft)		600
Thermoelasticity (°C, 0-65°)		0.00051
Elasticity Modulus		29,500,000
Thermal Conductivity		0.0298 cal/sec/cu cm/°C
Permeability		1.00004 at 2000 gauss and 70°F
Torsional Modulus		11,200,000 psi
Fatigue Strength	(Aged) 10,000,000 cycles @ 100,000 psi	in reverse bending

**Nominal Chemistry**

Cobalt	42.00%
Beryllium	0.04%
Chromium	20.00%
Carbon	0.15%
Nickel	13.00%
Silicon	0.50%
Molybdenum	2.00%
Tungsten	2.80%
Manganese	1.40%
Iron Balance	

**Heat Treatment & Annealing**

Arnavar derives its properties from a combination of cold work and heat treatment. Variation in either or both of these can be made to meet the requirements for specific applications.

**Heat Treatment:** 850° - 1,000°F for 3 to 5 hours.

Vacuum treatment provides a bright finish which can be maintained during treatment.

**Annealing:** 2,125° - 2,175°F for 2 to 10 minutes in a protective atmosphere.

**Aging:** Cold rolled strip is aged at 875°F for 4 hours.

**Workability**

Cold working hardens the alloy quickly, but even after rolling it can be sheared, coiled, or stamped into simple shapes. The percentage of cold reduction greatly influences the final physical properties of the material after aging. Arnavar also remains formable, to a limited extent, after age hardening.

**Machinability**

Arnavar is difficult to machine since it work hardens rapidly in front of the cutting tool. Carbide tools are recommended. Machining should be done prior to heat treatment.

MATERIAL NO: 10180928



DESCRIPTION: WINDOW TARGET ARNAVAR .0

SERIAL NO:

01

REV:

LOT: 0000976571

LOC: UNKNOWN



ASN: 0000967716  
PO: 1500776470

RESERVE  
EXP.DT:

**THE QUEEN'S MEDICAL CENTER**

**Docket: 030-38244**

**License: 53-29377-03**

Workload comparison of Queen's RDS 111 Cyclotron to published RDS 112 Cyclotron

<b>F18 production</b>	Queen's RDS 111 Cyclotron	Health Physics Article's RDS 112
Proton beam	11 MeV	11 MeV
Self-shielded	Yes	Yes
Typical curr. (uA)	35	40
Bombardment(min)	75	60
uA-hr per week	218.75	200
F18 yield (mCi)	1200	1000

- Comments: 1. The workload for the RDS 112 in the reference article was reported at 180 uA-hr/wk.  
 2. Typical workload parameters for F18 production in RDS 111 were obtained by interview with Queen's Cyclotron staff. Resulting workload for RDS 111 was calculated to be 218.75 uA-hr/wk.  
 3. The correction factor for the difference in workload is  $218.75/180 = 1.22$ .

**Cyclotron components**

Component	Weight (kg)
Magnet	21,020
Shields	16,000
Targets	10
Extractor Body	265
Ion source	5
Vacuum chamber	100

\*Ref. - Table 1, p590

\*Total weight of cyclotron calculated to be 37,400 kg, of which 99% of weight is magnet and shields.

**Concrete slab under RDS 111**

6m x 6m x 0.5m	Density	Weight
Volume (cubic meter)	(kg/cubic meter)	(kg)
18	2400	43200

\*Standard concrete density used.



**THE QUEEN'S MEDICAL CENTER**

**Docket: 030-38244**

**License: 53-29377-03**

Extractor Body and Target: Proton activated isotopes with half-life greater than 120 days

\*To account for unexpected variations from typical RDS cyclotron construction, the combined weight of Extractor body and Target conservatively taken to be 300kg.

\*Specific activity from Table 8, p594. Where multiple specific activity values were reported, the highest value was used.

\*The Possession values for each Activated element is a conservative value that exceeds actual calculated amounts.

Reaction	Activated element	Half-life	Specific activity (Bq kg-1)	Weight (kg)	Possession uCi	Appendix B uCi	Ratio (App.B x 10E4)	Calculated uCi
(p,n)	Zn-65	244.06 (d)	155000	300	2000	10	0.0200	1533.2432
(p,n)	Cd-109	461 (d)	155000	300	2000	10	0.0200	1533.2432
(p,n)	W-181	121.2 (d)	155000	300	2000	10	0.0200	1533.2432
(p,n)	Co-56	77.3 (d)	500	300	10	0.1	HL < 120(d)	4.9459
(p,n)	Mn-54	312.3 (d)	3-19	300	5	10	0.0001	3.1555

Ratio < 1 as specified in 10 CFR 30.35(d) for unsealed form 0.0601

Cyclotron Shields: Neutron activated isotopes with half-life greater than 120 days

\*Weight of shields conservatively taken to be 20000kg.

\*Specific activity from Table 5a, p593. Where multiple specific activity values were reported, the highest value was used.

\*For clarification, the Activated element labeled as "Other" in table below refers to "Any radionuclide other than alpha emitting radionuclides, not listed in 10 CFR Part 30 Appendix B or mixtures of beta emitters of unknown composition".

\*Based on values in Table 5a for "Other" isotope category, the specific activity for K-40, Cl-36, H-3 can be specified as 0.8 Bq/kg. However, a conservative value of 25 Bq/kg was used for K-40, Cl-36, H-3 which is comparable to values listed for C-14, Ca-41, Ar-39.

\*The Possession values for each Activated element is a conservative value that exceeds actual calculated amounts.

Reaction	Activated element	Half-life	Specific activity (Bq kg-1)	Weight (kg)	Possession uCi	Appendix B uCi	Ratio (App.B x 10E4)	Calculated uCi
(n,alpha)	Ar-39	269 (y)	28	20000	25	0.1	0.0250	18.4649
(n,p)	Ar-39	269 (y)	28	20000	25	0.1	0.0250	18.4649
(n,alpha)	C-14	5300 (y)	16.3	20000	25	100	0.0000	10.7492
(n,gamma)	Ca-41	103000 (y)	23.4	20000	25	0.1	0.0250	15.4314
(n,gamma)	Ca-45	163 (d)	5450	20000	5000	10	0.0500	3594.0541
(n,alpha)	Cl-36	301000 (y)	25	20000	25	10	0.0003	16.4865

**THE QUEEN'S MEDICAL CENTER**

**Docket: 030-38244**

**License: 53-29377-03**

(n,gamma)	Co-60	5.3 (y)	328	20000	250	1	0.0250	216.3027
(n,gamma)	Eu-152	13.6 (y)	895	20000	1000	1	0.1000	590.2162
(n,gamma)	Eu-154	8.8 (y)	75.6	20000	100	1	0.0100	49.8551
(n,gamma)	Fe-55	2.7 (y)	16600	20000	15000	100	0.0150	10947.0270
(n,gamma)	Fe-59	44.6 (d)	76.2	20000	100	10	HL < 120(d)	50.2508
(n,gamma)	H-3	12.3 (y)	25	20000	25	1000	0.0000	16.4865
(n,p)	K-40	1.28E+09 (y)	25	20000	25	0.1	0.0250	16.4865
(n,gamma)	K-40	1.28E+09 (y)	25	20000	25	0.1	0.0250	16.4865
(n,p)	Mn-54	312.3 (d)	52	20000	50	10	0.0005	34.2919
(n,gamma)	S-35	87 (d)	46	20000	50	100	HL < 120(d)	30.3351
	Other		0.828	20000	5	0.1	0.0050	0.5460

Ratio < 1 as specified in 10 CFR 30.35(d) for unsealed form 0.3308

Concrete Floor: Neutron activated isotopes with half-life greater than 120 days

\*Weight of concrete slab under cyclotron conservatively taken to be 50000kg.

\*Specific activity from Table 5b, p593

\*For clarification, the Activated element labeled as "Others" in table below refers to "Any radionuclide other than alpha emitting radionuclides, not listed in 10 CFR Part 30 Appendix B or mixtures of beta emitters of unknown composition".

Reaction	Activated element	Half-life	Specific activity (Bq kg-1)	Weight (kg)	Possession uCi	Appendix B uCi	Ratio (App.B x 10E4)	Calculated uCi
(n,alpha)	Ar-39	269 (y)	29.6	50000	50	0.1	0.0500	48.8
(n,gamma)	Ca-45	163 (d)	213	50000	500	10	0.0050	351.1622
(n,gamma)	Fe-55	2.7 (y)	654	50000	2000	100	0.0020	1078.2162
(n,gamma)	Fe-59	44.6 (d)	22	50000	50	10	HL < 120(d)	36.2703

**THE QUEEN'S MEDICAL CENTER**

**Docket: 030-38244**

**License: 53-29377-03**

(n,gamma)	Eu-152	13.6 (y)	47.5	50000	100	1	0.0100	78.3108
(n,gamma)	Eu-154	8.8 (y)	21.4	50000	50	1	0.0050	35.2811
(n,gamma)	Co-60	5.3 (y)	19	50000	50	1	0.0050	31.3243
(n,p)	Mn-54	312.3 (d)	35	50000	100	10	0.0010	57.7027
	Others		0.883	50000	5	0.1	0.0050	1.4558

Ratio < 1 as specified in 10 CFR 30.35(d) for unsealed form 0.0830

Cyclotron Shields: Activated isotopes with half-life greater than 120 days

\*Weight of shields conservatively taken to be 20000kg.

\*Specific activity from Table 5a, p593

Reaction	Activated element	Half-life	Specific activity (Bq kg-1)	Weight (kg)	Possession uCi	Appendix B uCi	Ratio (App.B x 10E4)	Calculated uCi
(n,gamma)	Pb-205	1.51E+07 (y)	0.013	20000	5	0.1	0.0050	0.0086
(n,2n)	Pb-205	1.51E+07 (y)	0.013	20000	5	0.1	0.0050	0.0086
(n,gamma)	Sb-124	6.02E+01 (d)	9380	20000	10000	10	HL < 120(d)	6185.7297

Ratio < 1 as specified in 10 CFR 30.35(d) for unsealed form 0.0100

Magnet: Neutron activated isotopes with half-life greater than 120 days

\*Weight of magnet conservatively taken to be 25000kg.

\*Specific activity from Table 7, p593

Reaction	Activated element	Half-life	Specific activity (Bq kg-1)	Weight (kg)	Possession uCi	Appendix B	Ratio (App.B x 10E4)	Calculated uCi
(n,p)	Co-60	5.27 (y)	62.2	25000	100	1	0.0100	51.2730
(n,gamma)	Co-60	5.27 (y)	62.2	25000	100	1	0.0100	51.2730
(n,alpha)	Fe-55	2.7 (y)	11400	25000	10000	100	0.0100	9397.2973
(n,gamma)	Fe-55	2.7 (y)	11400	25000	10000	100	0.0100	9397.2973
(n,gamma)	Ni-63	100.1 (y)	1290	25000	1475	10	0.0148	1063.3784

Ratio < 1 as specified in 10 CFR 30.35(d) for unsealed form 0.0548

**THE QUEEN'S MEDICAL CENTER**

**Docket: 030-38244**

**License: 53-29377-03**

Extractor body: Neutron activated isotopes with half-life greater than 120 days

\*Specific activity from Table 8, p594. Where multiple specific activity values were reported, the highest value was used.

Reaction	Activated element	Half-life	Specific activity (Bq kg-1)	Weight (kg)	Possession uCi	Appendix B	Ratio (App.B x 10E4)	Calculated uCi
(n,p)	Ni-63	100.1 (y)	728	300	25	100	0.00003	7.2013
(n,p)	Co-58	71 (d)	75.3	300	5	10	HL < 120(d)	0.7449
(n,alpha)	Co-60	5.27 (y)	1090	300	25	10	0.00025	10.7822

Ratio < 1 as specified in 10 CFR 30.35(d) for unsealed form 0.00028

Total Ratio = 0.539

**Comments:**

1. The Ratio calculations were done using Possession microcuries divided by (10E4 x Appendix B values) to evaluate qualification for Decommissioning Financial Assurance of \$225,000.
2. Total Ratio for Cyclotron components and concrete slab = 0.539  
 Total Ratio for ARNAVAR foils = 0.327  
 Total Possession Ratio = 0.539 + 0.327 = 0.866  
 This meets requirements for Decommissioning Financial Assurance of \$225,000.

## ARNAVAR FOIL SPECTRUM ANALYSIS

Counting Instrument: Captus 3000

Reference NIST Source	Photopeak Centroid	Activity (microcurie)	Measurement (CPM)	microcurie/CPM
Co-57	64	0.3	1848	0.000162
Co-60	577	0.65	12362	0.000053
Co-60	653	0.65	10040	0.000065

Comments:

- For conservative analysis, the highest measured activity/CPM ratio was used in calculations below.

Measurement #1: Old Arnavar foil with surface exposure rate = 0.4 mR/hr

Measurement #2: Old Arnavar foil with surface exposure rate = 0.8 mR/hr

Activated isotopes with half-life > 120 days

ARNAVAR Element	Reaction	Activated Element	Half life	Photopeak Centroid	Measurement#1 (CPM)	Measurement#2 (CPM)	Avg (CPM)	Measured microcurie/foil
Cobalt (42%)	(n,gamma)	Co-60	5.3(y)	not identified in spectrum				
Chromium (20%)	(p,n)	<b>Mn-54</b>	312.3(d)	411	3027	3325	3176	0.516
Nickel (13%)	(p,alpha)	<b>Co-57</b>	267(d)	65	2378	6942	4660	0.756
Tungsten (2.8%)	(n,gamma)	W-181	130(d)	not identified in spectrum				
Iron (18.2%)	(n,gamma)	<b>Co-56</b>	77(d)	628	1796	420	1108	0.180
Magnesium (not specified)	(p,alpha)	<b>Na-22</b>	2.58(y)	628	1796	420	1108	0.180

Comments:

- Both ARNAVAR foil samples showed Co-57 photopeak centroids matching the Co-57 ref source measurement.
- Both ARNAVAR foil samples did not show Co-60 photopeak centroids matching the Co-60 ref source measurement.
- Although not confirmed in the ARNAVAR spec sheet, the possibility of Sodium-22 was included for decommissioning purposes.

The following decommissioning analysis is based on the following conditions:

1. Old Arnavar foils are stored for decay to background levels prior to disposal.
2. The decay period is typically 3 years and a total of 50 to 60 old foils are stored in a lead container.
3. Nearly 33% of the old foils had exposure rates above 0.8 mR/hr.
4. The highest surface reading for a plastic bag containing about 20 old foils was 75 mR/hr.
5. The average surface reading of foils with elevated radioactivity levels is 75mR / 20 foils = 3.8 mR/hr.
6. Using a conservative approach, the activity of each old foil was corrected by 3.8mR / 0.8mR = 4.75

Activated Element	No. of foils in decay	Avg Surface Rdg (mR/hr)	Measured microcurie/foil	Adjusted microcurie/foil	Total microcurie	Possession microcurie	Appendix B uCi	Ratio (App.B x 10E4)
Co-60	60	4	not identified				1	
Mn-54	60	4	0.52	2.47	148.2	200	10	0.002
Co-57	60	4	0.76	3.61	216.6	250	0.1	0.25
W-181	60	4	not identified				10	
Co-56	60	4	0.18	0.855	51.3	75	0.1	
Na-22	60	4	0.18	0.855	51.3	75	0.1	0.075

**Total Ratio = 0.327**

Comments:

1. The Ratio for Financial Assurance purpose was calculated using (Possession activity / App. B x 10E4)
2. 10E4 was used as the multiplication factor to evaluate qualification for \$225,000 limit.
3. The Possession Activity for each Activated Product is a conservative value that exceeds actual calculated amounts.
3. Co-56 was excluded from Total Ratio sum due to its Half-life < 120 days.