Tgt_15_06 (b): Addendum to the BLIP canning record Tgt_15_06 - Production of High Specific Activity ^{186}Re from Osmium Metal for Research and Clinical Applications

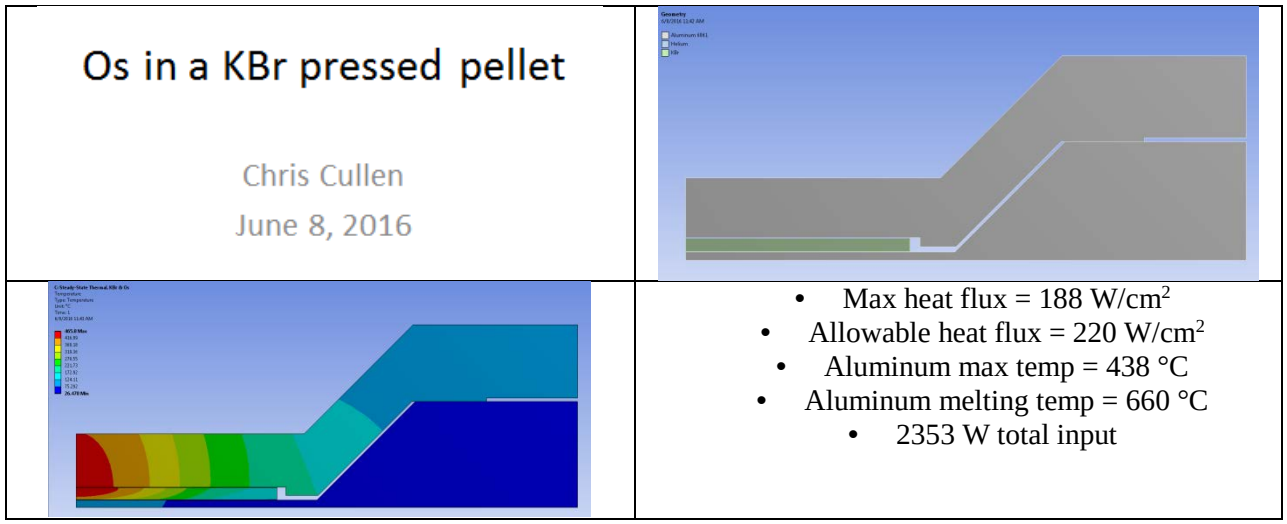
This addendum is submitted in relation to the irradiation of the Os target aiming to produce radioisotopes of rhenium such as Re-186 and Re-189. Hence in terms of dose rates and radioisotope impurities profile this irradiation is similar to the approved canning record Tgt_15_06.

The difference is in the target material: for this experiment Os will be irradiated is in the form of metal powder, not metal disk/foil. Due to the small quantities of Os available it was mixed with KBr in ratio 1:5 and pressed into pellets (Figure 1). The pellet manufacturing was performed at the University of Missouri.

Figure 1. A photograph of the Os_KBr pellet on an anvil. Pellet size: d×h=0.98×~0.032 inch, 1.25 g, V=~0.377 cm^3, atom density ratio: **K:Br:Os=1:1:0.031**

The pellets were pressed to 0.032 thicknesses and will be encapsulated in a bolted aluminum target holder. Target encapsulation procedure is the same as outline in Tgt_15_06. ***Thermal analysis was performed for the worst case scenario, when protons are stopped in the target, and power deposition for the target is the highest. There will be a number of very similar target arrays submitted when the power deposition is lower than in the analyzed case.*** Note the parameters for beam current are in the array spread sheet: Gaussian beam 11 mm, beam current 70 uA,

Thermal analysis



	Energy: 65.61 MeV	FY2016	Gaussian	focused	FWHM	11	mm		
				thickness			70	uA	power, W
layer number	Layer	Material	density	inches	mm	Ei	Eout	delta E	
1	Be window	Berillium	1.85	0.012	0.305	65.61	65.15	0.46	32.39
2	AlBeMet window	AlBeMet	2.10	0.012	0.305	65.15	64.62	0.53	37.02
3	Beamline window	stainless steel	7.99	0.031	0.787	64.62	60.15	4.47	312.72
4	water gap	water	1.00	0.106	2.692	60.15	57.20	2.95	206.64
5	box upstream window	stainless steel	7.99	0.020	0.508	57.20	54.06	3.14	219.79
6	water gap	water	1.00	0.100	2.540	54.06	50.99	3.07	214.81
7	Al degrader	aluminum	2.70	0.176	4.483	50.99	38.38	12.61	882.89
8	water gap	water	1.00	0.100	2.540	38.38	34.27	4.10	287.30
9	bolted can window	Aluminum	2.70	0.020	0.508	34.27	32.47	1.80	126.24
10	KBr_Os pellet	KBr_Os	3.20	0.032	0.806	32.47	29.49	2.98	208.61
11	bolted can back	Aluminum	2.70	0.155	3.937	29.49	0.66	28.83	2018.29
12	water outside well	water	1.00	0.298	7.569	0.66	stop		
13	water gap	water	1.00	0.100	2.540	stop	stop		
14	Al degrader	Aluminum	2.70	1.736	44.094	stop	stop		
15	water gap	water	1.00	0.100	2.540	stop	stop		
16	Al degrader	Aluminum	2.7	0.056	1.422	stop	stop		
17	water gap	water	1.00	0.100	2.540	stop	stop		

Comment on a KBr activation and dose rates

Since Os atoms are only 3% of the total pellet the activation of KBr pellet needs to be considered. The following isotopes can be formed from KBr proton activation (1 min<$T_{1/2}$<1 year). Activities were calculated using maximum cross section values and activation equation.

Isotope	Half life	Eγ, keV (I)	Pathway	Max sigma, mb	A at EOB/24 h past, Ci
					1 h at 70 uA
K-38	7.64 min	2167.5 (99.85%)	^{39}K(p,pn)	105 at 22 MeV	0.76/nil
Ar-37	35.011 d	X rays only	^{39}K(p,2pn)	No data	No data
Kr-79	35 h	261.3 (12.7%)	^{79}Br(p,n)	88 at 11.3 MeV	0.007/0.00043
Kr-77	74.4 min	129.7 (84%), 146.5(39%)	^{79}Br(p,3n)	174 at 32 MeV	0.09/nil
Br-77	55.9 h	238.9 (23.1%), 521.0 (23.6%)	^{79}Br(p,2np)	310 at 35 MeV	0.020/0.016
Br-78	6.46 min	613.6 (13.6%)	^{79}Br(p,np)	337 at 29.5 MeV	1.34/nil
Br-80	17.6 min	617 (7.2%)	^{81}Br(p,np)	86.8 at 32 MeV	0.29/nil

The dose rate to BLIP operator was estimated using Microshield 7 and the data is summarized in the Table below.

Exposure rate to BLIP operator, mR/h	
1 h at 70 uA of beam	
At EOB	24 hours after
0.83 mR/h	nil

As seen from the report below the contribution to the dose rate is due to K-38 (energy bin 2.0 MeV). Br-78 is not in the Microshield library of nuclides and it was not included in the dose estimation. However, based on the data below and Br-78 decay scheme the contribution from it to the dose rate is not substantial.

Submitted by D. Medvedev to RSC chair

Microshield report

MicroShield 7.02
BNL (7.02-0000)

Date	By	Checked

Filename	Run Date	Run Time	Duration
KBr_BLIP_EOB.ms7	June 10, 2016	11:48:41 AM	00:00:00

Project Info	
Case Title	Dose rate KBr
Description	BLIP EOB after 1h of beam at 70 uA
Geometry	3 - Disk

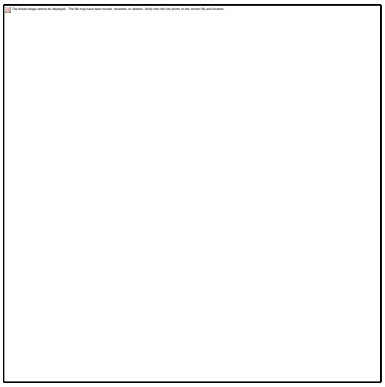
Source Dimensions	
Radius	2.54 cm (1.0 in)

Dose Points

A	X	Y	Z
#1	78.74 cm (2 ft 7.0 in)	0.0 cm (0.0 in)	0.0 cm (0.0 in)

Shields

Shield N	Dimension	Material	Density
Shield 1	30.48 cm	Air	0.00122
Shield 2	1.27 cm	Stainless steel	8



Submitted by D. Medvedev to RSC chair

Shield 3	15.24 cm	Lead	11.34
Shield 4	1.27 cm	Stainless steel	8
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices
Number of Groups: 25
Lower Energy Cutoff: 0.015
Photons < 0.015: Included
Library: ICRP-38

Nuclide	Ci	Bq	µCi/cm²	Bq/cm²
Br-77	2.0000e-002	7.4000e+008	9.8676e+002	3.6510e+007
Br-80	2.9000e-001	1.0730e+010	1.4308e+004	5.2940e+008
K-38	7.6000e-001	2.8120e+010	3.7497e+004	1.3874e+009
Kr-77	9.0000e-002	3.3300e+009	4.4404e+003	1.6430e+008
Kr-79	7.0000e-003	2.5900e+008	3.4537e+002	1.2779e+007

Buildup: The material reference is Shield 3
Integration Parameters

Radial	20
Circumferential	20

Results

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.565e+09	0.000e+00	2.637e-24	0.000e+00	2.262e-25

0.02	4.691e+05	0.000e+00	1.054e-27	0.000e+00	3.650e-29
0.04	5.439e+05	0.000e+00	2.583e-27	0.000e+00	1.142e-29
0.08	1.051e+07	7.791e-165	1.209e-25	1.233e-167	1.914e-28
0.1	4.233e+07	0.000e+00	1.931e-08	0.000e+00	2.955e-11
0.15	4.125e+09	1.154e-142	2.167e-21	1.901e-145	3.568e-24
0.2	2.137e+08	5.048e-70	7.396e-24	8.909e-73	1.305e-26
0.3	3.287e+08	6.920e-27	2.074e-23	1.313e-29	3.933e-26
0.4	4.742e+07	1.836e-15	4.489e-15	3.576e-18	8.746e-18
0.5	6.198e+10	3.149e-07	9.287e-07	6.182e-10	1.823e-09
0.6	9.507e+08	2.214e-06	7.131e-06	4.322e-09	1.392e-08
0.8	8.801e+07	1.014e-04	3.816e-04	1.928e-07	7.257e-07
1.0	1.348e+07	3.725e-04	1.528e-03	6.867e-07	2.816e-06
1.5	2.191e+07	2.307e-02	1.015e-01	3.882e-05	1.709e-04
2.0	2.807e+10	1.188e+02	5.327e+02	1.838e-01	8.238e-01
4.0	5.343e+07	1.025e+00	4.392e+00	1.268e-03	5.433e-03
Totals	**9.751e+10**	**1.199e+02**	**5.372e+02**	**1.851e-01**	**8.294e-01**