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SECOND REPORT OF WORK CARRIED OUT
BY THE INSTITUTE FOR NUCLEAR RESEARCH
FOR LOS ALAMOS NATIONAL LABORATORY
UNDER AGREEMENT 2493N000-35
2/23/96

This report provides information about work carried out to complete the tasks required of the Institute for Nuclear Research (INR) of the Russian Academy of Sciences in accordance with Agreement 2493N0005-35 with Los Alamos National Laboratory. This report details work carried out for the following parts of the agreement under Task Order 002:

c) The INR shall measure the ^{51}Cr source activity to an accuracy of at least 5% by measuring the amount of ^{51}Cr activity remaining in each of the irradiated enriched ^{50}Cr rods used in the Cr calibration experiment. This shall be done by direct counting using a high resolution Ge solid state detector.

d) The INR shall measure the level of any residual radioimpurities in the ^{51}Cr source by direct counting each of the rods of the ^{51}Cr source using a high resolution Ge solid state detector.

The following sections of this report shall constitute the following deliverables:

3.3. A report describing the procedures used to measure the amount of residual ^{51}Cr in the irradiated ^{50}Cr rods, along with the value of the ^{51}Cr source intensity determined using this method.

3.4. A list of the long-lived radioimpurities and their intensities in the irradiated ^{50}Cr rods.

A. Description of the procedures used to measure the amount of residual ^{51}Cr in the irradiated ^{50}Cr rods, along with the value of the ^{51}Cr source intensity determined using this method.

1) ^{51}Cr source was delivered to the hot chamber of the reactor BN-350 facility where it was disclosed using a remote handling system, and 44 irradiated ^{50}Cr rods were pulled out and weighed. The results of weighing are presented in the Table 1.

2) In the hot chamber there was installed a semiconductor Ge(Li) detector with a necessary equipment for measurements of a relative intensity of each rod. The intensity of each rod has been measured in its three points. The results of these measurements are presented in Table 2. Several rods, the unevenness of intensity distribution of which differed significantly from the average, were measured in 12 points. The results of measurements are presented in Figure 1 and Figure 2.

3) To determine its absolute intensity there was chosen a Cr rod No.7. To carry out the measurement it was completely dissolved in hydrochloric acid.

4) From the solution obtained there were selected samples and its absolute intensity was measured in a liquid as well in a drain state. The results of measurements are presented in Tables 3 and 4.

5) Results of measurements.

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Table 1.

Results of weighing of Cr rods.

No of rod case	weight of rod case (g)			weight of rod case with Cr (g)			weight of Cr rod (g)
	the first weighing	the second weighing	average	the first weighing	the second weighing	average	
01	18.224	18.223	18.224	29.780	29.781	29.781	11.557
02	18.000	18.000	18.000	29.752	29.751	29.752	11.752
03	17.676	17.698	17.687	29.555	29.551	29.553	11.866
04	19.024	19.023	19.024	30.713	30.715	30.714	11.690
05	18.242	18.241	18.242	30.046	30.043	30.045	11.803
06	18.153	18.153	18.153	29.906	29.903	29.905	11.752
07	18.517	18.517	18.517	30.353	30.350	30.352	11.835
08	18.357	18.357	18.357	30.003	30.003	30.003	11.646
09	17.873	17.872	17.873	29.362	29.360	29.361	11.488
10	17.785	17.784	17.785	29.514	29.515	29.515	11.730
11	18.503	18.499	18.501	30.159	30.156	30.158	11.657
12	17.741	17.740	17.741	29.507	29.506	29.507	11.766
13	17.893	17.892	17.893	29.607	29.610	29.609	11.716
14	18.732	18.730	18.731	30.393	30.389	30.391	11.660
15	18.189	18.187	18.188	29.879	29.880	29.880	11.692
16	18.035	18.033	18.034	29.419	29.421	29.420	11.386
17	17.639	17.637	17.638	29.370	29.370	29.370	11.732
18	17.856	17.850	17.853	29.507	29.508	29.508	11.655
19	17.636	17.636	17.636	29.348	29.349	29.349	11.713
20	17.988	17.992	17.990	29.569	29.568	29.569	11.579
21	17.856	17.851	17.853	29.512	29.514	29.513	11.660
22	17.992	17.984	17.988	29.542	29.544	29.543	11.555
23	17.921	17.920	17.921	29.720	29.722	29.721	11.800
24	19.774	19.775	19.775	31.488	31.496	31.492	11.717
25	17.528	17.524	17.526	29.198	29.197	29.198	11.672
26	18.212	18.210	18.211	29.881	29.878	29.880	11.669
27	18.216	18.215	18.216	29.988	29.987	29.988	11.772
28	17.878	17.876	17.877	29.661	29.662	29.662	11.785
29	18.158	18.161	18.089	29.727	29.730	29.729	11.640
30	18.198	18.186	18.192	29.888	29.886	29.887	11.695
31	17.616	17.609	17.612	29.238	29.238	29.238	11.626
32	18.356	18.356	18.356	30.005	30.003	30.004	11.648
33	18.478	18.472	18.475	30.165	30.163	30.164	11.689
34	18.216	18.210	18.213	30.009	30.006	30.008	11.795
35	17.784	17.783	17.784	29.585	29.584	29.585	11.801
36	17.559	17.556	17.557	29.409	29.408	29.409	11.852
37	18.553	18.552	18.553	30.242	30.240	30.241	11.688
38	18.252	18.251	18.252	29.848	29.849	29.849	11.597
39	17.479	17.473	17.476	29.111	29.110	29.111	11.635
40	17.776	17.775	17.776	29.324	29.323	29.324	11.548
41	17.584	17.582	17.583	29.375	29.374	29.375	11.792
42	17.972	17.983	17.976	29.722	29.720	29.721	11.745
43	18.800	18.801	18.801	30.529	30.529	30.529	11.728
44	19.497	19.501	19.499	31.010	31.009	31.010	11.511

Table 2.

Results of measurements of a relative intensity of Cr rods

No. of	Point of measurement			average +/-disp.
rod		1	2 3	
1	0.874±1.6%	0.893±2.9%	0.905±1.9%	0.891±1.3 %
2	0.655±1.9%	0.671±3.3%	0.694±2.1%	0.673±1.4 %
3	0.915±1.5%	0.899±2.4%	0.859±2.7%	0.891±1.3 %
4	0.501±1.7%	0.481±2.8%	0.469±2.3%	0.484±1.3 %
5	0.954±1.4%	0.965±2.7%	0.994±1.6%	0.971±1.1 %
6	0.949±2.1%	0.955±2.6%	0.942±3.4%	0.949±1.6 %
7	0.982±2.3%	0.998±2.3%	1.008±1.8%	0.996±1.2 %
8	0.968±1.5%	0.989±2.7%	0.976±3.6%	0.978±1.6 %
9	0.914±2.0%	0.913±3.2%	0.912±2.4%	0.913±1.5 %
10	0.569±2.2%	0.599±2.2%	0.607±1.6%	0.592±1.2 %
11	0.990±4.0%	0.965±2.0%	0.963±2.5%	0.973±1.7 %
12	0.600±2.6%	0.613±3.6%	0.642±1.2%	0.618±1.5 %
13	0.647±3.2%	0.611±1.4%	0.584±2.5%	0.614±1.4 %
14	0.260±2.7%	0.401±3.7%	0.668±3.3%	0.443±1.9 %
15	0.879±1.7%	0.859±2.0%	0.889±1.3%	0.876±1.0 %
16	0.658±2.9%	0.633±2.6%	0.604±0.5%	0.632±1.3 %
17	0.818±1.3%	0.834±3.3%	0.850±2.1%	0.834±1.4 %
18	0.832±1.8%	0.809±2.7%	0.805±2.2%	0.815±1.3 %
19	0.520±3.0%	0.540±1.9%	0.564±2.4%	0.541±1.4 %
20	0.796±1.9%	0.817±2.5%	0.847±1.2%	0.820±1.1 %
21	0.498±2.4%	0.467±1.8%	0.472±3.6%	0.479±1.6 %
22	0.709±2.3%	0.723±2.1%	0.746±3.2%	0.726±1.5 %
23	0.973±2.4%	0.997±2.8%	0.970±2.5%	0.980±1.5 %
24	0.952±2.2%	0.977±1.6%	0.978±2.6%	0.969±1.3 %
25	0.861±2.5%	0.870±2.3%	0.833±2.0%	0.855±1.3 %
26	0.084±6.2%	0.081±0.8%	0.103±1.8%	0.089±2.2 %
27	0.731±2.0%	0.759±2.8%	0.770±2.5%	0.753±1.4 %

28	1.000±0.0%	1.000±0.0%	1.000±0.0%	1.000±0.0 %
29	0.929±3.9%	0.959±1.5%	0.962±1.4%	0.950±1.5 %
30	0.667±1.1%	0.687±1.6%	0.714±0.7%	0.689±0.7 %
31	0.503±1.7%	0.514±2.4%	0.540±0.8%	0.519±1.0 %
32	0.430±0.6%	0.412±3.8%	0.402±0.7%	0.415±1.3 %
33	0.954±3.2%	0.941±3.1%	0.972±2.7%	0.956±1.7 %
34	0.750±3.6%	0.780±4.7%	0.789±2.5%	0.773±2.1 %
35	0.738±2.2%	0.726±4.1%	0.694±3.1%	0.719±1.9 %
36	0.712±3.2%	0.705±2.8%	0.671±2.9%	0.696±1.7 %
37	0.527±1.8%	0.566±3.2%	0.591±4.7%	0.561±2.0 %
38	0.427±1.5%	0.271±4.0%	0.237±1.8%	0.312±1.5 %
39	0.926±1.5%	0.912±1.0%	0.902±1.9%	0.913±0.9 %
40	0.868±1.4%	0.886±1.5%	0.894±1.5%	0.883±0.8 %
41	0.705±1.9%	0.792±2.2%	0.835±2.0%	0.777±1.2 %
42	0.979±2.0%	0.997±0.5%	0.984±3.4%	0.983±1.5 %
43	0.866±3.9%	0.856±1.7%	0.842±2.6%	0.851±2.0 %
44	0.819±1.5%	0.797±1.7%	0.762±2.7%	0.789±1.6 %
sum	32.89±0.5%	33.12±0.3%	33.40±0.7%	33.14±0.3 %

Table 3.
Results of measurements of liquid samples.

No of samp.	Date of preparation	Number of measur.	Result 01.10.95	Relative result	Part of solution
2	31.10.95	7	647 ± 0.9%	0.99	upper
3	31.10.95	16	651 ± 1.1%	1.00	upper
7	31.10.95	18	630 ± 1.3%	0.97	lower
11	31.10.95	7	635 ± 1.0%	0.98	lower
12	01.11.95	6	618 ± 0.5%	0.95	
13	01.11.95	6	612 ± 0.9%	0.94	
14	02.11.95	5	596 ± 1.0%	0.92	upper
15	02.11.95	5	626 ± 0.8%	0.96	upper
16	02.11.95	5	614 ± 0.8%	0.94	lower
17	02.11.95	8	603 ± 1.5%	0.93	lower

Figure 1. Results of measurements of rods No. 14, and No. 38

Figure 2. Results of measurements of Cr rods No. 26, and No. 28.

Figure 3. The spectrum of pulses from gamma-rays in rod No.8

Figure 4. The spectrum of pulses from background gamma-rays.

Figure 5. The spectrum of pulses from gamma-rays in rod No.28

Figure 6. The spectrum of pulses from gamma-rays in rod No.26.

Table 4.

Results of measurements of drain samples.

No of samp.	Date of preparation	Number of measur.	Result 01.10.95	Relative result Γ	Part of sample
31	31.10.95	4	$671 \pm 0.8\%$	1.00	upper
32	31.10.95	12	$655 \pm 1.5\%$	0.98	upper
33	31.10.95	17	$674 \pm 1.2\%$	1.00	upper
34	31.10.95	17	$659 \pm 1.0\%$	0.98	lower
35	31.10.95	6	$673 \pm 1.1\%$	1.00	lower
37	31.10.95	6	$667 \pm 0.8\%$	0.99	lower
38	01.11.95	5	$623 \pm 0.8\%$	0.93	
39	01.11.95	5	$639 \pm 1.0\%$	0.95	
40	01.11.95	5	$621 \pm 0.3\%$	0.93	
42	02.11.95	6	$625 \pm 0.6\%$	0.93	upper
43	02.11.95	6	$647 \pm 0.9\%$	0.96	upper
44	02.11.95	6	$618 \pm 0.9\%$	0.92	lower

6) Analysis of results

Measurements presented let determine the ^{51}Cr source activity. On October 1, 1995 (the date fixed for all results in the analysis) it was:

$$A = 476 \pm 17 \text{ Ci (October 1, 1995)}$$

Recalculation for the date of arrival of the ^{51}Cr source in the Baksan Neutrino Observatory gives:

$$A = 510 \pm 18 \text{ KCi (December 26, 1994)}$$

The resulting uncertainty of measurements was received using the following partial uncertainties: the uncertainty of a relative summary source activity - 0.3%; the uncertainty of a relative intensity of the rod No.7 (attitude towards monitor) - 1.2%; the uncertainty of the absolute intensity of the rod No.7 - 3.4%.

But we call this estimation of the uncertainty of 3.6% the "optimistic" one, as it was calculated without results of measurements of samples on November 1 and 2, 1995 because of a systematical error attributed to them (unstable solution). As at the moment it is though a likely one but a hypothesis,

another estimation, a "pessimistic" one, has the right for existence. It includes a scattering in the intensity of samples prepared on October 10, 1995, November 1 and November 2, 1995. This scattering is at the level of 3%, so a "pessimistic" evaluation of the uncertainty is 4.7%. At the moment we consider this estimation to be the most proved one. Therefore the final result of our measurements gives the value of the ^{51}Cr source intensity

$$A = 510 \pm 24 \text{ (4.7\%)} \text{ kCi (at 18:00 on December 26, 1994).}$$

B. A list of the long-lived radioimpurities and their intensities in the irradiated ^{50}Cr rods.

To determine the long-lived radioimpurities in the ^{51}Cr source there were carried out many hour's measurements of spectra in rods No.8, 26, 28, and measurements of a background. The spectra are presented in Figures 3, 4, 5, 6.

From these measurements the intensity of radioimpurities in the attitude toward the ^{51}Cr activity is:

Isotope/rod No.	28	26	8
Sc-46	$3.1 \cdot 10^{-4}$	-	-
Co-60	$4.6 \cdot 10^{-4}$	$2.2 \cdot 10^{-3}$	$9.2 \cdot 10^{-4}$

C. Level of Effort Expended

As agreed to under the terms of Agreement 2493N0005-35, the level of effort expended by the INR is carrying out Task Order 002 to date is follows:

c) A total of 24 man-months of effort were expended by the INR in completing part c) of the Task Order: The INR shall prepare a report describing the procedures used to measure the amount of residual ^{51}Cr in the irradiated ^{50}Cr rods, along with the value of the ^{51}Cr source intensity determined using this method.

d) A total of 7 man-months of effort were expended by the INR in completing part d) of the Task Order: The INR shall measure the long-lived radioimpurities and their intensities in the irradiated ^{50}Cr rods.

Thus, the total level of effort expended in completing parts c), d) of Task Order 002 is 31 man-months of effort. At the agreed-upon standard rate \$400 per month of effort, this [art of the work completed under task Order 002 comes to a total of \$12,400.00.

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