1H-53

Los Alamos
NATIONAL LABORATORY
memorandum
Los Alamos Neutron Science Center

To/MS: Chris Steele, DOE-OLASO, MS A316
Thru/MS: Kyo Kim, PS-OAB, MS K561
From/MS: Joey Donahue, LANSCE-7, MS H840
Phone/Fax: 7-2856/Fax 5-4049

Symbol: LANSCE7-JBD-02-002
Date: June 19, 2002

Inventory Report

Attached is our fourth inventory report for the 1L Target covering the period October 31, 2001 through December 24, 2001. This report fulfills one of the conditions of approval specified in the SER for the target [Safety Evaluation Report for LANSCE (TA-53) 1L Target BIO, Rev. 1, March 22, 2000]. The SER states, "A report summarizing the results of the inventory control program shall be delivered to DOE every six months after beam irradiation begins." Irradiation began on June 17, 2000 and ceased on December 24, 2001. From October 8, 2001, the facility was operated under a JCO [Justification for Continued Operations for Los Alamos Neutron Science Center (LANSCE) Lujan Neutron Scattering Center Target 1L, Revision 0, 8 October 2001] that expired on January 31, 2002. Since December 25, 2001, the facility has been in "Beam-Not-Allowed" MODE for extended maintenance.

The target insert that contains the tungsten targets (Mark I) was replaced with a new insert (Mark II) during the maintenance period. The old insert is being stored as a spare in Area A East under the conditions of the A6 BIO [TA-53-BIO-05.0, April 6, 2002] that was approved on April 6, 2002. The new insert is identical to the old insert except for changes to the upper and lower reflectors [53-USQ-1L-02-013] and to the upper target cooling-water manifold [53-USQ-1L-02-012]. These changes were made in response to operational upsets that occurred in calendar year 2001 and both of the USQDs were negative. Another USQD is being prepared to restore the 1L BIO control set in the facility procedures.

The report shows that the target inventory is well within the limits specified in the 1L BIO [53-BIO-004, Rev. 2, March 14, 2000] and below the limits specified in the A6 BIO. Since we do not plan any further irradiation of the Mark I insert, we did not estimate the inventory that would accumulate during the next irradiation period. The integrated current for the new insert will start at zero and the isotope inventory limits will not be exceeded during the next six months even under the most conservative assumptions. We plan to begin irradiation of the new insert on or about July 5, 2002 under the conditions of the above-mentioned 1L BIO and SER. We will then deliver inventory reports to your office for the new insert at the six-month intervals specified in the SER.

If you have any questions, please contact me at 667-2856.

Attachment 31

Distribution:
Ivan Trujillo, DOE-OLASO, MS A316
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Alan Hurd, LANSCE-12, MS H805
Ron Nelson, LANSCE-12, MS H805

Calc-Note Number: **CN-LANSCEFM-02-001**

Title: 1L Target Radionuclide Inventory Calculation, October – December 2001

Author: Jeffrey S. Bull

Signature *Jeffrey S Bull* Date 2/13/02

Reviewer: Eric J. Pitcher

Signature *Eric J Pitcher* Date 2/13/02

Summary:
The isotope inventory and off-site CEDE was calculated for the 1L target during beam operations from October 31 through the end of the 2001 beam delivery period (December 24, 2001). None of the nuclide activities exceeded the threshold limits established in the 1L target authorization basis. Since the tungsten targets are to be replaced during the 2002 outage period, no estimate was made of the off-site dose from continued operation. The decay heat of the used targets was calculated, and was found to be insignificant for both targets.

APPROVED FOR USE IN THE
1 L TARGET NUCLEAR FACILITY

Joe R. Daniels 4/12/02
Nuclear Operations Manager

Review Comments and Responses

<u>None</u>

1L Target Radionuclide Inventory Calculation, October - December 2001

Jeffrey S. Bull
Los Alamos National Laboratory

1.0 Introduction

This note fulfills the requirement contained in the 1L target authorization basis for a report documenting the calculation of the isotope inventory of the 1L tungsten targets. This report covers the operating period from October 31, 2001 through December 24, 2001, the end of the 2001 beam operating period. The calculations were performed per the instructions contained in procedure LANSCE-7-OP-1-10.00, "1L Target Isotope Inventory Calculation Procedure."[1]

2.0 Operational History

Previous analyses of the nuclide inventory for the 1L Target have been performed, covering the time period from when beam was first delivered to the present target (October 1998) through October 30, 2001.[2, 3, 4, 5] This nuclide inventory assessment builds on the previous assessments and covers the period from October 31 through December 24, 2001. On December 24, an extended maintenance period began. One of the major tasks during this outage is the replacement of the 1L target.

The computer codes used to calculate the nuclide inventory are limited in the number of time steps they can accommodate. Therefore, the operational history was simplified by taking the average beam current for each day. If the average beam current for the day was less than 2.5 μA, 0 μA was used for the beam current. Although this will underestimate the activities of the short-lived nuclides for those days, the limits on the beam current ensure that those nuclides will not exceed their thresholds. This change also has little effect on the integrated current; the difference is less than 0.01% to the integrated current.

Figure 1 shows the beam current delivered to the 1L target along with the simplified operational history used for the radionuclide inventory calculation. The integrated current for the simplified history is equal to the total amount of beam delivered to the 1L target from October 31, 2001 through December 24, 2001, 46.8 mA-hrs. The maximum beam delivered to the target during this period was 62 μA.

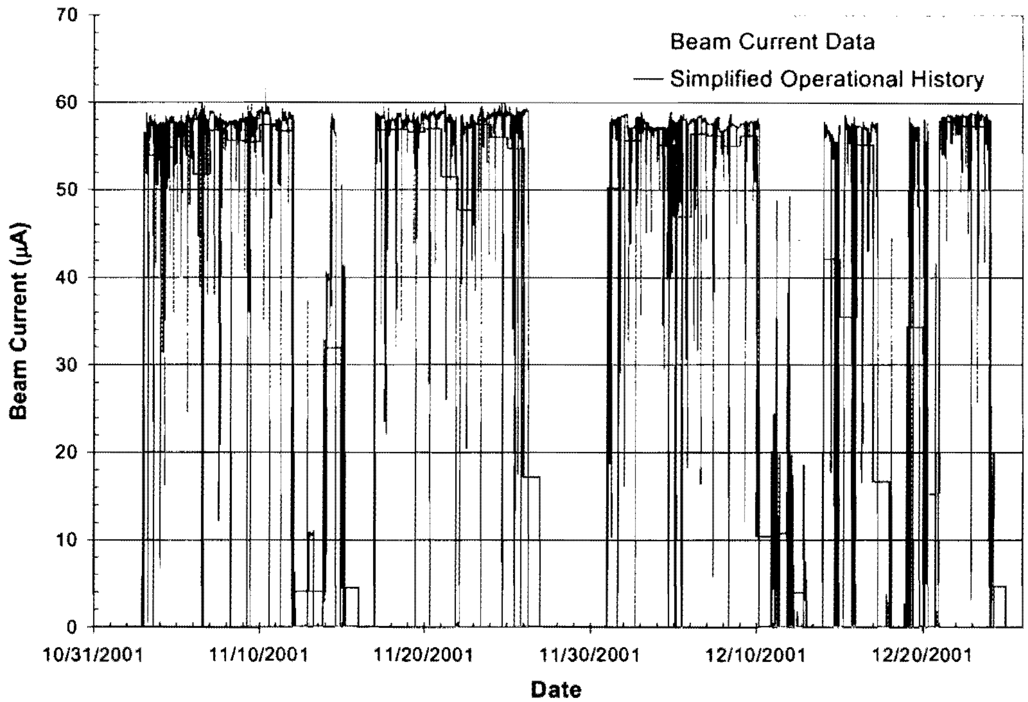

Figure 1. Beam current and simplified irradiation history for the 1L target from October 31through December 24, 2001.

3.0 Radionuclide Inventory Calculation

The radionuclide inventory was calculated using CINDER90 (version c98g, 8/9/98), as modified per Memo PPO-MEM-02201, "Spallation Product Isomers," which more accurately calculates the activity of isomers.[6] The input files describing the spallation products, neutron flux, material descriptions, and volumes for the 1L target were the same files used in previous calculations of the 1L target nuclide inventory. The codes were checked against a test set of problems to ensure that they were setup properly.

Using the irradiation history from Figure 1, the radionuclide inventory was calculated at the end of each day of the assessment period. Attachment 1 contains the CINDER input file for this calculation. The maximum radionuclide activity for each nuclide was determined and compared to the threshold for the 1L target. These results are summarized in Table 1. Since the nominal operating beam current was one third of the maximum allowed, the nuclide with the longest half-life, Gd-148 (half-life 75 yrs) came closest to its threshold at 40%. No nuclide exceeded the activity threshold established in the 1L target authorization basis.

Table 1

Maximum Activity and Percent of the Threshold during the Assessment Period

Nuclide	Half-life	Maximum Activity (Curies)	Percent of Threshold	Nuclide	Half-life	Maximum Activity (Curies)	Percent of Threshold
Dy-155	10.0 h	1.0E+02	38%	Lu-171	8.22 d	3.1E+02	28%
Dy-157	8.1 h	1.1E+02	38%	Lu-172	6.70 d	1.3E+02	31%
Dy-159	144.4 d	7.3E+01	24%	Lu-173	1.37 y	1.4E+02	31%
Er-161	3.24 h	1.5E+02	38%	Re-181	20 h	1.2E+02	37%
Eu-145	5.94 d	3.1E+01	31%	Re-182b	64.0 h	2.4E+01	35%
Eu-146	4.61 d	3.7E+01	25%	Re-184	38.0 d	2.0E+01	25%
Eu-147	24 d	3.5E+01	25%	Ta-173	3.65 h	3.7E+02	39%
Gd-146	48.3 d	2.6E+01	24%	Ta-174	1.2 h	4.2E+02	38%
Gd-147	38.1 h	4.1E+01	37%	Ta-175	10.5 h	5.0E+02	38%
Gd-148	75 y	5.2E-01	40%	Ta-176	8.08 h	6.2E+02	39%
Gd-149	9.4 d	4.2E+01	28%	Ta-182	115.0 d	1.3E+02	24%
Gd-153	242 d	3.1E+01	28%	Ta-183	5.1 d	2.3E+02	30%
Hf-170	16.01 h	2.9E+02	38%	Ta-184	8.7 h	9.9E+01	38%
Hf-172	1.87 y	9.7E+01	32%	Tb-151	17.6 h	6.1E+01	38%
Hf-173	24.0 h	4.4E+02	37%	Tm-166	7.70 h	2.6E+02	35%
Hf-175	70 d	3.4E+02	22%	Tm-167	9.24 d	1.9E+02	28%
Hf-181	42.4 d	2.0E+01	24%	W-177	135 m	4.6E+02	38%
I-124	4.18 d	2.4E-01	32%	W-178	21.7 d	5.2E+02	26%
I-125	60.14 d	7.9E-01	23%	W-181	121.2 d	1.3E+03	23%
I-126	13.02 d	7.0E-02	26%	W-185	75.1 d	3.8E+03	24%
I-131	8.04 d	3.7E-02	28%	W-187	23.9 h	1.3E+04	38%
Lu-169	34.06 h	3.0E+02	37%	Yb-166	56.7 h	2.5E+02	35%
Lu-170	2.00 d	3.3E+02	36%	Yb-169	32.01 d	2.2E+02	23%

4.0 Committed Effective Dose Equivalent Calculation

A calculation of the committed effective dose equivalent (CEDE) was also performed. The 1L Basis for Interim Operation (BIO) identified the worst-case accident for the 1L target system as a loss of cooling, followed by the release of the radionuclide inventory due to oxidation of the tungsten target. For these calculations, an airborne release fraction and respirable fraction of one is assumed. For the uncontrolled scenario, a ground level release was modeled with a leak path factor of one. Dose conversion factors were calculated for the 1L BIO using the MELCOR Accident Consequence Code System.[7] As in the BIO, a factor of 1.5 is included in the final result to account for nuclides that do not have dose conversion factors assigned. For this analysis, only the dose consequence for the off-site receptor is considered. This receptor is located at the site boundary, 960 m from the 1L target.

The CEDE at the site boundary was estimated for the end of each day during the time beam was delivered to the 1L target. During the maintenance periods, time steps of various lengths were used in order to produce a smooth curve. Figure 2 shows a graph of the off-site dose equivalent. The maximum dose, 5.9 rem, occurs twice in December.

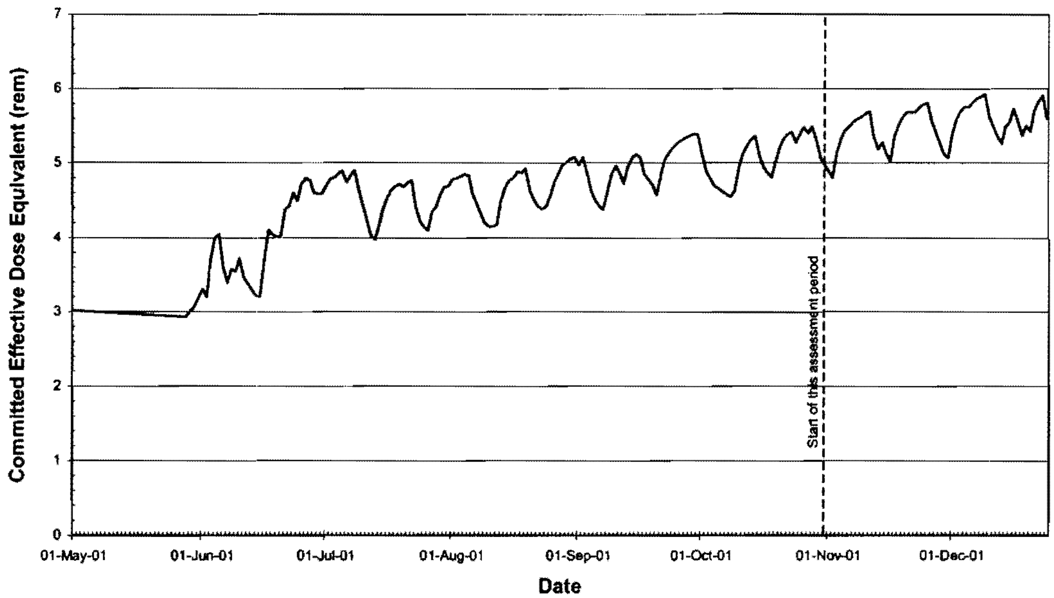

Figure 2. Committed Effective Dose Equivalent at the site boundary for an uncontrolled release of the nuclide inventory of the 1L target. The dashed line shows the beginning of the assessment period covered in this report.

5.0 Nuclide Inventory and CEDE at the End of the Next Assessment Period

This assessment period extends to the end of the 2001 beam delivery period. During the 2002 outage period, the 1L target will be replaced. Since the target will receive no additional beam, an estimate of the CEDE at the end of the next assessment period was not calculated. Prior to beam delivery on the new target, the CEDE at the site boundary should be calculated.

6.0 Conclusion

The isotope inventory and off-site CEDE was calculated for the 1L target for the period October 31 through the end of the 2001 beam delivery period, December 24, 2001. None of the nuclide activities exceeded the threshold limits established in the 1L target authorization basis. Since the 1L target will be replaced during the 2002 outage, no estimate was made of the CEDE at the end of the next assessment period.

7.0 References

[1]LANSCE-7-OP-1-10.00, "1L Target Isotope Inventory Calculation Procedure," October 6, 2000.

[2]J. S. Bull, "Radionuclide Inventory and Consequence Analysis for the 1L Target System,"CN-LANSCEFM-99-002, Rev. 1, December 13, 1999.

[3]J. S. Bull, "1L Target Radionuclide Inventory Calculation, June-September, 2000," CN-LANSCE-FM-01-001, October 16, 2000.

[4]J. S. Bull, "1L Target Radionuclide Inventory Calculation, October 2000 – April 2001," CN-LANSCE-FM-01-003, June 7, 2001.

[5]J. S. Bull, "1L Target Radionuclide Inventory Calculation, May – October 2001," CN-LANSCE-FM-01-005, December 12, 2001.

[6]R. B Kidman. E. J. Pitcher, and W. B. Wilson, "Spallation Product Isomers," Memo PPO-MEM-02201 to M. W. Cappiello, May 25, 1999.

[7]G. Heindel, "Atmospheric Dispersion Model for 1L the Target," Memo ESH-3:99-113 to J. B. Donahue, November 17, 1999.

Attachment 1a: CINDER90 Input File – First Stage
(The beam current data is presented in three columns to reduce the number of pages.)

```
LANSCE 1L target, beam current for Oct 31 - Dec 24, 2001
7.06859E+02, 6.242Q+14,1.Q-04,1.Q-10,,,,,,,2,0,2,1/
Tungsten in upper target
Input files from P. Ferguson -- Startup date 1/15/00
 Calculated with CINDER'90 (c98g) and 1998 Library (LibB2-Q) of 3400 Nuclides
tally104
mat 21
1    0.00
        3 'd'
1    0.54
        1 'd'
1    0.55
        1 'd'
1    0.57
        1 'd'
1    0.52
        1 'd'
1    0.57
        1 'd'
1    0.56
        1 'd'
1    0.55
        1 'd'
1    0.57
        1 'd'
1    0.57
        1 'd'
1    0.04
        1 'd'
1    0.04
        1 'd'
1    0.32
        1 'd'
1    0.04
        1 'd'
1    0.00
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1    0.57
        1 'd'
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        1 'd'
1    0.57
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1    0.51
        1 'd'
1    0.48
        1 'd'
1    0.57
        1 'd'
1    0.56
        1 'd'
1    0.55
        1 'd'
1    0.17
        1 'd'
1    0.00
        3 'd'
1    0.00
        1 'd'
1    0.50
        1 'd'
1    0.56
        1 'd'
1    0.57
        1 'd'
1    0.55
        1 'd'
1    0.47
        1 'd'
1    0.56
        1 'd'
1    0.56
        1 'd'
1    0.55
        1 'd'
1    0.56
        1 'd'
1    0.10
        1 'd'
1    0.11
        1 'd'
1    0.04
        1 'd'
1    0.00
        1 'd'
1    0.42
        1 'd'
1    0.35
        1 'd'
1    0.55
        1 'd'
1    0.17
        1 'd'
1    0.00
        1 'd'
1    0.34
        1 'd'
1    0.15
        1 'd'
1    0.58
        1 'd'
1    0.57
        1 'd'
1    0.57
        1 'd'
1    0.05
        1 'd'
```

TA 53

Calc-Note Number: CN-LANSCEFM-02-004

Title: WNR Target 4 Radionuclide Inventory Calculation for Start of the 2002 Run Cycle

Author: Charles Kelsey

Signature Date

Reviewer: Jeff Bull

Signature Date

Summary:

A Target 4 radionuclide inventory calculation was completed for irradiation of the "new" target during the 2001 run cycle. The maximum Hazard Category 3 threshold ratio was 0.37 on 11/25/01. Combined with the "old" target inventory as previously evaluated, the maximum threshold ratio was 0.98. The "old" target was removed during the 2002 outage, and going into the 2002 run cycle, the Hazard Category 3 threshold ratio for the "new" target is less than ten percent. Integrated beam current limits were determined for continued irradiation of the target. Assuming that a maximum beam current of 5 μA is established, the integrated beam current limit is 25,088 μA-hours. Selection of a higher maximum beam current will require a lower integrated beam current limit. Limits were evaluated for maximum beam currents up to 10 μA.

Attachment 32

Review Comments and Responses

None.

WNR Target 4 Radionuclide Inventory Calculation for Start of the 2002 Run Cycle

Charles Kelsey
Los Alamos Neutron Science Center

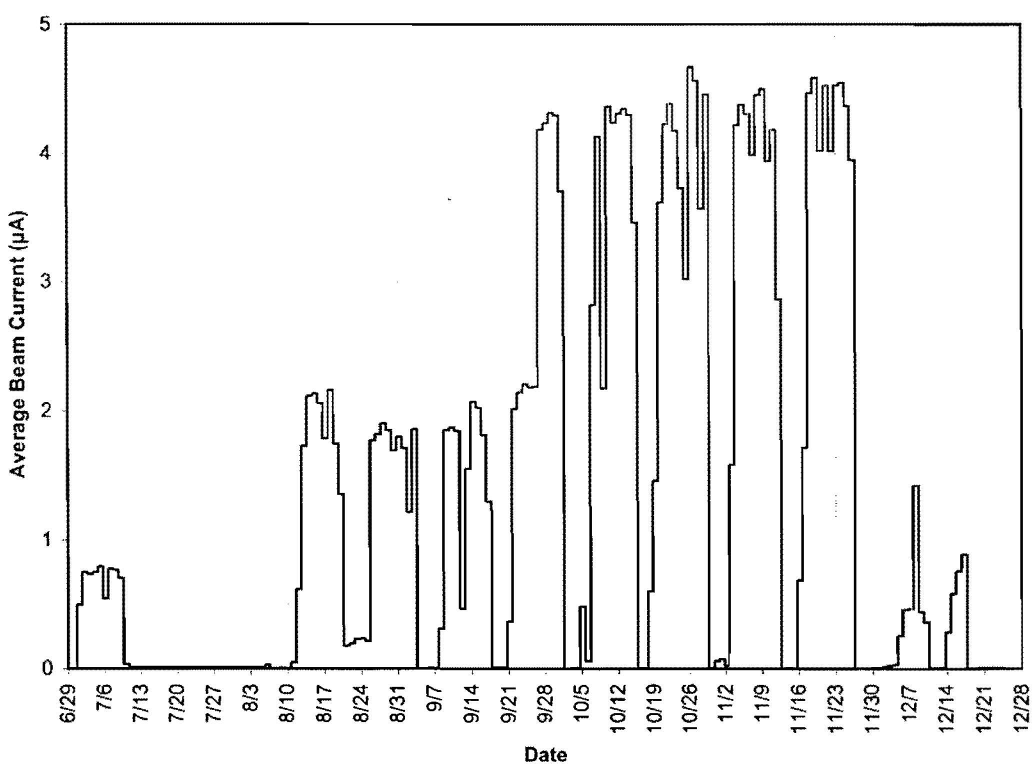
I. Introduction

This calculation satisfies the Justification for Continued Operation (JCO) commitment to evaluate the "new" target radionuclide inventory prior to the start of each run cycle [1]. The calculation was performed independent of past evaluations for the same purpose, and its results are consistent with the interim results for the 2001 run cycle [2]. Additionally, as required by LANSCE-3 routine operating procedure, an integrated beam current limit was calculated for the "new" target, assuming the 2001 run cycle's maximum beam current of 5 μA [3]. LANSCE-3 has however suggested that they may need to raise the maximum beam current, so, integrated beam current limits were also evaluated for maximum currents up to 10 μA.

II. Operational History

The "new" target was installed during the 2001 outage and received beam during the 2001 run cycle. The "old" target was physically isolated from the beam line and the cooling system for the 2001 run cycle. It was then removed from the Weapons Neutron Research (WNR) Target 4 facility during the 2002 outage. LANSCE-3 provided beam delivery data for the 2001 run cycle based on the 1RCM01 current monitor. The daily average beam current delivered to Target 4 was determined using this data, imposing the assumption that all beam delivered to WNR went to this target. A plot of the daily average beam current through the 2001 run cycle is presented in Figure 1.

Figure 1: Daily Average Beam Current Delivered to "New" Target During the 2001 Run Cycle



III. Radionuclide Inventory Calculation

The radionuclide inventory calculation was performed using the code systems MCNPX, Version 2.1.5, and CINDER90, Version c98f. MCNPX was used to calculate spallation product yields and the distribution of the neutron flux at energies below 25 MeV, both on a per micro-amp basis assuming an 800 MeV proton beam was incident on the target. The MCNPX input file is listed in Appendix A. CINDER90 was used for the time dependent evaluation of the inventory and integrated beam current limits based on the MCNPX results. CINDER90 input decks are listed in Appendices B, C, and D, respectively for the periods 6/30/01 to 9/17/01, 9/18/01 to 6/18/02, and 6/19/02 on. The first two decks provide the irradiation history by day as plotted in Figure 1 followed by the 2002 outage. For determination of an integrated beam current limit, the third deck provides continuous 5 μA beam delivery for 240 days beginning on 6/19/02. This deck was revised for the additional integrated current limit evaluations assuming continuous currents of 6, 7, 8, 9, and 10 μA.

Calculated Hazard Category 3 threshold ratios are plotted in Figure 2. The integrated beam currents resulting in threshold ratios of 0.95 assuming continuous delivery of maximum currents of 5 to 10 μA are listed in Table 1. These integrated beam current limits are for additional beam, assuming delivery begins on 6/19/02. Since the "new" target was installed, WNR has seen an integrated current of 5983 μA-hours, all of which was assumed to have been delivered to Target 4 for the present inventory calculation. If the maximum current is raised, the appropriate lower integrated current limit becomes applicable until a revised inventory calculation is completed. Table 2 lists activities of radionuclides identified as major contributors to the maximum Hazard Category 3 threshold ratios. During the 2001 run cycle the maximum threshold ratio of 0.37 was reached on 11/25. For comparison of this calculation with earlier evaluation results, the radionuclide activities on 9/16 are also listed.

Figure 2: Hazard Category 3 Threshold Ratios

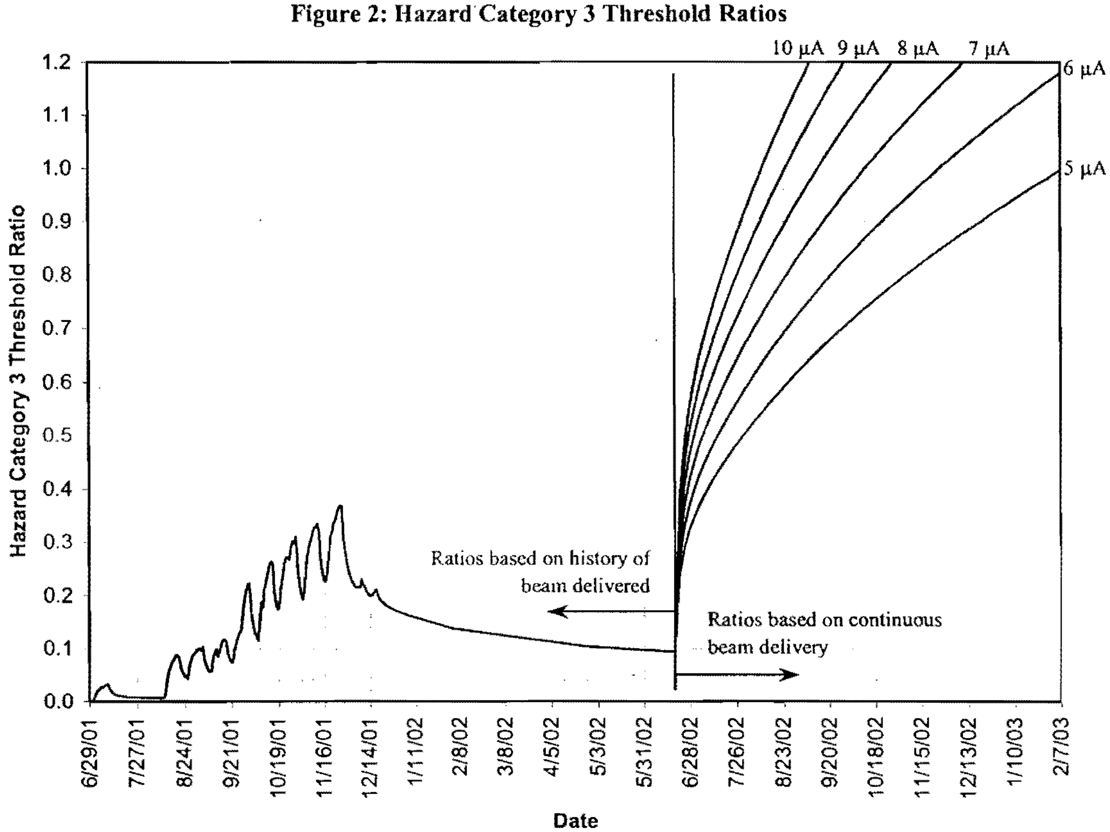


Table 1: Integrated Beam Current Limits

Maximum Beam Current (μA)	Integrated Beam Current Limit (μA-hours)
5	25088
6	20452
7	17136
8	14651
9	12686
10	11072

Table 2: Major Contributors to Maximum Hazard Category 3 Threshold Ratios

Inventory Date	Hazard Category 3 Threshold Ratio	Inventory Activities of Radionuclides that are Major Contributors to the Threshold Ratio (Curies)				
		I-125	Gd-148	Lu-170	Ta-176	Yb-166
9/16/01 (Ref. 2)	0.12	0.012	0.0013	6.0	8.1	4.5
9/16/01	0.12	0.011	0.0012	5.9	8.4	5.0
11/25/01	0.37	0.041	0.0055	15	21	12

IV. Conclusion

A Target 4 radionuclide inventory calculation was completed for irradiation of the "new" target during the 2001 run cycle. The maximum Hazard Category 3 threshold ratio was 0.37 on 11/25/01. Combined with the "old" target inventory as previously evaluated, the maximum threshold ratio was 0.98. The "old" target was removed during the 2002 outage, and going into the 2002 run cycle, the Hazard Category 3 threshold ratio for the "new" target is less than ten percent. Integrated beam current limits were determined for continued irradiation of the target. Assuming that a maximum beam current of 5 μA is established, the integrated beam current limit is 25,088 μA-hours. Selection of a higher maximum beam current will require a lower integrated beam current limit. Limits were evaluated for maximum beam currents up to 10 μA.

V. References

1. "Justification for Continued Operation for Los Alamos Neutron Science Center (LANSCE) Weapons Neutron Research (WNR) Facility – Target 4," Revision 0, August 30, 2001.
2. J. S. Bull, "WNR Target 4 Radionuclide Inventory Calculation, June 2001 – September 2001," CN-LANSCEFM-01-004.
3. "WNR Target-4 Nuclide Inventory Control," LANSCE-3-ROP-20, June 29, 2001.

Appendix A: MCNPX Input for Spallation Product and Flux Calculations

```
Target 4 Inventory Calculation
1  1 -19.3 -1 2 -3 $ active target
2  2 -1.00 1 -4 2 -3 $ active target cooling water
3  3 -7.92 4 -5 2 -3 $ steel jacket on active target
4  1 -19.3 -24 2 -3 $ stored target
5  0       24 -25 2 -3 $ stored target void cooling water region
6  3 -7.92 25 -26 2 -3 $ steel jacket on stored target
7  0       (26:-2:3) (5:-2:3) 6 -7 8 -9 10 -11 $ void space in target cell
8  4 -7.87 (-6:7:-8:9:-10:11) 12 -13 14 -15 16 -17 $ steel shld around target
9  5 -4.00 (-12:13:-14:15:-16:17) -27 $ steel concrete mix around steel shld
10 5 -4.00 27 18 -19 20 -21 22 -23 $ more of concrete mix in target cube
11 0       -18:19:-20:21:-22:23 $ external void
999 0 -999 u=1 $ ccc

1  cx  1.4986
2  px  0
3  px  7.493
4  cx  1.5748
5  cx  1.7335
6  px  -91.44
7  px  91.44
8  py  -60.96
9  py  60.96
10 pz  -60.96
11 pz  60.96
12 px  -121.92
13 px  274.32
14 py  -91.44
15 py  91.44
16 pz  -91.44
17 pz  91.44
18 px  -609.6
19 px  609.6
20 py  -609.6
21 py  609.6
22 pz  -609.6
23 pz  609.6
24 c/x -30.48 0 1.4986
25 c/x -30.48 0 1.5748
26 c/x -30.48 0 1.7335
27 so 400
999 sq 25 100 0 0 0 0 -4 0 0 0

m1 74182.24 0.2652984 &
   74183.24 0.1433120 &
   74184.24 0.3067881 &
   74186.24 0.2846015
m2  1001.24 0.1118262 &
    1002.24 0.0000168 &
    8016.24 0.8881570
mt2 lwtr.02 hwtr.02
m3 26054.24 0.0402636 &
   26056.24 0.6314840 &
   26057.24 0.0145912 &
   26058.60 0.0019271 &
   24050.24 0.0087908 &
   24052.24 0.1693288 &
   24053.24 0.0191983 &
   24054.24 0.0047693 &
   28058.24 0.0609410 &
   28060.24 0.0234705 &
   28061.24 0.0010205 &
   28062.24 0.0032494 &
```

```
   28064.24 0.0008325 &
   25055.60 0.0201332
m4 26054.24 0.0585000 &
   26056.24 0.9175000 &
   26057.24 0.0212000 &
   26058.60 0.0028000
m5  1001.24 0.0069990 &
    1002.24 0.0000011 &
    6000.24 0.0009000 &
    8016.24 0.2109000 &
   11023.60 0.0045000 &
   12000.60 0.0009000 &
   13027.24 0.0120000 &
   14028.24 0.0967493 &
   14029.24 0.0048988 &
   14030.24 0.0032519 &
   16000.60 0.0006000 &
   19000.60 0.0030000 &
   20000.60 0.0428000 &
   26054.24 0.0358313 &
   26056.24 0.5619688 &
   26057.24 0.0129850 &
   26058.60 0.0017150
mode n h / d t s a
imp:n,h,/,d,t,s,a 1 6r .25 .0625 .015625 0 1
sdef par 9 erg 800 wgt 6.242+12 dir 1 vec 0 0 1 x d1 y d2 z 0 ccc 999 tr 1
sp1 -41 .470964 0
sp2 -41 .2358482 0
tr1 -2 0 0 0 1 0 0 0 1 1 0 0
phys:h 810 j 0
phys:n 810 3j 25
f4:n 1
e4 1.-11 5.-9 1.-8 1.5-8 2.-8 2.5-8 3.-8 3.5-8 4.2-8 5.-8 5.8-8 6.7-8 &
   8.-8 1.-7 1.52-7 2.51-7 4.14-7 6.83-7 1.125-6 1.855-6 3.059-6 5.043-6 &
   8.315-6 1.371-5 2.26-5 3.727-5 6.144-5 1.013-4 1.67-4 2.754-4 4.54-4 &
   7.485-4 1.234-3 2.035-3 2.404-3 2.840-3 3.355-3 5.531-3 9.119-3 1.503-2 &
   1.989-2 2.554-2 4.087-2 6.738-2 1.111-1 1.832-1 3.02-1 3.887-1 4.979-1 &
   6.39279-1 8.2085-1 1.10803+0 1.35335+0 1.73774+0 2.2313+0 2.86505+0 &
   3.67879+0 4.96585+0 6.065+0 1.+1 1.49182+1 1.69046+1 2.+1 2.5+1
histp 1
prdmp j -180
nps 4+6
```

Appendix B: CINDER90 Input for Inventory Calculations from 6/30/01 to 9/17/01

```
WNR Target 4 Radionuclide Inventory
5.28661E+01,1.,1.E-4,1.E-10,,,,,,,2,-1,2,1/
New Target
For TQ3 ratios and integrated beam current limit from 6-30-01 to 9-17-01
 Calculated with CINDER'90 (c98f) and 1998 Library (LibB2-Q) of 3400 Nuclides
cell  1
m1
1 0.497
     1 'd'
1 0.754
     1 'd'
1 0.737
     1 'd'
1 0.754
     1 'd'
1 0.794
     1 'd'
1 0.549
     1 'd'
1 0.775
     1 'd'
1 0.766
     1 'd'
1 0.706
     1 'd'
1 0.037
     1 'd'
1 0.006
     1 'd'
1 0.006
     1 'd'
1 0.006
     1 'd'
1 0.006
     1 'd'
1 0.011
     1 'd'
1 0.012
     1 'd'
1 0.010
     1 'd'
1 0.009
     1 'd'
1 0.014
     1 'd'
1 0.011
     1 'd'
1 0.011
     1 'd'
1 0.009
     1 'd'
1 0.009
     1 'd'
1 0.007
     1 'd'
1 0.007
     1 'd'
1 0.010
     1 'd'
1 0.008
     1 'd'
1 0.015
     1 'd'
```

```
1 0.013
     1 'd'
1 0.015
     1 'd'
1 0.010
     1 'd'
1 0.014
     1 'd'
1 0.015
     1 'd'
1 0.014
     1 'd'
1 0.010
     1 'd'
1 0.013
     1 'd'
1 0.030
     1 'd'
1 0.004
     1 'd'
1 0.004
     1 'd'
1 0.006
     1 'd'
1 0.004
     1 'd'
1 0.049
     1 'd'
1 0.615
     1 'd'
1 1.727
     1 'd'
1 2.117
     1 'd'
1 2.138
     1 'd'
1 2.059
     1 'd'
1 1.785
     1 'd'
1 2.161
     1 'd'
1 1.745
     1 'd'
1 1.355
     1 'd'
1 0.174
     1 'd'
1 0.194
     1 'd'
1 0.229
     1 'd'
1 0.233
     1 'd'
1 0.212
     1 'd'
1 1.772
     1 'd'
1 1.818
     1 'd'
1 1.903
     1 'd'
1 1.851
     1 'd'
1 1.692
```

```
      1 'd'
1 1.797
      1 'd'
1 1.712
      1 'd'
1 1.216
      1 'd'
1 1.858
      1 'd'
1 0.004
      1 'd'
1 0.001
      1 'd'
1 0.007
      1 'd'
1 0.004
      1 'd'
1 0.307
      1 'd'
1 1.848
      1 'd'
1 1.869
      1 'd'
1 1.841
      1 'd'
1 0.462
      1 'd'
1 1.550
      1 'd'
1 2.070
      1 'd'
1 2.024
      1 'd'
1 1.811
      1 'd'
1 1.292
      1 'd'
```

Appendix C: CINDER90 Input for Inventory Calculations from 9/18/01 to 6/18/02

```
WNR Target 4 Radionuclide Inventory
5.28661E+01,1.,1.E-4,1.E-10,,,,,,,2,79,2,1/
New Target
For TQ3 ratios and integrated beam current limit from 9-18-01 to 6-18-02
 Calculated with CINDER'90 (c98f) and 1998 Library (LibB2-Q) of 3400 Nuclides
cell  1
m1
1 0.009
     1 'd'
1 0.009
     1 'd'
1 0.009
     1 'd'
1 0.363
     1 'd'
1 2.014
     1 'd'
1 2.144
     1 'd'
1 2.207
     1 'd'
1 2.181
     1 'd'
1 2.187
     1 'd'
1 4.183
     1 'd'
1 4.234
     1 'd'
1 4.315
     1 'd'
1 4.294
     1 'd'
1 3.708
     1 'd'
1 0.003
     1 'd'
1 0.003
     1 'd'
1 0.007
     1 'd'
1 0.481
     1 'd'
1 0.056
     1 'd'
1 2.817
     1 'd'
1 4.129
     1 'd'
1 2.174
     1 'd'
1 4.362
     1 'd'
1 4.238
     1 'd'
1 4.312
     1 'd'
1 4.345
     1 'd'
1 4.301
     1 'd'
1 3.463
     1 'd'
```

```
1 0.006
     1 'd'
1 0.008
     1 'd'
1 0.597
     1 'd'
1 1.456
     1 'd'
1 3.620
     1 'd'
1 4.228
     1 'd'
1 4.388
     1 'd'
1 4.173
     1 'd'
1 3.734
     1 'd'
1 3.021
     1 'd'
1 4.670
     1 'd'
1 4.562
     1 'd'
1 3.573
     1 'd'
1 4.458
     1 'd'
1 0.002
     1 'd'
1 0.057
     1 'd'
1 0.074
     1 'd'
1 0.023
     1 'd'
1 1.581
     1 'd'
1 4.221
     1 'd'
1 4.378
     1 'd'
1 4.307
     1 'd'
1 3.985
     1 'd'
1 4.451
     1 'd'
1 4.500
     1 'd'
1 3.944
     1 'd'
1 4.183
     1 'd'
1 2.862
     1 'd'
1 0.002
     1 'd'
1 0.008
     1 'd'
1 0.005
     1 'd'
1 0.686
     1 'd'
1 1.715
```

```
      1 'd'
1 4.471
      1 'd'
1 4.589
      1 'd'
1 4.022
      1 'd'
1 4.527
      1 'd'
1 4.019
      1 'd'
1 4.529
      1 'd'
1 4.551
      1 'd'
1 4.368
      1 'd'
1 3.952
      1 'd'
1 0.003
      1 'd'
1 0.003
      1 'd'
1 0.003
      1 'd'
1 0.006
      1 'd'
1 0.007
      1 'd'
1 0.011
      1 'd'
1 0.023
      1 'd'
1 0.029
      1 'd'
1 0.254
      1 'd'
1 0.455
      1 'd'
1 0.461
      1 'd'
1 1.421
      1 'd'
1 0.439
      1 'd'
1 0.361
      1 'd'
1 0.008
      1 'd'
1 0.007
      1 'd'
1 0.007
      1 'd'
1 0.278
      1 'd'
1 0.585
      1 'd'
1 0.757
      1 'd'
1 0.883
      1 'd'
1 0.005
      1 'd'
1 0.005
      1 'd'
```

```
1 0.008
     1 'd'
1 0.007
     1 'd'
1 0.009
     1 'd'
1 0.006
     1 'd'
1 0.008
     1 'd'
1 0.0
     1 'd'
1 0.0
     3 'd'
1 0.0
     9 'd'
1 0.0
     27 'd'
1 0.0
     81 'd'
1 0.0
     55 'd'
```

Appendix D: CINDER90 Input for Inventory Calculations for 2002 Run Cycle

```
WNR Target 4 Radionuclide Inventory
5.28661E+01,1.,1.E-4,1.E-10,,,,,,,2,104,2,1/
New Target
For TQ3 ratios and integrated beam current limit from 6-19-02 to 1-25-05
 Calculated with CINDER'90 (c98f) and 1998 Library (LibB2-Q) of 3400 Nuclides
cell  1
m1
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
1 5.000
     3 'd'
```

```
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
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      3 'd'
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      3 'd'
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      3 'd'
1 5.000
      3 'd'
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      3 'd'
1 5.000
      3 'd'
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      3 'd'
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      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
```

```
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
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      3 'd'
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      3 'd'
1 5.000
      3 'd'
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      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
1 5.000
      3 'd'
```