UKAEA FUS 390

UKAEA Fusion
(UKAEA/Euratom Fusion Association)

Experimental Validation of the Decay Power Calculation Code and Nuclear Databases - FISPACT-97 and EAF-97 & FENDL/A-2.0

J-Ch Sublet

January 1998

UKAEA
Fusion

Culham Science Centre, Abingdon
Oxfordshire, OX14 3DB
United Kingdom
Telephone +44 1235 463492
Facsimile +44 1235 463435

Abstract

The calculation of activation inventories is a key input to virtually all aspects of the safety and environmental assessment of fusion power devices, such as ITER. For the licensing of such devices, regulatory authorities will require proof that the calculations of activation, and calculations to which activation quantities are inputs, are either correct or conservative. An important aspect of activation is decay heat power.

In fusion power plants, decay power arises after shutdown from the energy released in the decay of the products of neutron activation, mainly from gamma and beta rays. Computation of the decay power is performed by sophisticated computer codes which solve the large number of coupled differential equations which govern the generation and decay chains for the many nuclides involved. They rely on a large volume of nuclear data, both neutron activation cross-sections and radioactive decay data.

Validation of decay power code predictions by means of direct comparison with integral data measurements of sample structural materials under fusion-typical neutron spectra generates confidence in the decay power values calculated. It also permits an assessment of the adequacy of the methods and nuclear data and indicates any inaccuracy or omission that may have led to erroneous results.

No experimental data on decay power existed for fusion reactor structural materials and irradiation conditions before a series of experiments were performed using the Fusion Neutron Source FNS facility at the Japan Atomic Energy Research Institute JAERI. Fusion relevant material samples were irradiated in a simulated D-T neutron field for times up to 7 hours and the decay power so generated measured for cooling times up to three months. Using the highly sensitive Whole Energy Absorption Spectrometer (WEAS) method, both β and γ rays decay energies were measured at selected cooling times as early as one minute after the irradiation ended. Coupled to the experiments, and at the request of ITER JCT, a validation exercise was launched.

Overall the results of this particular validation exercise indicate that the calculational methods and nuclear data bases, with some notable exceptions, generally allow predictions, with acceptable margins, of the decay power of the tested materials. This statement is only valid within the framework defined by the conditions of the experimental set-up in terms of materials, cooling times and neutron spectrum. The spectrum is very different from the spectra expected in next generation fusion devices, being very low in lower-energy neutrons: as a result, the reactions dominating the decay heat production in the FNS assembly, and validated in the experiment-calculational comparisons presented in this report, are often not the reactions predicted to dominate in the fusion power plant conditions.

Experimental Validation of the Decay Power Calculation Code FISPACT-97 and the Nuclear Data Bases EAF-97 & FENDL/A-2.0

1. INTRODUCTION

Safety and environmental (S&E) impact issues have acquired increasing importance for the development of fusion power. As part of the fusion programme and especially in connection with engineering feasibility studies, S&E and R&D analyses require a sound and reliable data base for the neutron-induced primary and secondary responses. The words primary and secondary define two very different types of response: the former relates to neutronic and gamma-ray time independent responses when the plant is in operation, while the latter refers to time dependent responses which are important after shutdown. In fusion power plants, decay heat will arise after plasma shutdown from the energy released in the decay of the products of neutron activation.

The calculation of activation inventories is an important input to virtually all aspects of S&E analysis. For the licensing of ITER, the regulatory authorities will require proof of either the correctness or conservatism of the calculations of activation and of calculations which use activation as input. The radioactive inventory and residual decay power generation depend on the specific design of the tokamak and its components, its geometrical configuration and material choices, as well as the given irradiation conditions: fusion power, operational scenario, and neutron source distribution. It is essential to include in the plant development properly performed activation inventory calculations that are consistent with the overall plant design. An important aspect of activation is residual decay power. The residual decay power, in the event of a postulated accident in which cooling is lost, might induce structural damage in certain plant components. Temperature transients may promote hydrogen-generating chemical reactions and, in plant of higher power density than ITER, may promote the mobilisation of activation products.

There is thus a strong motivation to limit accidental temperature transients and to ensure that the design and material provide for removal of decay heat, preferably by passive means. Safety studies assess the efficiency of the design in this regard, by computer models which require as a starting point an accurate assessment of the decay heat levels in the plant. Computation of the decay power is performed by sophisticated computer codes which solve the large number of coupled differential equations which govern the generation and decay chains for the many nuclides involved. They rely on a large volume of nuclear data, both neutron activation cross-sections and radioactive decay data.

Validation of decay power code predictions by means of direct comparison with integral data measurements of sample structural materials under fusion-typical neutron spectra allow confidence to be given to the decay power values calculated. It also permits an assessment of the adequacy of the methods and nuclear data and indicates any inaccuracy or omission that may have led to erroneous code predictions. Safety authorities world-wide tend to request experimental validation results that can be used by them to assess the adequacy of the safety features. It is clear that certain safety margins can be derived from such a validation exercise, if relevant to plant operation, materials and design, and applied as bounding conditions in S&E analyses.

Little experimental data exists for material samples irradiated under prototypical fusion spectra and the quantities measured are either specific activity and/or γ spectroscopy. However, no experimental data on decay power previously existed for fusion plant structural materials and irradiation conditions. It is to fill that gap that a series of experiments were performed using the Fusion Neutron Source (FNS) facility at the Japan Atomic Energy Research Institute JAERI. Fusion relevant material samples were irradiated in a simulated D-T neutron field and the decay power so generated measured for cooling times of up to three months. Using the highly sensitive Whole Energy Absorption Spectrometer (WEAS) method, both β and γ rays decay energies were measured at selected cooling times and, quite impressively, as soon as one minute after the end of irradiation.

Coupled to the experiments, an international validation exercise was launched [1] at the request of, and under the auspices of, the ITER Joint Central Team Safety, Environmental and Health division, in which users of the principal activation and decay codes and data would perform calculations of decay heat for comparison with the measurements. This is the first time that such exercise has been attempted for decay power modelling in a fusion neutron environment.

2. EXPERIMENTAL SET-UP

2.1 FNS assembly

14 MeV neutrons are generated by a 2 mA deuteron beam impinging on a stationary tritium bearing titanium target. The total neutron flux at the sample location, for this experiment, is in the range of 1.0 10^{10} [$n.cm^{-2}.s^{-1}$], the same order of magnitude as in the first wall of the JET tokamak when operating with D-T plasma. As a point of reference an ITER first wall total flux is more in the region of 3.0 10^{14} [$n.cm^{-2}.s^{-1}$], four orders of magnitude higher, when pulsing with plasma of 1.5 GW of fusion power.

Thin samples, 25x25 mm^2 and typically 10 μm thick, have been used, either as metallic foil or powder sandwiched between tape. Use of a thin sample minimises the self-absorption of β rays emitted in the sample itself and allows their measurement. A total of 32 different materials have been used in this phase of the experiment.

The decay energy in each irradiated sample was measured in the Whole Energy Absorption Spectrometer (WEAS) which comprises two large bismuth-germanate BGO scintillators in a geometric arrangement which provides almost 100% detection efficiency for both β and γ-rays. Correction factors need to be applied for γ-ray efficiency and for β and electron energy loss in the sample itself (less than 15% generally) and other effects such as the decay heat due to the plastic tape for the powder sample. The overall experimental uncertainty totals between 6 to 10% in most cases, although it rises to higher levels at particular cooling time for certain samples. The WEAS provides high sensitivity, less than 1 pW, which is valuable for measurement of some nuclides with long half-lives. It also has a wide dynamic range: measurements of up to a few μW have been achieved in that experiment.

2.2 Irradiation conditions

Two batches of irradiation have been performed for all 32 samples in order to extract the maximum information possible from such experiments. First, a 5 minutes irradiation time period rapidly followed by a time dependent series of decay power measurements from one minute up to one hour cooling was used. Such prompt measurements are allowed by the use of a small sample rapidly transported from the irradiation zone to the measurement areas by means of pneumatic tubes. This particular batch of measurements allows very short half-lived nuclides to be detected and measured. Second, a 7 hours irradiation time period was repeated for all samples and then followed by a more relaxed time-dependent series of decay power measurement spanning from half a day up to 3 months cooling.

In the 5 minutes irradiation experiments, three different positions were used: positions 1, 2, 3; while only one sample position, 7, was used in the 7 hours irradiation period. Different neutron spectra, in the 175 Vitamin-J group structure, were calculated using the Monte Carlo code MCNP [2] with a geometrical configuration portraying the assembly layout, and are plotted in Figure 1. Slight spectral differences exist between position 1, 2 and 3; however the neutron flux profiles indicate a marked 14 MeV fusion peak and very few neutrons of energy lower than one MeV. The flux profile corresponding to position 7 is sufficiently shifted from the others to be treated separately. It is clear from both Figure 1 and the very poor standard deviation (typically greater than 20% [2]) calculated for all the groups with energy range below one keV, that no reaction rates can be well characterised in that energy range. This means that, due to a poor knowledge of the spectral data below 1 keV, if this energy range is important in the production pathways of a measured radionuclide, no clear conclusion could be drawn from the comparison.

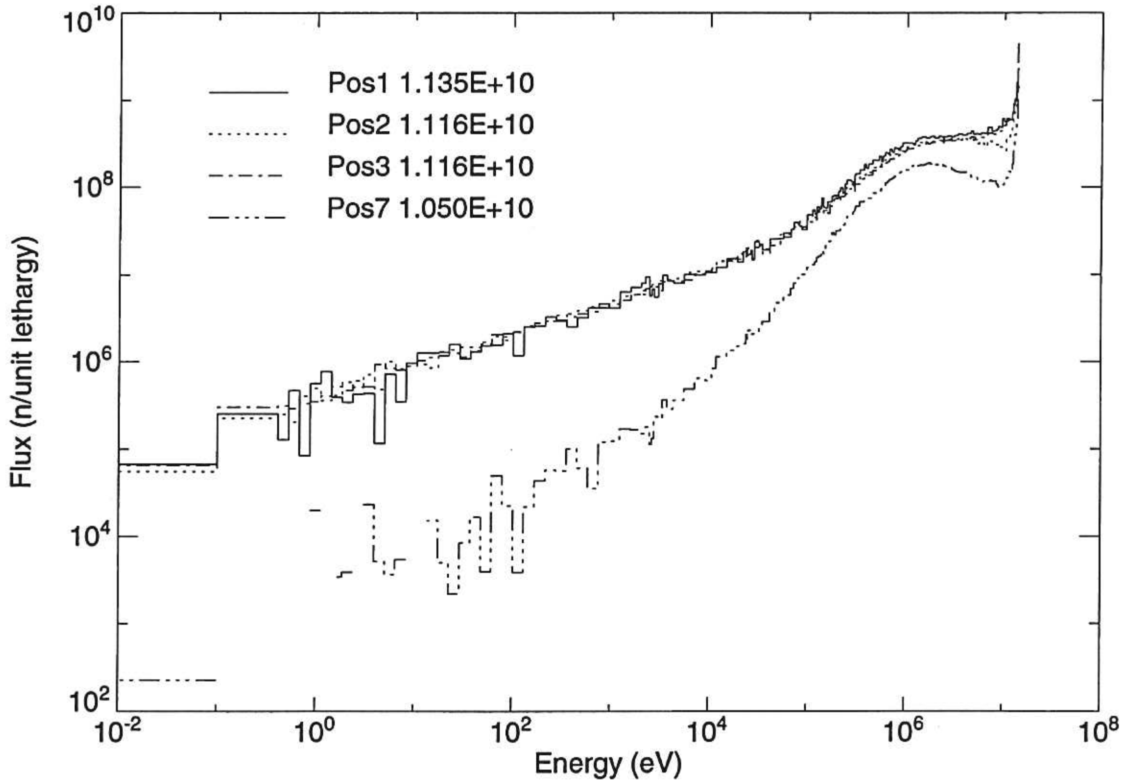


Figure 1 FNS neutron spectra showing total neutron flux at the four measurement areas.

2.3 Material data

For each material sample, the percentage elemental weight has been supplied by JAERI. These tend to correspond to the theoretical weight distribution calculated from the compound or material formulae for the major isotopes. No impurity levels have been given and so no isotopes other than the major ones have been used in the input data of the calculational scheme. The lack of real chemical analysis of the sample irradiated, although not thought to be important at the preparatory stage of this validation exercise, will be shown to be a drawback for certain materials that seem to have contained a specified (by the manufacturer), but un-quantified, amount of impurities. If those levels of impurities are not known then the code predictions cannot be accurate, and so the comparison will be inconclusive at times when impurities are proven to be important.

3. CODE AND LIBRARIES

The European Activation System, EASY-97 [3], has been used to perform this validation exercise. Two cross-section data bases have been accessed using the 97 version of the FISPACT code [4]: EAF-97 [5] and FENDL/A-2.0 [6]. The decay data libraries used with the two cross-sections libraries are different as well: the EAF-97 decay data and the FENDL/D-2.0 data. In chronological and quality terms EAF-97 is the more up to date nuclear data library. In order not to bias the experimental spectral data, the groupwise libraries used in the calculational scheme both correspond to a 175 Vitamin-J groups structure collapsed using a flat micro flux weighting function.

These calculations required the collapse of both nuclear data libraries for each flux at positions 1, 2, 3 and 7. The now well known FISPACT features that allow a determination of the dominant radionuclides, and pathways analysis of their formation, have been used and are reflected in the detailed comparison analysis.

Also for the first time the method used in EASY-97 to assess the calculational uncertainties from the unique data base EAF_UN_97 could be related to either the (C-E)/E results or the experimental uncertainties. This provides a unique opportunity to assess the adequacy of the uncertainty data that have been assembled from a wide variety of sources and their singular but unique treatment in the EASY-97 code system.

4. COMPARISON OF THE RESULTS

For each material sample and irradiation conditions, FISPACT-97 - EAF-97 & FENDL/A-2.0 calculations have been performed. Tabular and graphical comparisons of the results are presented. On the graphs FNS refers to the experimental measurements for which the uncertainties are plotted as well. Careful interpretation needs to be made from those graphs since they are in Log-Linear co-ordinates. Such plots allow a direct visual interpretation of nuclide half-life at times when one isotope is clearly dominant. A departure from parallelism overall would indicate a mismatch in term of half-life between measurement and calculation. A table gives more information, such as the calculational uncertainties, and allows a more precise interpretation of the comparison. This is followed by, for each irradiation experiment, the list of the dominant radionuclides that contribute at a level of more than 5% to the total decay power at all cooling times. Their half-life, and so the timescale at which they are predominant, is also printed. Their production pathways, extracted by FISPACT, are followed by the percentage contribution of each route, if more than one exists. All these quantities allow a judgement to be made on whether the experimental result is able to validate the calculational method for the production paths and decay data. The judgement is shown in the final column.

Careful consideration needs to be given when analysing such an experiment. The fact is that the measured quantities may, or may not, be directly related to the pathways of production of a particular radionuclide. There is only a strong possibility that, firstly the major radionuclides measured are the one predicted by the code, and secondly that their amount has been properly calculated before their respective decay power is derived from these quantities. Although improbable, one may envisage a 20% underprediction in terms of atomic amount of a nuclide, balanced by a 20% overprediction through the decay data scheme. This would lead to a perfect (C-E)/E value. Such possibilities of error compensation, though unlikely, may well exist at a certain level and so make the interpretation of the results difficult. However, such scenarios, if difficult to detect are made less probable when the experimental results are analysed by different activation codes, cross-section and decay data [1], and are used with other comparison methods such as C/E values for the cross-sections themselves.

The last entry field has then been determined to be:

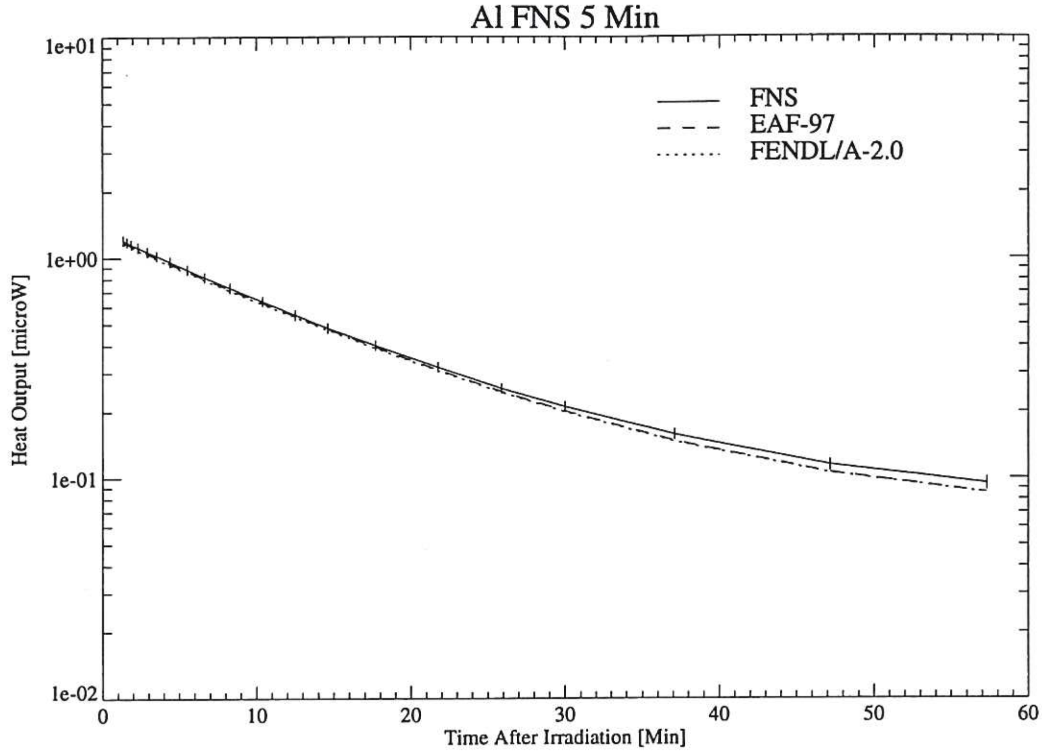
VAL : when the cross-sections and decay data have been validated. This flag highlights an excellent agreement (< 10%) and certifies the calculational model and the cross-section and decay data for a particular radionuclide.

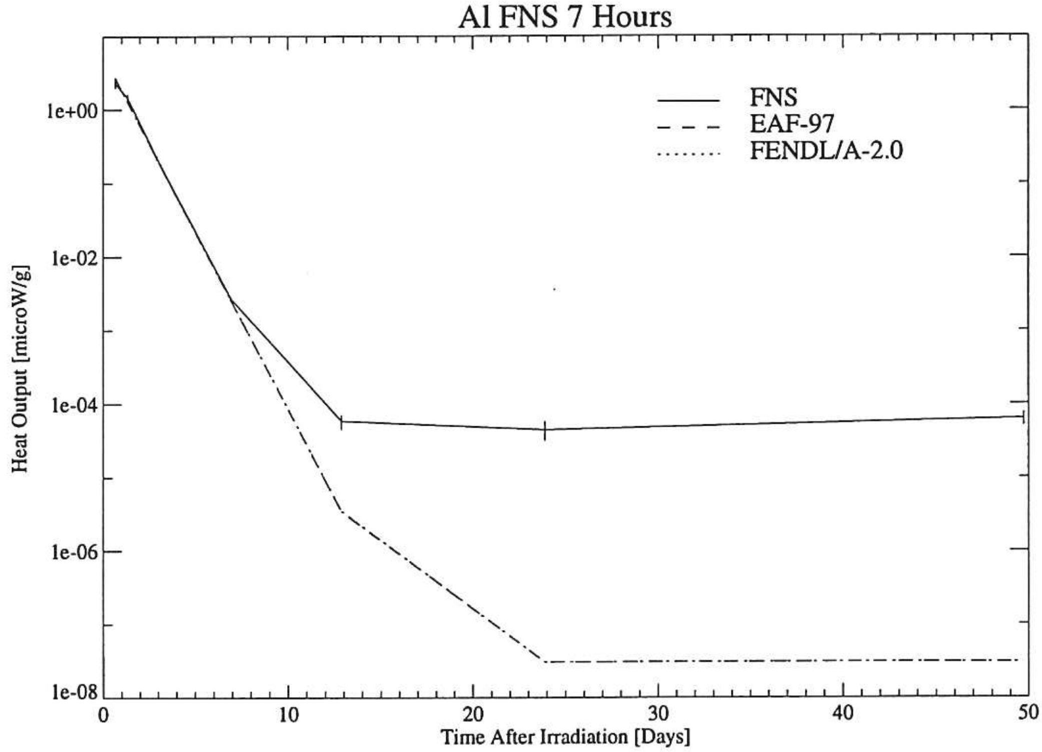
TBA : when the cross-sections and/or decay data need to be analysed with other sources of information in order to certify and correct appropriately the difference noticed in this validation exercise. The pathways of production involved will need to be compared with the EXFOR experimental data-base. The decay data need to be verified as well.

?? : when no clear conclusion could be drawn on these production pathways and radionuclides from this experiment.

Each of the following 32 materials samples are analysed in the method described above:

Al, B_4C, $BaCO_3$, Bi, CaO_3, CF_2, Co, Cr, Cu, Fe, Inc, K_2CO_3, Mn, Mo, Na_2CO_3, Nb, Ni, NiCr, Pb, Re, S, SiO_2, SnO_2, $SrCO_3$, SS-304, SS-316, Ta, Ti, V, W, Y_2O_3, Zr.





Excellent agreement, within the experimental uncertainty, is found for the Al decay power up to 7 days cooling time, where Mg-27, Na-24m and Na-24 isotopes are predominant. This is quite fortunate since the Al-27(n,a)Na-24 reaction is used as a fluence monitor. The divergence that appears after 10 days has been traced to Mn-54. This isotope cannot be produced from Al, but most likely arises from Fe-54 and Mn-55. The Al sample manufacturer quotes impurities levels for Mn and Fe of up to 1000 and 7000 ppm: these are more than enough to produce that amount of Mn-54. This is unfortunate since the Al-26 production cannot be well determined with such an overshadowing amount of Mn-54.

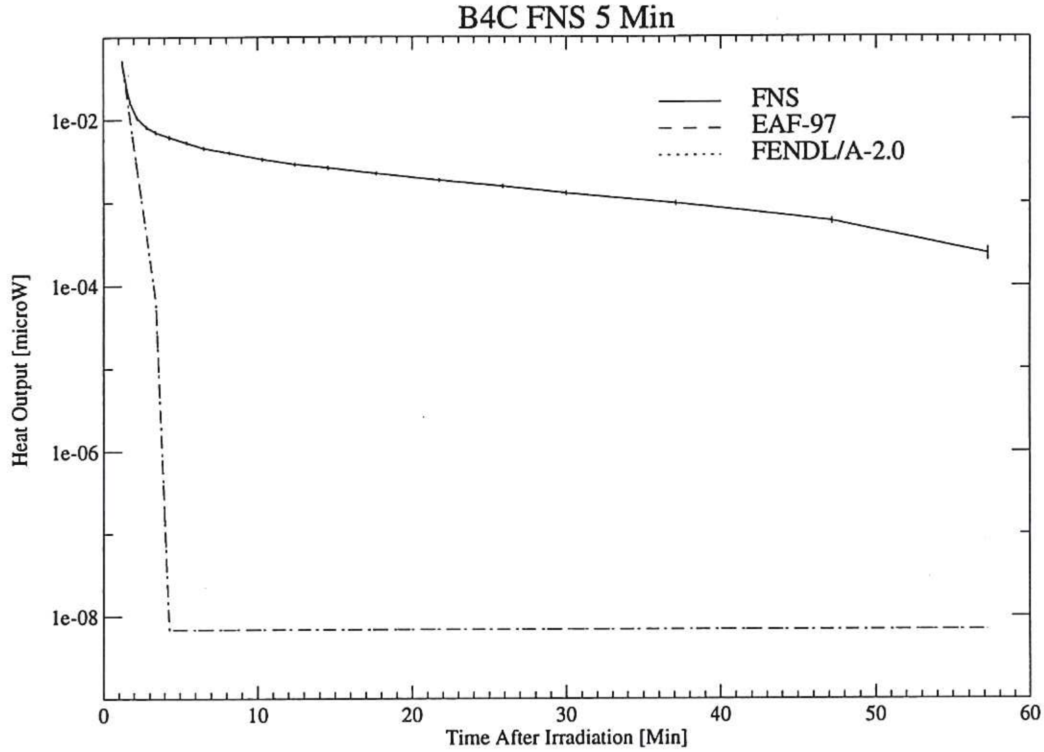
Times Min.	FNS EXP. 5 Min. microW/g	EAF-97 microW/g	(C-E)/E	FENDL/A-2 microW/g	(C-E)/E
1.35	1.20E+00+/- 5%	1.18E+00+/- 22%	-1%	1.16E+00	-3%
1.60	1.18E+00+/- 5%	1.16E+00+/- 22%	-2%	1.14E+00	-3%
1.87	1.15E+00+/- 5%	1.13E+00+/- 22%	-1%	1.12E+00	-2%
2.32	1.12E+00+/- 5%	1.10E+00+/- 22%	-1%	1.08E+00	-3%
2.93	1.07E+00+/- 5%	1.05E+00+/- 22%	-1%	1.03E+00	-3%
3.55	1.02E+00+/- 5%	1.00E+00+/- 22%	-2%	9.88E-01	-3%
4.42	9.60E-01+/- 5%	9.40E-01+/- 21%	-2%	9.28E-01	-3%
5.53	8.85E-01+/- 5%	8.69E-01+/- 21%	-1%	8.57E-01	-3%
6.65	8.16E-01+/- 5%	8.04E-01+/- 21%	-1%	7.93E-01	-2%
8.28	7.32E-01+/- 5%	7.19E-01+/- 21%	-1%	7.10E-01	-2%
10.40	6.35E-01+/- 5%	6.24E-01+/- 21%	-1%	6.16E-01	-2%
12.52	5.51E-01+/- 5%	5.44E-01+/- 20%	-1%	5.37E-01	-2%
14.63	4.80E-01+/- 5%	4.75E-01+/- 20%	-1%	4.70E-01	-2%
17.72	4.00E-01+/- 5%	3.93E-01+/- 19%	-1%	3.88E-01	-2%
21.78	3.18E-01+/- 5%	3.09E-01+/- 18%	-2%	3.06E-01	-3%
25.90	2.54E-01+/- 5%	2.47E-01+/- 17%	-2%	2.44E-01	-3%
30.02	2.10E-01+/- 5%	2.00E-01+/- 15%	-4%	1.99E-01	-5%
37.10	1.57E-01+/- 5%	1.47E-01+/- 12%	-6%	1.46E-01	-7%
47.17	1.15E-01+/- 6%	1.06E-01+/- 31%	-7%	1.05E-01	-8%
57.30	9.43E-02+/- 6%	8.57E-02+/- 38%	-9%	8.55E-02	-9%
Times Days	**FNS EXP. 7 Hrs. microW/g**	**EAF-97 microW/g**	**(C-E)/E**	**FENDL/A-2 microW/g**	**(C-E)/E**
0.66	2.31E+00+/- 14%	2.74E+00+/- 0%	18%	2.74E+00	18%
1.34	1.46E+00+/- 11%	1.29E+00+/- 0%	-11%	1.29E+00	-11%
2.92	2.25E-01+/- 6%	2.22E-01+/- 0%	-1%	2.23E-01	-1%
6.93	2.68E-03+/- 6%	2.56E-03+/- 0%	-4%	2.57E-03	-4%
12.89	5.78E-05+/- 22%	3.42E-06+/- 48%	-94%	3.46E-06	-94%
23.89	4.40E-05+/- 28%	3.07E-08+/- 53%	-99%	3.07E-08	-99%
49.74	6.28E-05+/- 20%	3.06E-08+/- 53%	-99%	3.06E-08	-99%

FNS 5 Min Al

Nuclide	$T_{1/2}$	Pathways		
Na 24m	20.2ms	Al27(n,a)Na24m	100.0%	VAL
Al 26m	6.3s	Al27(n,2n)Al26m	100.0%	VAL
Mg 27	9.4m	Al27(n,p)Mg27	100.0%	VAL
Na 24	14.9h	Al27(n,a)Na24	69.1%	VAL
		Al27(n,a)Na24m(IT)Na24	30.8%	VAL

FNS 7 Hrs Al

Na 24m	20.2ms	Al27(n,a)Na24m	100.0%	
Mg 27	9.4m	Al27(n,p)Mg27	100.0%	
Na 24	14.9h	Al27(n,a)Na24	69.1%	
		Al27(n,a)Na24m(IT)Na24	30.8%	
H 3	12.3 y	Al27(n,X)H3	100.0%	??
Al 26	720.0ky	Al27(n,2n)Al26	100.0%	??

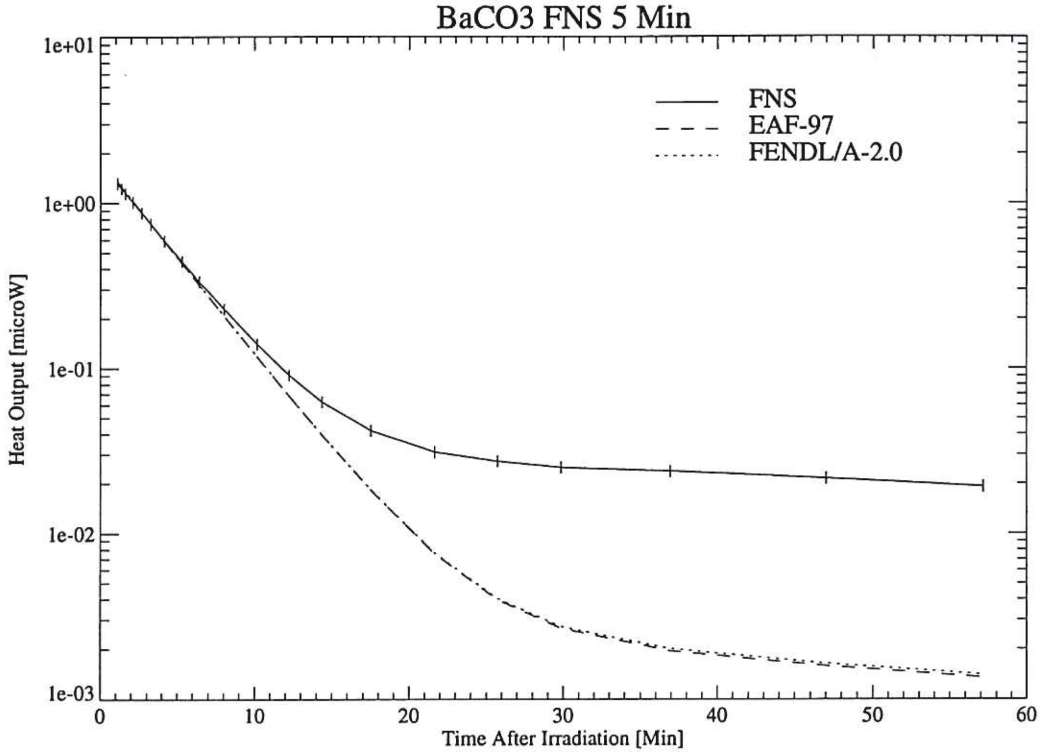


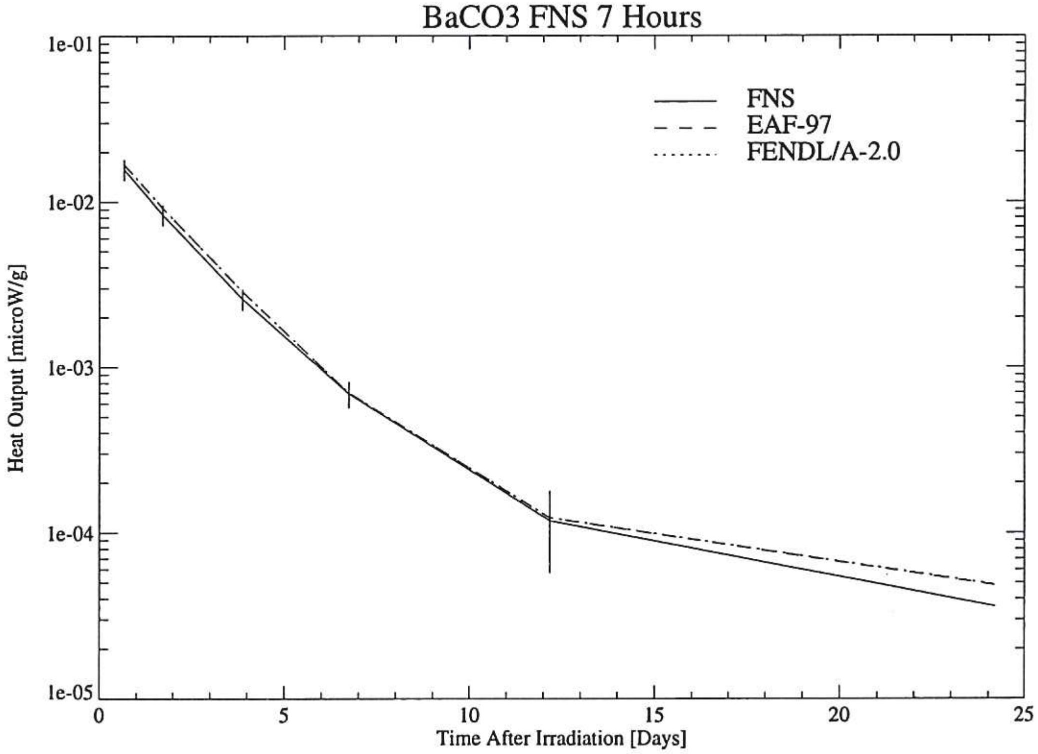
A powder sample, in the form of pyrex glass sandwiched by plastic foil, that certainly contains a large amount of unspecified impurity elements, a neutron absorber in the thermal region; one can only notice the very large underestimation of the code predictions. Although one notices that one of the two predominant but short lived isotopes, Be-11, seems to have been predicted with an excellent accuracy.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.22	4.98E-02+/- 5%	5.09E-02+/- 50%	2%	5.09E-02	2%
1.48	2.72E-02+/- 5%	2.28E-02+/- 50%	-16%	2.28E-02	-16%
1.75	1.63E-02+/- 5%	1.02E-02+/- 50%	-37%	1.02E-02	-37%
2.20	1.06E-02+/- 5%	2.63E-03+/- 50%	-75%	2.63E-03	-75%
2.82	8.20E-03+/- 5%	4.11E-04+/- 50%	-94%	4.11E-04	-94%
3.43	7.06E-03+/- 5%	6.42E-05+/- 49%	-99%	6.42E-05	-99%
4.32	6.20E-03+/- 5%	6.89E-09+/- 43%	-99%	6.89E-09	-99%
5.43	5.29E-03+/- 5%	6.89E-09+/- 43%	-99%	6.89E-09	-99%
6.55	4.53E-03+/- 5%	6.89E-09+/- 43%	-99%	6.89E-09	-99%
8.18	3.97E-03+/- 5%	6.89E-09+/- 43%	-99%	6.89E-09	-99%
10.30	3.32E-03+/- 5%	6.89E-09+/- 43%	-99%	6.89E-09	-99%
12.42	2.88E-03+/- 5%	6.89E-09+/- 43%	-99%	6.89E-09	-99%
14.55	2.61E-03+/- 5%	6.89E-09+/- 43%	-99%	6.89E-09	-99%
17.68	2.23E-03+/- 5%	6.89E-09+/- 43%	-99%	6.89E-09	-99%
21.75	1.86E-03+/- 5%	6.89E-09+/- 43%	-99%	6.89E-09	-99%
25.87	1.56E-03+/- 6%	6.89E-09+/- 43%	-99%	6.89E-09	-99%
30.00	1.28E-03+/- 6%	6.89E-09+/- 43%	-99%	6.89E-09	-99%
37.08	9.61E-04+/- 7%	6.89E-09+/- 43%	-99%	6.89E-09	-99%
47.17	5.91E-04+/- 9%	6.89E-09+/- 43%	-99%	6.89E-09	-99%
57.23	2.43E-04+/- 18%	6.89E-09+/- 43%	-99%	6.89E-09	-99%

FNS 5 Mins B4C

Nuclide	$T_{1/2}$	Pathways		
Li 8	838.0ms	B11(n,a)Li8	100.0%	??
Be 11	13.8 s	B11(n,p)Be11	100.0%	VAL
H 3	12.3 y	B10(n,2a)H3	60.3%	??
		B11(nn2a)H3	39.6%	??





Good agreement up to 10 mn cooling but degrading thereafter. Cs-138, Ba135m, Ba139 and Ba129m all contribute significantly to the decay power and their contributions vary with time; thus no clearer information can be drawn. However the predictions at cooling times from half a day up to 25 days are within the experimental uncertainties, although those climb to a level of 142%.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	1.31E+00+/- 8%	1.36E+00+/- 64%	3%	1.36E+00	3%
1.37	1.22E+00+/- 8%	1.26E+00+/- 64%	2%	1.26E+00	2%
1.63	1.14E+00+/- 7%	1.17E+00+/- 64%	2%	1.17E+00	2%
2.10	1.01E+00+/- 7%	1.03E+00+/- 64%	1%	1.03E+00	1%
2.67	8.76E-01+/- 7%	8.83E-01+/- 64%	0%	8.83E-01	0%
3.28	7.48E-01+/- 7%	7.47E-01+/- 64%	0%	7.47E-01	0%
4.18	5.92E-01+/- 7%	5.86E-01+/- 64%	0%	5.86E-01	0%
5.30	4.44E-01+/- 7%	4.34E-01+/- 64%	-2%	4.34E-01	-2%
6.42	3.35E-01+/- 7%	3.21E-01+/- 63%	-4%	3.21E-01	-4%
8.05	2.28E-01+/- 7%	2.07E-01+/- 63%	-9%	2.07E-01	-9%
10.18	1.40E-01+/- 7%	1.17E-01+/- 62%	-16%	1.17E-01	-16%
12.25	9.09E-02+/- 7%	6.82E-02+/- 61%	-24%	6.83E-02	-24%
14.38	6.25E-02+/- 7%	3.94E-02+/- 59%	-36%	3.95E-02	-36%
17.53	4.19E-02+/- 8%	1.82E-02+/- 55%	-56%	1.83E-02	-56%
21.65	3.10E-02+/- 8%	7.56E-03+/- 45%	-75%	7.63E-03	-75%
25.72	2.72E-02+/- 8%	3.98E-03+/- 36%	-85%	4.04E-03	-85%
29.85	2.49E-02+/- 8%	2.67E-03+/- 36%	-89%	2.74E-03	-89%
36.93	2.36E-02+/- 8%	1.95E-03+/- 39%	-91%	2.01E-03	-91%
47.03	2.15E-02+/- 8%	1.59E-03+/- 39%	-92%	1.64E-03	-92%
57.15	1.92E-02+/- 8%	1.35E-03+/- 38%	-92%	1.41E-03	-92%
Times	**FNS EXP. 7 Hrs.**	**EAF-97**	**(C-E)/E**	**FENDL/A-2**	**(C-E)/E**
Days	microW/g	microW/g		microW/g	
0.67	1.57E-02+/- 14%	1.68E-02+/- 47%	6%	1.68E-02	6%
1.72	8.33E-03+/- 14%	9.14E-03+/- 47%	9%	9.14E-03	9%
3.88	2.58E-03+/- 14%	2.86E-03+/- 44%	10%	2.86E-03	10%
6.74	6.90E-04+/- 18%	6.98E-04+/- 37%	1%	6.98E-04	1%
12.18	1.18E-04+/- 51%	1.23E-04+/- 25%	4%	1.23E-04	4%
24.18	3.60E-05+/-142%	4.83E-05+/- 30%	34%	4.87E-05	35%

FNS 5 Mins BaCO3

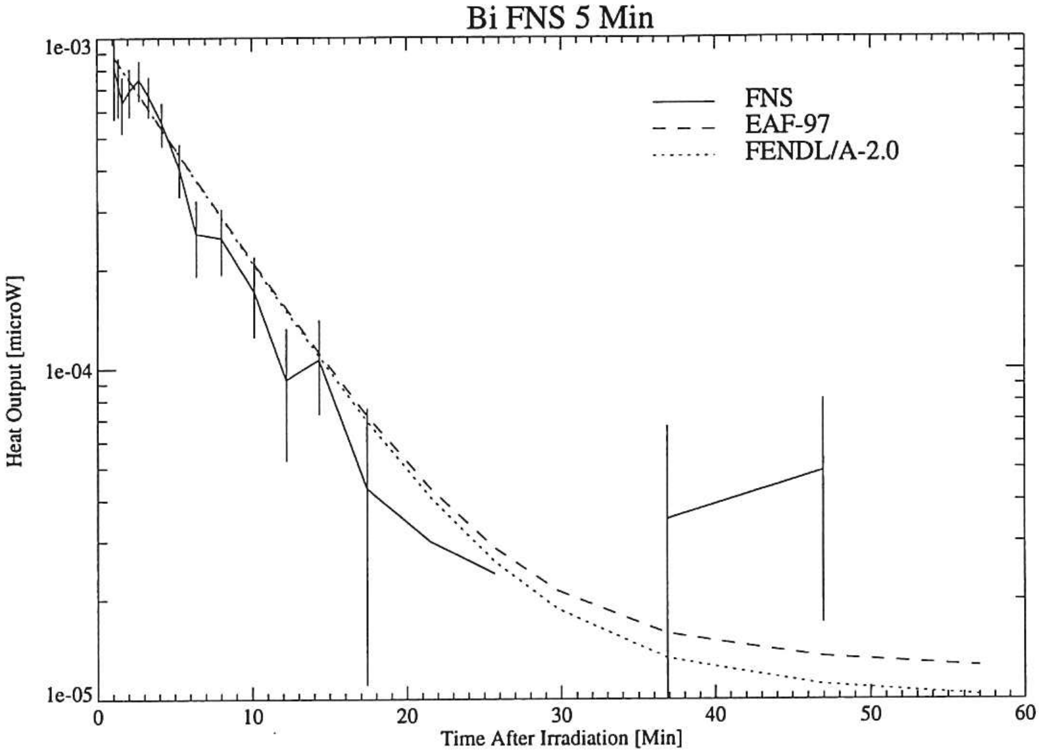
Nuclide	$T_{1/2}$	Pathways		
Ba136m	308.4ms	Ba136(n,n')Ba136m	10.2%	??
		Ba137(n,2n)Ba136m	89.6%	??
N 16	7.1 s	O16(n,p)N16	99.9%	VAL
Ba137m	2.5 m	Ba137(n,n')Ba137m	3.7%	??
		Ba138(n,2n)Ba137m	96.2%	??
Xe135m	15.6 m	Ba138(n,a)Xe135m	99.9%	??
Cs138	32.2 m	Ba138(n,p)Cs138	82.5%	??
		Ba138(n,p)Cs138m(IT)Cs138	17.4%	??
Ba139	1.3 h	Ba138(n,g)Ba139	100.0%	??
Ba129m	2.14 h	Ba130(n,2n)Ba129m	100.0%	??
Ba135m	1.1 d	Ba135(n,n')Ba135m	16.1%	??
		Ba136(n,2n)Ba135m	83.7%	??

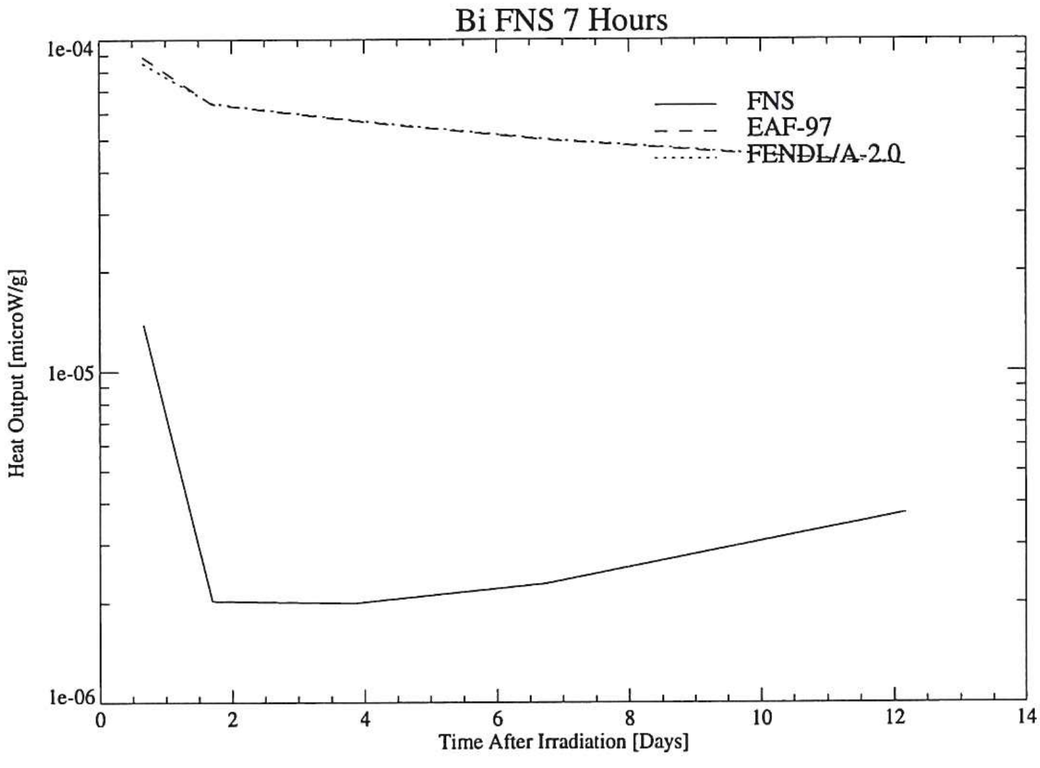
FNS 7 Hrs BaCO3

Ba136m	308.4ms	Ba136(n,n')Ba136m	9.9%	
		Ba137(n,2n)Ba136m	89.9%	
N 16	7.1 s	O16(n,p)N16	99.9%	
Ba137m	2.5 m	Ba137(n,n')Ba137m	3.1%	
		Ba138(n,2n)Ba137m	96.7%	
Ba135m	1.1 d	Ba135(n,n')Ba135m	14.4%	VAL
		Ba136(n,2n)Ba135m	85.5%	VAL
Ba133m	1.5 d	Ba134(n,2n)Ba133m	99.9%	VAL
Cs136	13.0 d	Ba136(n,p)Cs136	58.9%	VAL
		Ba137(n,d)Cs136	21.1%	VAL

		Ba138(n,t)Cs136	1.7%	??
		Ba136(n,p)Cs136m(IT)Cs136	16.5%	VAL
		Ba137(n,d)Cs136m(IT)Cs136	1.4%	??
Ba131	11.5 d	Ba132(n,2n)Ba131	35.7%	VAL
		Ba132(n,2n)Ba131m(IT)Ba131	63.6%	VAL
Ba133	10.5 y	Ba134(n,2n)Ba133	93.6%	VAL
		Ba134(n,2n)Ba133m(IT)Ba133	6.2%	??

This page is intentionally left blank





Poor experimental results do not allow much weight to be given to any comparison, although for cooling time up to 1 hour the code prediction curve profile seems to be correct.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	8.15E-04+/- 30%	8.76E-04+/- 81%	7%	8.74E-04	7%
1.37	7.23E-04+/- 20%	8.39E-04+/- 81%	16%	8.37E-04	15%
1.63	6.38E-04+/- 19%	8.04E-04+/- 81%	25%	8.01E-04	25%
2.08	6.92E-04+/- 16%	7.48E-04+/- 80%	8%	7.45E-04	7%
2.70	7.50E-04+/- 13%	6.77E-04+/- 80%	-9%	6.74E-04	-10%
3.32	6.69E-04+/- 13%	6.13E-04+/- 80%	-8%	6.10E-04	-8%
4.20	5.54E-04+/- 15%	5.32E-04+/- 80%	-3%	5.29E-04	-4%
5.32	4.04E-04+/- 18%	4.45E-04+/- 79%	10%	4.42E-04	9%
6.40	2.56E-04+/- 25%	3.75E-04+/- 79%	46%	3.72E-04	45%
8.03	2.48E-04+/- 22%	2.90E-04+/- 78%	16%	2.87E-04	15%
10.15	1.71E-04+/- 27%	2.09E-04+/- 77%	21%	2.06E-04	20%
12.22	9.24E-05+/- 43%	1.53E-04+/- 75%	65%	1.50E-04	62%
14.33	1.06E-04+/- 31%	1.12E-04+/- 72%	5%	1.09E-04	2%
17.42	4.34E-05+/- 74%	7.22E-05+/- 68%	66%	6.95E-05	60%
21.53	2.99E-05+/-105%	4.35E-05+/- 58%	45%	4.09E-05	36%
25.67	2.39E-05+/-141%	2.87E-05+/- 48%	19%	2.61E-05	9%
29.78	*******+/-112%	2.13E-05+/- 42%	-168%	1.87E-05	-160%
36.88	3.50E-05+/- 90%	1.58E-05+/- 41%	-54%	1.33E-05	-62%
46.97	4.90E-05+/- 65%	1.35E-05+/- 45%	-72%	1.11E-05	-77%
57.05	********+/- 75%	1.26E-05+/- 46%	-129%	1.03E-05	-124%
Times	FNS EXP. 7 Hrs.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Days	microW/g	microW/g		microW/g	
0.66	1.39E-05+/-104%	8.88E-05+/- 56%	539%	8.51E-05	513%
1.70	2.03E-06+/-451%	6.41E-05+/- 66%	3056%	6.44E-05	3072%
3.85	2.00E-06+/-306%	5.68E-05+/- 55%	2740%	5.71E-05	2755%
6.73	2.28E-06+/-218%	4.98E-05+/- 42%	2082%	5.01E-05	2093%
12.17	3.73E-06+/-127%	4.19E-05+/- 52%	1022%	4.21E-05	1028%

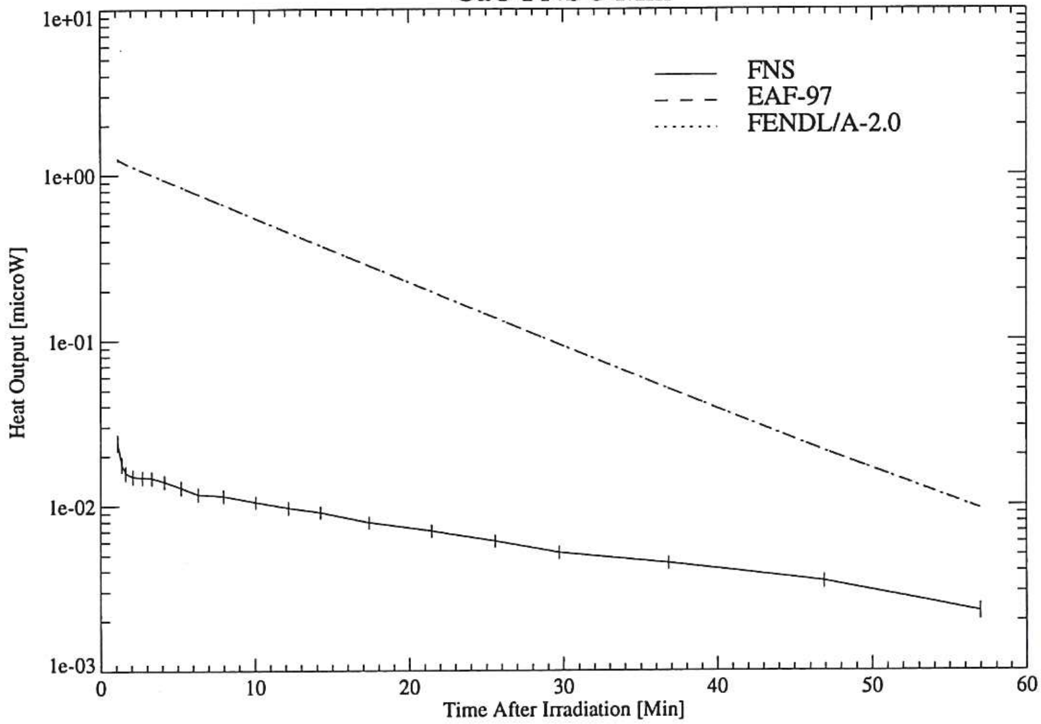
FNS 5 Mins Bi

Nuclide	$T_{1/2}$	Pathways		
Bi208m	2.5ms	Bi209(n,2n)Bi208m	100.0%	??
Tl206	4.2 m	Bi209(n,a)Tl206	99.8%	??
Pb209	3.2 h	Bi209(n,p)Pb209	100.0%	??
Bi210	5.0 d	Bi209(n,g)Bi210	100.0%	??

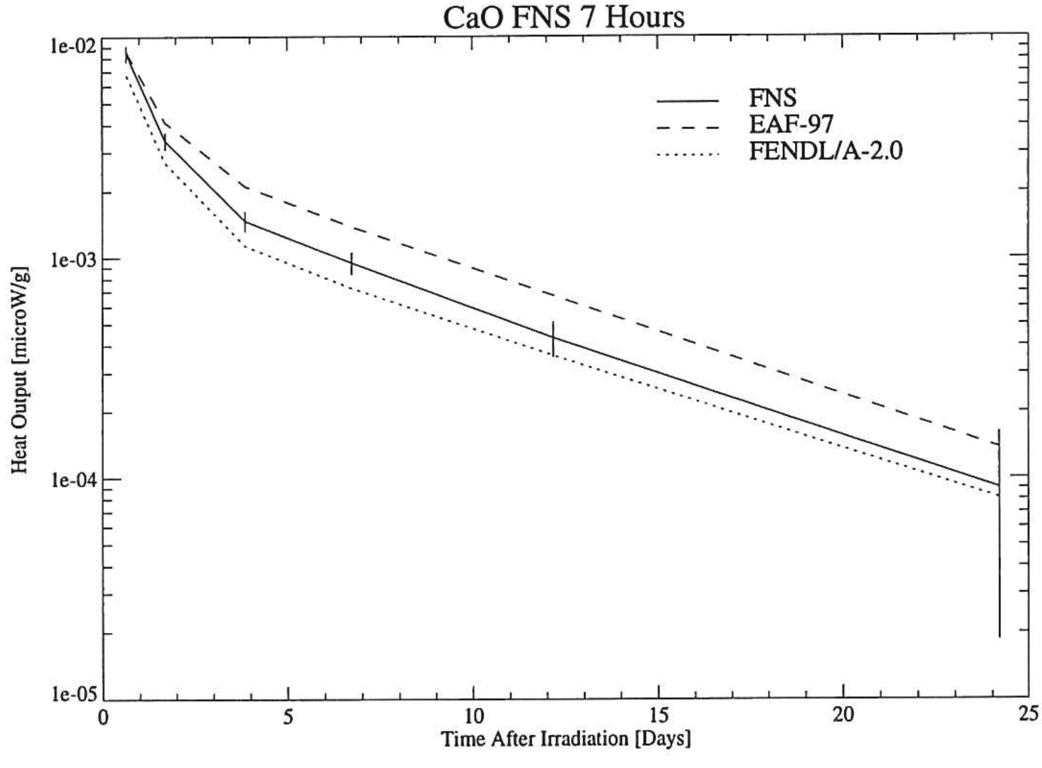
FNS 7 Hrs Bi

Bi208m	2.5ms	Bi209(n,2n)Bi208m	100.0%	??
Bi210	5.0 d	Bi209(n,g)Bi210	100.0%	??
Pb209	3.2 h	Bi209(n,p)Pb209	100.0%	??
Po210	138.4 d	Bi209(n,g)Bi210(b-)Po210	100.0%	??

CaO FNS 5 Min



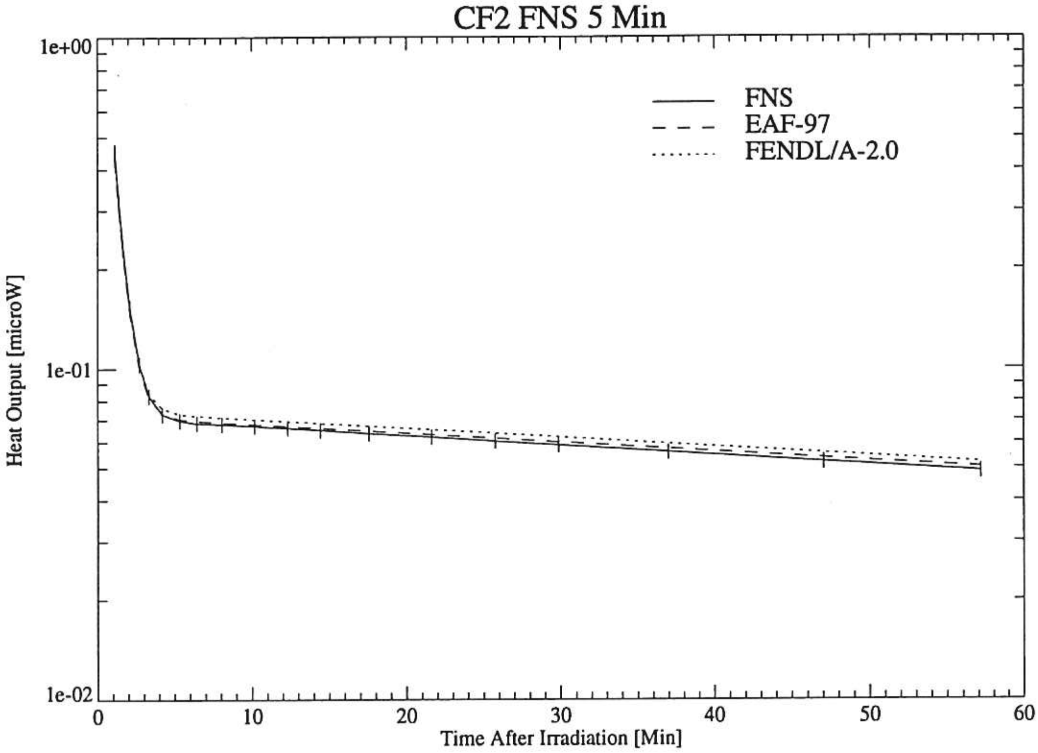
CaO FNS 7 Hours



Rather interesting results for the 5 minutes irradiation comparison where the reasons for the large (C-E)/E could be traced to an inflated cross-section of Ca-40(n,t)K-38 and Ca-40(n,t)K-38m in FENDL/A-2.0 and EAF-97. This strong overestimation does not exist in JENDL/ACT-96 that could be proposed as a replacement. Ca-44(n,p)K-44 data needs to be checked as well. When considering cooling times after 2 days, the multiple production paths of the predominant isotopes K-42, K-43, Ca-47, Sc-47 and Ar-37 do not allow any straight forward conclusions to be drawn.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	2.42E-02+/- 12%	1.26E+00+/- 82%	5096%	1.24E+00	5009%
1.37	1.79E-02+/- 10%	1.21E+00+/- 83%	6684%	1.20E+00	6629%
1.63	1.58E-02+/- 10%	1.18E+00+/- 83%	7328%	1.17E+00	7304%
2.08	1.50E-02+/- 10%	1.12E+00+/- 84%	7382%	1.12E+00	7385%
2.70	1.49E-02+/- 9%	1.06E+00+/- 84%	7039%	1.06E+00	7054%
3.32	1.47E-02+/- 9%	1.00E+00+/- 84%	6704%	1.01E+00	6720%
4.15	1.40E-02+/- 9%	9.30E-01+/- 84%	6542%	9.32E-01	6559%
5.22	1.29E-02+/- 9%	8.44E-01+/- 84%	6455%	8.47E-01	6472%
6.33	1.17E-02+/- 9%	7.63E-01+/- 84%	6406%	7.65E-01	6423%
7.97	1.15E-02+/- 9%	6.58E-01+/- 83%	5650%	6.60E-01	5664%
10.05	1.05E-02+/- 9%	5.45E-01+/- 83%	5099%	5.47E-01	5112%
12.18	9.68E-03+/- 9%	4.50E-01+/- 83%	4547%	4.51E-01	4558%
14.25	9.09E-03+/- 8%	3.73E-01+/- 83%	4009%	3.74E-01	4019%
17.38	7.90E-03+/- 8%	2.82E-01+/- 83%	3467%	2.82E-01	3476%
21.45	7.01E-03+/- 8%	1.96E-01+/- 82%	2692%	1.96E-01	2698%
25.57	6.07E-03+/- 8%	1.35E-01+/- 82%	2133%	1.36E-01	2137%
29.70	5.16E-03+/- 9%	9.39E-02+/- 81%	1718%	9.41E-02	1721%
36.78	4.47E-03+/- 9%	5.05E-02+/- 79%	1028%	5.05E-02	1029%
46.90	3.47E-03+/- 9%	2.13E-02+/- 74%	514%	2.13E-02	513%
56.98	2.28E-03+/- 11%	9.51E-03+/- 66%	317%	9.46E-03	315%
Times	FNS EXP. 7 Hrs.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Days	microW/g	microW/g		microW/g	
0.66	8.41E-03+/- 8%	8.56E-03+/- 24%	1%	6.71E-03	-20%
1.71	3.40E-03+/- 8%	4.12E-03+/- 30%	21%	2.70E-03	-20%
3.87	1.47E-03+/- 10%	2.11E-03+/- 40%	43%	1.13E-03	-22%
6.73	9.49E-04+/- 11%	1.38E-03+/- 40%	45%	7.27E-04	-23%
12.18	4.32E-04+/- 18%	6.71E-04+/- 36%	55%	3.59E-04	-16%
24.19	9.00E-05+/- 79%	1.38E-04+/- 28%	52%	8.10E-05	-9%

```
FNS 5 Mins CaO
Nuclide  T1/2     Pathways
  N  16  7.1 s   O16(n,p)N16                          99.9%  VAL
  K  38  7.6 m   Ca40(n,t)K38                        100.0%  TBA
  K  38m 924.0ms Ca40(n,t)K38m                       100.0%  TBA
  K  44  22.1 m  Ca44(n,p)K44                        100.0%  TBA
FNS 7 Hrs CaO
  N  16  7.1 s   O16(n,p)N16                          99.9%
  K  38  7.6 m   Ca40(n,t)K38                        100.0%
  K  38m 924.0ms Ca40(n,t)K38m                       100.0%
  K  42  12.3 h  Ca42(n,p)K42                         97.8%  ??
                 Ca43(n,d)K42                          2.1%  ??
  K  43  22.2 h  Ca43(n,p)K43                         42.1%  ??
                 Ca44(n,d)K43                         57.8%  ??
  Sc 47  3.3 d   Ca48(n,2n)Ca47(b-)Sc47               51.6%  ??
  Ca 47  4.5 d   Ca48(n,2n)Ca47                       51.6%  ??
                 Ca48(n,d)K47(b-)Ca47                 48.3%  ??
  Ar 37  35.0 d  Ca40(n,a)Ar37                       100.0%  ??
```

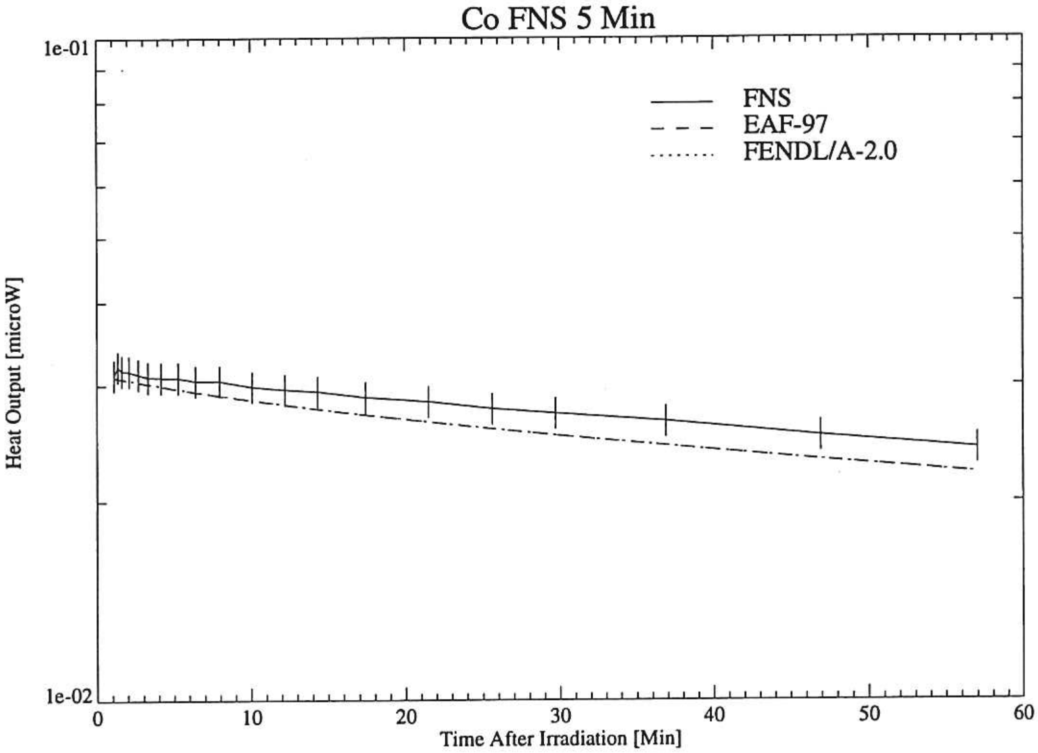


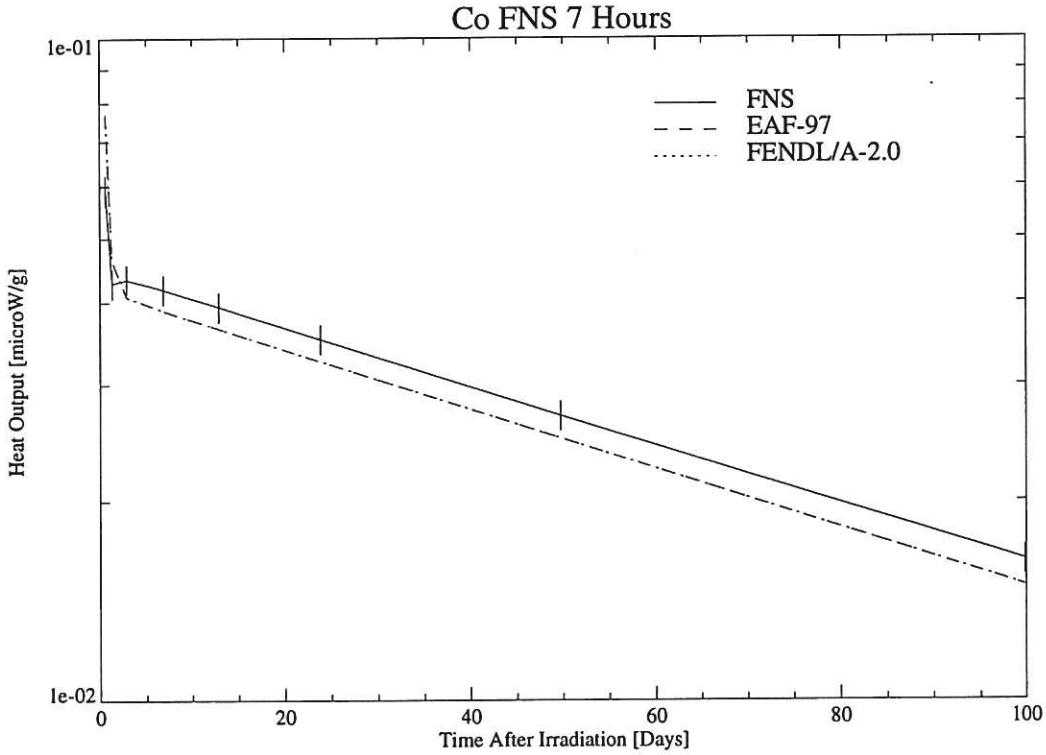
The excellent agreement that can be seen, particularly for EAF-97, enables a high level of confidence in the three pathways and cross-sections involved.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.12	4.52E-01+/- 5%	4.28E-01+/- 19%	-5%	4.31E-01	-4%
1.38	3.19E-01+/- 5%	3.01E-01+/- 18%	-5%	3.03E-01	-5%
1.65	2.31E-01+/- 5%	2.22E-01+/- 16%	-4%	2.24E-01	-3%
2.08	1.53E-01+/- 5%	1.48E-01+/- 12%	-3%	1.50E-01	-1%
2.70	1.03E-01+/- 5%	1.00E-01+/- 8%	-2%	1.03E-01	0%
3.32	8.29E-02+/- 5%	8.20E-02+/- 10%	-1%	8.45E-02	1%
4.20	7.27E-02+/- 5%	7.31E-02+/- 11%	0%	7.56E-02	3%
5.32	6.95E-02+/- 5%	7.02E-02+/- 0%	1%	7.27E-02	4%
6.43	6.83E-02+/- 5%	6.93E-02+/- 0%	1%	7.18E-02	5%
8.07	6.78E-02+/- 5%	6.85E-02+/- 0%	1%	7.09E-02	4%
10.18	6.68E-02+/- 5%	6.76E-02+/- 0%	1%	7.00E-02	4%
12.30	6.59E-02+/- 5%	6.67E-02+/- 0%	1%	6.91E-02	4%
14.43	6.49E-02+/- 5%	6.58E-02+/- 0%	1%	6.81E-02	4%
17.57	6.34E-02+/- 5%	6.45E-02+/- 0%	1%	6.68E-02	5%
21.63	6.19E-02+/- 5%	6.29E-02+/- 0%	1%	6.51E-02	5%
25.75	6.01E-02+/- 5%	6.13E-02+/- 0%	1%	6.34E-02	5%
29.87	5.84E-02+/- 5%	5.97E-02+/- 0%	2%	6.18E-02	5%
36.95	5.57E-02+/- 5%	5.71E-02+/- 0%	2%	5.91E-02	6%
47.03	5.22E-02+/- 5%	5.36E-02+/- 0%	2%	5.54E-02	6%
57.15	4.89E-02+/- 5%	5.02E-02+/- 0%	2%	5.20E-02	6%

FNS 5 Mins CF2

Nuclide		$T_{1/2}$	Pathways		
N	16	7.1 s	F19(n,a)N16	100.0%	VAL
O	19	26.9 s	F19(n,p)O19	100.0%	VAL
F	18	1.8 h	F19(n,2n)F18	100.0%	VAL





An important element for which the decay power is predicted with an accuracy very much within the experimental uncertainty, although it is, systematically, lower than the experiment. One should note that Co-60m is produced through an (n,g) reaction that cannot be relied upon in such an experimental set-up.

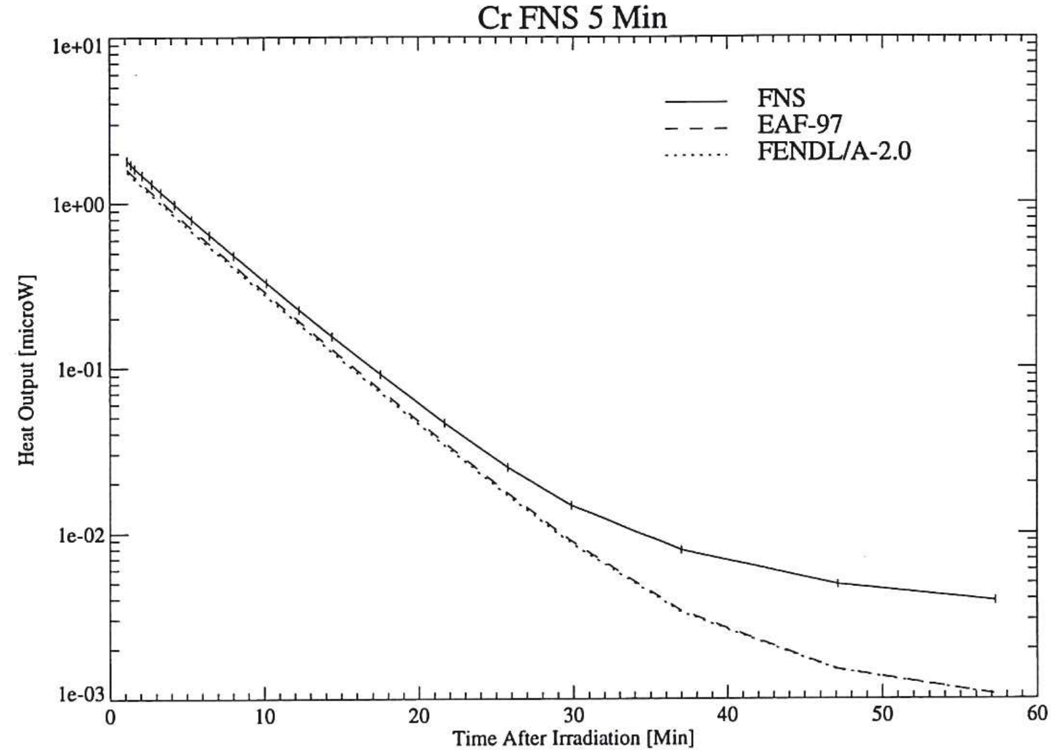
Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	3.11E-02+/- 5%	3.08E-02+/- 52%	0%	3.09E-02	0%
1.35	3.20E-02+/- 5%	3.08E-02+/- 52%	-3%	3.08E-02	-3%
1.62	3.16E-02+/- 5%	3.07E-02+/- 52%	-2%	3.07E-02	-2%
2.07	3.15E-02+/- 5%	3.05E-02+/- 52%	-3%	3.06E-02	-3%
2.68	3.12E-02+/- 5%	3.03E-02+/- 52%	-2%	3.04E-02	-2%
3.30	3.09E-02+/- 5%	3.02E-02+/- 52%	-2%	3.02E-02	-2%
4.18	3.08E-02+/- 5%	2.99E-02+/- 52%	-3%	2.99E-02	-2%
5.28	3.08E-02+/- 5%	2.96E-02+/- 53%	-3%	2.96E-02	-3%
6.40	3.05E-02+/- 5%	2.93E-02+/- 53%	-3%	2.94E-02	-3%
7.98	3.04E-02+/- 5%	2.89E-02+/- 53%	-4%	2.90E-02	-4%
10.10	2.98E-02+/- 5%	2.85E-02+/- 54%	-4%	2.85E-02	-4%
12.22	2.95E-02+/- 5%	2.80E-02+/- 54%	-5%	2.80E-02	-5%
14.33	2.93E-02+/- 5%	2.76E-02+/- 54%	-5%	2.76E-02	-5%
17.42	2.87E-02+/- 5%	2.70E-02+/- 55%	-5%	2.70E-02	-5%
21.48	2.83E-02+/- 5%	2.64E-02+/- 55%	-6%	2.64E-02	-6%
25.62	2.76E-02+/- 5%	2.57E-02+/- 55%	-6%	2.57E-02	-6%
29.73	2.72E-02+/- 5%	2.52E-02+/- 56%	-7%	2.52E-02	-7%
36.87	2.64E-02+/- 5%	2.42E-02+/- 56%	-8%	2.43E-02	-8%
46.93	2.51E-02+/- 5%	2.31E-02+/- 56%	-8%	2.31E-02	-8%
57.00	2.41E-02+/- 5%	2.21E-02+/- 56%	-8%	2.21E-02	-8%
Times	FNS EXP. 7 Hrs.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Days	microW/g	microW/g		microW/g	
0.63	5.90E-02+/- 5%	7.68E-02+/- 31%	30%	7.68E-02	30%
1.31	4.28E-02+/- 5%	4.63E-02+/- 40%	8%	4.63E-02	8%
2.89	4.33E-02+/- 5%	4.08E-02+/- 45%	-5%	4.08E-02	-5%
6.86	4.19E-02+/- 5%	3.89E-02+/- 46%	-7%	3.89E-02	-7%
12.85	3.94E-02+/- 5%	3.65E-02+/- 46%	-7%	3.65E-02	-7%
23.84	3.52E-02+/- 5%	3.26E-02+/- 46%	-7%	3.26E-02	-7%
49.70	2.69E-02+/- 5%	2.49E-02+/- 47%	-7%	2.49E-02	-7%
99.89	1.63E-02+/- 5%	1.49E-02+/- 48%	-8%	1.49E-02	-8%

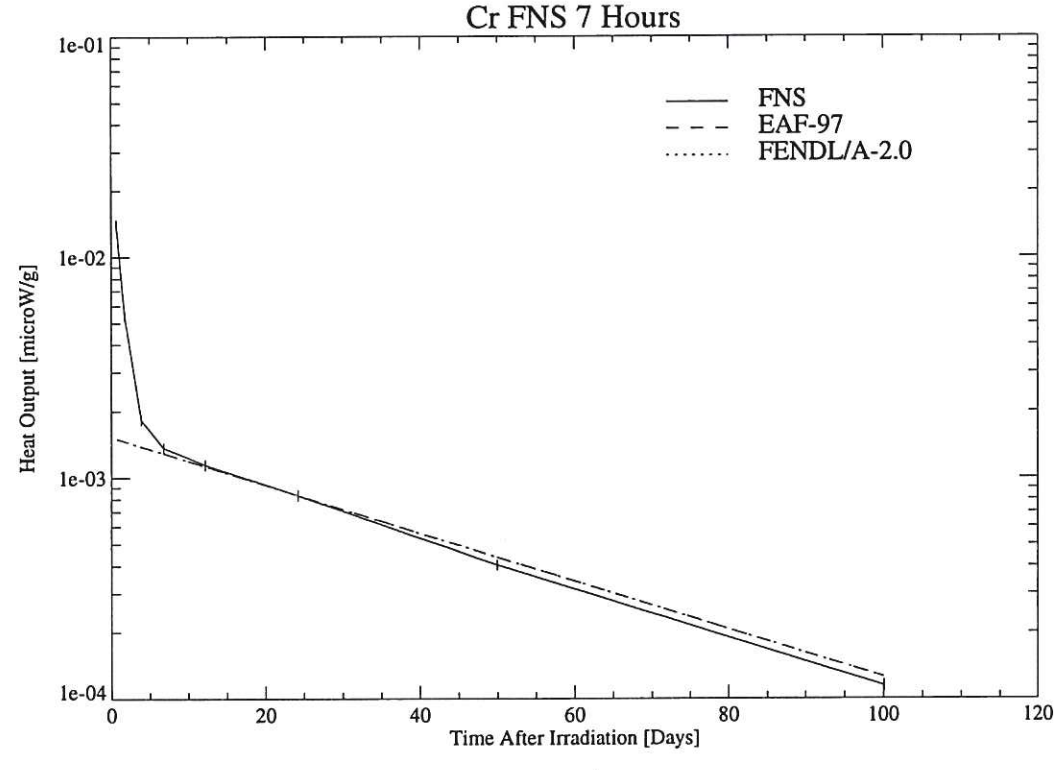
FNS 5 Min Co

Nuclide	$T_{1/2}$	Pathways		
Co 60m	10.4 m	Co59(n,g)Co60m	100.0%	??
Mn 56	2.5 h	Co59(n,a)Mn56	100.0%	VAL
Co 58m	8.9 h	Co59(n,2n)Co58m	100.0%	VAL

FNS 7 Hrs Co

Mn 56	2.5 h	Co59(n,a)Mn56	100.0%	
Co 58m	8.9 h	Co59(n,2n)Co58m	100.0%	
Co 58	70.8 d	Co59(n,2n)Co58	77.6%	VAL
		Co59(n,2n)Co58m(IT)Co58	22.3%	VAL
Fe 59	44.5 d	Co59(n,p)Fe59	100.0%	VAL

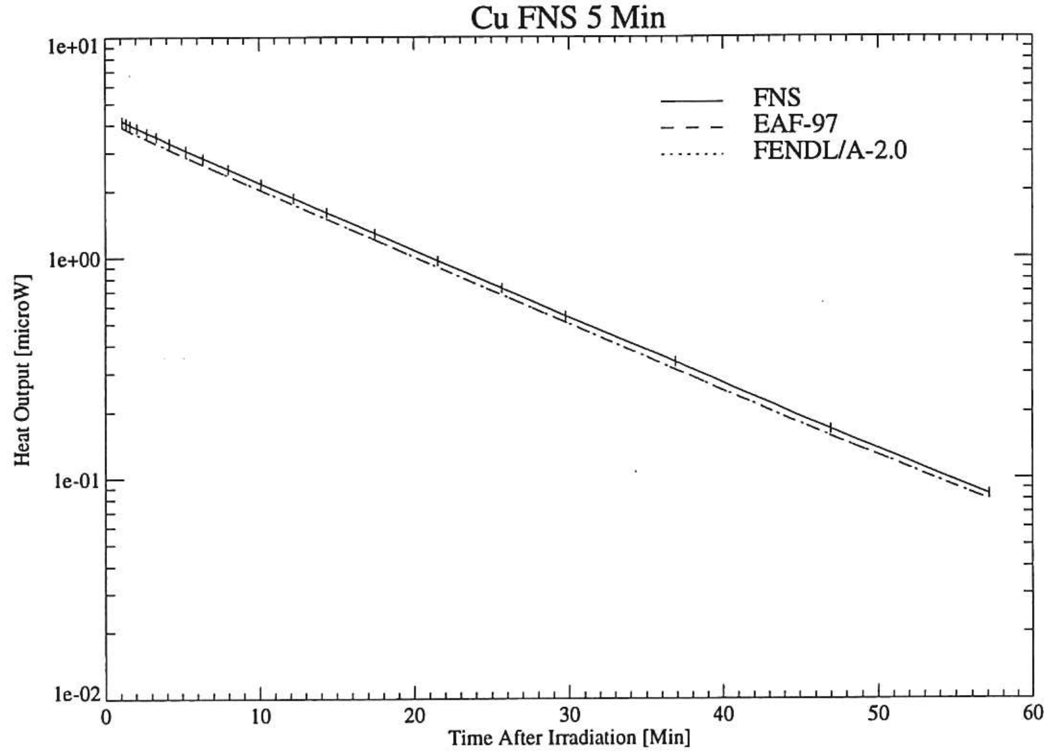


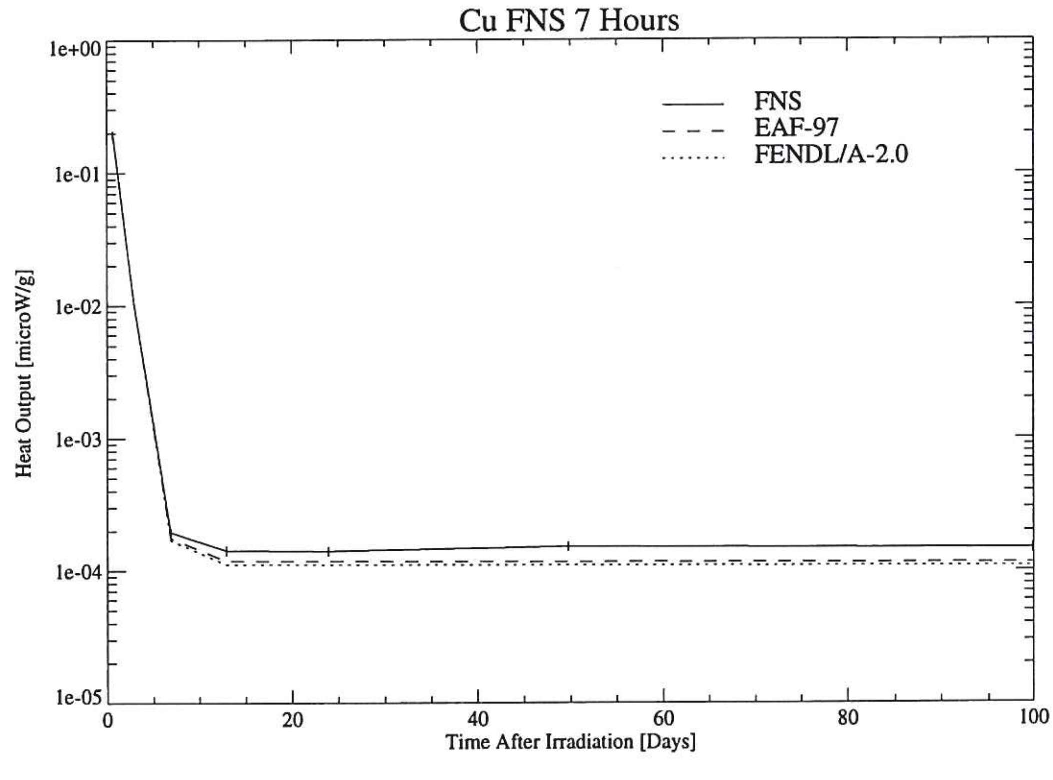


Good agreement for this element if one accounts for the fact that Al and Fe impurities could be present in the sample at levels up to respectively 2000 and 6000 ppm. Such impurities could give rise to Na-22 and Mn-56 that will dominate the decay power exactly where the discrepancies occur for both graphs.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.12	1.80E+00+/- 6%	1.60E+00+/- 21%	-11%	1.54E+00	-14%
1.37	1.71E+00+/- 6%	1.52E+00+/- 21%	-11%	1.46E+00	-14%
1.63	1.62E+00+/- 6%	1.44E+00+/- 22%	-10%	1.39E+00	-14%
2.10	1.48E+00+/- 6%	1.31E+00+/- 22%	-11%	1.26E+00	-14%
2.72	1.31E+00+/- 6%	1.16E+00+/- 22%	-11%	1.12E+00	-14%
3.33	1.16E+00+/- 6%	1.03E+00+/- 22%	-11%	9.89E-01	-14%
4.22	9.82E-01+/- 6%	8.67E-01+/- 22%	-11%	8.34E-01	-15%
5.33	7.93E-01+/- 6%	7.00E-01+/- 22%	-11%	6.73E-01	-15%
6.47	6.42E-01+/- 6%	5.65E-01+/- 22%	-11%	5.43E-01	-15%
8.05	4.81E-01+/- 6%	4.20E-01+/- 22%	-12%	4.03E-01	-16%
10.17	3.28E-01+/- 6%	2.83E-01+/- 23%	-13%	2.72E-01	-17%
12.28	2.24E-01+/- 6%	1.92E-01+/- 23%	-14%	1.84E-01	-17%
14.42	1.54E-01+/- 6%	1.30E-01+/- 22%	-16%	1.24E-01	-19%
17.55	9.11E-02+/- 6%	7.33E-02+/- 22%	-19%	7.05E-02	-22%
21.68	4.60E-02+/- 5%	3.51E-02+/- 22%	-23%	3.37E-02	-26%
25.75	2.48E-02+/- 5%	1.74E-02+/- 21%	-29%	1.68E-02	-32%
29.87	1.46E-02+/- 5%	8.93E-03+/- 19%	-38%	8.64E-03	-40%
37.00	7.87E-03+/- 5%	3.39E-03+/- 15%	-56%	3.31E-03	-57%
47.13	4.89E-03+/- 5%	1.51E-03+/- 17%	-69%	1.50E-03	-69%
57.25	3.89E-03+/- 5%	1.07E-03+/- 19%	-72%	1.07E-03	-72%
Times	FNS EXP. 7 Hrs.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Days	microW/g	microW/g		microW/g	
0.69	1.40E-02+/- 5%	1.50E-03+/- 0%	-89%	1.50E-03	-89%
1.74	5.39E-03+/- 5%	1.46E-03+/- 0%	-72%	1.46E-03	-72%
3.89	1.83E-03+/- 5%	1.38E-03+/- 0%	-24%	1.38E-03	-24%
6.75	1.37E-03+/- 5%	1.29E-03+/- 0%	-5%	1.29E-03	-5%
12.20	1.14E-03+/- 5%	1.12E-03+/- 0%	-1%	1.12E-03	-1%
24.21	8.31E-04+/- 5%	8.33E-04+/- 0%	0%	8.32E-04	0%
49.96	4.03E-04+/- 5%	4.38E-04+/- 23%	8%	4.37E-04	8%
100.09	1.15E-04+/- 6%	1.26E-04+/- 23%	9%	1.26E-04	9%

```
FNS 5 Mins Cr
Nuclide T1/2     Pathways
  V  53  1.6 m   Cr53(n,p)V53          98.0%  TBA
                 Cr54(n,d)V53           1.9%  ??
  V  52  3.7 m   Cr52(n,p)V52          96.9%  TBA
                 Cr53(n,d)V52           2.9%  ??
  Cr 49  41.9 m  Cr50(n,2n)Cr49       100.0%  ??
FNS 7 Hrs Cr
  V  53  1.6 m   Cr53(n,p)V53          98.4%
                 Cr54(n,d)V53           1.5%
  V  52  3.7 m   Cr52(n,p)V52          97.5%
                 Cr53(n,d)V52           2.4%
  Cr 51  27.7 d  Cr52(n,2n)Cr51        99.9%  VAL
```





Excellent agreement can be seen up to 1 hour cooling time for the 5 Min. irradiation test. This trend is repeated for up to 6 days cooling time in the 7 hours irradiation, although some underestimation is noticed thereafter. This can be traced to the Co-60 isotope produced through the Cu-63(n,a) reaction. The total cross-section value at 14.5 Mev is 0.0362 barns for FENDL/A-2, 0.0384 for EAF-97 but 0.042 +/- 5% in the latest JAERI measurement. The reaction is split between the Cu-63(n,a)Co-60 and Cu-63(n,a)Co-60m (0.0232 and 0.0152 barns respectively in EAF-97) and the metastable state half-life is 10.47 minutes. The discrepancy occurs only after 6 days cooling which suggests an increase of the ground state excitation function alone to bring the total to the value of 0.042 barns. Such a proposed increase of 11% of the channel to the ground state will reduce the (C-E)/E to a level nearly equal to the experimental uncertainty values, at that time, of 8%. However, care should be taken if such a cross-section correction is carried out that in fact this underestimation is not due to the decay mode schemes and/or energies contained in the decay files.

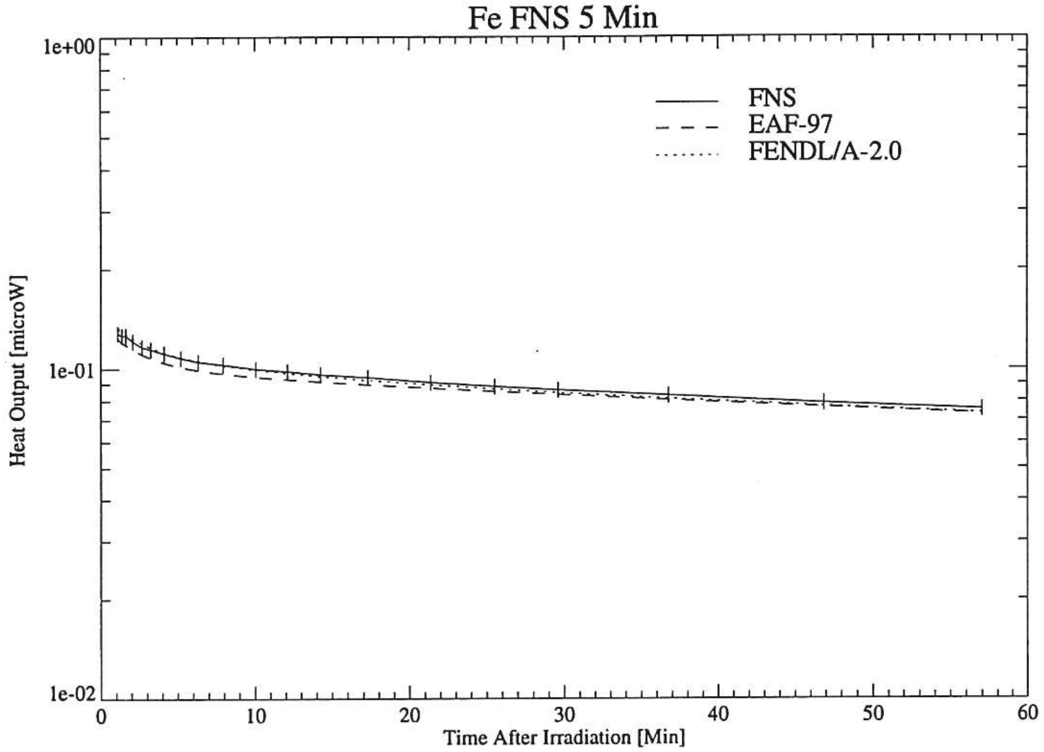
Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	4.16E+00+/- 5%	3.89E+00+/- 29%	-6%	3.89E+00	-6%
1.37	4.08E+00+/- 5%	3.81E+00+/- 29%	-6%	3.81E+00	-6%
1.63	3.99E+00+/- 5%	3.73E+00+/- 29%	-6%	3.73E+00	-6%
2.08	3.86E+00+/- 5%	3.61E+00+/- 29%	-6%	3.60E+00	-6%
2.70	3.69E+00+/- 5%	3.44E+00+/- 29%	-6%	3.44E+00	-6%
3.32	3.53E+00+/- 5%	3.28E+00+/- 29%	-6%	3.29E+00	-6%
4.20	3.29E+00+/- 5%	3.08E+00+/- 29%	-6%	3.08E+00	-6%
5.27	3.05E+00+/- 5%	2.85E+00+/- 29%	-6%	2.85E+00	-6%
6.37	2.82E+00+/- 5%	2.63E+00+/- 29%	-6%	2.63E+00	-6%
8.00	2.51E+00+/- 5%	2.34E+00+/- 29%	-6%	2.34E+00	-6%
10.12	2.15E+00+/- 5%	2.01E+00+/- 29%	-6%	2.01E+00	-6%
12.23	1.85E+00+/- 5%	1.73E+00+/- 29%	-6%	1.73E+00	-6%
14.35	1.59E+00+/- 5%	1.49E+00+/- 29%	-6%	1.49E+00	-6%
17.47	1.28E+00+/- 5%	1.20E+00+/- 29%	-6%	1.20E+00	-6%
21.53	9.62E-01+/- 5%	8.98E-01+/- 29%	-6%	8.99E-01	-6%
25.65	7.22E-01+/- 5%	6.72E-01+/- 29%	-6%	6.73E-01	-6%
29.77	5.38E-01+/- 5%	5.04E-01+/- 29%	-6%	5.05E-01	-6%
36.90	3.33E-01+/- 5%	3.07E-01+/- 29%	-7%	3.08E-01	-7%
46.97	1.66E-01+/- 5%	1.55E-01+/- 28%	-6%	1.55E-01	-6%
57.10	8.44E-02+/- 5%	7.97E-02+/- 26%	-5%	7.99E-02	-5%
Times	**FNS EXP. 7 Hrs.**	**EAF-97**	**(C-E)/E**	**FENDL/A-2**	**(C-E)/E**
Days	microW/g	microW/g		microW/g	
0.65	1.95E-01+/- 6%	2.05E-01+/- 0%	4%	2.05E-01	4%
1.32	8.31E-02+/- 5%	8.42E-02+/- 0%	1%	8.42E-02	1%
2.90	1.07E-02+/- 5%	1.07E-02+/- 23%	0%	1.07E-02	0%
6.87	1.96E-04+/- 7%	1.77E-04+/- 22%	-9%	1.70E-04	-13%
12.89	1.42E-04+/- 8%	1.18E-04+/- 32%	-16%	1.11E-04	-21%
23.90	1.40E-04+/- 8%	1.17E-04+/- 32%	-16%	1.11E-04	-20%
49.72	1.51E-04+/- 8%	1.16E-04+/- 32%	-23%	1.10E-04	-27%
99.92	1.48E-04+/- 8%	1.14E-04+/- 32%	-22%	1.08E-04	-26%

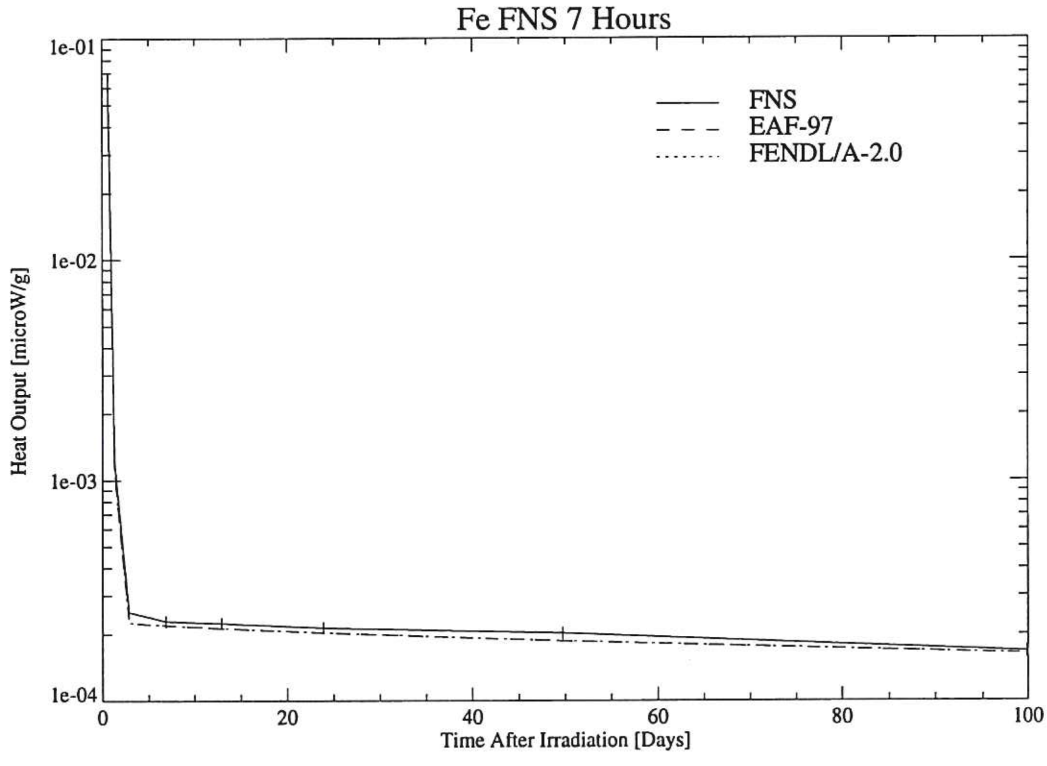
FNS 5 Min Cu

Nuclide	$T_{1/2}$	Pathways		
Co 62	1.5 m	Cu65(n,a)Co62	99.9%	VAL
Cu 62	9.7 m	Cu63(n,2n)Cu62	100.0%	VAL
Cu 64	12.7 h	Cu63(n,g)Cu64	1.3%	??
		Cu65(n,2n)Cu64	98.6%	VAL

FNS 7 Hrs Cu

Cu 62	9.7 m	Cu63(n,2n)Cu62	100.0%	
Cu 64	12.7 h	Cu63(n,g)Cu64	.7%	
		Cu65(n,2n)Cu64	99.2%	
Co 60	5.2 y	Cu63(n,a)Co60	61.3%	TBA
		Cu63(n,a)Co60m(IT)Co60	39.9%	TBA

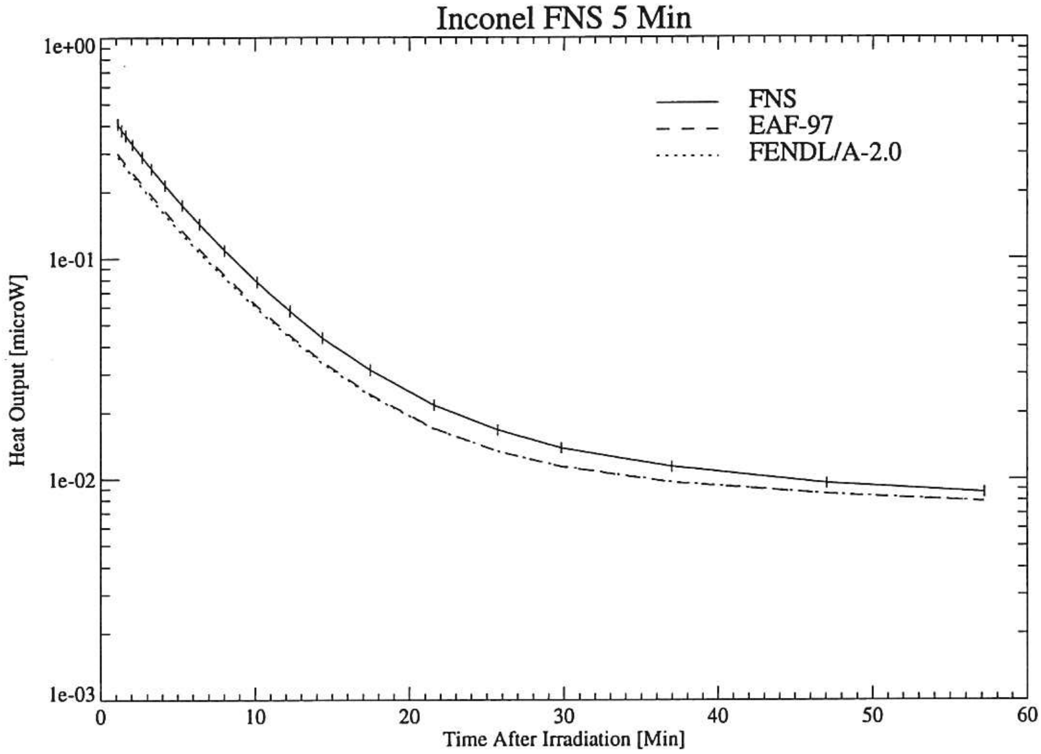


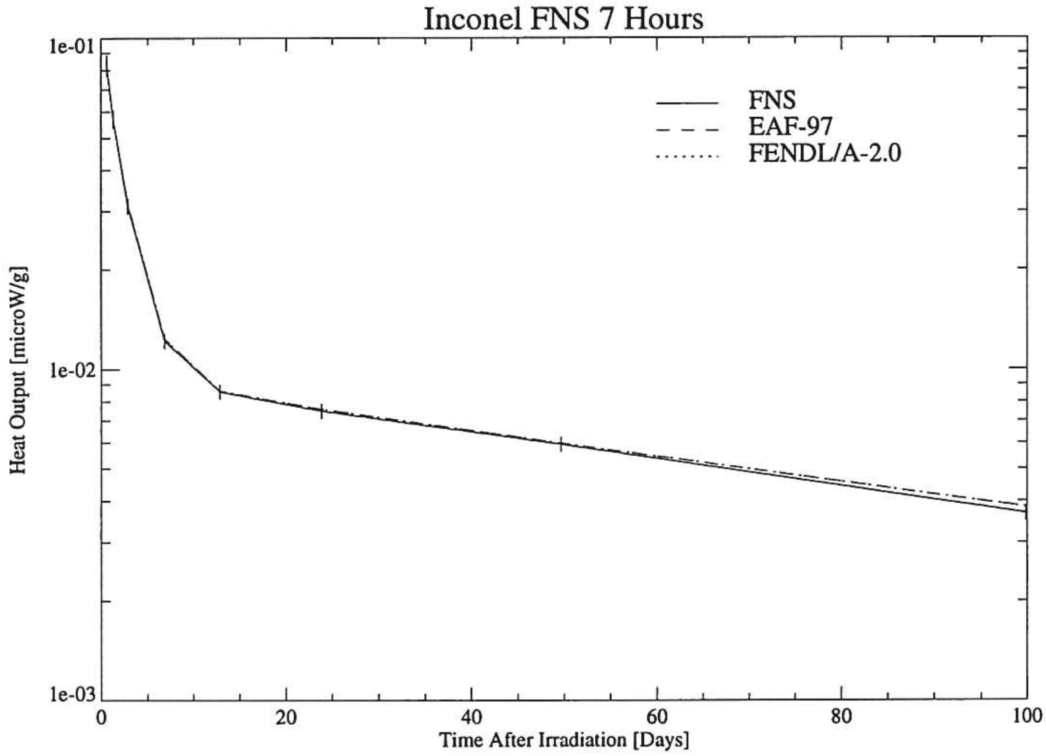


Superb agreement, well within the experimental uncertainties, can be seen here for both irradiation tests and all cooling periods.

Times Min.	FNS EXP. 5 Min. microW/g	EAF-97 microW/g	(C-E)/E	FENDL/A-2 microW/g	(C-E)/E
1.10	1.28E-01+/- 5%	1.23E-01+/- 16%	-3%	1.33E-01	3%
1.37	1.26E-01+/- 5%	1.21E-01+/- 15%	-4%	1.30E-01	3%
1.63	1.26E-01+/- 5%	1.18E-01+/- 15%	-6%	1.28E-01	1%
2.08	1.21E-01+/- 5%	1.15E-01+/- 15%	-5%	1.24E-01	1%
2.68	1.17E-01+/- 5%	1.11E-01+/- 15%	-4%	1.20E-01	2%
3.25	1.15E-01+/- 5%	1.08E-01+/- 15%	-5%	1.16E-01	1%
4.13	1.11E-01+/- 5%	1.04E-01+/- 16%	-6%	1.12E-01	0%
5.23	1.08E-01+/- 5%	1.01E-01+/- 16%	-6%	1.08E-01	0%
6.35	1.05E-01+/- 5%	9.89E-02+/- 16%	-5%	1.05E-01	0%
7.95	1.03E-01+/- 5%	9.65E-02+/- 17%	-6%	1.02E-01	0%
10.07	9.98E-02+/- 5%	9.42E-02+/- 16%	-5%	9.91E-02	0%
12.13	9.80E-02+/- 5%	9.25E-02+/- 17%	-5%	9.67E-02	-1%
14.25	9.58E-02+/- 5%	9.11E-02+/- 17%	-4%	9.46E-02	-1%
17.33	9.38E-02+/- 5%	8.92E-02+/- 17%	-4%	9.20E-02	-1%
21.40	9.06E-02+/- 5%	8.70E-02+/- 17%	-3%	8.90E-02	-1%
25.52	8.80E-02+/- 5%	8.50E-02+/- 0%	-3%	8.65E-02	-1%
29.63	8.58E-02+/- 5%	8.31E-02+/- 0%	-3%	8.42E-02	-1%
36.77	8.26E-02+/- 5%	8.01E-02+/- 0%	-3%	8.09E-02	-2%
46.88	7.84E-02+/- 5%	7.63E-02+/- 0%	-2%	7.67E-02	-2%
57.02	7.51E-02+/- 5%	7.28E-02+/- 0%	-3%	7.31E-02	-2%
Times Days	**FNS EXP. 7 Hrs. microW/g**	**EAF-97 microW/g**	**(C-E)/E**	**FENDL/A-2 microW/g**	**(C-E)/E**
0.63	6.58E-02+/- 5%	6.39E-02+/- 17%	-2%	6.37E-02	-3%
1.30	1.23E-03+/- 5%	1.08E-03+/- 14%	-12%	1.08E-03	-12%
2.88	2.53E-04+/- 6%	2.26E-04+/- 15%	-10%	2.26E-04	-10%
6.89	2.30E-04+/- 6%	2.20E-04+/- 15%	-4%	2.20E-04	-3%
12.88	2.25E-04+/- 6%	2.13E-04+/- 15%	-5%	2.14E-04	-4%
23.89	2.14E-04+/- 6%	2.04E-04+/- 15%	-4%	2.04E-04	-4%
49.72	2.03E-04+/- 6%	1.87E-04+/- 16%	-7%	1.87E-04	-7%
99.91	1.67E-04+/- 6%	1.63E-04+/- 16%	-2%	1.63E-04	-2%

```
FNS 5 Min Fe
Nuclide   T1/2       Pathways
  Mn 57   1.6 m    Fe57(n,p)Mn57                          98.4%  VAL
                   Fe58(n,d)Mn57                           1.5%  ??
  Fe 53   8.5 m    Fe54(n,2n)Fe53                        100.0%  VAL
  Mn 56   2.5 h    Fe56(n,p)Mn56                          99.1%  VAL
                   Fe57(n,d)Mn56                            .8%  ??
FNS 7 Hrs Fe
  Mn 56    2.5 h    Fe56(n,p)Mn56                         99.3%
                    Fe57(n,d)Mn56                           .6%
  Cr 51    27.7 d   Fe54(n,a)Cr51                        100.0%  VAL
  Mn 54    312.3 d  Fe54(n,p)Mn54                         99.6%  VAL
  Fe 55    2.7 y    Fe56(n,2n)Fe55                        99.9%  VAL
```





An interesting analogy can be drawn here when V-52 is dominant up to 30 minutes cooling time. It is produced through multiple channels from Cr-52, Cr-53 and Mn-55 and here seems to be underpredicted by around 20%. This trend is corroborated, in a sense when considering its production from Cr isotopes. The Cr graph indicates as well an underprediction, but of only around 10%. Interestingly enough the predictions of the second irradiation test are well within the experimental uncertainties, enabling the production paths and decay data for the Ni-57 and Co-58 isotopes to be certified.

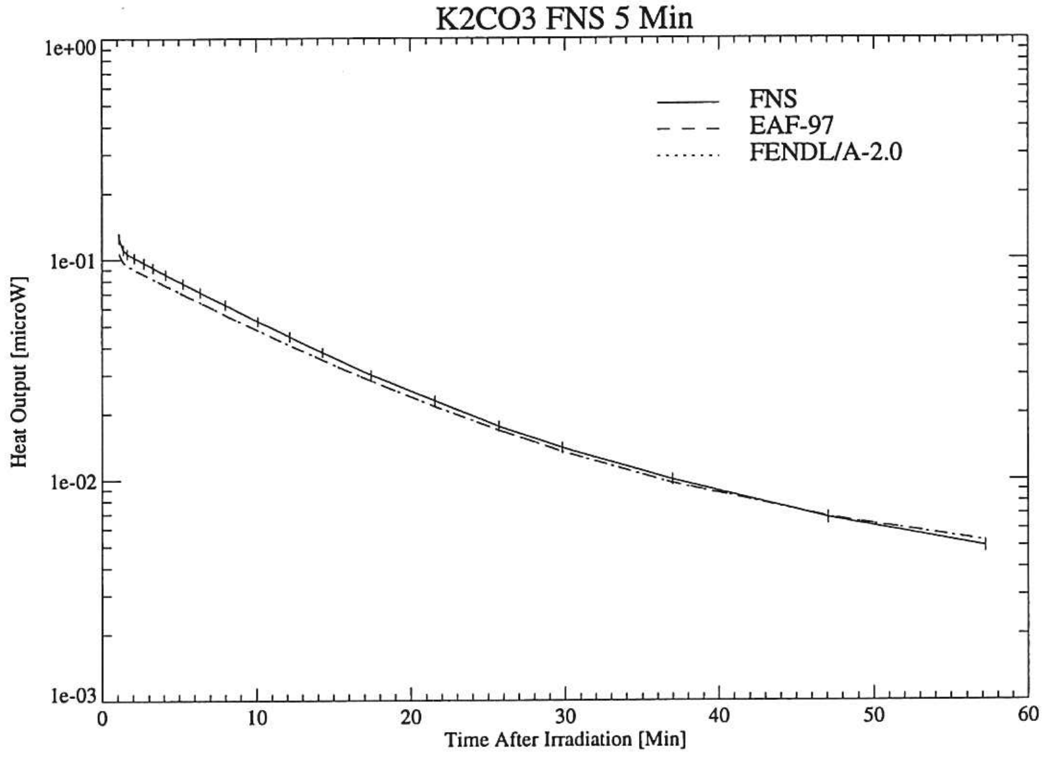
Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	4.07E-01+/- 5%	2.99E-01+/- 19%	-26%	2.88E-01	-29%
1.35	3.81E-01+/- 5%	2.83E-01+/- 19%	-25%	2.74E-01	-28%
1.62	3.62E-01+/- 5%	2.68E-01+/- 19%	-25%	2.59E-01	-28%
2.05	3.29E-01+/- 5%	2.46E-01+/- 19%	-25%	2.37E-01	-27%
2.67	2.89E-01+/- 5%	2.17E-01+/- 19%	-24%	2.10E-01	-27%
3.28	2.56E-01+/- 5%	1.93E-01+/- 19%	-24%	1.86E-01	-27%
4.17	2.15E-01+/- 5%	1.64E-01+/- 19%	-23%	1.58E-01	-26%
5.28	1.74E-01+/- 5%	1.34E-01+/- 19%	-23%	1.29E-01	-25%
6.40	1.43E-01+/- 5%	1.10E-01+/- 19%	-23%	1.07E-01	-25%
8.03	1.09E-01+/- 5%	8.41E-02+/- 18%	-22%	8.15E-02	-25%
10.13	7.82E-02+/- 5%	6.07E-02+/- 17%	-22%	5.90E-02	-24%
12.27	5.76E-02+/- 5%	4.48E-02+/- 16%	-22%	4.37E-02	-24%
14.38	4.35E-02+/- 5%	3.40E-02+/- 15%	-21%	3.34E-02	-23%
17.47	3.11E-02+/- 5%	2.41E-02+/- 14%	-22%	2.38E-02	-23%
21.58	2.16E-02+/- 5%	1.70E-02+/- 13%	-21%	1.69E-02	-21%
25.70	1.67E-02+/- 5%	1.33E-02+/- 13%	-20%	1.33E-02	-20%
29.82	1.38E-02+/- 5%	1.13E-02+/- 13%	-17%	1.14E-02	-17%
36.95	1.14E-02+/- 5%	9.64E-03+/- 13%	-15%	9.68E-03	-14%
47.07	9.58E-03+/- 5%	8.54E-03+/- 13%	-10%	8.57E-03	-10%
57.18	8.70E-03+/- 5%	7.90E-03+/- 13%	-9%	7.92E-03	-8%
Times	**FNS EXP. 7 Hrs.**	**EAF-97**	**(C-E)/E**	**FENDL/A-2**	**(C-E)/E**
Days	microW/g	microW/g		microW/g	
0.62	8.29E-02+/- 7%	8.29E-02+/- 23%	0%	8.29E-02	0%
1.31	5.70E-02+/- 6%	5.68E-02+/- 25%	0%	5.68E-02	0%
2.89	3.11E-02+/- 5%	3.14E-02+/- 24%	1%	3.14E-02	1%
6.86	1.22E-02+/- 5%	1.24E-02+/- 32%	1%	1.24E-02	1%
12.86	8.55E-03+/- 5%	8.61E-03+/- 42%	0%	8.61E-03	0%
23.84	7.47E-03+/- 5%	7.57E-03+/- 43%	1%	7.57E-03	1%
49.69	5.92E-03+/- 5%	5.97E-03+/- 43%	0%	5.97E-03	0%
99.88	3.68E-03+/- 5%	3.84E-03+/- 41%	4%	3.84E-03	4%

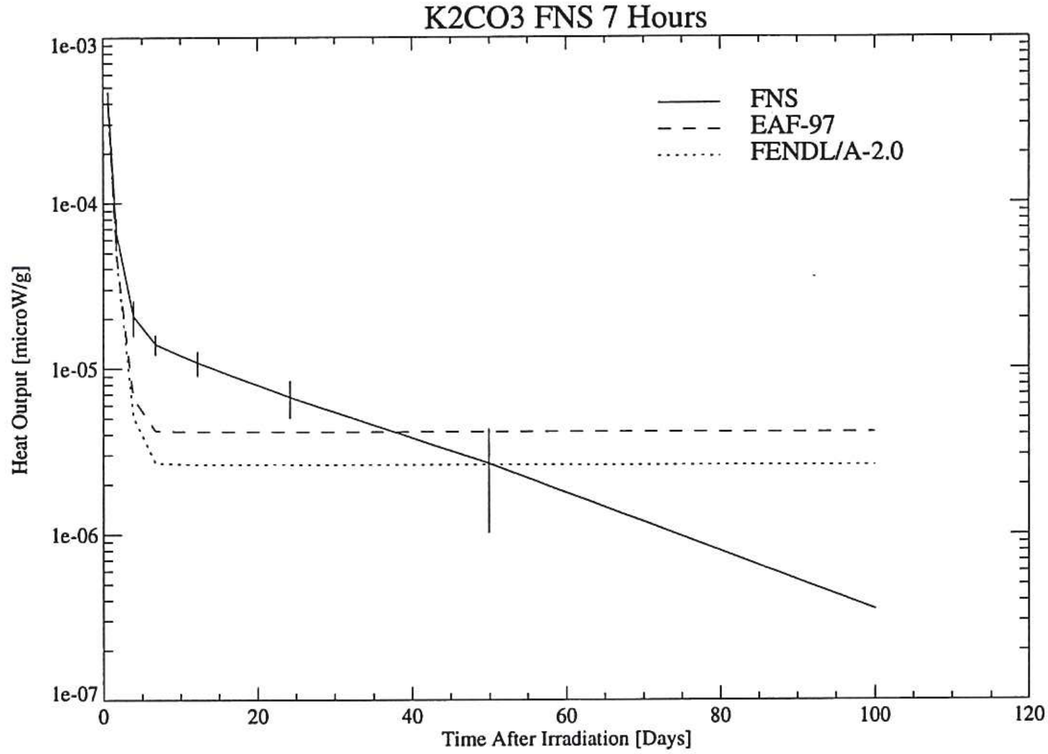
FNS 5 Min Inc600

Nuclide	$T_{1/2}$	Pathways		
Co 62	1.5 m	Ni62(n,p)Co62	99.9%	TBA
V 53	1.6 m	Cr53(n,p)V53	97.9%	TBA
		Cr54(n,d)V53	2.0%	??
V 52	3.7 m	Cr52(n,p)V52	95.7%	TBA
		Cr53(n,d)V52	3.1%	??
		Mn55(n,a)V52	1.0%	??
Co 62m	13.9 m	Ni62(n,p)Co62m	99.9%	TBA
Mn 56	2.5 h	Fe56(n,p)Mn56	98.8%	VAL
		Fe57(n,d)Mn56	.8%	??
Ni 57	1.4 d	Ni58(n,2n)Ni57	100.0%	VAL

FNS 7 Hrs Inc600

V 52	3.7 m	Cr52(n,p)V52	96.5%	
		Cr53(n,d)V52	2.4%	
		Mn55(n,a)V52	1.0%	
Mn 56	2.5 h	Fe56(n,p)Mn56	99.2%	
		Fe57(n,d)Mn56	.6%	
Co 58m	8.9 h	Ni58(n,p)Co58m	99.9%	VAL
Ni 57	1.4 d	Ni58(n,2n)Ni57	100.0%	VAL
Co 58	70.8 d	Ni58(n,p)Co58	76.4%	VAL
		Ni58(n,p)Co58m(IT)Co58	23.5%	VAL
Co 57	271.7 d	Ni58(n,d)Co57	99.5%	VAL



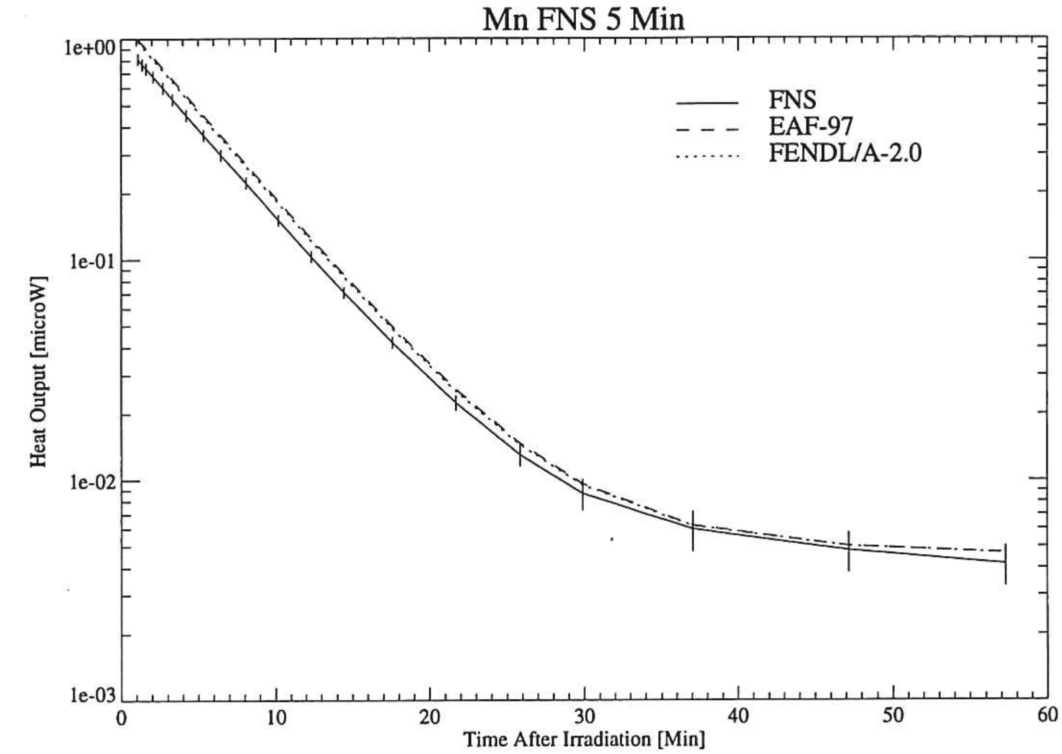


The slight underestimation of the decay power up to 8 minutes cooling time could be traced to the K-38 isotope produced through K-39(n,2n)K-38 although it may well be due to some defect in the decay data as well. It seems to be clear that the Cl-38 and Ar-41 pathways and decay data are more reliable. The rather high uncertainties of the experimental results for the 7 hours irradiation test does not allow any firm conclusions to be drawn, although the trends are very different.

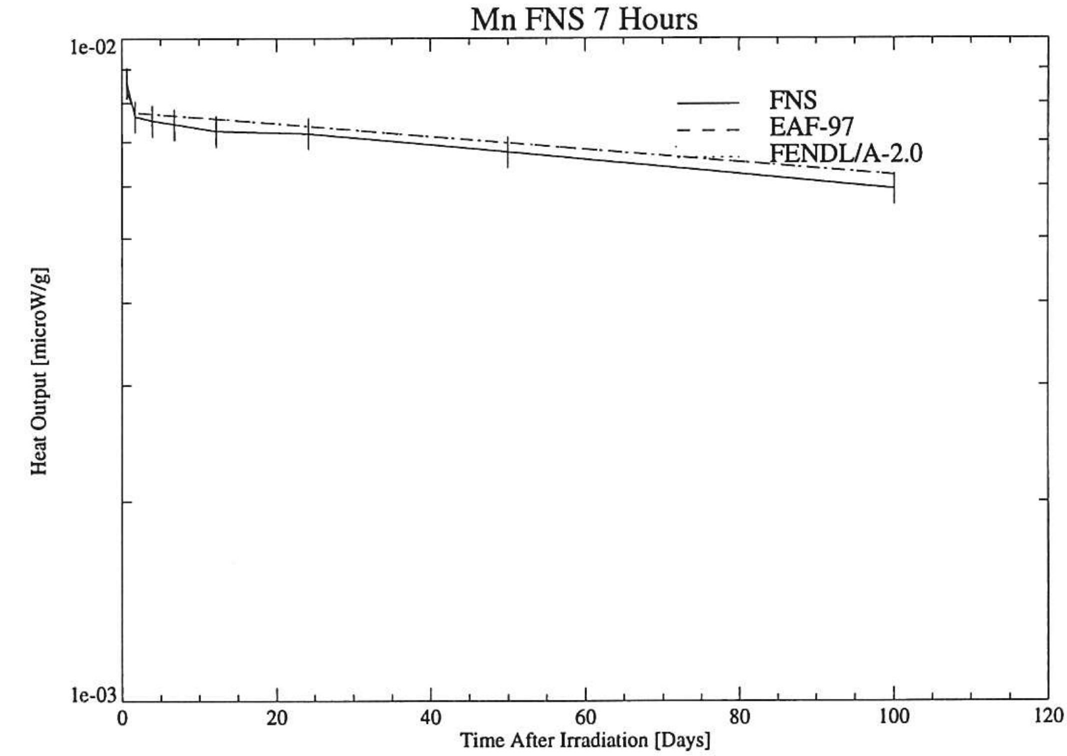
Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	1.25E-01+/- 5%	1.07E-01+/- 54%	-14%	1.07E-01	-14%
1.37	1.11E-01+/- 5%	9.74E-02+/- 58%	-12%	9.76E-02	-12%
1.63	1.06E-01+/- 5%	9.38E-02+/- 59%	-11%	9.40E-02	-11%
2.08	1.02E-01+/- 5%	9.00E-02+/- 59%	-11%	9.02E-02	-11%
2.70	9.64E-02+/- 5%	8.56E-02+/- 58%	-11%	8.58E-02	-11%
3.30	9.19E-02+/- 5%	8.15E-02+/- 58%	-11%	8.17E-02	-11%
4.13	8.55E-02+/- 5%	7.62E-02+/- 58%	-10%	7.63E-02	-10%
5.25	7.79E-02+/- 5%	6.97E-02+/- 57%	-10%	6.98E-02	-10%
6.37	7.10E-02+/- 5%	6.37E-02+/- 56%	-10%	6.39E-02	-10%
8.00	6.22E-02+/- 5%	5.61E-02+/- 55%	-9%	5.62E-02	-9%
10.12	5.25E-02+/- 5%	4.77E-02+/- 54%	-9%	4.77E-02	-9%
12.18	4.46E-02+/- 5%	4.08E-02+/- 52%	-8%	4.09E-02	-8%
14.32	3.77E-02+/- 5%	3.50E-02+/- 50%	-7%	3.50E-02	-7%
17.45	2.99E-02+/- 5%	2.81E-02+/- 48%	-6%	2.81E-02	-6%
21.57	2.28E-02+/- 5%	2.15E-02+/- 44%	-5%	2.15E-02	-5%
25.68	1.74E-02+/- 5%	1.68E-02+/- 40%	-3%	1.68E-02	-3%
29.80	1.40E-02+/- 5%	1.34E-02+/- 36%	-3%	1.34E-02	-3%
36.95	1.00E-02+/- 6%	9.68E-03+/- 32%	-3%	9.66E-03	-3%
47.07	6.73E-03+/- 6%	6.81E-03+/- 27%	1%	6.79E-03	0%
57.18	4.99E-03+/- 6%	5.27E-03+/- 29%	5%	5.25E-03	5%
Times	FNS EXP. 7 Hrs.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Days	microW/g	microW/g		microW/g	
0.65	4.21E-04+/- 12%	3.87E-04+/- 25%	-8%	3.83E-04	-8%
1.71	6.62E-05+/- 21%	4.84E-05+/- 43%	-26%	4.69E-05	-29%
3.87	2.07E-05+/- 24%	6.61E-06+/- 23%	-68%	5.09E-06	-75%
6.73	1.40E-05+/- 13%	4.22E-06+/- 23%	-69%	2.70E-06	-80%
12.18	1.09E-05+/- 17%	4.16E-06+/- 23%	-61%	2.64E-06	-75%
24.19	6.72E-06+/- 25%	4.16E-06+/- 23%	-38%	2.64E-06	-60%
49.94	2.68E-06+/- 61%	4.15E-06+/- 24%	54%	2.63E-06	-1%
100.07	3.53E-07+/-469%	4.14E-06+/- 24%	1070%	2.62E-06	640%

```
FNS 5 Mins K2CO3
Nuclide   T1/2      Pathways
  N  16   7.1 s    O16(n,p)N16                           99.9%  VAL
  K  38   7.6 m    K39(n,2n)K38                         100.0%  TBA
  Cl 38   37.2 m   K39(n,2p)Cl38                          2.9%  ??
                   K41(n,a)Cl38                          68.0%  VAL
                   K39(n,2p)Cl38m(IT)Cl38                 4.7%  ??
                   K41(n,a)Cl38m(IT)Cl38                 24.3%  VAL
  Ar 41   1.8 h    K41(n,p)Ar41                         100.0%  VAL
FNS 7 Hrs K2CO3
  N  16   7.1 s    O16(n,p)N16                           99.9%  ??
  K  38   7.6 m    K39(n,2n)K38                         100.0%  ??
  Ar 41   1.8 h    K41(n,p)Ar41                         100.0%  ??
  K  42   12.3 h   K41(n,g)K42                          100.0%  ??
  Ar 39   269.0 y  K39(n,p)Ar39                          99.9%  ??
  K  40   1.2 Gy                                                ??
```

Mn FNS 5 Min



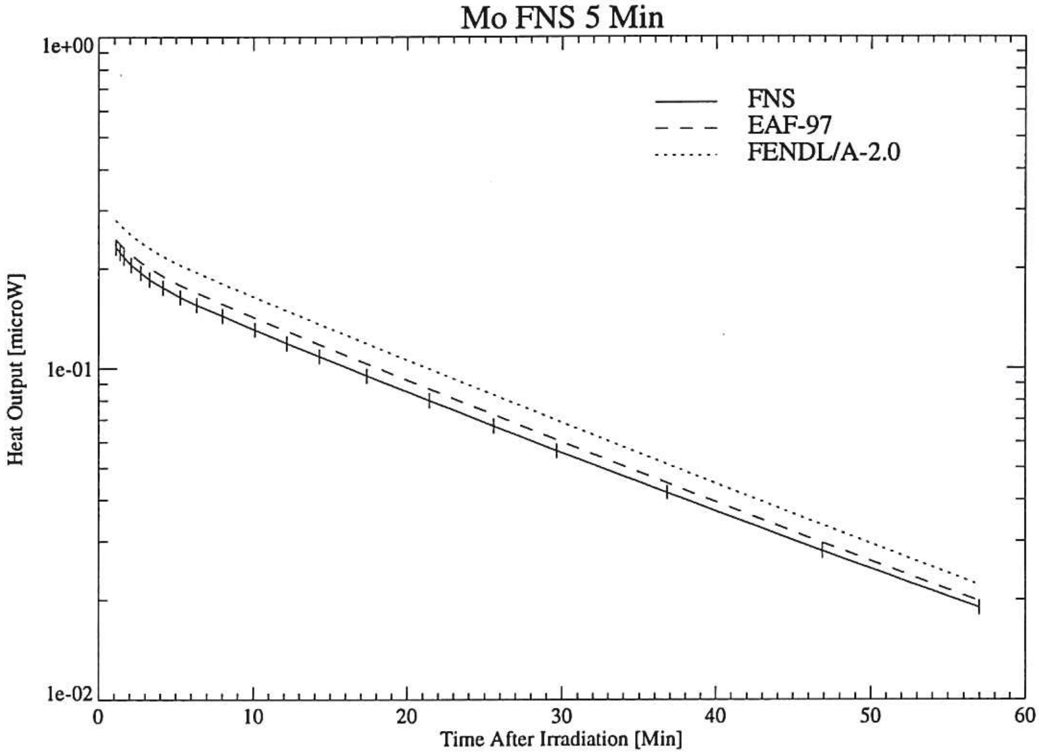
Mn FNS 7 Hours

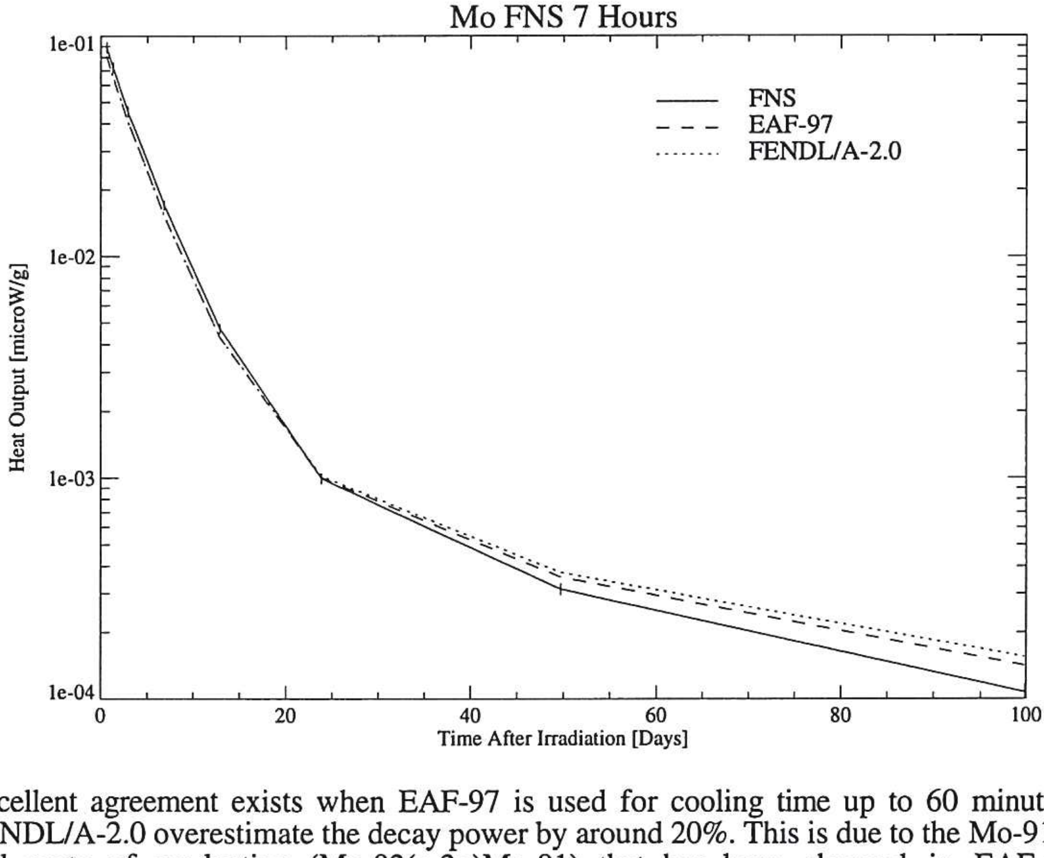


An important element for which the decay power seems to be overpredicted for cooling times up to 30 minutes. It could be due to either V-52 or Cr-55, since these isotopes have nearly similar half lives and production rates. It is clear that the Mn-56 and Mn-54 routes of production and decay data are more reliable leading to an excellent agreement for cooling times up to 100 days.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	8.11E-01+/- 6%	9.95E-01+/- 33%	22%	9.71E-01	19%
1.37	7.67E-01+/- 6%	9.47E-01+/- 33%	23%	9.24E-01	20%
1.63	7.34E-01+/- 6%	9.01E-01+/- 33%	22%	8.79E-01	19%
2.08	6.74E-01+/- 6%	8.28E-01+/- 33%	22%	8.07E-01	19%
2.70	6.00E-01+/- 6%	7.37E-01+/- 33%	22%	7.19E-01	19%
3.32	5.33E-01+/- 6%	6.57E-01+/- 33%	23%	6.41E-01	20%
4.22	4.51E-01+/- 6%	5.55E-01+/- 33%	23%	5.41E-01	20%
5.33	3.67E-01+/- 6%	4.51E-01+/- 33%	22%	4.39E-01	19%
6.45	2.98E-01+/- 6%	3.66E-01+/- 33%	22%	3.57E-01	19%
8.08	2.22E-01+/- 6%	2.71E-01+/- 33%	21%	2.64E-01	18%
10.18	1.51E-01+/- 6%	1.84E-01+/- 33%	22%	1.79E-01	19%
12.32	1.03E-01+/- 6%	1.25E-01+/- 33%	21%	1.22E-01	18%
14.45	7.07E-02+/- 6%	8.54E-02+/- 32%	20%	8.32E-02	17%
17.58	4.20E-02+/- 6%	4.97E-02+/- 31%	18%	4.85E-02	15%
21.70	2.23E-02+/- 7%	2.58E-02+/- 27%	15%	2.52E-02	12%
25.83	1.30E-02+/- 11%	1.47E-02+/- 24%	13%	1.44E-02	11%
29.90	8.65E-03+/- 16%	9.58E-03+/- 26%	10%	9.45E-03	9%
37.03	5.96E-03+/- 20%	6.20E-03+/- 31%	3%	6.17E-03	3%
47.17	4.79E-03+/- 20%	5.01E-03+/- 36%	4%	5.01E-03	4%
57.28	4.16E-03+/- 20%	4.66E-03+/- 37%	12%	4.66E-03	12%
Times	**FNS EXP. 7 Hrs.**	**EAF-97**	**(C-E)/E**	**FENDL/A-2**	**(C-E)/E**
Days	microW/g	microW/g		microW/g	
0.68	8.58E-03+/- 5%	8.31E-03+/- 28%	-3%	8.31E-03	-3%
1.73	7.64E-03+/- 5%	7.74E-03+/- 0%	1%	7.74E-03	1%
3.89	7.52E-03+/- 5%	7.71E-03+/- 0%	2%	7.71E-03	2%
6.75	7.43E-03+/- 5%	7.66E-03+/- 0%	3%	7.66E-03	3%
12.20	7.25E-03+/- 5%	7.57E-03+/- 0%	4%	7.57E-03	4%
24.21	7.19E-03+/- 5%	7.37E-03+/- 0%	2%	7.37E-03	2%
49.96	6.74E-03+/- 5%	6.96E-03+/- 0%	3%	6.96E-03	3%
100.10	5.93E-03+/- 5%	6.22E-03+/- 0%	4%	6.22E-03	4%

```
FNS 5 Mins Mn
Nuclide  T1/2     Pathways
  V  52  3.7 m   Mn55(n,a)V52                          100.0%  TBA
  Cr 55  3.5 m   Mn55(n,p)Cr55                         100.0%  TBA
  Mn 56  2.5 h   Mn55(n,g)Mn56                         100.0%  VAL
FNS 7 Hrs Mn
  V  52  3.7 m   Mn55(n,a)V52                          100.0%
  Cr 55  3.5 m   Mn55(n,p)Cr55                         100.0%
  Mn 56  2.5 h   Mn55(n,g)Mn56                         100.0%
  Mn 54  312.3 d Mn55(n,2n)Mn54                        100.0%  VAL
```





Excellent agreement exists when EAF-97 is used for cooling time up to 60 minutes while FENDL/A-2.0 overestimate the decay power by around 20%. This is due to the Mo-91 isotope and route of production (Mo-92(n,2n)Mo-91) that has been changed in EAF-97. The complexity and shear number of predominant isotopes present for cooling times up to 100 days do not allow any clear picture to be extracted, although the (C-E/E) values are never very large.

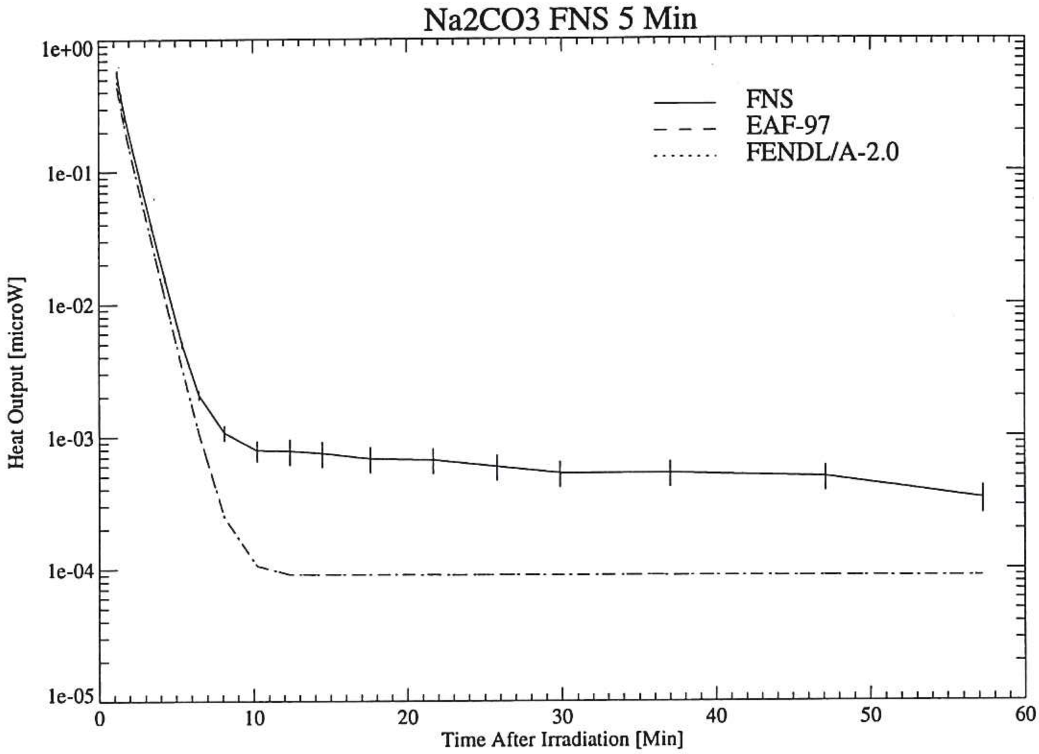
Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	2.32E-01+/- 5%	2.45E-01+/- 57%	5%	2.80E-01	20%
1.37	2.24E-01+/- 5%	2.38E-01+/- 58%	5%	2.71E-01	21%
1.63	2.17E-01+/- 5%	2.31E-01+/- 59%	6%	2.64E-01	21%
2.08	2.05E-01+/- 5%	2.21E-01+/- 60%	7%	2.53E-01	23%
2.70	1.95E-01+/- 5%	2.09E-01+/- 62%	7%	2.40E-01	23%
3.27	1.85E-01+/- 5%	2.01E-01+/- 63%	8%	2.31E-01	24%
4.17	1.75E-01+/- 5%	1.90E-01+/- 64%	8%	2.18E-01	24%
5.28	1.64E-01+/- 5%	1.78E-01+/- 65%	8%	2.05E-01	25%
6.35	1.55E-01+/- 5%	1.69E-01+/- 65%	8%	1.94E-01	25%
8.00	1.44E-01+/- 5%	1.56E-01+/- 66%	8%	1.80E-01	25%
10.12	1.30E-01+/- 5%	1.42E-01+/- 66%	8%	1.63E-01	25%
12.18	1.19E-01+/- 5%	1.29E-01+/- 66%	8%	1.49E-01	25%
14.30	1.08E-01+/- 5%	1.18E-01+/- 66%	8%	1.36E-01	25%
17.38	9.46E-02+/- 5%	1.03E-01+/- 65%	8%	1.18E-01	25%
21.45	7.96E-02+/- 5%	8.63E-02+/- 65%	8%	9.91E-02	24%
25.58	6.67E-02+/- 5%	7.22E-02+/- 64%	8%	8.29E-02	24%
29.65	5.62E-02+/- 5%	6.07E-02+/- 64%	7%	6.95E-02	23%
36.78	4.20E-02+/- 5%	4.50E-02+/- 63%	7%	5.12E-02	22%
46.87	2.80E-02+/- 5%	2.97E-02+/- 61%	5%	3.36E-02	19%
56.98	1.89E-02+/- 5%	1.98E-02+/- 58%	4%	2.22E-02	17%
Times	**FNS EXP. 7 Hrs.**	**EAF-97**	**(C-E)/E**	**FENDL/A-2**	**(C-E)/E**
Days	microW/g	microW/g		microW/g	
0.64	8.87E-02+/- 5%	8.11E-02+/- 8%	-8%	8.10E-02	-8%
1.31	7.23E-02+/- 5%	6.53E-02+/- 8%	-9%	6.52E-02	-9%
2.90	4.54E-02+/- 5%	4.11E-02+/- 8%	-9%	4.10E-02	-9%
6.86	1.70E-02+/- 5%	1.52E-02+/- 9%	-10%	1.52E-02	-10%
12.86	4.71E-03+/- 5%	4.29E-03+/- 15%	-8%	4.30E-03	-8%
23.86	9.95E-04+/- 5%	1.00E-03+/- 31%	0%	1.02E-03	2%
49.71	3.14E-04+/- 6%	3.57E-04+/- 36%	13%	3.74E-04	18%
99.90	1.07E-04+/- 9%	1.42E-04+/- 39%	32%	1.55E-04	44%

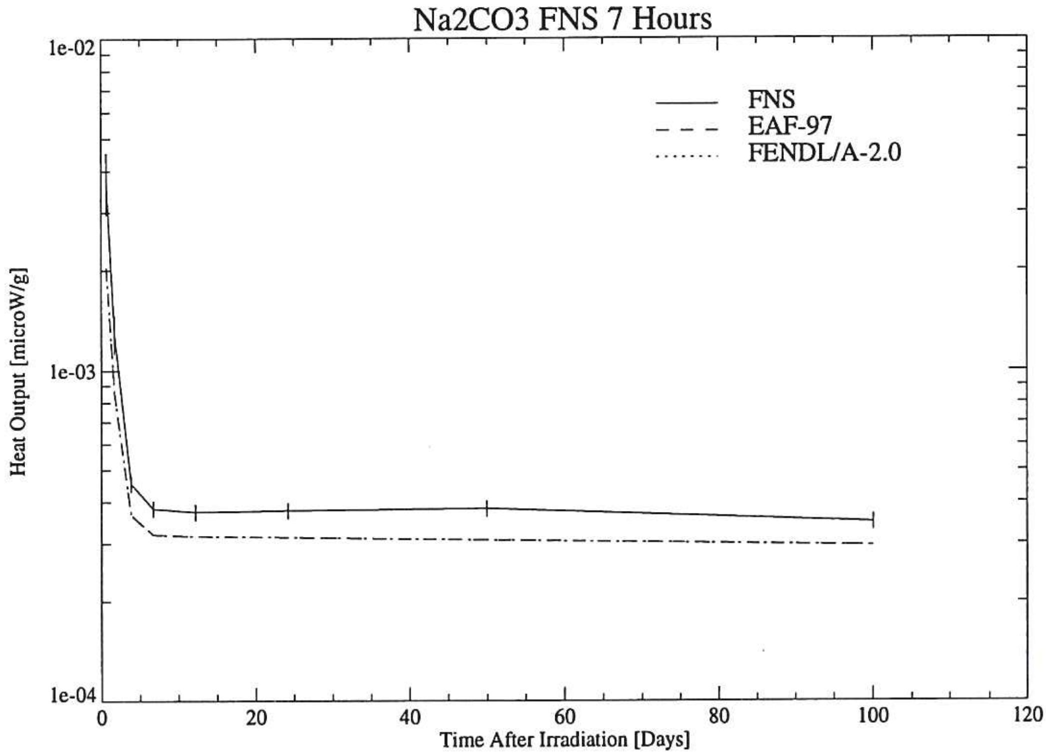
FNS 5 Min Mo

Nuclide	$T_{1/2}$	Pathways		
Mo 91m	1.0 m	Mo92(n,2n)Mo91m	100.0%	VAL
Mo 91	15.4 m	Mo92(n,2n)Mo91	97.2%	VAL
		Mo92(n,2n)Mo91m(IT)Mo91	2.7%	??

FNS 7 Hrs Mo

Nb 91m	1.0 m	Mo92(n,d)Nb91m	100.0%	
Mo 91	15.4 m	Mo92(n,2n)Mo91	96.2%	
		Mo92(n,2n)Mo91m(IT)Mo91	3.7%	
Tc 99m	6.0 h	Mo98(n,g)Mo99(b-)Tc99m	.5%	??
		Mo100(n,2n)Mo99(b-)Tc99m	99.2%	VAL
Nb 96	23.3 h	Mo96(n,p)Nb96	96.5%	VAL
		Mo97(n,d)Nb96	3.3%	??
Mo 99	2.748 d	Mo98(n,g)Mo99	.5%	??
		Mo100(n,2n)Mo99	99.2%	VAL
Nb 92m	10.1 d	Mo92(n,p)Nb92m	99.9%	VAL
Nb 95	34.9 d	Mo95(n,p)Nb95	78.2%	TBA
		Mo96(n,d)Nb95	20.6%	TBA
Zr 95	64.0 d	Mo96(n,2p)Zr95	.7%	??
		Mo98(n,a)Zr95	99.0%	TBA

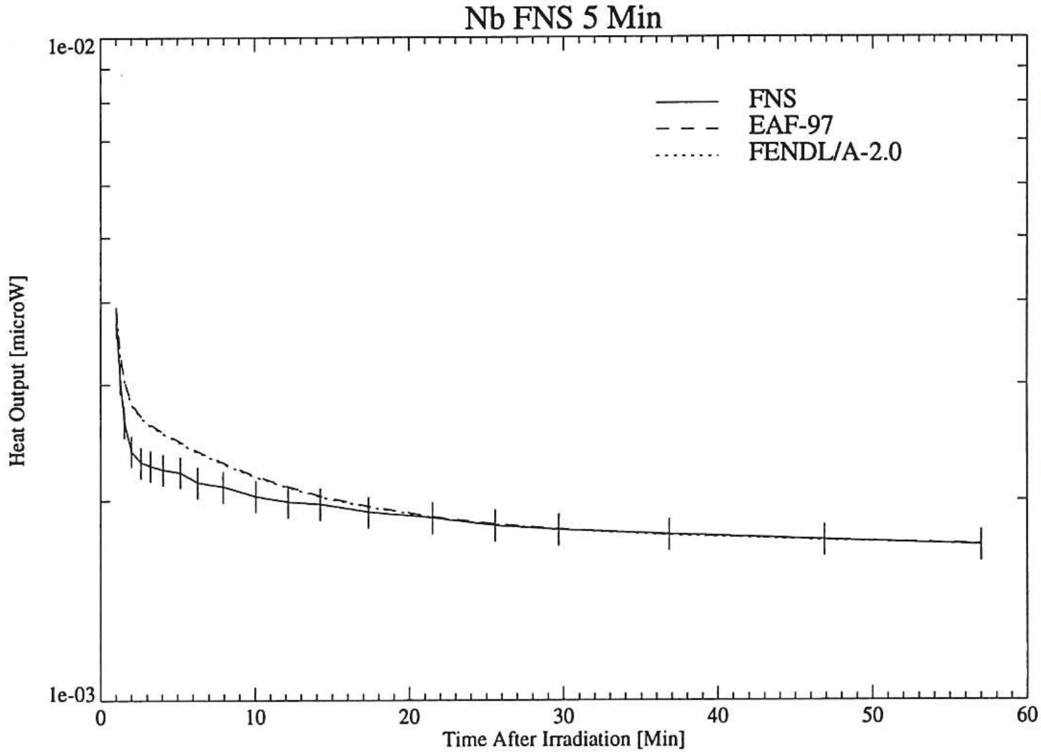


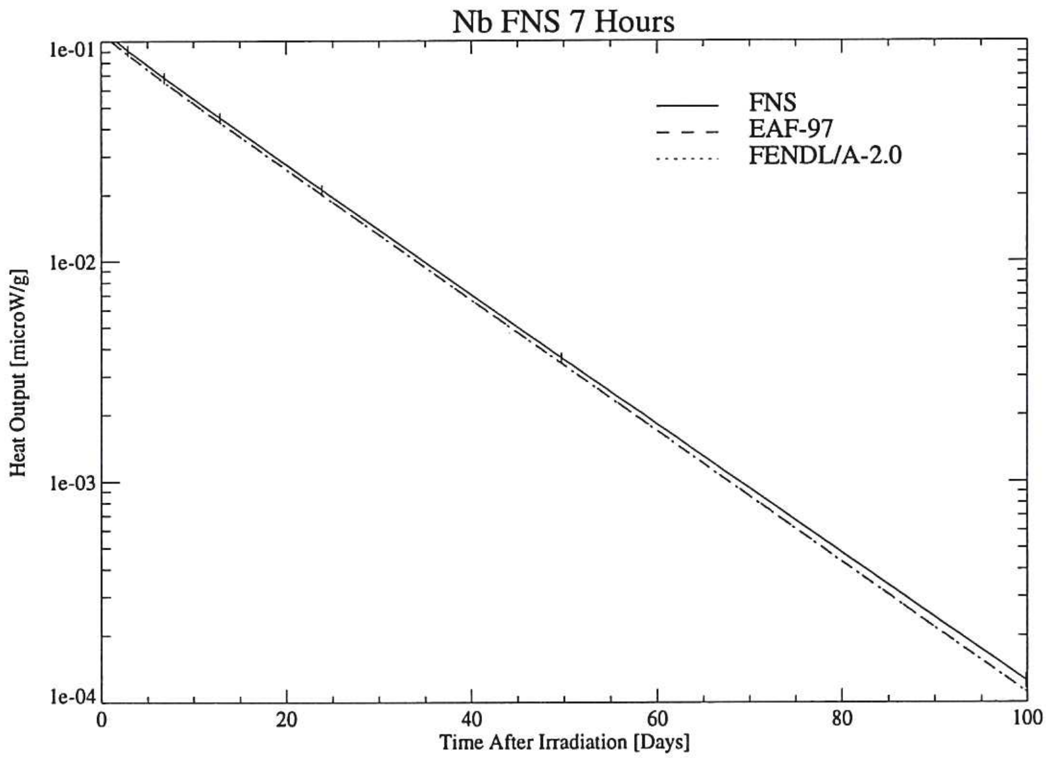


In this particular case the major route of production of Na-24 that predominates in the upper graph in the plateau are (n,g) channels that cannot be properly calculated with the spectral data, and so do not allow any conclusions to be drawn. It seems, however, that either the F-20 or Ne-23 routes of production or decay data would lead the code to underpredict the experiment by around 20%. As an exercise, if one took the decision to correct this underprediction by correcting the cross-section with no other source of information, the dilemma would be to choose between either increasing the Na-23(n,p) Ne-23 cross-section by 20% or doubling the Na-23(n,a)F-20 channels. The second option would not be too drastic when the cross-sections used in that benchmark are plotted against the EXFOR experimental data base. From the second graph the same conclusion can be drawn but one should notice that the plateau there is due to Na-22 from Na-23(n,2n)Na-22, leading to an underprediction also by about 20%.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.20	5.54E-01+/- 5%	4.41E-01+/- 20%	-20%	4.82E-01	-13%
1.47	3.68E-01+/- 5%	2.95E-01+/- 21%	-19%	3.10E-01	-15%
1.73	2.59E-01+/- 5%	2.08E-01+/- 22%	-19%	2.13E-01	-17%
2.18	1.53E-01+/- 5%	1.21E-01+/- 23%	-21%	1.22E-01	-20%
2.80	7.62E-02+/- 5%	6.00E-02+/- 23%	-21%	6.01E-02	-21%
3.42	3.85E-02+/- 5%	3.01E-02+/- 23%	-21%	3.01E-02	-21%
4.30	1.55E-02+/- 5%	1.13E-02+/- 23%	-27%	1.13E-02	-27%
5.42	4.97E-03+/- 5%	3.30E-03+/- 23%	-33%	3.30E-03	-33%
6.48	2.08E-03+/- 8%	1.06E-03+/- 22%	-48%	1.06E-03	-48%
8.12	1.08E-03+/- 13%	2.48E-04+/- 19%	-76%	2.48E-04	-77%
10.23	7.92E-04+/- 18%	1.06E-04+/- 28%	-86%	1.06E-04	-86%
12.37	7.82E-04+/- 22%	9.12E-05+/- 33%	-88%	9.12E-05	-88%
14.47	7.49E-04+/- 22%	9.11E-05+/- 33%	-87%	9.10E-05	-87%
17.60	6.82E-04+/- 22%	9.09E-05+/- 33%	-86%	9.08E-05	-86%
21.68	6.66E-04+/- 22%	9.06E-05+/- 33%	-86%	9.06E-05	-86%
25.80	5.93E-04+/- 22%	9.03E-05+/- 33%	-84%	9.03E-05	-84%
29.87	5.28E-04+/- 22%	9.01E-05+/- 33%	-82%	9.00E-05	-82%
37.00	5.28E-04+/- 22%	8.96E-05+/- 33%	-83%	8.95E-05	-83%
47.13	4.95E-04+/- 22%	8.89E-05+/- 33%	-82%	8.89E-05	-82%
57.25	3.42E-04+/- 23%	8.83E-05+/- 33%	-74%	8.82E-05	-74%
Times	FNS EXP. 7 Hrs.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Days	microW/g	microW/g		microW/g	
0.67	3.73E-03+/- 21%	2.04E-03+/- 47%	-45%	2.04E-03	-45%
1.72	1.29E-03+/- 13%	8.52E-04+/- 36%	-34%	8.53E-04	-33%
3.87	4.55E-04+/- 5%	3.66E-04+/- 22%	-19%	3.66E-04	-19%
6.74	3.82E-04+/- 5%	3.19E-04+/- 23%	-16%	3.19E-04	-16%
12.19	3.73E-04+/- 5%	3.15E-04+/- 23%	-15%	3.15E-04	-15%
24.20	3.77E-04+/- 5%	3.13E-04+/- 23%	-17%	3.13E-04	-17%
49.95	3.82E-04+/- 5%	3.07E-04+/- 23%	-19%	3.07E-04	-19%
100.08	3.49E-04+/- 5%	2.96E-04+/- 23%	-15%	2.96E-04	-15%

```
FNS 5 Mins Na2CO3
Nuclide  T1/2      Pathways
  N  16  7.1 s    O16(n,p)N16                                99.9%  VAL
  F  20  11.0 s   Na23(n,a)F20                              100.0%  TBA
  Ne 23  37.2 s   Na23(n,p)Ne23                             100.0%  TBA
  Na 24  14.9 h   Na23(n,g)Na24                              47.1%  ??
                  Na23(n,g)Na24m(IT)Na24                     52.8%  ??
  Na 22  2.6 y    Na23(n,2n)Na22                            100.0%  ??
FNS 7 Hrs Na2CO3
  N  16  7.1 s    O16(n,p)N16                                99.9%
  F  20  11.0 s   Na23(n,a)F20                              100.0%
  Ne 23  37.2 s   Na23(n,p)Ne23                             100.0%
  Na 24  14.9 h   Na23(n,g)Na24                              65.6%  ??
                  Na23(n,g)Na24m(IT)Na24                     34.3%  ??
  Na 22   2.6 y   Na23(n,2n)Na22                            100.0%  TBA
```

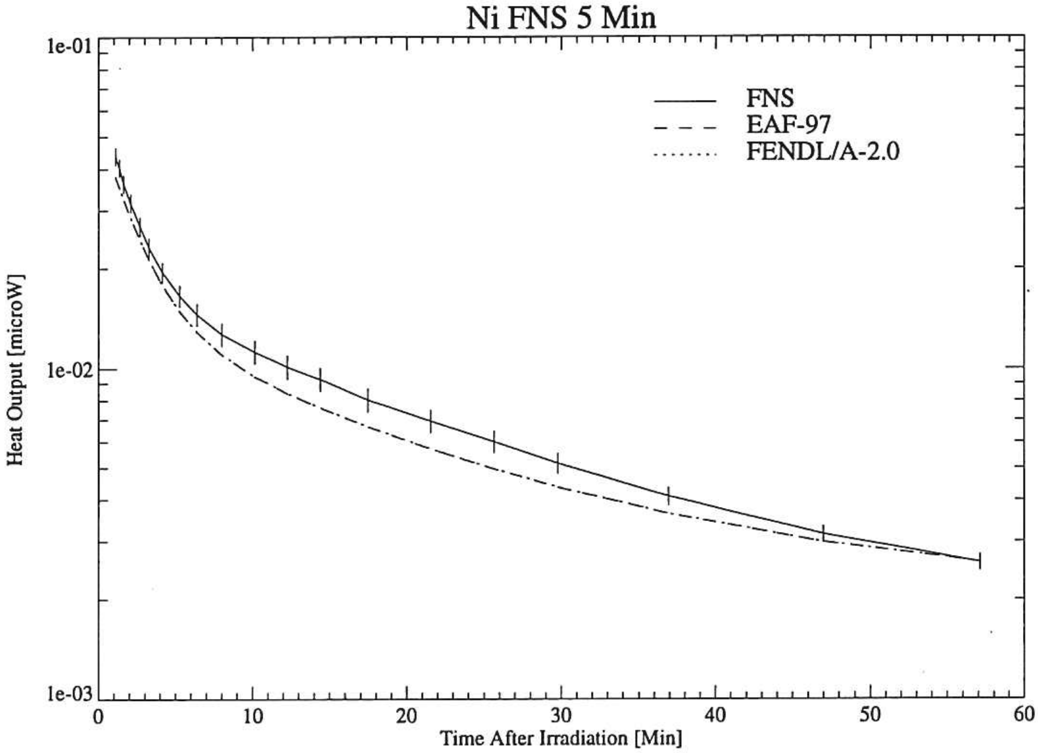


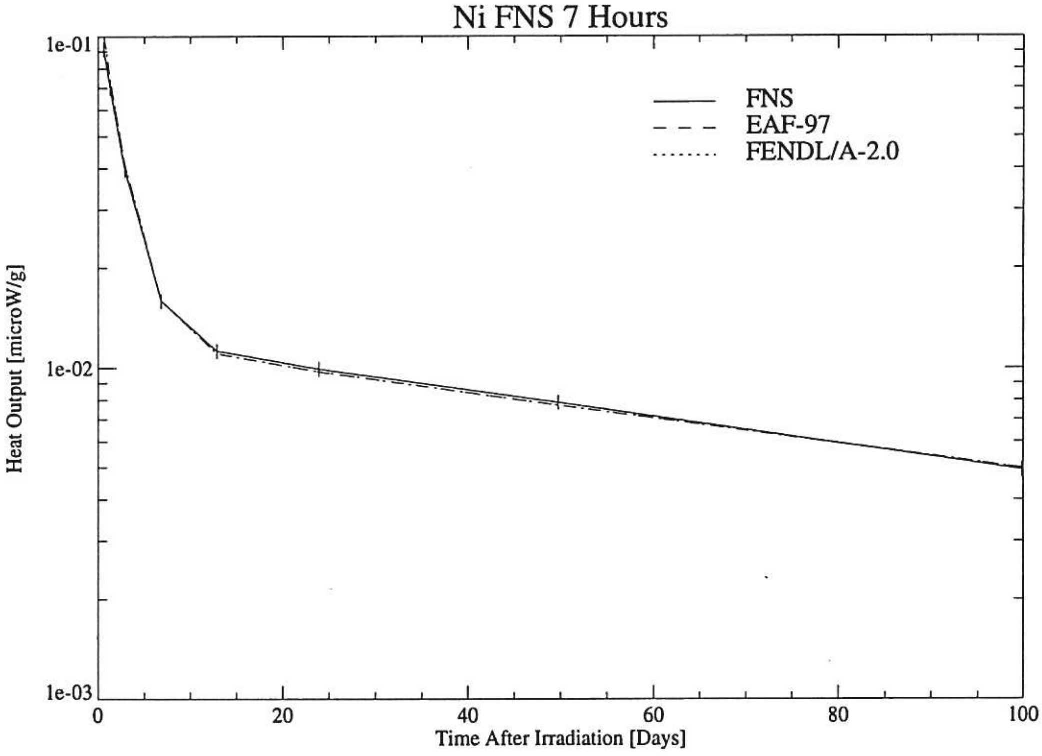


Excellent agreement at all cooling times except between 2 and 6 minutes. Nb-94m seems to be the cause of the discrepancies, but as this is produced through Nb-93(n,g)Nb94m, which cannot be accurately predicted with the spectral data given, no firm conclusions can be drawn.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.02	3.73E-03+/- 5%	3.90E-03+/- 31%	4%	3.88E-03	4%
1.28	3.07E-03+/- 5%	3.34E-03+/- 30%	8%	3.32E-03	8%
1.55	2.63E-03+/- 5%	3.04E-03+/- 31%	15%	3.03E-03	14%
2.00	2.38E-03+/- 5%	2.81E-03+/- 32%	18%	2.80E-03	17%
2.62	2.29E-03+/- 5%	2.68E-03+/- 33%	17%	2.67E-03	16%
3.23	2.26E-03+/- 5%	2.61E-03+/- 33%	15%	2.60E-03	14%
4.07	2.23E-03+/- 5%	2.54E-03+/- 34%	13%	2.53E-03	13%
5.18	2.21E-03+/- 5%	2.45E-03+/- 34%	11%	2.44E-03	10%
6.30	2.13E-03+/- 5%	2.38E-03+/- 35%	11%	2.37E-03	11%
7.93	2.10E-03+/- 5%	2.28E-03+/- 36%	8%	2.27E-03	8%
10.05	2.03E-03+/- 5%	2.18E-03+/- 37%	7%	2.17E-03	6%
12.17	1.99E-03+/- 5%	2.10E-03+/- 38%	5%	2.09E-03	4%
14.23	1.98E-03+/- 5%	2.03E-03+/- 39%	2%	2.03E-03	2%
17.37	1.92E-03+/- 5%	1.96E-03+/- 40%	2%	1.95E-03	1%
21.50	1.88E-03+/- 5%	1.89E-03+/- 41%	0%	1.88E-03	0%
25.57	1.83E-03+/- 5%	1.84E-03+/- 42%	0%	1.84E-03	0%
29.68	1.81E-03+/- 5%	1.81E-03+/- 42%	0%	1.81E-03	0%
36.82	1.78E-03+/- 5%	1.77E-03+/- 43%	0%	1.77E-03	0%
46.90	1.74E-03+/- 5%	1.74E-03+/- 43%	0%	1.74E-03	0%
57.02	1.71E-03+/- 5%	1.72E-03+/- 44%	0%	1.71E-03	0%
Times	**FNS EXP. 7 Hrs.**	**EAF-97**	**(C-E)/E**	**FENDL/A-2**	**(C-E)/E**
Days	microW/g	microW/g		microW/g	
0.62	1.09E-01+/- 5%	1.05E-01+/- 55%	-3%	1.05E-01	-4%
1.32	1.03E-01+/- 5%	9.85E-02+/- 56%	-4%	9.82E-02	-4%
2.90	9.08E-02+/- 5%	8.72E-02+/- 57%	-3%	8.69E-02	-4%
6.86	6.81E-02+/- 5%	6.51E-02+/- 58%	-4%	6.49E-02	-4%
12.86	4.48E-02+/- 5%	4.27E-02+/- 59%	-4%	4.26E-02	-5%
23.85	2.10E-02+/- 5%	2.00E-02+/- 0%	-4%	2.00E-02	-4%
49.70	3.62E-03+/- 5%	3.43E-03+/- 0%	-5%	3.42E-03	-5%
99.89	1.25E-04+/- 7%	1.12E-04+/- 59%	-10%	1.12E-04	-10%

```
FNS 5 Mins Nb
Nuclide   T1/2       Pathways
  Y  89m 16.0 s   Nb93(n,na)Y89m                     100.0%  VAL
  Nb 94m 6.2 m    Nb93(n,g)Nb94m                     100.0%  ??
  Y  90m 3.1 h    Nb93(n,a)Y90m                      100.0%  VAL
  Nb 92m 10.1 d   Nb93(n,2n)Nb92m                    100.0%  VAL
FNS 7 Hrs Nb
  Y  89m 16.0 s   Nb93(n,na)Y89m                     100.0%  VAL
  Y  90m 3.1 h    Nb93(n,a)Y90m                      100.0%  VAL
  Y  90  2.6 d    Nb93(n,a)Y90                        65.0%  VAL
                  Nb93(n,a)Y90m(IT)Y90                34.9%  VAL
  Nb 92m 10.1 d   Nb93(n,2n)Nb92m                    100.0%  VAL
```





A very large number of radioisotopes are generated from the element Ni, that make the analysis difficult. First Co-62 alone and then Fe-61, Co-60m and Co-62m could be responsible for the fluctuating underestimation. Their production paths and decay data need to be analysed in line with other sources of information in order for any conclusion to be drawn. It would be premature and unjustified in view of such narrow evidence to correct any cross-sections or decay data, particularly in view of the fact that the 7 hours irradiation comparison is well within the experimental uncertainty bounds.

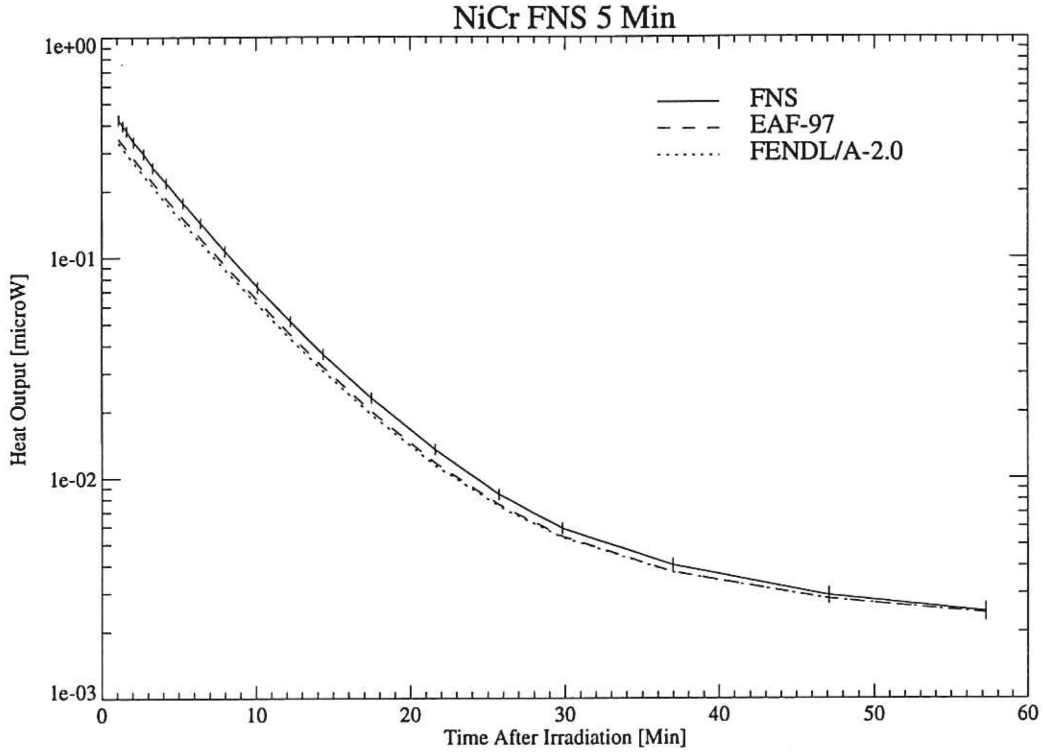
Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	4.37E-02+/- 6%	3.79E-02+/- 50%	-13%	3.79E-02	-13%
1.35	4.04E-02+/- 6%	3.51E-02+/- 49%	-13%	3.51E-02	-13%
1.62	3.61E-02+/- 6%	3.24E-02+/- 47%	-10%	3.24E-02	-10%
2.07	3.15E-02+/- 6%	2.86E-02+/- 44%	-9%	2.86E-02	-9%
2.68	2.68E-02+/- 6%	2.44E-02+/- 41%	-9%	2.44E-02	-8%
3.28	2.31E-02+/- 6%	2.12E-02+/- 38%	-8%	2.13E-02	-7%
4.17	1.95E-02+/- 7%	1.78E-02+/- 36%	-8%	1.78E-02	-8%
5.28	1.65E-02+/- 7%	1.49E-02+/- 34%	-10%	1.49E-02	-10%
6.40	1.45E-02+/- 7%	1.29E-02+/- 34%	-11%	1.29E-02	-11%
8.03	1.26E-02+/- 8%	1.10E-02+/- 34%	-13%	1.10E-02	-13%
10.15	1.12E-02+/- 8%	9.43E-03+/- 35%	-15%	9.45E-03	-15%
12.27	1.01E-02+/- 8%	8.39E-03+/- 35%	-16%	8.40E-03	-16%
14.40	9.26E-03+/- 8%	7.58E-03+/- 35%	-18%	7.59E-03	-17%
17.48	8.02E-03+/- 8%	6.65E-03+/- 34%	-17%	6.67E-03	-16%
21.55	6.92E-03+/- 7%	5.70E-03+/- 32%	-17%	5.71E-03	-17%
25.65	5.99E-03+/- 7%	4.96E-03+/- 30%	-17%	4.97E-03	-17%
29.78	5.16E-03+/- 7%	4.37E-03+/- 29%	-15%	4.38E-03	-15%
36.92	4.10E-03+/- 6%	3.63E-03+/- 26%	-11%	3.64E-03	-11%
46.98	3.15E-03+/- 5%	2.99E-03+/- 23%	-5%	2.99E-03	-5%
57.10	2.59E-03+/- 5%	2.60E-03+/- 21%	0%	2.60E-03	0%
Times	**FNS EXP. 7 Hrs.**	**EAF-97**	**(C-E)/E**	**FENDL/A-2**	**(C-E)/E**
Days	microW/g	microW/g		microW/g	
0.60	9.17E-02+/- 5%	1.03E-01+/- 25%	12%	1.03E-01	12%
1.31	7.01E-02+/- 5%	7.45E-02+/- 25%	6%	7.45E-02	6%
2.89	3.96E-02+/- 5%	4.11E-02+/- 25%	3%	4.11E-02	3%
6.86	1.59E-02+/- 5%	1.60E-02+/- 33%	0%	1.60E-02	0%
12.85	1.13E-02+/- 5%	1.10E-02+/- 44%	-1%	1.10E-02	-1%
23.85	9.92E-03+/- 5%	9.74E-03+/- 44%	-1%	9.74E-03	-1%
49.70	7.87E-03+/- 5%	7.72E-03+/- 44%	-1%	7.72E-03	-1%
99.89	4.93E-03+/- 5%	4.98E-03+/- 41%	1%	4.98E-03	1%

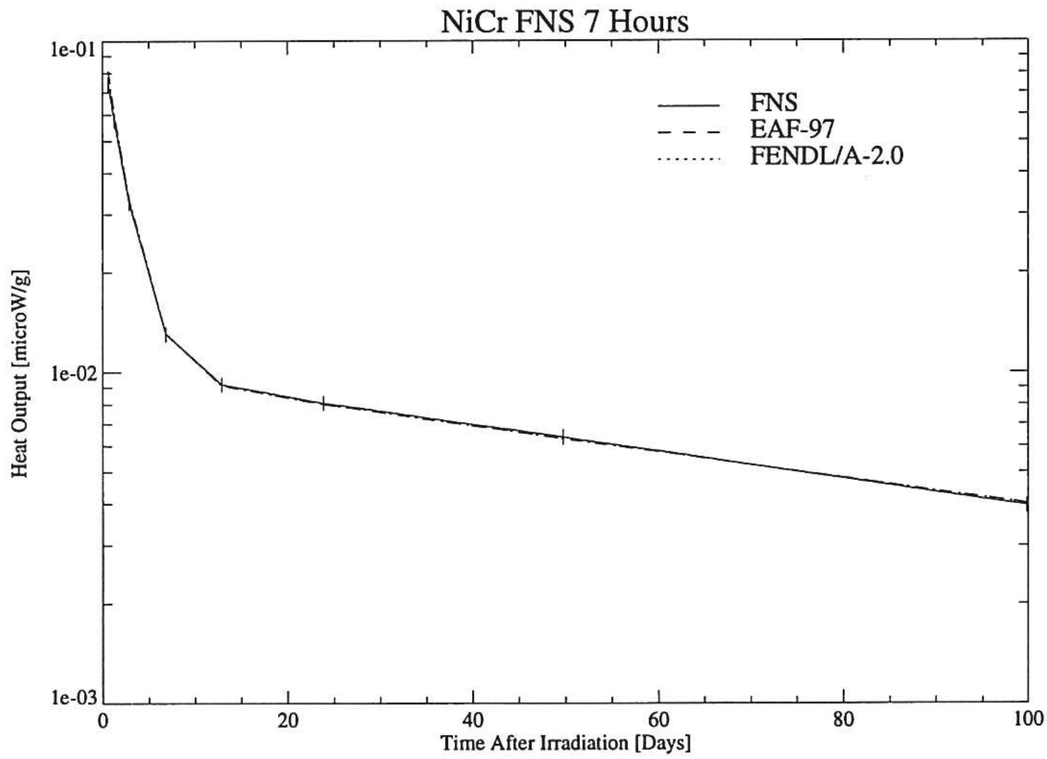
FNS 5 Mins Ni

Nuclide	$T_{1/2}$	Pathways		
Co 64	300.0ms	Ni64(n,p)Co64	100.0%	??
Co 62	1.5 m	Ni62(n,p)Co62	99.9%	TBA
Fe 61	5.9 m	Ni64(n,a)Fe61	100.0%	TBA
Co 62m	13.9 m	Ni62(n,p)Co62m	99.9%	??
Co 60m	10.4 m	Ni60(n,p)Co60m	93.8%	??
		Ni61(n,d)Co60m	6.1%	??
Co 61	1.6 h	Ni61(n,p)Co61	75.8%	TBA
		Ni62(n,d)Co61	22.6%	TBA
Co 58m	8.9 h	Ni58(n,p)Co58m	99.9%	??
Ni 57	1.4 d	Ni58(n,2n)Ni57	100.0%	??

FNS 7 Hrs Ni

Co 62	1.5 m	Ni62(n,p)Co62	99.4%	
Co 60m	10.4 m	Ni60(n,p)Co60m	94.9%	
		Ni61(n,d)Co60m	5.0%	
Co 62m	13.9 m	Ni62(n,p)Co62m	99.9%	
Co 58m	8.9 h	Ni58(n,p)Co58m	99.9%	
Ni 57	1.4 d	Ni58(n,2n)Ni57	100.0%	VAL
Co 58	70.8 d	Ni58(n,p)Co58	76.4%	VAL
		Ni58(n,p)Co58m(IT)Co58	23.5%	VAL
Co 57	271.7 d	Ni58(n,d)Co57	99.5%	VAL





The first 15 minutes of cooling time are dominated by the Cr produced isotope V-52 and the trend is the same as seem in Cr alone but the comparison gets better when Ni-57 (produced by Ni-58(n,2n)Ni-57 reaction) isotope starts to dominate. The 7 hours irradiation comparison is very well within the experimental uncertainty bounds.

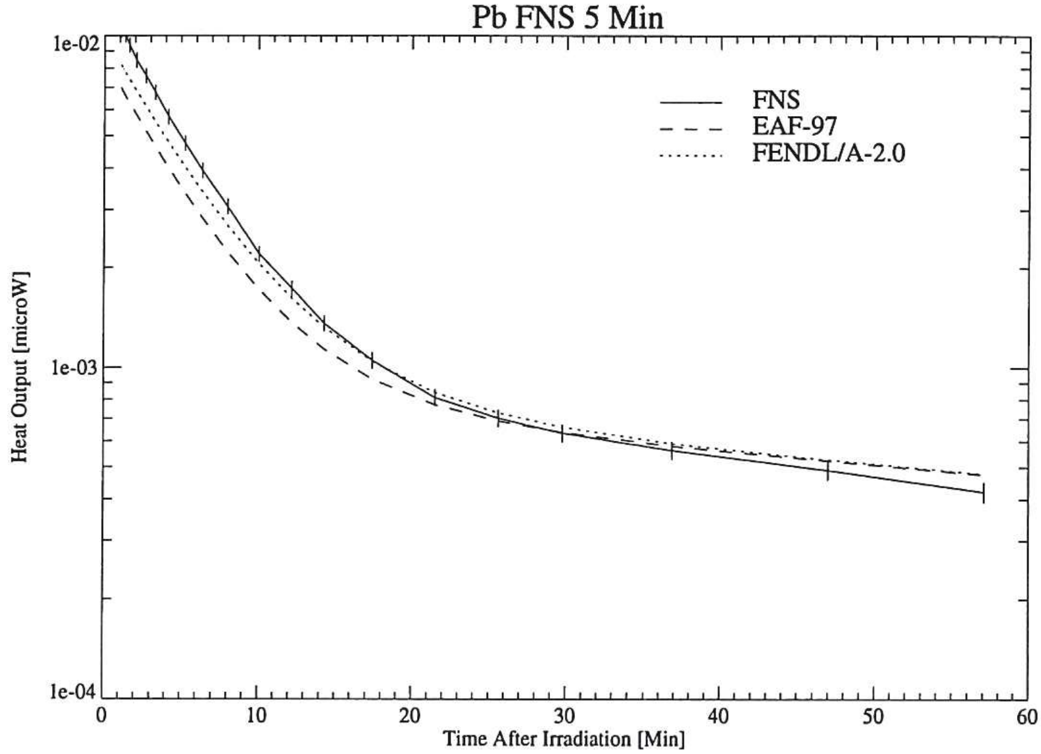
Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	4.22E-01+/- 5%	3.46E-01+/- 20%	-18%	3.32E-01	-21%
1.37	3.96E-01+/- 5%	3.27E-01+/- 20%	-17%	3.13E-01	-21%
1.63	3.75E-01+/- 5%	3.09E-01+/- 20%	-17%	2.96E-01	-21%
2.08	3.35E-01+/- 5%	2.81E-01+/- 20%	-15%	2.69E-01	-19%
2.72	2.96E-01+/- 5%	2.47E-01+/- 20%	-16%	2.37E-01	-20%
3.33	2.57E-01+/- 5%	2.19E-01+/- 20%	-14%	2.09E-01	-18%
4.22	2.18E-01+/- 5%	1.84E-01+/- 21%	-15%	1.76E-01	-19%
5.28	1.77E-01+/- 5%	1.51E-01+/- 21%	-15%	1.44E-01	-18%
6.40	1.44E-01+/- 5%	1.23E-01+/- 21%	-14%	1.17E-01	-18%
7.98	1.07E-01+/- 5%	9.24E-02+/- 20%	-13%	8.83E-02	-17%
10.10	7.32E-02+/- 5%	6.40E-02+/- 20%	-12%	6.13E-02	-16%
12.22	5.15E-02+/- 5%	4.50E-02+/- 20%	-12%	4.31E-02	-16%
14.35	3.65E-02+/- 5%	3.20E-02+/- 19%	-12%	3.08E-02	-15%
17.48	2.31E-02+/- 5%	2.01E-02+/- 18%	-12%	1.94E-02	-15%
21.60	1.35E-02+/- 5%	1.17E-02+/- 18%	-12%	1.14E-02	-15%
25.72	8.42E-03+/- 5%	7.57E-03+/- 19%	-10%	7.42E-03	-11%
29.83	5.89E-03+/- 6%	5.43E-03+/- 20%	-7%	5.36E-03	-8%
36.97	4.02E-03+/- 7%	3.74E-03+/- 21%	-6%	3.72E-03	-7%
47.10	2.93E-03+/- 8%	2.83E-03+/- 20%	-3%	2.83E-03	-3%
57.22	2.47E-03+/- 9%	2.43E-03+/- 19%	-1%	2.43E-03	-1%
Times	**FNS EXP. 7 Hrs.**	**EAF-97**	**(C-E)/E**	**FENDL/A-2**	**(C-E)/E**
Days	microW/g	microW/g		microW/g	
0.64	7.40E-02+/- 5%	8.12E-02+/- 25%	9%	8.12E-02	9%
1.30	5.75E-02+/- 5%	6.04E-02+/- 25%	4%	6.04E-02	4%
2.88	3.26E-02+/- 5%	3.34E-02+/- 24%	2%	3.34E-02	2%
6.85	1.31E-02+/- 5%	1.31E-02+/- 32%	0%	1.31E-02	0%
12.85	9.18E-03+/- 5%	9.10E-03+/- 43%	0%	9.10E-03	0%
23.85	8.07E-03+/- 5%	7.99E-03+/- 43%	0%	7.99E-03	0%
49.70	6.36E-03+/- 5%	6.29E-03+/- 43%	-1%	6.29E-03	-1%
99.89	3.96E-03+/- 5%	4.03E-03+/- 41%	1%	4.03E-03	1%

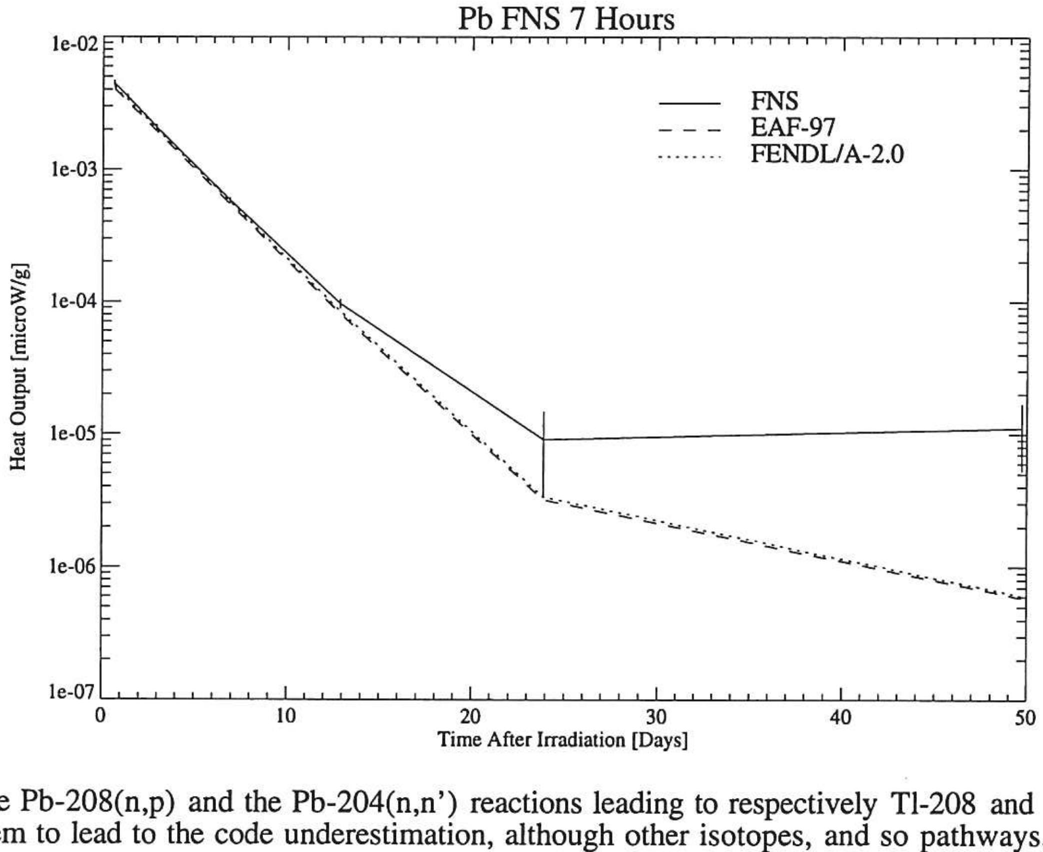
FNS 5 Min NiCr

Nuclide	$T_{1/2}$	Pathways		
Co 62	1.5 m	Ni62(n,p)Co62	99.9%	??
V 53	1.6 m	Cr53(n,p)V53	97.8%	TBA
		Cr54(n,d)V53	2.1%	??
V 52	3.7 m	Cr52(n,p)V52	96.6%	TBA
		Cr53(n,d)V52	3.3%	??
Co 62m	13.9 m	Ni62(n,p)Co62m	99.9%	??
Co 60m	10.4 m	Ni60(n,p)Co60m	93.1%	??
		Ni61(n,d)Co60m	6.8%	??
Cr 49	41.9 m	Cr50(n,2n)Cr49	100.0%	TBA
Co 61	1.6 h	Ni61(n,p)Co61	73.4%	TBA
		Ni62(n,d)Co61	24.9%	TBA
Co 58m	8.9 h	Ni58(n,p)Co58m	99.9%	??
Ni 57	1.4 d	Ni58(n,2n)Ni57	100.0%	??

FNS 7 Hrs NiCr

V 52	3.7 m	Cr52(n,p)V52	97.5%	
		Cr53(n,d)V52	2.4%	
Co 58m	8.9 h	Ni58(n,p)Co58m	99.9%	
Ni 57	1.4 d	Ni58(n,2n)Ni57	100.0%	VAL
Co 58	70.8 d	Ni58(n,p)Co58	76.4%	VAL
		Ni58(n,p)Co58m(IT)Co58	23.5%	VAL
Co 57	271.7 d	Ni58(n,d)Co57	99.5%	VAL





The Pb-208(n,p) and the Pb-204(n,n') reactions leading to respectively Tl-208 and Pb204m seem to lead to the code underestimation, although other isotopes, and so pathways, are just emerging in the few percent participation range. Their pathways and decay data need to be analysed in more depth to get a clearer picture. When concerned with the large (C-E)/E values after 13 days cooling, a quick look at the unphysical upward trend of the experimental values and their large uncertainties eased the decision not to act on them prematurely.

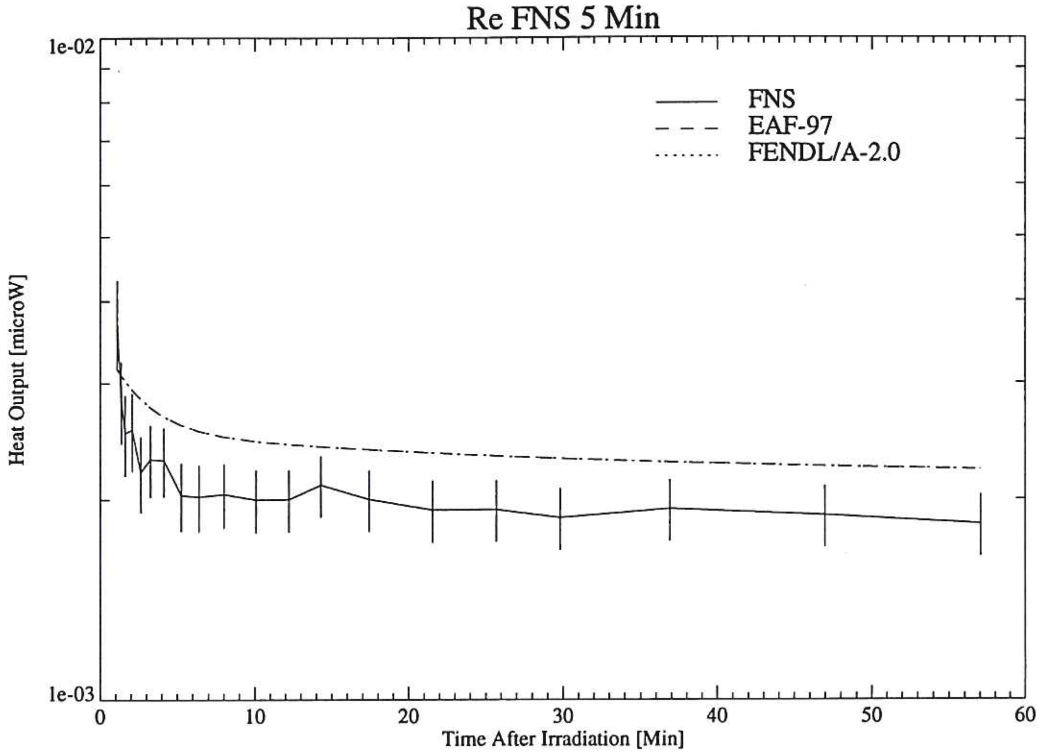
Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	1.04E-02+/- 5%	6.97E-03+/- 23%	-33%	8.17E-03	-21%
1.35	1.01E-02+/- 5%	6.61E-03+/- 23%	-34%	7.77E-03	-22%
1.63	9.40E-03+/- 5%	6.27E-03+/- 23%	-33%	7.39E-03	-21%
2.08	8.45E-03+/- 5%	5.78E-03+/- 23%	-31%	6.83E-03	-19%
2.70	7.59E-03+/- 5%	5.18E-03+/- 23%	-31%	6.13E-03	-19%
3.32	6.77E-03+/- 5%	4.65E-03+/- 23%	-31%	5.52E-03	-18%
4.20	5.71E-03+/- 5%	4.00E-03+/- 23%	-29%	4.77E-03	-16%
5.27	4.74E-03+/- 5%	3.36E-03+/- 24%	-29%	4.02E-03	-15%
6.38	3.93E-03+/- 5%	2.82E-03+/- 25%	-28%	3.39E-03	-13%
8.02	3.05E-03+/- 5%	2.23E-03+/- 27%	-26%	2.68E-03	-12%
10.08	2.20E-03+/- 5%	1.72E-03+/- 32%	-21%	2.05E-03	-6%
12.20	1.73E-03+/- 5%	1.37E-03+/- 37%	-21%	1.62E-03	-6%
14.32	1.36E-03+/- 5%	1.14E-03+/- 43%	-16%	1.32E-03	-2%
17.45	1.05E-03+/- 5%	9.21E-04+/- 50%	-12%	1.04E-03	0%
21.52	8.10E-04+/- 5%	7.71E-04+/- 57%	-4%	8.40E-04	3%
25.63	7.01E-04+/- 5%	6.88E-04+/- 62%	-1%	7.27E-04	3%
29.77	6.32E-04+/- 6%	6.36E-04+/- 64%	0%	6.60E-04	4%
36.85	5.61E-04+/- 6%	5.78E-04+/- 65%	2%	5.88E-04	4%
46.98	4.89E-04+/- 6%	5.22E-04+/- 65%	6%	5.26E-04	7%
57.07	4.21E-04+/- 7%	4.75E-04+/- 65%	12%	4.78E-04	13%
Times	FNS EXP. 7 Hrs.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Days	microW/g	microW/g		microW/g	
0.61	4.46E-03+/- 5%	4.07E-03+/- 0%	-8%	4.22E-03	-5%
1.33	3.52E-03+/- 5%	3.22E-03+/- 0%	-8%	3.34E-03	-5%
2.91	2.07E-03+/- 5%	1.94E-03+/- 0%	-6%	2.02E-03	-2%
6.88	5.83E-04+/- 5%	5.45E-04+/- 46%	-6%	5.68E-04	-2%
12.87	9.62E-05+/- 7%	8.06E-05+/- 45%	-16%	8.45E-05	-12%
23.88	9.09E-06+/- 63%	3.19E-06+/- 33%	-64%	3.36E-06	-63%
49.73	1.11E-05+/- 52%	5.87E-07+/- 30%	-94%	6.09E-07	-94%

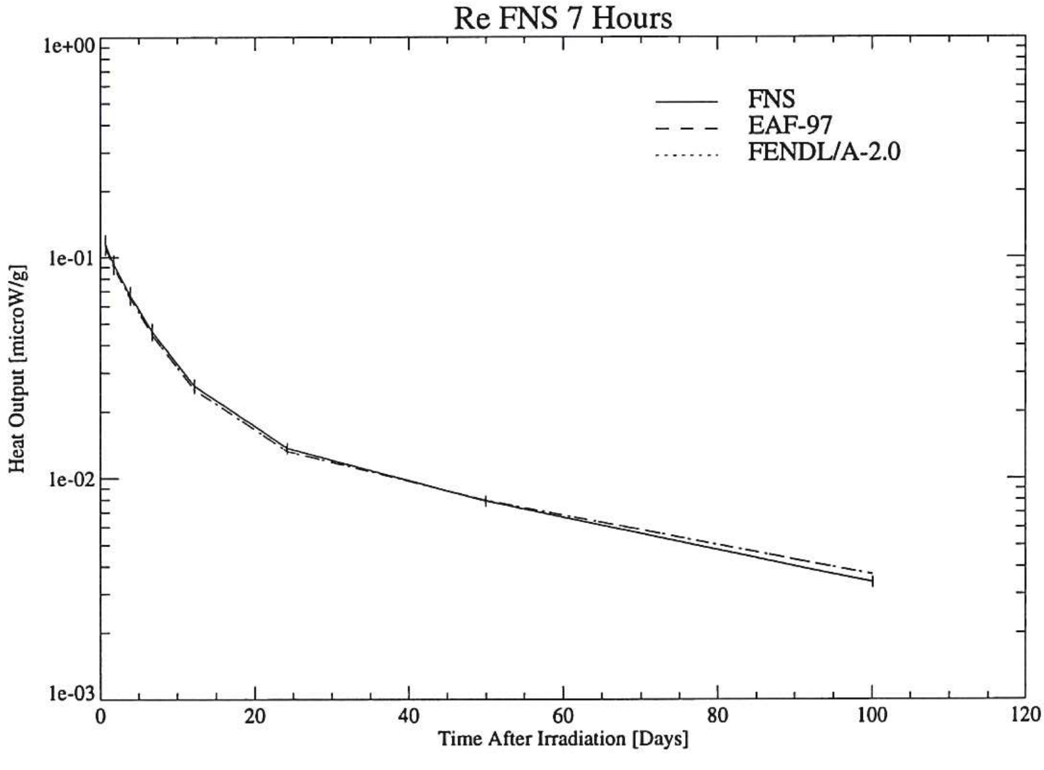
FNS 5 Mins Pb

Nuclide	$T_{1/2}$	Pathways		
Pb207m	805.0ms	Pb207(n,n')Pb207m	3.1%	??
		Pb208(n,2n)Pb207m	96.8%	??
Tl208	3.0 m	Pb208(n,p)Tl208	100.0%	TBA
Tl206	4.2 m	Pb206(n,p)Tl206	96.4%	??
		Pb207(n,d)Tl206	1.1%	??
		Pb208(n,t)Tl206	2.0%	??
Tl207	4.7 m	Pb207(n,p)Tl207	53.9%	??
		Pb208(n,d)Tl207	1.6%	??
		Pb207(n,p)Tl207m(IT)Tl207	42.3%	??
		Pb208(n,d)Tl207m(IT)Tl207	2.0%	??
Pb204m	1.1 h	Pb204(n,n')Pb204m	100.0%	TBA
Pb203	2.1 d	Pb204(n,2n)Pb203	40.5%	??
		Pb204(n,2n)Pb203m(IT)Pb203	60.7%	??

FNS 7 Hrs Pb

Pb207m	805.0ms	Pb207(n,n')Pb207m	2.6%	
		Pb208(n,2n)Pb207m	97.3%	
Pb203	2.1 d	Pb204(n,2n)Pb203	39.4%	VAL
		Pb204(n,2n)Pb203m(IT)Pb203	60.0%	VAL
Hg203	46.5 d	Pb206(n,a)Hg203	93.8%	??
		Pb207(n,na)Hg203	6.1%	??





The excellent agreement of the 7 hours irradiation test is only impaired by a systematic overestimation of the decay power found in the 5 minutes test experiment. However, the presence of three (n,g) pathways does tend to explain the discrepancies.

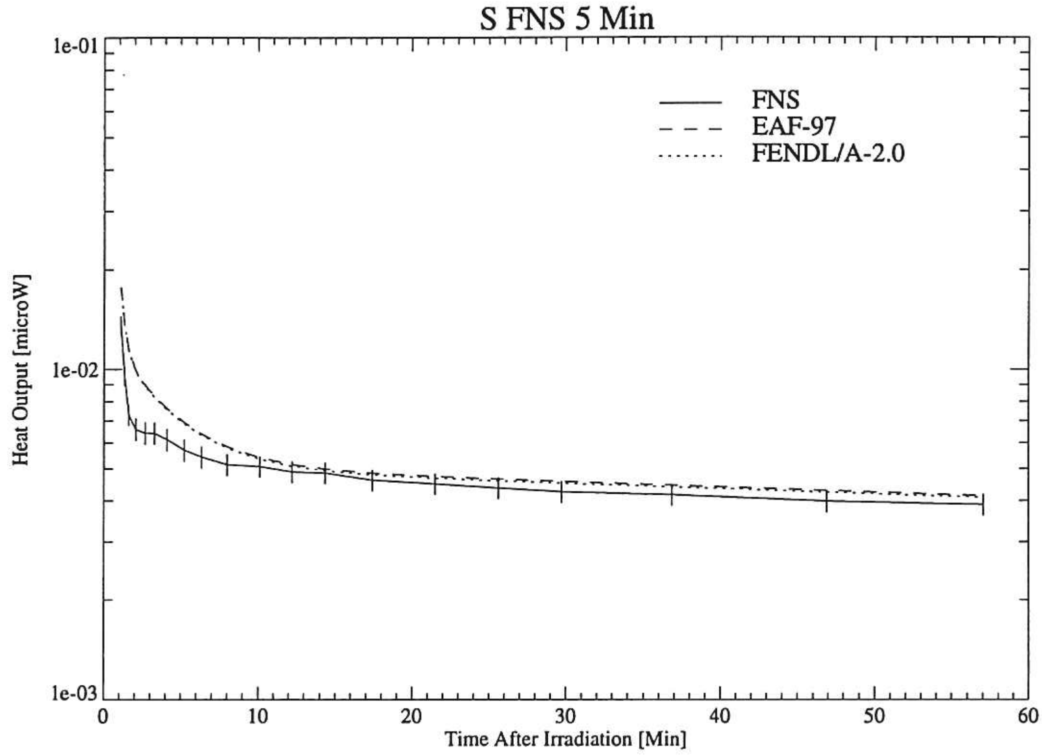
Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	3.72E-03+/- 15%	3.16E-03+/- 31%	-15%	3.16E-03	-15%
1.37	2.83E-03+/- 14%	3.09E-03+/- 31%	8%	3.09E-03	8%
1.63	2.52E-03+/- 13%	3.02E-03+/- 31%	19%	3.02E-03	19%
2.08	2.55E-03+/- 13%	2.93E-03+/- 31%	14%	2.93E-03	14%
2.63	2.20E-03+/- 13%	2.84E-03+/- 32%	29%	2.84E-03	29%
3.27	2.30E-03+/- 12%	2.76E-03+/- 32%	19%	2.76E-03	19%
4.15	2.29E-03+/- 11%	2.67E-03+/- 33%	16%	2.67E-03	16%
5.27	2.03E-03+/- 11%	2.59E-03+/- 33%	27%	2.59E-03	27%
6.40	2.02E-03+/- 11%	2.54E-03+/- 34%	25%	2.54E-03	25%
8.03	2.04E-03+/- 11%	2.49E-03+/- 35%	22%	2.49E-03	22%
10.10	2.00E-03+/- 10%	2.45E-03+/- 35%	22%	2.45E-03	22%
12.22	2.00E-03+/- 10%	2.42E-03+/- 35%	21%	2.42E-03	21%
14.30	2.10E-03+/- 10%	2.40E-03+/- 36%	14%	2.40E-03	14%
17.43	2.00E-03+/- 10%	2.38E-03+/- 36%	18%	2.38E-03	18%
21.55	1.93E-03+/- 10%	2.35E-03+/- 36%	21%	2.35E-03	21%
25.68	1.93E-03+/- 10%	2.33E-03+/- 37%	20%	2.33E-03	20%
29.80	1.88E-03+/- 10%	2.31E-03+/- 37%	22%	2.31E-03	22%
36.90	1.94E-03+/- 10%	2.28E-03+/- 37%	17%	2.28E-03	17%
46.98	1.89E-03+/- 10%	2.24E-03+/- 38%	18%	2.24E-03	18%
57.05	1.84E-03+/- 10%	2.22E-03+/- 38%	20%	2.22E-03	20%
Times	FNS EXP. 7 Hrs.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Days	microW/g	microW/g		microW/g	
0.69	1.14E-01+/- 10%	1.09E-01+/- 53%	-4%	1.09E-01	-4%
1.74	9.32E-02+/- 10%	9.04E-02+/- 53%	-3%	9.04E-02	-3%
3.90	6.71E-02+/- 9%	6.50E-02+/- 51%	-3%	6.50E-02	-3%
6.76	4.61E-02+/- 8%	4.44E-02+/- 48%	-3%	4.44E-02	-3%
12.21	2.61E-02+/- 7%	2.52E-02+/- 46%	-3%	2.52E-02	-3%
24.22	1.37E-02+/- 5%	1.32E-02+/- 58%	-3%	1.32E-02	-3%
49.97	7.88E-03+/- 5%	7.95E-03+/- 63%	0%	7.95E-03	0%
100.10	3.39E-03+/- 5%	3.68E-03+/- 60%	8%	3.68E-03	8%

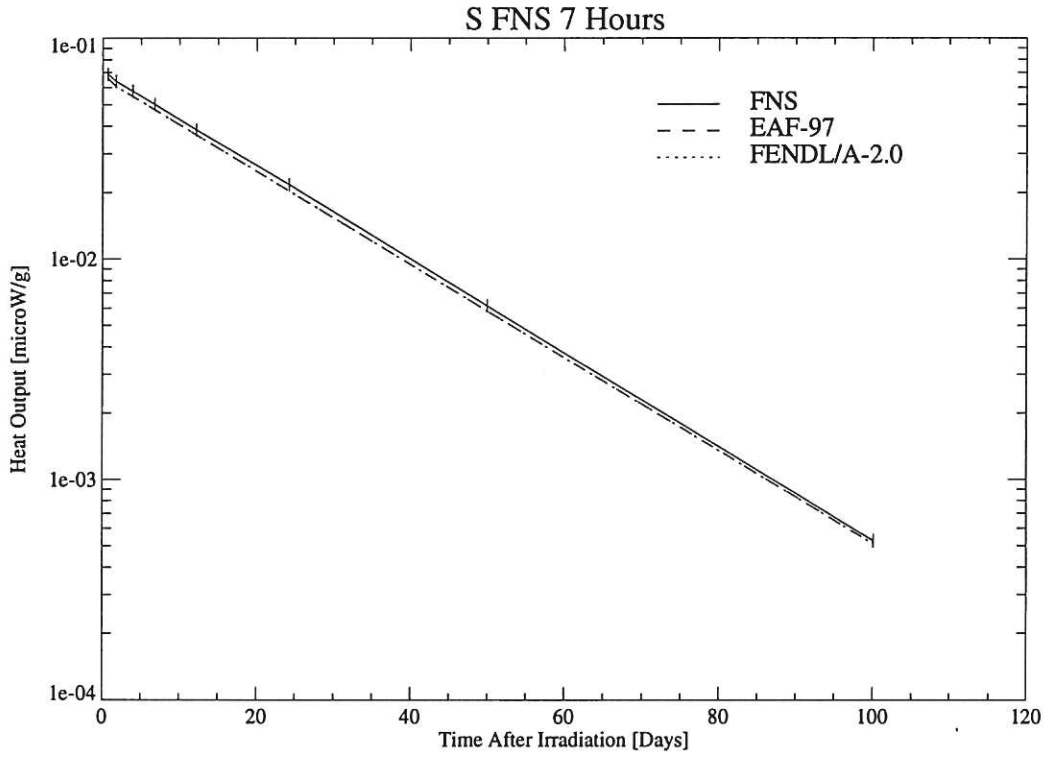
FNS 5 Mins Re

Nuclide	$T_{1/2}$	Pathways		
W 185m	1.6 m	Re185(n,p)W185m	86.9%	??
		Re187(n,t)W185m	13.1%	??
Re188m	18.6 m	Re187(n,g)Re188m	100.0%	??
Re188	16.9 h	Re187(n,g)Re188	99.5%	??
Re186	3.7 d	Re185(n,g)Re186	5.5%	??
		Re187(n,2n)Re186	94.4%	??
Re184	37.9 d	Re185(n,2n)Re184	100.0%	??

FNS 7 Hrs Re

Re188	16.9 h	Re187(n,g)Re188	88.8%	??
		Re187(n,g)Re188m(IT)Re188	11.1%	??
Re186	3.7 d	Re187(n,2n)Re186	99.6%	VAL
Re184	37.9 d	Re185(n,2n)Re184	99.9%	VAL
Re184m	165.5 d	Re185(n,2n)Re184m	100.0%	VAL





Apart for cooling up to 8 minutes the agreement is remarkable. P-34 and P-30 produced through respectively S-34(n,p) and S-32 (n,t) reactions could be the reason for the overestimation.

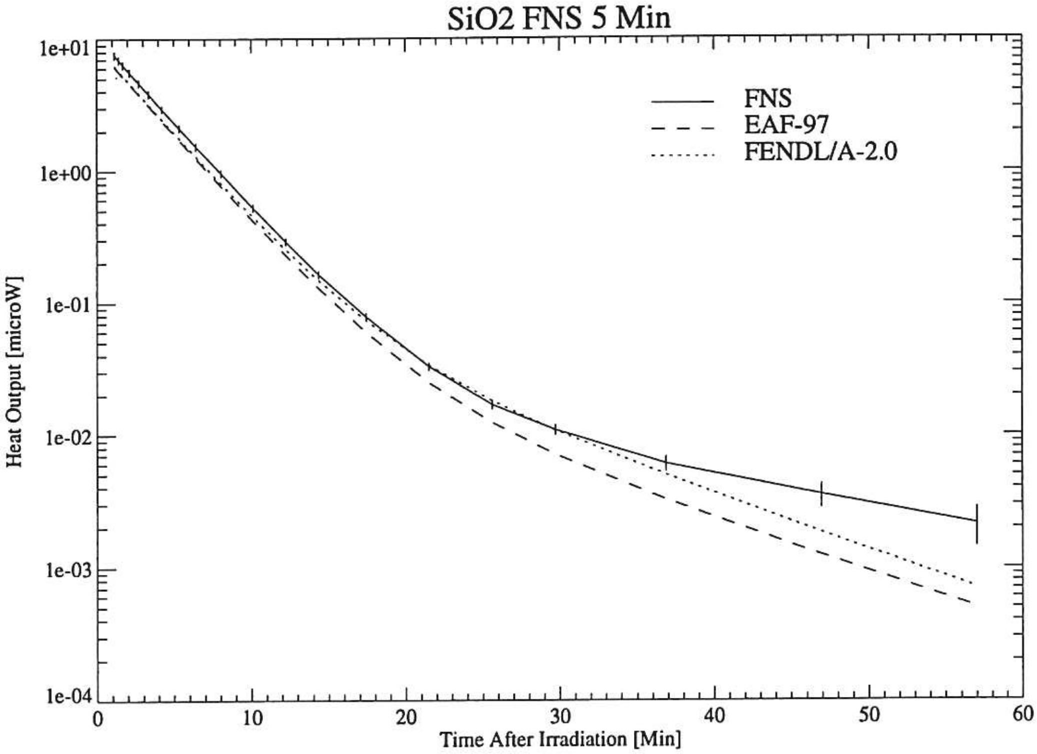
Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	1.36E-02+/- 6%	1.77E-02+/- 34%	29%	1.76E-02	29%
1.35	9.54E-03+/- 6%	1.35E-02+/- 41%	42%	1.34E-02	40%
1.62	7.28E-03+/- 7%	1.15E-02+/- 47%	57%	1.14E-02	56%
2.07	6.60E-03+/- 7%	9.94E-03+/- 52%	50%	9.85E-03	49%
2.68	6.43E-03+/- 7%	8.97E-03+/- 55%	39%	8.90E-03	38%
3.30	6.41E-03+/- 7%	8.31E-03+/- 57%	29%	8.24E-03	28%
4.13	6.14E-03+/- 7%	7.62E-03+/- 61%	24%	7.55E-03	23%
5.25	5.70E-03+/- 7%	6.91E-03+/- 65%	21%	6.84E-03	20%
6.37	5.43E-03+/- 7%	6.38E-03+/- 69%	17%	6.32E-03	16%
8.00	5.15E-03+/- 7%	5.84E-03+/- 74%	13%	5.78E-03	12%
10.12	5.08E-03+/- 7%	5.41E-03+/- 79%	6%	5.34E-03	5%
12.23	4.89E-03+/- 7%	5.15E-03+/- 82%	5%	5.09E-03	3%
14.35	4.85E-03+/- 7%	4.99E-03+/- 84%	2%	4.93E-03	1%
17.43	4.61E-03+/- 7%	4.85E-03+/- 85%	5%	4.79E-03	3%
21.50	4.49E-03+/- 7%	4.73E-03+/- 85%	5%	4.67E-03	4%
25.62	4.37E-03+/- 7%	4.65E-03+/- 85%	6%	4.59E-03	5%
29.73	4.26E-03+/- 7%	4.57E-03+/- 85%	7%	4.51E-03	6%
36.83	4.17E-03+/- 7%	4.45E-03+/- 85%	6%	4.40E-03	5%
46.90	3.98E-03+/- 7%	4.29E-03+/- 84%	7%	4.24E-03	6%
57.03	3.89E-03+/- 7%	4.14E-03+/- 83%	6%	4.09E-03	5%
Times	FNS EXP. 7 Hrs.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Days	microW/g	microW/g		microW/g	
0.68	6.87E-02+/- 6%	6.58E-02+/- 28%	-4%	6.58E-02	-4%
1.74	6.38E-02+/- 6%	6.06E-02+/- 0%	-5%	6.06E-02	-4%
3.89	5.77E-02+/- 6%	5.45E-02+/- 0%	-5%	5.46E-02	-5%
6.76	5.02E-02+/- 6%	4.75E-02+/- 0%	-5%	4.75E-02	-5%
12.20	3.84E-02+/- 6%	3.64E-02+/- 0%	-5%	3.65E-02	-5%
24.21	2.17E-02+/- 6%	2.03E-02+/- 0%	-6%	2.03E-02	-6%
49.96	6.13E-03+/- 6%	5.83E-03+/- 0%	-4%	5.82E-03	-5%
100.09	5.27E-04+/- 7%	5.13E-04+/- 29%	-2%	5.11E-04	-2%

FNS 5 Mins S

Nuclide	$T_{1/2}$	Pathways		
P 34	12.4 s	S34(n,p)P34	100.0%	TBA
P 30	2.4 m	S32(n,t)P30	100.0%	TBA
Si 31	2.6 h	S32(n,2p)Si31	49.7%	VAL
		S34(n,a)Si31	50.2%	VAL
P 32	14.2 d	S32(n,p)P32	99.7%	VAL

FNS 7 Hrs S

P 34	12.4 s	S34(n,p)P34	100.0%	VAL
Si 31	2.6 h	S32(n,2p)Si31	43.2%	VAL
		S34(n,a)Si31	56.7%	VAL
P 32	14.2 d	S32(n,p)P32	99.7%	VAL

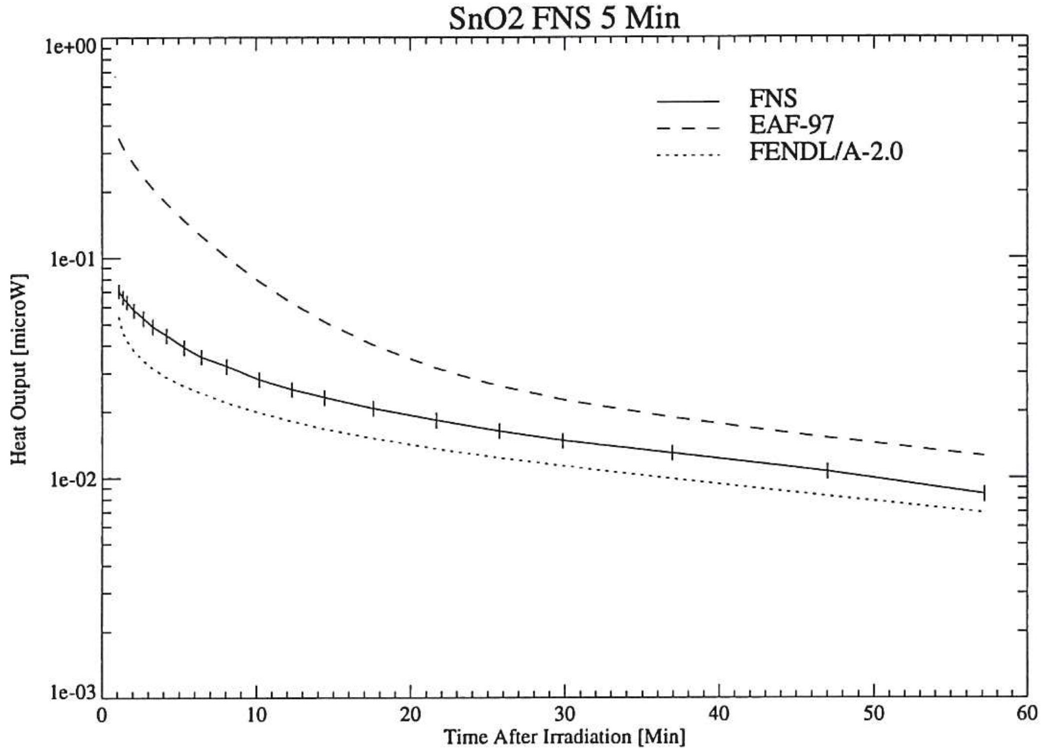


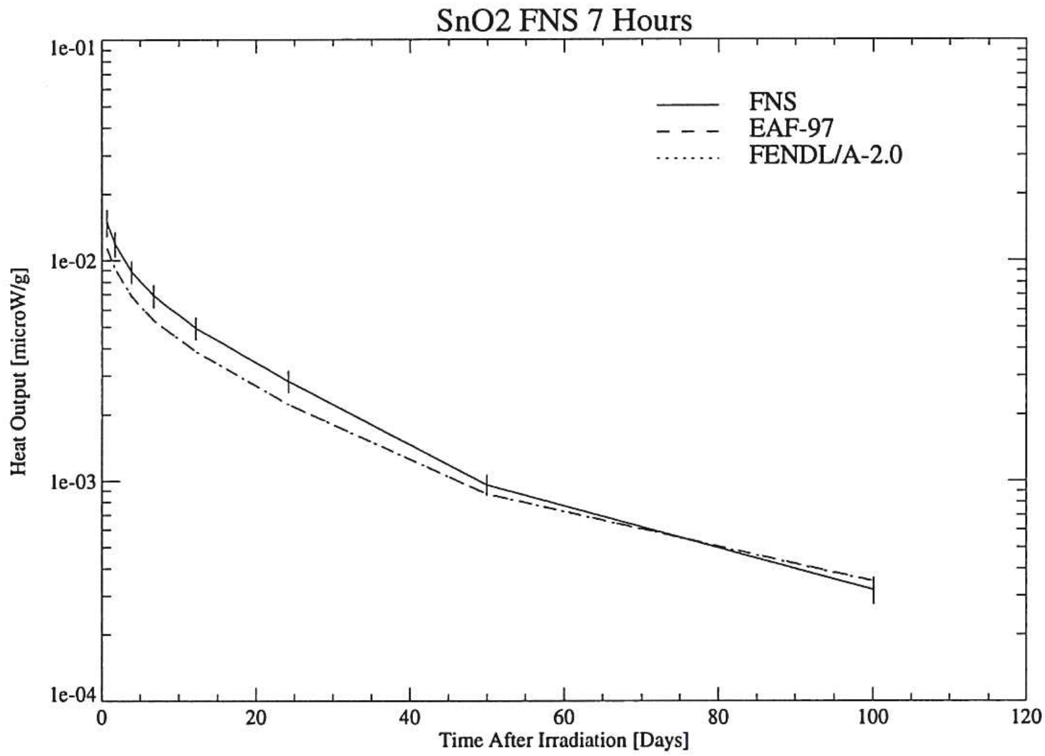
Al-28, Al-29 and Mg-27 all seem to be underestimated by around 20%, but the larger underestimation after 30 minutes cooling could be due to certain impurities in the sample. Due to the impurity uncertanties, and with no other sources of information, the differences could not be explained.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.15	7.55E+00+/- 6%	6.17E+00+/- 23%	-18%	6.24E+00	-17%
1.42	6.94E+00+/- 6%	5.68E+00+/- 23%	-18%	5.75E+00	-17%
1.68	6.37E+00+/- 6%	5.23E+00+/- 23%	-17%	5.30E+00	-16%
2.12	5.59E+00+/- 6%	4.58E+00+/- 23%	-18%	4.65E+00	-16%
2.73	4.63E+00+/- 6%	3.80E+00+/- 23%	-18%	3.86E+00	-16%
3.37	3.83E+00+/- 6%	3.13E+00+/- 23%	-18%	3.19E+00	-16%
4.23	2.95E+00+/- 6%	2.41E+00+/- 23%	-18%	2.46E+00	-16%
5.35	2.11E+00+/- 6%	1.72E+00+/- 22%	-18%	1.77E+00	-16%
6.43	1.53E+00+/- 6%	1.24E+00+/- 22%	-18%	1.29E+00	-16%
8.07	9.59E-01+/- 6%	7.64E-01+/- 22%	-20%	8.01E-01	-16%
10.13	5.24E-01+/- 6%	4.18E-01+/- 21%	-20%	4.47E-01	-14%
12.25	2.89E-01+/- 6%	2.30E-01+/- 20%	-20%	2.53E-01	-12%
14.37	1.63E-01+/- 6%	1.29E-01+/- 19%	-20%	1.48E-01	-9%
17.45	7.77E-02+/- 6%	5.95E-02+/- 16%	-23%	7.31E-02	-6%
21.52	3.28E-02+/- 7%	2.48E-02+/- 12%	-24%	3.36E-02	2%
25.63	1.68E-02+/- 7%	1.23E-02+/- 11%	-26%	1.80E-02	6%
29.72	1.09E-02+/- 9%	7.09E-03+/- 12%	-34%	1.08E-02	0%
36.85	6.04E-03+/- 13%	3.25E-03+/- 13%	-46%	4.98E-03	-17%
46.93	3.53E-03+/- 20%	1.24E-03+/- 14%	-64%	1.83E-03	-47%
57.00	2.13E-03+/- 32%	5.00E-04+/- 14%	-76%	7.03E-04	-66%

FNS 5 Mins SiO2

Nuclide	$T_{1/2}$	Pathways		
N 16	7.1 s	O16(n,p)N16	99.9%	VAL
Al 28	2.2 m	Si28(n,p)Al28	99.5%	TBA
Al 29	6.5 m	Si29(n,p)Al29	97.8%	TBA
		Si30(n,d)Al29	2.1%	??
Mg 27	9.4 m	Si30(n,a)Mg27	99.9%	TBA





Rather different results are given by EAF-97 and FENDL/A-2.0, with a better but still unsatisfactory agreement for the latter. The production paths and decay data of In-123, In-118m, In119, Sn-123m and In-116m need to be compared between the two libraries and if possible with EXFOR. The code prediction for the 7 hours irradiation test gave results too near to the experimental uncertainties to be able to draw any sensible conclusions.

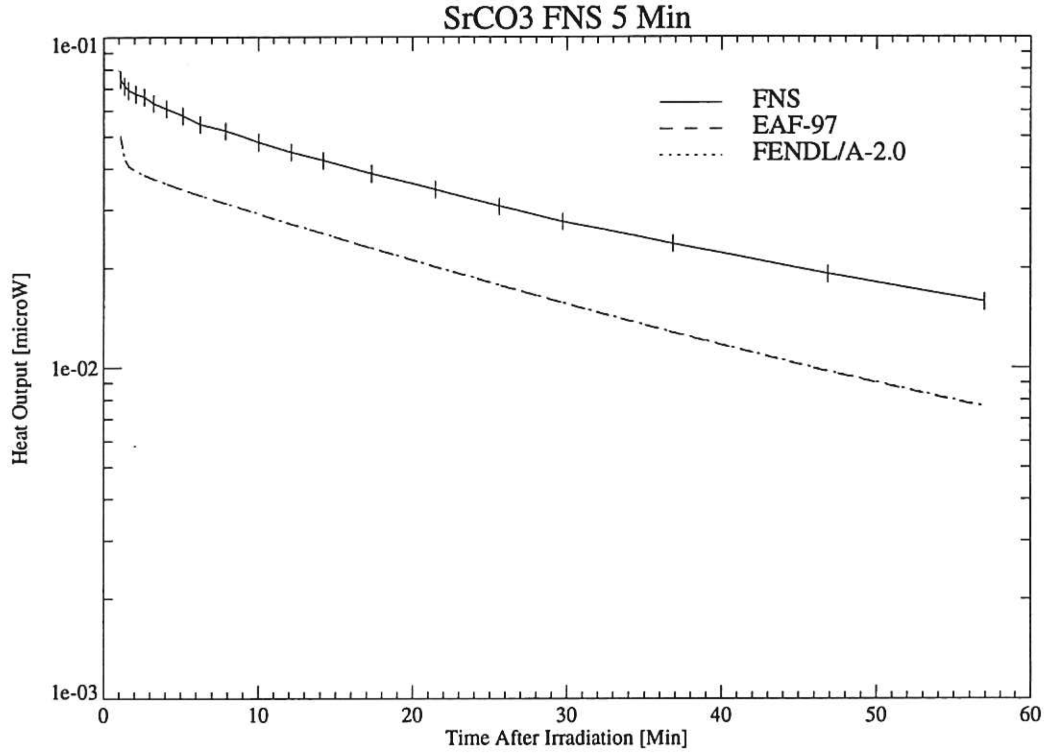
Times Min.	FNS EXP. 5 Min. microW/g	EAF-97 microW/g	(C-E)/E	FENDL/A-2 microW/g	(C-E)/E
1.10	7.07E-02+/- 7%	3.50E-01+/- 42%	395%	5.40E-02	-23%
1.37	6.61E-02+/- 7%	3.20E-01+/- 44%	384%	4.59E-02	-30%
1.63	6.31E-02+/- 7%	2.97E-01+/- 44%	371%	4.20E-02	-33%
2.08	5.78E-02+/- 7%	2.67E-01+/- 45%	360%	3.79E-02	-34%
2.70	5.32E-02+/- 7%	2.33E-01+/- 45%	338%	3.41E-02	-35%
3.32	4.88E-02+/- 8%	2.07E-01+/- 45%	323%	3.15E-02	-35%
4.22	4.45E-02+/- 8%	1.76E-01+/- 45%	296%	2.87E-02	-35%
5.33	3.92E-02+/- 8%	1.48E-01+/- 44%	276%	2.61E-02	-33%
6.45	3.55E-02+/- 8%	1.25E-01+/- 43%	253%	2.42E-02	-31%
8.08	3.21E-02+/- 8%	1.01E-01+/- 41%	212%	2.20E-02	-31%
10.22	2.80E-02+/- 8%	7.78E-02+/- 38%	177%	1.97E-02	-29%
12.33	2.52E-02+/- 8%	6.21E-02+/- 35%	146%	1.80E-02	-28%
14.45	2.31E-02+/- 8%	5.10E-02+/- 33%	120%	1.66E-02	-28%
17.58	2.06E-02+/- 8%	4.00E-02+/- 31%	94%	1.51E-02	-27%
21.67	1.81E-02+/- 7%	3.13E-02+/- 29%	72%	1.35E-02	-25%
25.78	1.62E-02+/- 7%	2.60E-02+/- 30%	59%	1.23E-02	-24%
29.87	1.47E-02+/- 7%	2.25E-02+/- 31%	53%	1.13E-02	-23%
36.95	1.29E-02+/- 7%	1.87E-02+/- 32%	44%	9.85E-03	-23%
47.02	1.07E-02+/- 7%	1.51E-02+/- 33%	41%	8.24E-03	-22%
57.15	8.42E-03+/- 8%	1.26E-02+/- 33%	49%	6.92E-03	-17%
Times Days	**FNS EXP. 7 Hrs. microW/g**	**EAF-97 microW/g**	**(C-E)/E**	**FENDL/A-2 microW/g**	**(C-E)/E**
0.68	1.49E-02+/- 14%	1.14E-02+/- 37%	-23%	1.13E-02	-24%
1.73	1.19E-02+/- 12%	9.20E-03+/- 40%	-22%	9.17E-03	-23%
3.88	8.88E-03+/- 11%	6.87E-03+/- 45%	-22%	6.85E-03	-22%
6.75	6.93E-03+/- 11%	5.36E-03+/- 50%	-22%	5.35E-03	-22%
12.20	4.94E-03+/- 11%	3.87E-03+/- 53%	-21%	3.86E-03	-21%
24.20	2.83E-03+/- 11%	2.22E-03+/- 50%	-21%	2.22E-03	-21%
49.95	9.57E-04+/- 10%	8.72E-04+/- 41%	-8%	8.69E-04	-9%
100.08	3.20E-04+/- 14%	3.51E-04+/- 45%	9%	3.49E-04	9%

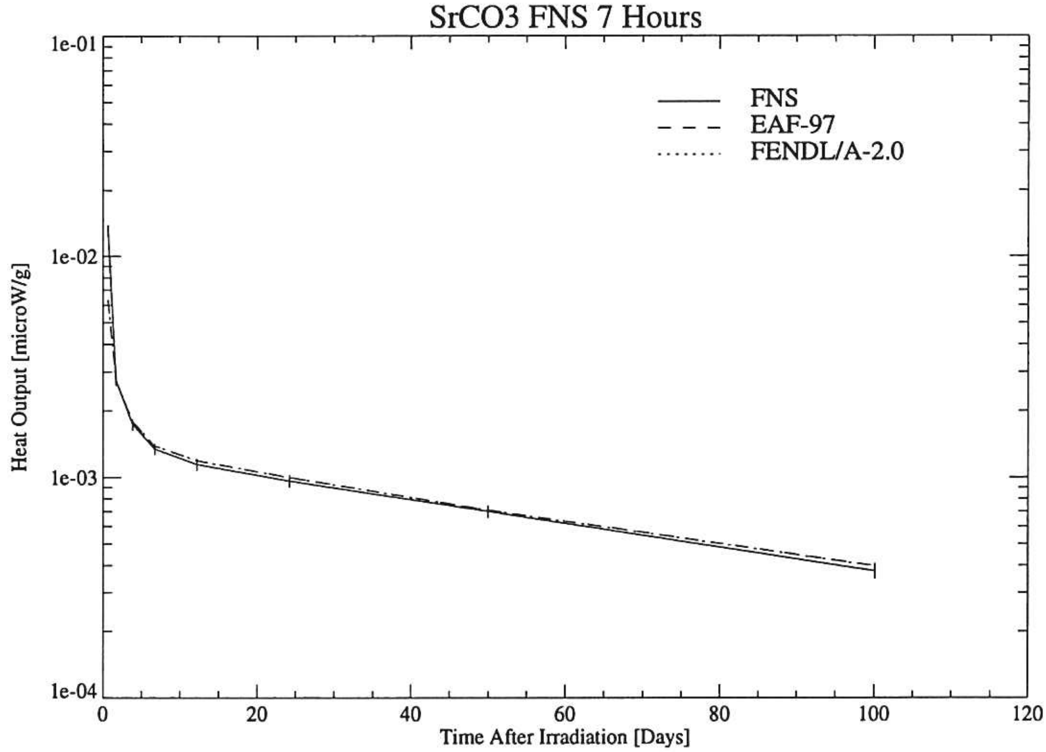
FNS 5 Mins SnO2

Nuclide	$T_{1/2}$	Pathways		
N 16	7.1 s	O16(n,p)N16	99.9%	VAL
In123	5.9 s	Sn124(n,d)In123	100.0%	TBA
In123m	47.8 s	Sn124(n,d)In123m	100.0%	
In120m	44.4 s	Sn120(n,p)In120m	48.6%	
		Sn122(n,t)In120m	51.3%	
In118m	4.4 m	Sn118(n,p)In118m	5.4%	??
		Sn120(n,t)In118m	75.8%	TBA
		Sn118(n,p)In118n(IT)In118m	3.2%	??
		Sn120(n,t)In118n(IT)In118m	15.5%	TBA
In119	2.4 m	Sn119(n,p)In119	1.7%	??
		Sn120(n,d)In119	98.0%	TBA
In119m	18.0 m	Sn119(n,p)In119m	.8%	
		Sn114(n,2n)Sn113m	99.1%	
Sn123m	40.1 m	Sn124(n,2n)Sn123m	59.5%	
		Sn124(n,d)In123(b-)Sn123m	31.9%	
		Sn124(n,d)In123m(b-)Sn123m	8.3%	
In116m	54.6 m	Sn116(n,p)In116m	25.7%	
		Sn117(n,d)In116m	1.2%	
		Sn118(n,t)In116m	53.6%	
		Sn116(n,p)In116n(IT)In116m	7.8%	
		Sn118(n,t)In116n(IT)In116m	11.3%	

Sn111	35.3 m	Sn112(n,2n)Sn111	100.0%	
FNS 7 Hrs SnO2				
N 16	7.1 s	O16(n,p)N16	99.9%	??
Sn119m	18.0 m	Sn119(n,n')Sn119m	4.7%	??
		Sn120(n,2n)Sn119m	94.9%	??
Sn123	40.1 m	Sn124(n,2n)Sn123	99.6%	TBA
In113m	1.6 h	Sn114(n,d)In113m	51.4%	??
		Sn115(n,t)In113m	1.9%	??
		Sn114(n,2n)Sn113(b+)In113m	13.3%	??
		Sn114(n,2n)Sn113m(IT)Sn113(b+)In113m	32.9%	??
Sn121	1.1 d	Sn120(n,g)Sn121	1.9%	??
		Sn122(n,2n)Sn121	97.6%	??
In111	2.8 d	Sn112(n,d)In111	9.0%	??
		Sn112(n,d)In111m(IT)In111	2.2%	??
		Sn112(n,2n)Sn111(b+)In111	88.7%	??
Sn117m	13.6 d	Sn117(n,n')Sn117m	6.7%	??
		Sn118(n,2n)Sn117m	93.2%	TBA

This page is intentionally left blank





A systematic 40 % underestimation can be seem when the isotope Rb-88 and to a certain extend, Sr-87m are predominant. These cross-sections pathways, and decay data will need to be analysed and compared against other sources of information. The 7 hours irradiation comparison is well within the uncertainty values, bearing in mind the remark made earlier for the Sr-87m.

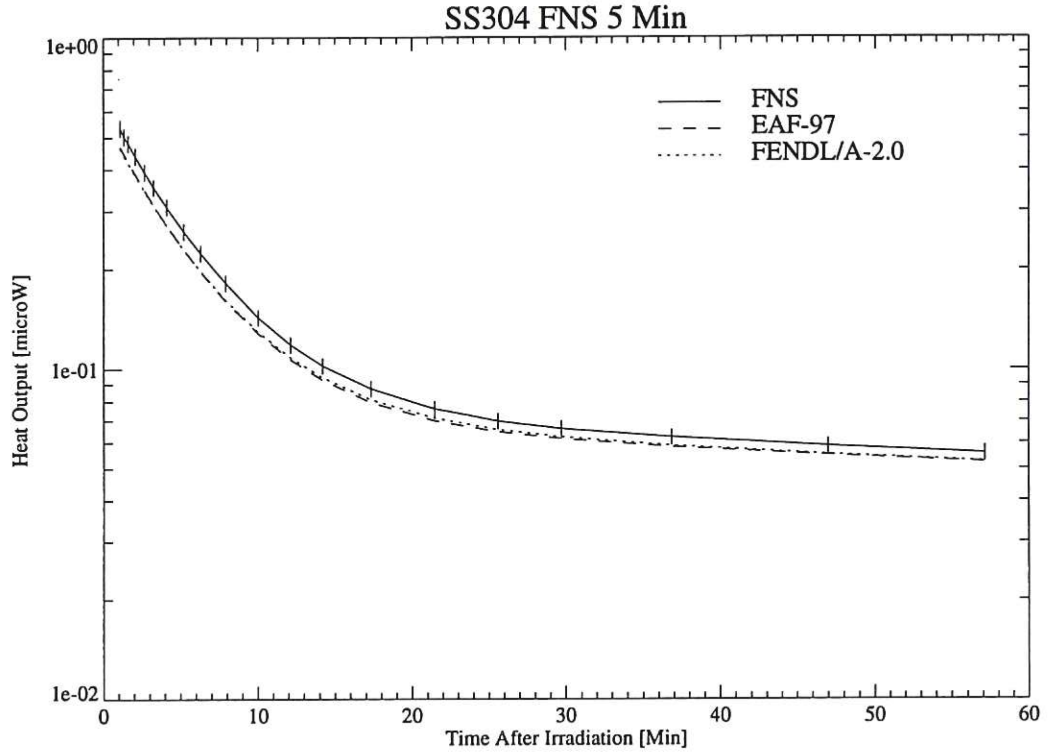
Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	7.48E-02+/- 6%	5.03E-02+/- 34%	-32%	5.02E-02	-32%
1.37	7.14E-02+/- 6%	4.28E-02+/- 40%	-40%	4.28E-02	-40%
1.63	6.92E-02+/- 6%	4.07E-02+/- 41%	-41%	4.07E-02	-41%
2.07	6.75E-02+/- 6%	3.93E-02+/- 42%	-41%	3.94E-02	-41%
2.63	6.61E-02+/- 6%	3.82E-02+/- 42%	-42%	3.82E-02	-42%
3.25	6.32E-02+/- 6%	3.71E-02+/- 42%	-41%	3.72E-02	-41%
4.08	6.08E-02+/- 6%	3.59E-02+/- 43%	-40%	3.59E-02	-40%
5.15	5.79E-02+/- 6%	3.45E-02+/- 43%	-40%	3.45E-02	-40%
6.27	5.44E-02+/- 6%	3.31E-02+/- 42%	-39%	3.32E-02	-39%
7.90	5.20E-02+/- 6%	3.13E-02+/- 42%	-39%	3.13E-02	-39%
10.03	4.80E-02+/- 6%	2.91E-02+/- 42%	-39%	2.92E-02	-39%
12.15	4.48E-02+/- 6%	2.71E-02+/- 41%	-39%	2.72E-02	-39%
14.22	4.23E-02+/- 6%	2.53E-02+/- 41%	-40%	2.54E-02	-39%
17.35	3.86E-02+/- 6%	2.29E-02+/- 41%	-40%	2.29E-02	-40%
21.47	3.45E-02+/- 6%	2.01E-02+/- 40%	-41%	2.01E-02	-41%
25.60	3.07E-02+/- 6%	1.77E-02+/- 39%	-42%	1.77E-02	-42%
29.72	2.76E-02+/- 6%	1.56E-02+/- 38%	-43%	1.56E-02	-43%
36.82	2.36E-02+/- 6%	1.27E-02+/- 37%	-46%	1.27E-02	-46%
46.88	1.91E-02+/- 6%	9.69E-03+/- 36%	-49%	9.74E-03	-49%
56.97	1.58E-02+/- 6%	7.60E-03+/- 36%	-51%	7.64E-03	-51%
Times	**FNS EXP. 7 Hrs.**	**EAF-97**	**(C-E)/E**	**FENDL/A-2**	**(C-E)/E**
Days	microW/g	microW/g		microW/g	
0.67	1.31E-02+/- 5%	6.26E-03+/- 37%	-52%	6.33E-03	-51%
1.73	2.76E-03+/- 5%	2.72E-03+/- 39%	-1%	2.74E-03	0%
3.88	1.73E-03+/- 5%	1.78E-03+/- 39%	3%	1.79E-03	3%
6.75	1.34E-03+/- 5%	1.39E-03+/- 44%	3%	1.39E-03	3%
12.19	1.14E-03+/- 6%	1.19E-03+/- 48%	4%	1.19E-03	3%
24.20	9.61E-04+/- 6%	9.97E-04+/- 51%	3%	9.95E-04	3%
49.95	7.01E-04+/- 6%	7.12E-04+/- 53%	1%	7.11E-04	1%
100.08	3.76E-04+/- 7%	3.97E-04+/- 56%	5%	3.96E-04	5%

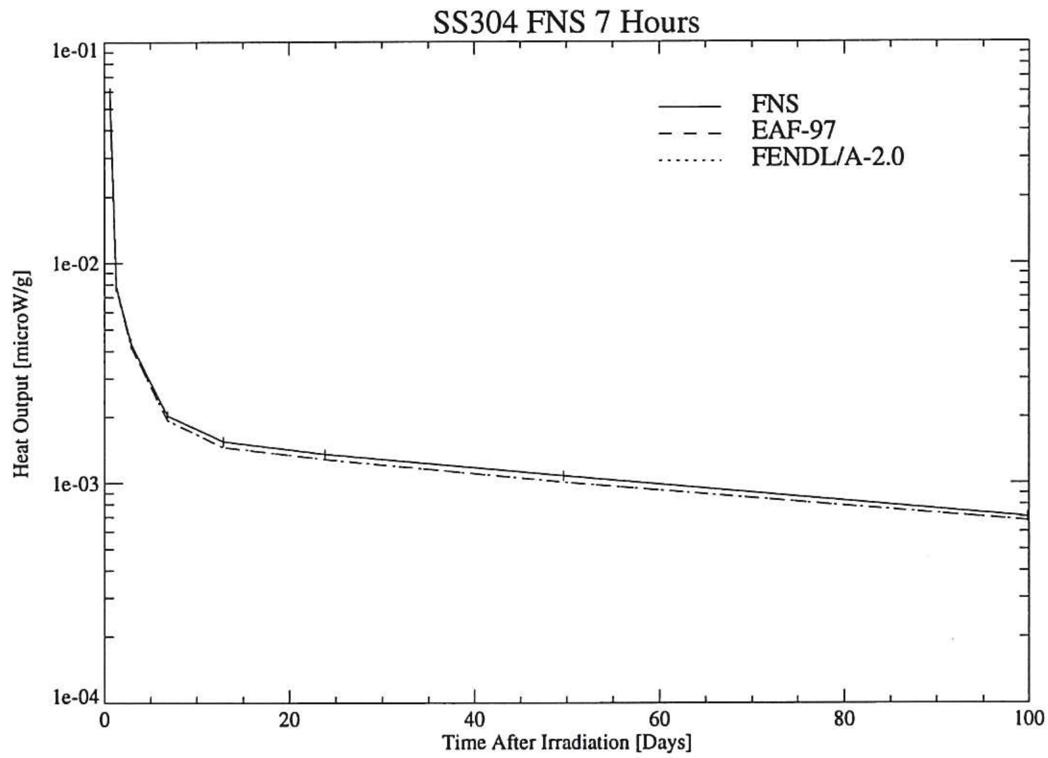
FNS 5 Mins SrCO3

Nuclide	$T_{1/2}$	Pathways		
N 16	7.1 s	O16(n,p)N16	99.9%	??
Rb 88	17.8 m	Sr88(n,p)Rb88	100.0%	TBA
Sr 87m	2.8 h	Sr87(n,n')Sr87m	2.2%	??
		Sr88(n,2n)Sr87m	97.5%	TBA
Sr 85m	1.1 h	Sr86(n,2n)Sr85m	99.8%	??

FNS 7 Hrs SrCO3

N 16	7.1 s	O16(n,p)N16	99.9%	
Sr 87m	2.8 h	Sr87(n,n')Sr87m	2.0%	
		Sr88(n,2n)Sr87m	97.8%	
Sr 83	1.3 d	Sr84(n,2n)Sr83	89.1%	VAL
		Sr84(n,2n)Sr83m(IT)Sr83	10.8%	VAL
Sr 85	64.8 d	Sr86(n,2n)Sr85	83.5%	VAL
		Sr86(n,2n)Sr85m(IT)Sr85	16.4%	VAL
Rb 86	18.6 d	Sr86(n,p)Rb86	66.0%	VAL
		Sr87(n,d)Rb86	8.6%	VAL
		Sr88(n,t)Rb86	.6%	??
		Sr86(n,p)Rb86m(IT)Rb86	16.9%	VAL
		Sr87(n,d)Rb86m(IT)Rb86	7.2%	VAL

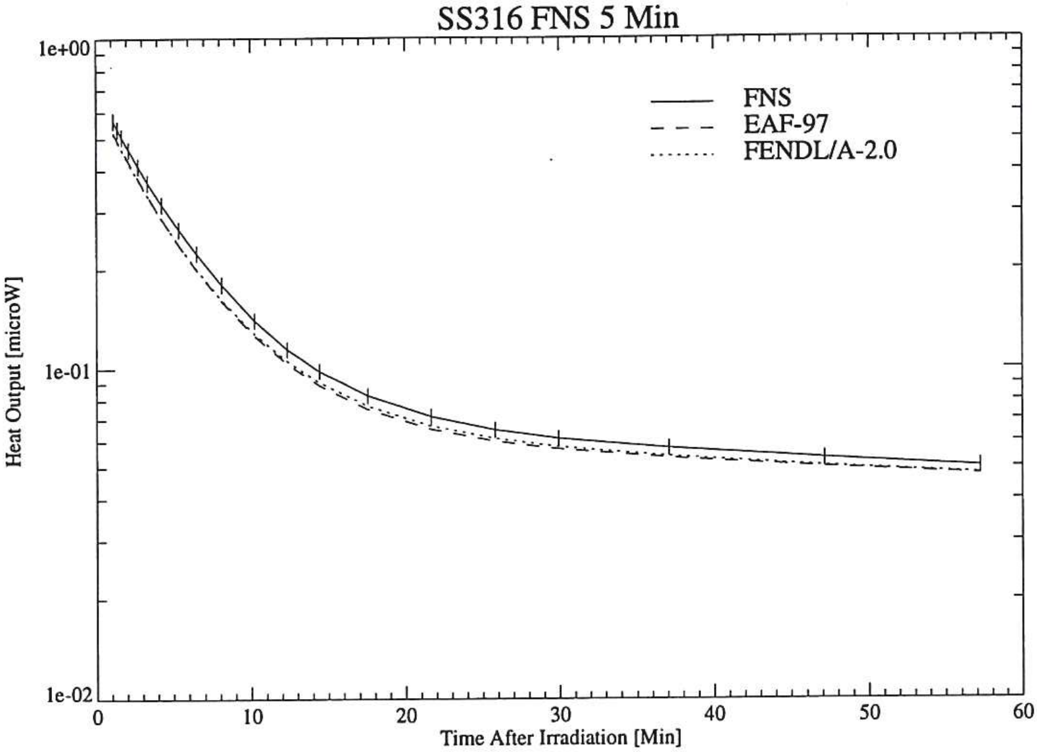


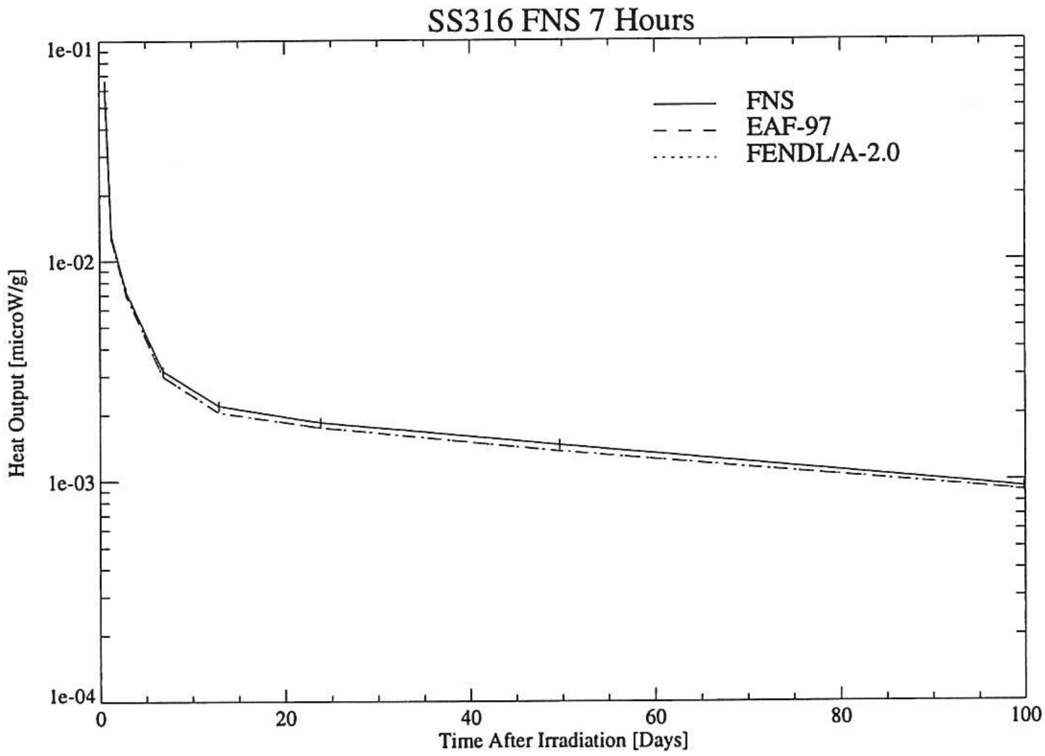


As in Cr a slight underestimation of the decay heat arising from V-52 can be noticed. The same trend as in SiO2 can be detected when the Al-28 is predominant as well. A remarkable agreement between experiment and prediction exist for this stainless steel for cooling times up to 3 months.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	5.33E-01+/- 5%	4.67E-01+/- 14%	-12%	4.62E-01	-13%
1.35	5.02E-01+/- 5%	4.45E-01+/- 14%	-11%	4.40E-01	-12%
1.62	4.80E-01+/- 5%	4.22E-01+/- 14%	-11%	4.18E-01	-12%
2.07	4.39E-01+/- 5%	3.88E-01+/- 14%	-11%	3.85E-01	-12%
2.68	3.93E-01+/- 5%	3.47E-01+/- 14%	-11%	3.44E-01	-12%
3.28	3.54E-01+/- 5%	3.12E-01+/- 14%	-11%	3.11E-01	-12%
4.12	3.08E-01+/- 5%	2.72E-01+/- 14%	-11%	2.71E-01	-12%
5.23	2.59E-01+/- 5%	2.29E-01+/- 13%	-11%	2.29E-01	-11%
6.30	2.23E-01+/- 5%	1.97E-01+/- 13%	-11%	1.97E-01	-11%
7.92	1.82E-01+/- 5%	1.60E-01+/- 13%	-11%	1.61E-01	-11%
10.03	1.43E-01+/- 5%	1.28E-01+/- 13%	-10%	1.29E-01	-9%
12.15	1.18E-01+/- 5%	1.07E-01+/- 13%	-9%	1.08E-01	-8%
14.22	1.02E-01+/- 5%	9.25E-02+/- 13%	-9%	9.42E-02	-7%
17.35	8.70E-02+/- 5%	7.92E-02+/- 14%	-9%	8.07E-02	-7%
21.47	7.57E-02+/- 5%	6.96E-02+/- 15%	-8%	7.09E-02	-6%
25.58	6.94E-02+/- 5%	6.45E-02+/- 16%	-7%	6.55E-02	-5%
29.70	6.59E-02+/- 5%	6.14E-02+/- 17%	-6%	6.22E-02	-5%
36.83	6.21E-02+/- 5%	5.81E-02+/- 17%	-6%	5.86E-02	-5%
46.97	5.85E-02+/- 5%	5.49E-02+/- 17%	-6%	5.52E-02	-5%
57.10	5.57E-02+/- 5%	5.23E-02+/- 17%	-6%	5.25E-02	-5%
Times	**FNS EXP. 7 Hrs.**	**EAF-97**	**(C-E)/E**	**FENDL/A-2**	**(C-E)/E**
Days	microW/g	microW/g		microW/g	
0.63	5.90E-02+/- 5%	5.72E-02+/- 15%	-2%	5.71E-02	-3%
1.30	7.85E-03+/- 5%	7.79E-03+/- 21%	0%	7.79E-03	0%
2.88	4.32E-03+/- 5%	4.19E-03+/- 21%	-3%	4.19E-03	-3%
6.85	2.02E-03+/- 5%	1.93E-03+/- 24%	-4%	1.93E-03	-4%
12.84	1.54E-03+/- 5%	1.45E-03+/- 29%	-5%	1.45E-03	-5%
23.84	1.35E-03+/- 5%	1.28E-03+/- 30%	-5%	1.28E-03	-5%
49.69	1.07E-03+/- 5%	1.00E-03+/- 30%	-6%	1.00E-03	-6%
99.88	7.03E-04+/- 5%	6.74E-04+/- 27%	-4%	6.74E-04	-4%

```
FNS 5 Min SS304
Nuclide  T1/2     Pathways
  V  52  3.7 m   Cr52(n,p)V52                      93.5%  TBA
                 Cr53(n,d)V52                       3.0%  ??
                 Mn55(n,a)V52                       3.3%  ??
  Al 28  2.2 m   Si28(n,p)Al28                     99.5%  TBA
  Mn 56  2.5 h   Fe56(n,p)Mn56                     98.9%  VAL
                 Fe57(n,d)Mn56                       .8%  ??
FNS 7 Hrs SS304
  V  52  3.7 m   Cr52(n,p)V52                      94.2%
                 Cr53(n,d)V52                       2.3%
                 Mn55(n,a)V52                       3.3%
  Mn 56  2.5 h   Fe56(n,p)Mn56                     99.3%
                 Fe57(n,d)Mn56                       .6%
  Ni 57  1.4 d   Ni58(n,2n)Ni57                   100.0%  VAL
  Co 58  70.8 d  Ni58(n,p)Co58                     76.4%  VAL
                 Ni58(n,p)Co58m(IT)Co58            23.5%  VAL
  Cr 51  27.7 d  Cr52(n,2n)Cr51                    94.3%  VAL
                 Fe54(n,a)Cr51                      5.6%  ??
  Mn 54  312.3 d Mn55(n,2n)Mn54                    46.6%  VAL
                 Fe54(n,p)Mn54                     53.1%  VAL
  Co 57  271.7 d Ni58(n,d)Co57                     99.5%  VAL
```





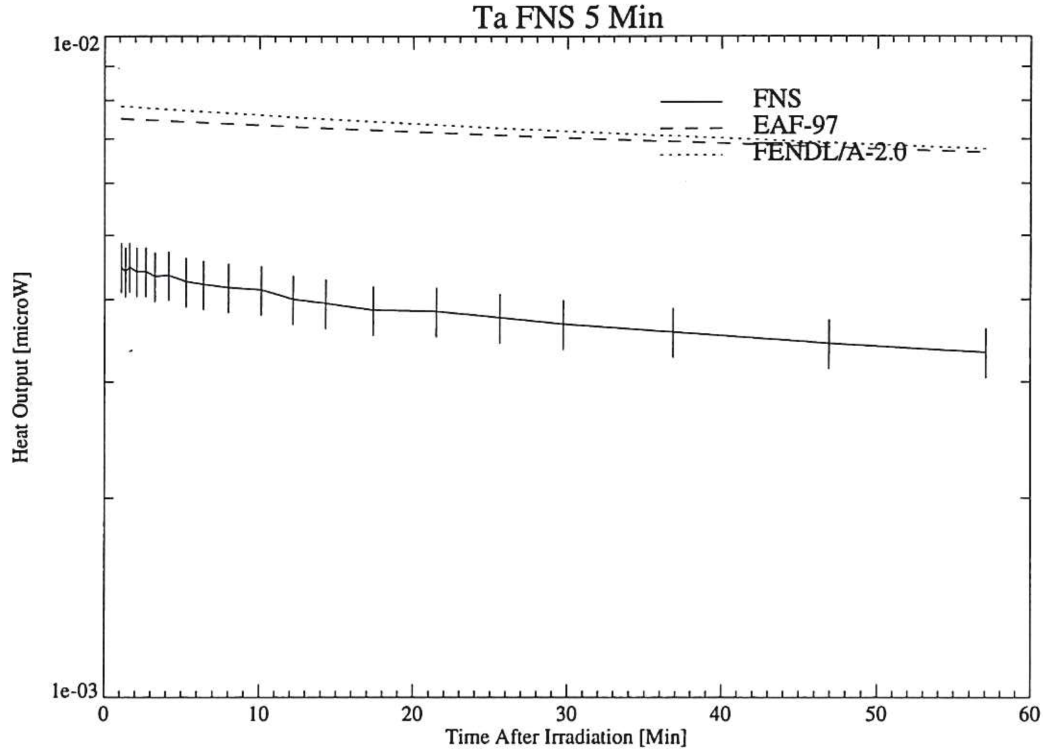
As in Cr a slight underestimation of the decay heat arising from V-52 can be noticed. The same trend as in SiO2 can be detected when the Al-28 is predominant as well. A remarkable agreement between experiment and prediction exist for this stainless steel for cooling times up to 3 months.

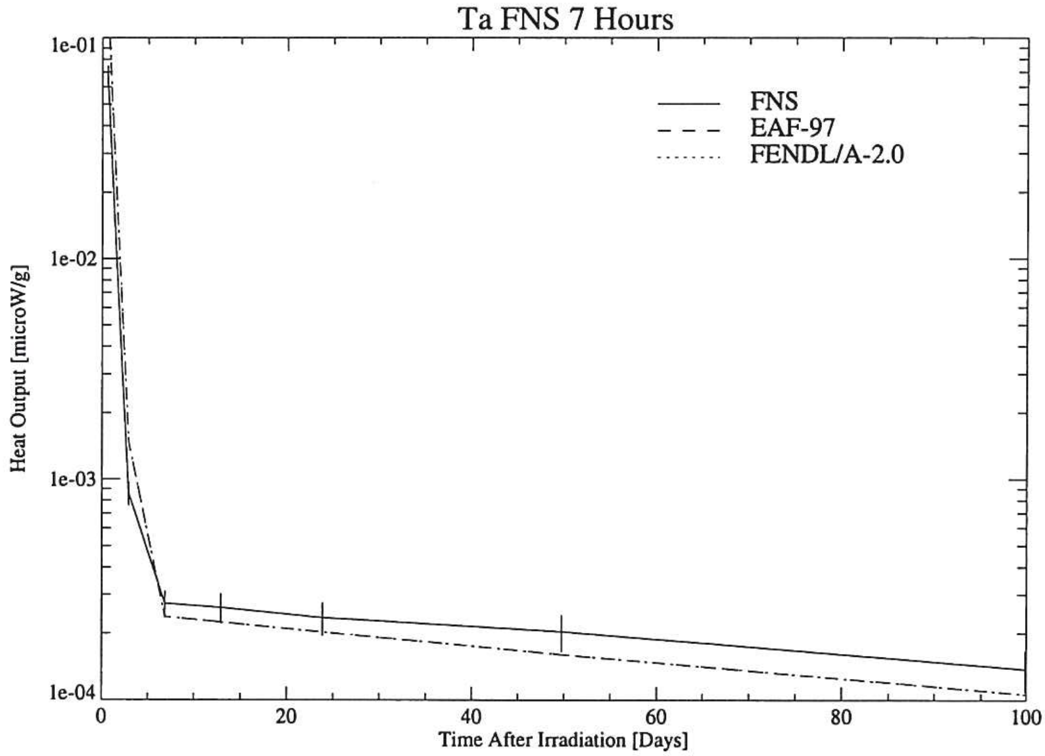
Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.13	5.65E-01+/- 5%	5.20E-01+/- 13%	-8%	5.15E-01	-8%
1.40	5.33E-01+/- 5%	4.92E-01+/- 13%	-7%	4.88E-01	-8%
1.67	5.05E-01+/- 5%	4.65E-01+/- 13%	-7%	4.62E-01	-8%
2.12	4.62E-01+/- 5%	4.25E-01+/- 13%	-8%	4.22E-01	-8%
2.75	4.11E-01+/- 5%	3.76E-01+/- 13%	-8%	3.74E-01	-9%
3.37	3.67E-01+/- 5%	3.35E-01+/- 13%	-8%	3.34E-01	-9%
4.27	3.15E-01+/- 5%	2.86E-01+/- 13%	-9%	2.85E-01	-9%
5.38	2.65E-01+/- 5%	2.38E-01+/- 13%	-10%	2.38E-01	-10%
6.50	2.24E-01+/- 5%	2.01E-01+/- 13%	-10%	2.01E-01	-10%
8.13	1.80E-01+/- 5%	1.61E-01+/- 12%	-10%	1.62E-01	-10%
10.25	1.40E-01+/- 5%	1.26E-01+/- 12%	-10%	1.28E-01	-8%
12.37	1.14E-01+/- 5%	1.03E-01+/- 12%	-9%	1.05E-01	-7%
14.43	9.80E-02+/- 5%	8.88E-02+/- 13%	-9%	9.07E-02	-7%
17.57	8.26E-02+/- 5%	7.50E-02+/- 13%	-9%	7.68E-02	-7%
21.68	7.12E-02+/- 5%	6.52E-02+/- 15%	-8%	6.66E-02	-6%
25.82	6.48E-02+/- 5%	5.98E-02+/- 16%	-7%	6.10E-02	-5%
29.93	6.09E-02+/- 5%	5.66E-02+/- 16%	-7%	5.75E-02	-5%
37.07	5.70E-02+/- 5%	5.32E-02+/- 17%	-6%	5.38E-02	-5%
47.13	5.31E-02+/- 5%	5.00E-02+/- 17%	-5%	5.03E-02	-5%
57.22	5.01E-02+/- 5%	4.74E-02+/- 17%	-5%	4.76E-02	-4%
Times	**FNS EXP. 7 Hrs.**	**EAF-97**	**(C-E)/E**	**FENDL/A-2**	**(C-E)/E**
Days	microW/g	microW/g		microW/g	
0.62	6.24E-02+/- 5%	5.98E-02+/- 14%	-4%	5.97E-02	-4%
1.30	1.30E-02+/- 5%	1.26E-02+/- 20%	-3%	1.26E-02	-3%
2.88	7.24E-03+/- 5%	6.97E-03+/- 20%	-3%	6.97E-03	-3%
6.85	3.17E-03+/- 5%	2.99E-03+/- 24%	-5%	2.99E-03	-5%
12.84	2.19E-03+/- 5%	2.04E-03+/- 32%	-6%	2.04E-03	-6%
23.83	1.84E-03+/- 5%	1.74E-03+/- 34%	-5%	1.74E-03	-5%
49.69	1.45E-03+/- 5%	1.36E-03+/- 33%	-6%	1.36E-03	-6%
99.88	9.30E-04+/- 5%	8.98E-04+/- 31%	-3%	8.99E-04	-3%

```
FNS 5 Min SS316
Nuclide  T1/2     Pathways
  V  52  3.7 m   Cr52(n,p)V52                              93.5%  TBA
                 Cr53(n,d)V52                               3.0%  ??
                 Mn55(n,a)V52                               3.3%  ??
  Al 28  2.2 m   Si28(n,p)Al28                             99.5%  TBA
  Mn 56  2.5 h   Fe56(n,p)Mn56                             98.9%  VAL
                 Fe57(n,d)Mn56                               .8%  ??
FNS 7 Hrs SS316
  Al 28  2.2 m   Si28(n,p)Al28                             99.6%
  V  52  3.7 m   Cr52(n,p)V52                              94.3%
                 Cr53(n,d)V52                               2.3%
                 Mn55(n,a)V52                               3.3%
  Mn 56  2.5 h   Fe56(n,p)Mn56                             99.3%
                 Fe57(n,d)Mn56                               .6%
  Ni 57  1.4 d   Ni58(n,2n)Ni57                           100.0%  VAL
  Mo 99  2.7 d   Mo98(n,g)Mo99                               .5%  ??
                 Mo100(n,2n)Mo99                           99.2%  VAL
  Co 58  70.8 d  Ni58(n,p)Co58                             76.4%  VAL
                 Ni58(n,p)Co58m(IT)Co58                    23.5%  VAL
  Cr 51  27.7 d  Cr52(n,2n)Cr51                            94.9%  VAL
                 Fe54(n,a)Cr51                              5.0%  ??
  Mn 54  312.3 d Mn55(n,2n)Mn54                            49.3%  VAL
```

		Fe54(n,p)Mn54	50.4%	VAL
Co 57	271.7 d	Ni58(n,d)Co57	99.5%	VAL

This page is intentionally left blank

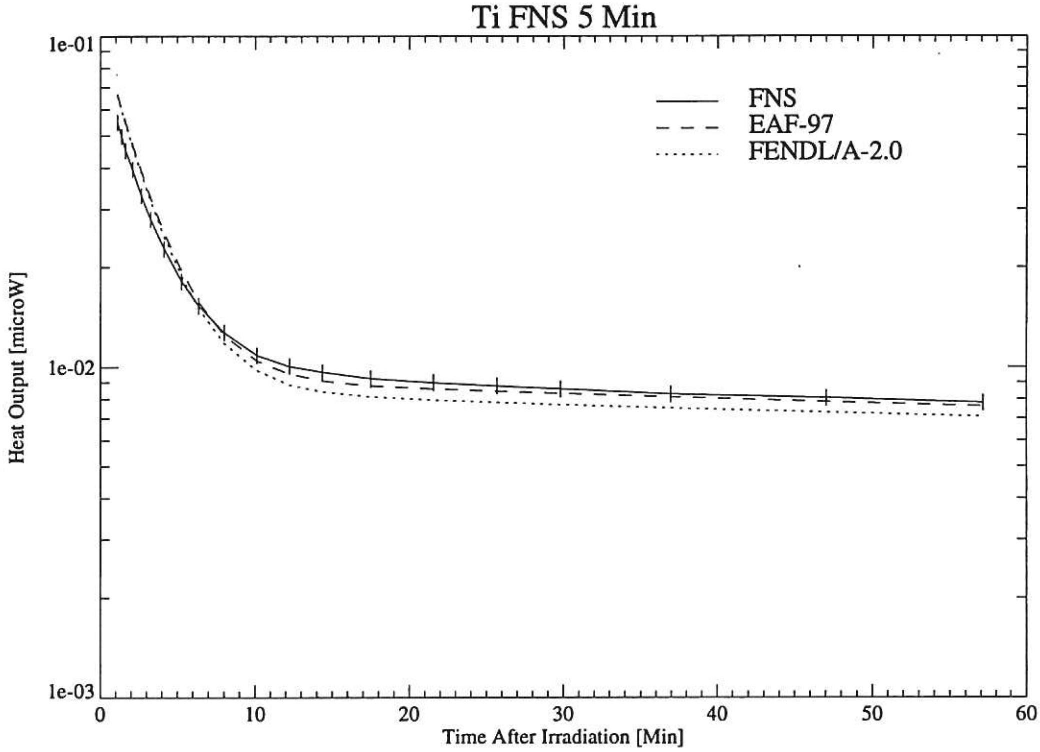


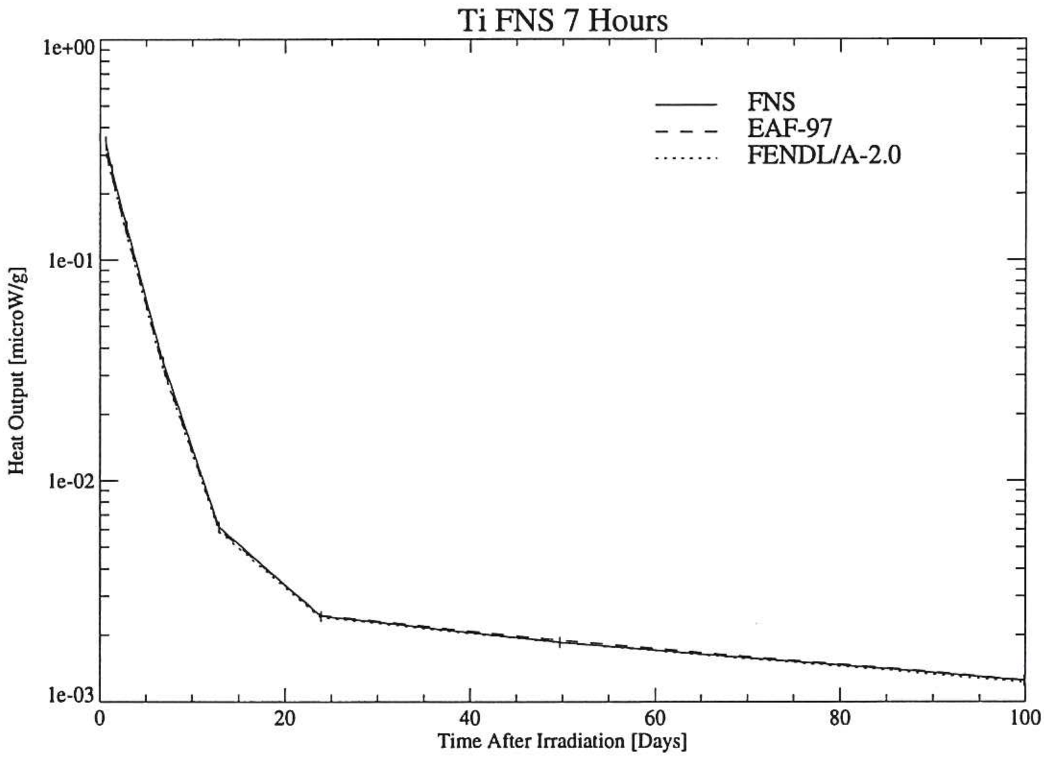


With a 70 to 100% overestimation when Lu-178 and Ta-180 isotopes dominate; this indicates either a gross overestimation of the cross-section or faulty decay data. The 7 hours irradiation experiment gives results within the large experimental uncertainties for cooling times greater than 3 days.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.08	4.48E-03+/- 8%	7.51E-03+/- 68%	67%	7.84E-03	74%
1.35	4.41E-03+/- 8%	7.50E-03+/- 68%	69%	7.83E-03	77%
1.62	4.48E-03+/- 8%	7.49E-03+/- 68%	67%	7.82E-03	74%
2.07	4.41E-03+/- 8%	7.48E-03+/- 68%	69%	7.80E-03	76%
2.68	4.41E-03+/- 8%	7.47E-03+/- 68%	69%	7.79E-03	76%
3.28	4.34E-03+/- 8%	7.46E-03+/- 68%	71%	7.77E-03	79%
4.17	4.36E-03+/- 8%	7.44E-03+/- 68%	70%	7.75E-03	77%
5.28	4.26E-03+/- 8%	7.42E-03+/- 68%	74%	7.72E-03	81%
6.40	4.22E-03+/- 8%	7.40E-03+/- 69%	75%	7.69E-03	82%
8.03	4.17E-03+/- 8%	7.37E-03+/- 69%	76%	7.64E-03	83%
10.13	4.13E-03+/- 8%	7.33E-03+/- 69%	77%	7.59E-03	83%
12.20	4.00E-03+/- 8%	7.29E-03+/- 69%	82%	7.54E-03	88%
14.32	3.94E-03+/- 8%	7.26E-03+/- 69%	84%	7.49E-03	90%
17.40	3.85E-03+/- 8%	7.21E-03+/- 69%	87%	7.42E-03	92%
21.48	3.83E-03+/- 8%	7.14E-03+/- 69%	86%	7.34E-03	91%
25.60	3.75E-03+/- 8%	7.08E-03+/- 70%	88%	7.26E-03	93%
29.72	3.67E-03+/- 8%	7.02E-03+/- 70%	91%	7.18E-03	95%
36.85	3.57E-03+/- 8%	6.92E-03+/- 70%	94%	7.06E-03	97%
46.93	3.43E-03+/- 8%	6.79E-03+/- 70%	98%	6.90E-03	101%
57.05	3.33E-03+/- 8%	6.68E-03+/- 71%	100%	6.76E-03	103%
Times	**FNS EXP. 7 Hrs.**	**EAF-97**	**(C-E)/E**	**FENDL/A-2**	**(C-E)/E**
Days	microW/g	microW/g		microW/g	
0.60	6.79E-02+/- 10%	1.42E-01+/- 71%	109%	1.42E-01	109%
1.33	1.62E-02+/- 8%	3.18E-02+/- 71%	96%	3.18E-02	96%
2.91	8.64E-04+/- 12%	1.47E-03+/- 60%	69%	1.47E-03	69%
6.88	2.73E-04+/- 13%	2.39E-04+/- 41%	-12%	2.39E-04	-12%
12.88	2.63E-04+/- 15%	2.25E-04+/- 42%	-14%	2.25E-04	-14%
23.88	2.36E-04+/- 17%	2.03E-04+/- 43%	-14%	2.03E-04	-14%
49.72	2.04E-04+/- 19%	1.61E-04+/- 45%	-21%	1.61E-04	-21%
99.91	1.38E-04+/- 21%	1.06E-04+/- 49%	-22%	1.06E-04	-22%

```
FNS 5 Mins Ta
Nuclide  T1/2     Pathways
  Ta180  8.0 h    Ta181(n,2n)Ta180                     99.9%  TBA
  Lu178  28.4 m   Ta181(n,a)Lu178                     100.0%  TBA
FNS 7 Hrs Ta
  Ta180  8.0 h    Ta181(n,2n)Ta180                    100.0%
  Hf181  42.3 d   Ta181(n,p)Hf181                     100.0%  VAL
  Ta182  114.7 d  Ta181(n,g)Ta182                      76.9%  ??
                  Ta181(n,g)Ta182m(IT)Ta182            22.1%  ??
```





A rather good agreement could be seems from both graphs for this particular element.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	5.49E-02+/- 5%	6.66E-02+/- 47%	21%	6.61E-02	20%
1.37	4.97E-02+/- 5%	6.02E-02+/- 47%	21%	5.96E-02	19%
1.63	4.51E-02+/- 5%	5.47E-02+/- 46%	21%	5.41E-02	19%
2.08	3.95E-02+/- 5%	4.69E-02+/- 45%	18%	4.62E-02	17%
2.65	3.30E-02+/- 5%	3.91E-02+/- 43%	18%	3.84E-02	16%
3.27	2.79E-02+/- 5%	3.25E-02+/- 40%	16%	3.18E-02	13%
4.15	2.28E-02+/- 5%	2.55E-02+/- 36%	11%	2.47E-02	8%
5.27	1.81E-02+/- 5%	1.95E-02+/- 31%	7%	1.88E-02	3%
6.38	1.53E-02+/- 5%	1.57E-02+/- 26%	2%	1.50E-02	-1%
8.02	1.27E-02+/- 5%	1.25E-02+/- 21%	-1%	1.18E-02	-7%
10.13	1.08E-02+/- 5%	1.04E-02+/- 18%	-3%	9.73E-03	-10%
12.25	1.00E-02+/- 5%	9.50E-03+/- 19%	-5%	8.83E-03	-12%
14.37	9.61E-03+/- 5%	9.07E-03+/- 19%	-5%	8.40E-03	-12%
17.50	9.19E-03+/- 5%	8.76E-03+/- 19%	-4%	8.10E-03	-11%
21.57	8.95E-03+/- 5%	8.56E-03+/- 20%	-4%	7.92E-03	-11%
25.68	8.74E-03+/- 5%	8.41E-03+/- 20%	-3%	7.78E-03	-10%
29.80	8.56E-03+/- 5%	8.29E-03+/- 20%	-3%	7.67E-03	-10%
36.93	8.25E-03+/- 5%	8.09E-03+/- 20%	-1%	7.50E-03	-9%
47.02	8.05E-03+/- 5%	7.83E-03+/- 20%	-2%	7.27E-03	-9%
57.13	7.79E-03+/- 5%	7.60E-03+/- 20%	-2%	7.07E-03	-9%
Times	**FNS EXP. 7 Hrs.**	**EAF-97**	**(C-E)/E**	**FENDL/A-2**	**(C-E)/E**
Days	microW/g	microW/g		microW/g	
0.65	3.38E-01+/- 7%	3.06E-01+/- 28%	-9%	3.00E-01	-11%
1.32	2.54E-01+/- 6%	2.37E-01+/- 28%	-6%	2.32E-01	-8%
2.90	1.41E-01+/- 5%	1.32E-01+/- 28%	-6%	1.30E-01	-8%
6.87	3.44E-02+/- 5%	3.23E-02+/- 25%	-6%	3.17E-02	-8%
12.87	6.16E-03+/- 5%	6.01E-03+/- 23%	-2%	5.88E-03	-4%
23.86	2.43E-03+/- 5%	2.46E-03+/- 40%	1%	2.40E-03	-1%
49.71	1.85E-03+/- 5%	1.89E-03+/- 42%	2%	1.84E-03	0%
99.90	1.25E-03+/- 5%	1.25E-03+/- 41%	0%	1.22E-03	-2%

FNS 5 Mins Ti

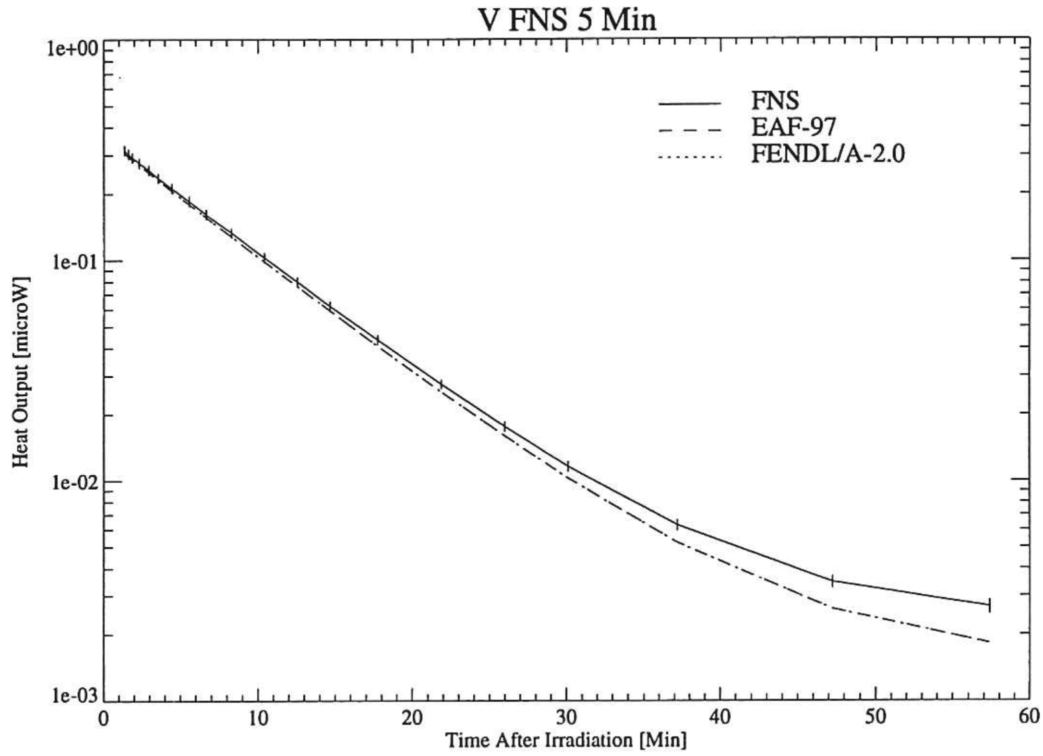
Nuclide	$T_{1/2}$	Pathways		
Sc 46m	18.7 s	Ti46(n,p)Sc46m	65.4%	TBA
		Ti47(n,d)Sc46m	34.5%	TBA
Sc 50	1.7 m	Ti50(n,p)Sc50	61.3%	TBA
		Ti50(n,p)Sc50m(IT)Sc50	38.6%	TBA
Sc 49	57.2 m	Ti49(n,p)Sc49	85.6%	VAL
		Ti50(n,d)Sc49	14.3%	VAL
Ti 45	3.0 h	Ti46(n,2n)Ti45	100.0%	VAL
Sc 44	3.9 h	Ti46(n,t)Sc44	99.9%	VAL
Sc 48	1.8 d	Ti48(n,p)Sc48	98.5%	VAL
		Ti49(n,d)Sc48	1.4%	??

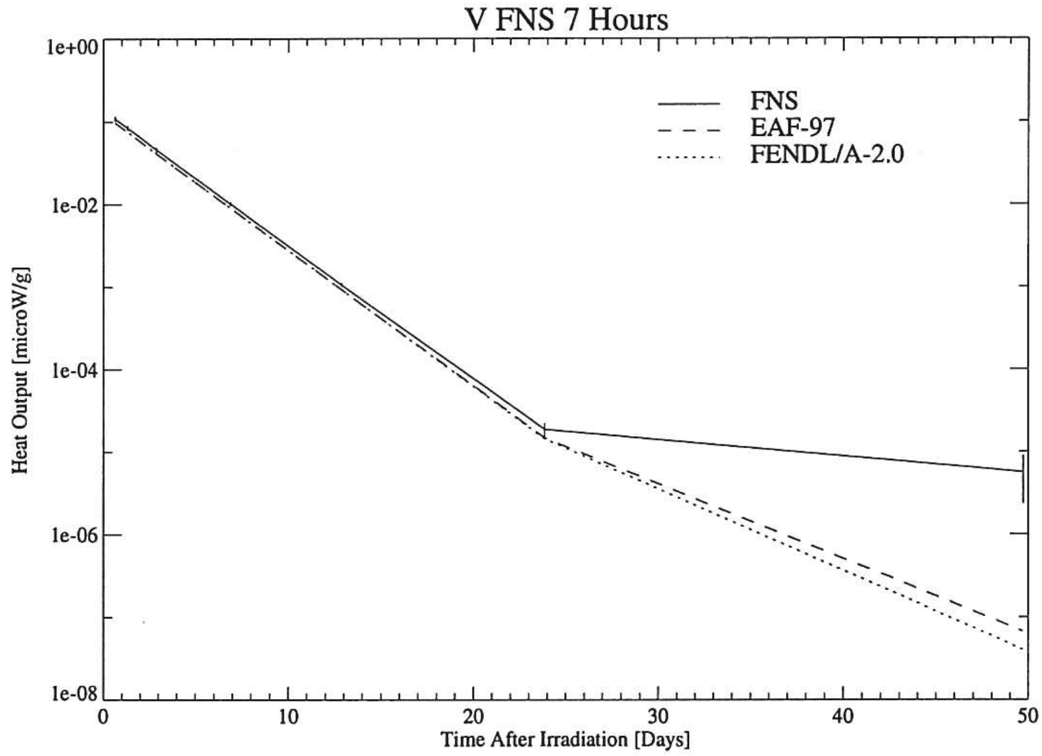
FNS 7 Hrs Ti

Sc 50	1.7 m	Ti50(n,p)Sc50	61.0%	
		Ti50(n,p)Sc50m(IT)Sc50	38.9%	
Ti 45	3.0 h	Ti46(n,2n)Ti45	100.0%	
Sc 49	57.2 m	Ti49(n,p)Sc49	87.3%	
		Ti50(n,d)Sc49	12.6%	
Sc 48	1.8 d	Ti48(n,p)Sc48	98.8%	VAL
		Ti49(n,d)Sc48	1.1%	??
Sc 47	3.3 d	Ti47(n,p)Sc47	43.1%	VAL
		Ti48(n,d)Sc4	56.5%	VAL

Sc 46	83.7 d	Ti46(n,p)Sc46	60.2%	VAL
		Ti47(n,d)Sc46	16.9%	VAL
		Ti46(n,p)Sc46m(IT)Sc46	15.6%	VAL
		Ti47(n,d)Sc46m(IT)Sc46	7.1%	VAL

This page is intentionally left blank





A clear underestimation can be seem for cooling times greater than 30 minutes, when Sc-48 dominates markedly. The production pathway V-51(n,a)Sc-48 may need to be revisited. A good agreement exists up to 24 days cooling for the 7 hours irradiation test. At longer cooling time one should notice that the experimental values reach the minimum resolution and so cannot be relied upon.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.35	3.14E-01+/- 5%	3.05E-01+/- 26%	-2%	3.05E-01	-2%
1.62	3.03E-01+/- 5%	2.95E-01+/- 26%	-2%	2.95E-01	-2%
1.88	2.92E-01+/- 5%	2.85E-01+/- 26%	-2%	2.85E-01	-2%
2.33	2.76E-01+/- 5%	2.70E-01+/- 26%	-2%	2.70E-01	-2%
2.95	2.56E-01+/- 5%	2.49E-01+/- 26%	-2%	2.49E-01	-2%
3.57	2.36E-01+/- 5%	2.31E-01+/- 26%	-2%	2.31E-01	-2%
4.45	2.12E-01+/- 5%	2.06E-01+/- 26%	-2%	2.06E-01	-2%
5.57	1.85E-01+/- 5%	1.79E-01+/- 26%	-3%	1.79E-01	-3%
6.68	1.61E-01+/- 5%	1.56E-01+/- 27%	-2%	1.56E-01	-2%
8.32	1.33E-01+/- 5%	1.28E-01+/- 27%	-3%	1.28E-01	-3%
10.42	1.03E-01+/- 5%	9.85E-02+/- 27%	-4%	9.85E-02	-4%
12.55	7.97E-02+/- 5%	7.60E-02+/- 27%	-4%	7.60E-02	-4%
14.67	6.15E-02+/- 5%	5.89E-02+/- 27%	-4%	5.89E-02	-4%
17.75	4.35E-02+/- 5%	4.08E-02+/- 27%	-6%	4.08E-02	-6%
21.87	2.73E-02+/- 5%	2.53E-02+/- 27%	-7%	2.52E-02	-7%
25.98	1.75E-02+/- 5%	1.59E-02+/- 26%	-9%	1.59E-02	-9%
30.10	1.15E-02+/- 5%	1.03E-02+/- 25%	-11%	1.02E-02	-11%
37.18	6.28E-03+/- 5%	5.23E-03+/- 21%	-16%	5.22E-03	-16%
47.25	3.46E-03+/- 6%	2.61E-03+/- 17%	-24%	2.61E-03	-24%
57.38	2.67E-03+/- 7%	1.83E-03+/- 24%	-31%	1.83E-03	-31%

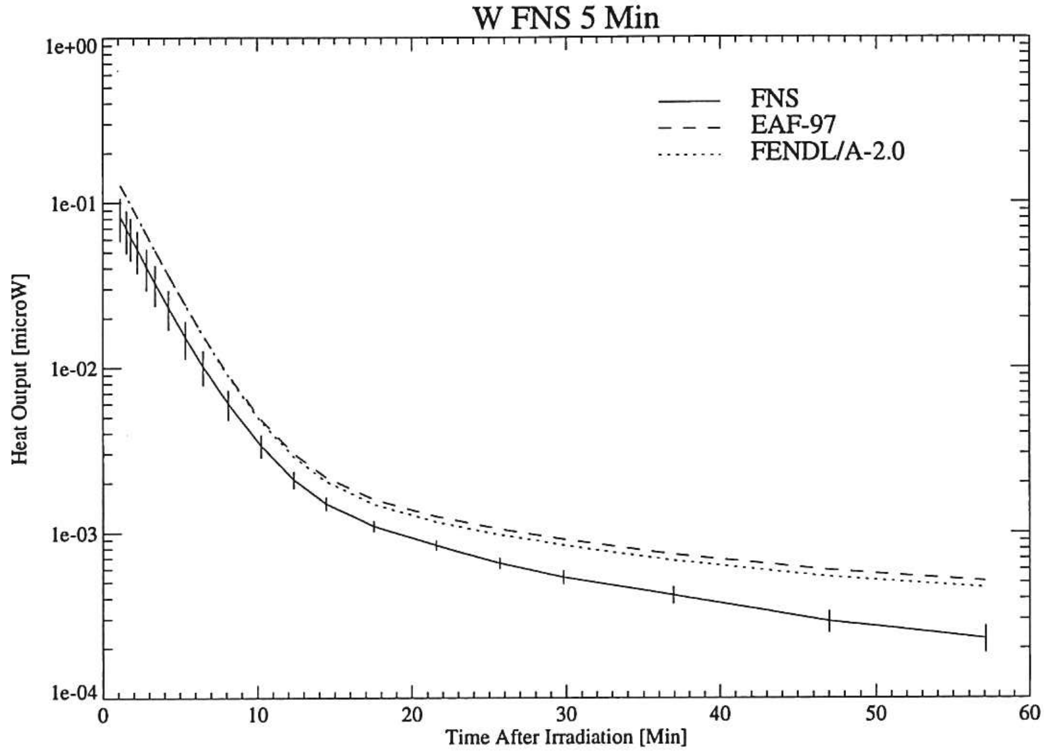
Times	FNS EXP. 7 Hrs.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Days	microW/g	microW/g		microW/g	
0.65	1.08E-01+/- 6%	9.71E-02+/- 0%	-10%	9.71E-02	-10%
1.32	8.42E-02+/- 6%	7.52E-02+/- 0%	-10%	7.52E-02	-10%
2.90	4.61E-02+/- 5%	4.12E-02+/- 0%	-10%	4.12E-02	-10%
6.87	1.02E-02+/- 5%	9.10E-03+/- 29%	-10%	9.09E-03	-11%
12.86	1.06E-03+/- 5%	9.31E-04+/- 29%	-11%	9.28E-04	-12%
23.86	1.86E-05+/- 18%	1.47E-05+/- 28%	-21%	1.43E-05	-23%
49.73	5.62E-06+/- 58%	6.72E-08+/- 36%	-98%	4.03E-08	-99%

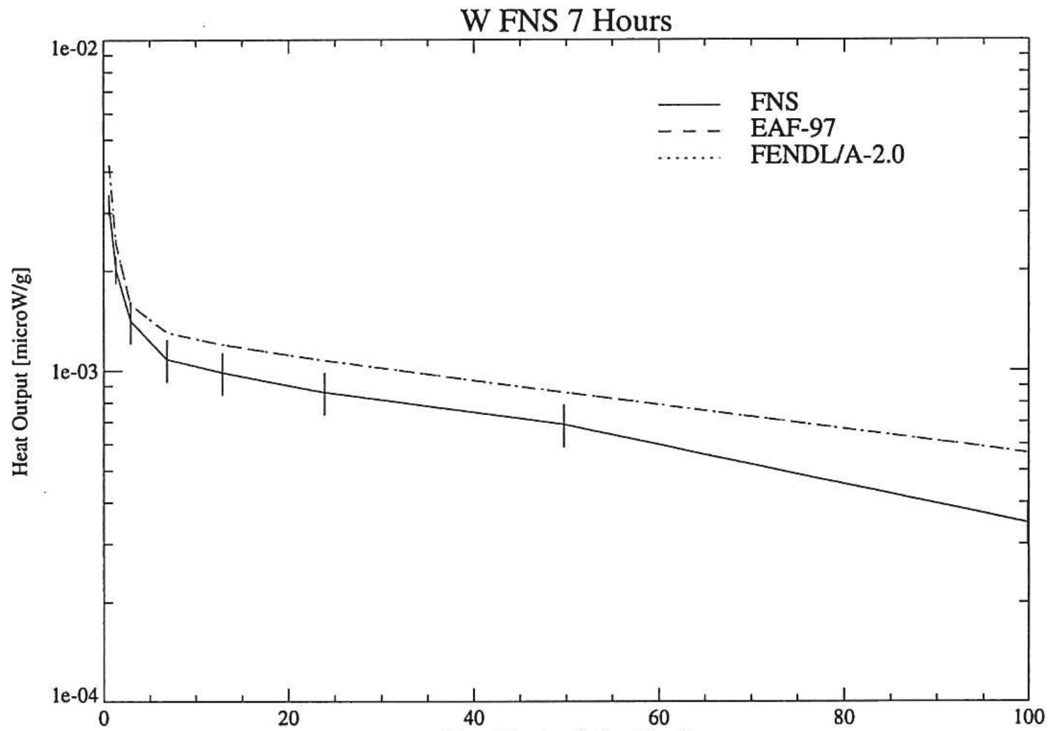
FNS 5 Min V

Nuclide	$T_{1/2}$	Pathways		
Ti 51	5.8 m	V51(n,p)Ti51	100.0%	VAL
V 52	3.7 m	V51(n,g)V52	100.0%	??
Sc 48	1.8 d	V51(n,a)Sc48	100.0%	TBA

FNS 7 Hrs V

Ti 51	5.8 m	V51(n,p)Ti51	100.0%	
Sc 48	1.8 d	V51(n,a)Sc48	100.0%	
V 49	330.0 d	V50(n,2n)V49	100.0%	??
Sc 46	83.7 d	V50(n,na)Sc46	96.5%	??
		V50(n,na)Sc46m(IT)Sc46	3.4%	??





Better than expected level of agreement should be noticed for this element that has presented many difficulties [8]. First, the experimental values measured do have high uncertainties due to the fact that the γ rays emitted are of low energy at the limit of the sensitivity of the detector. Second, the most predominant isotopes are produced through (n,g) reaction channels that cannot be properly represented with the spectral data calculated.

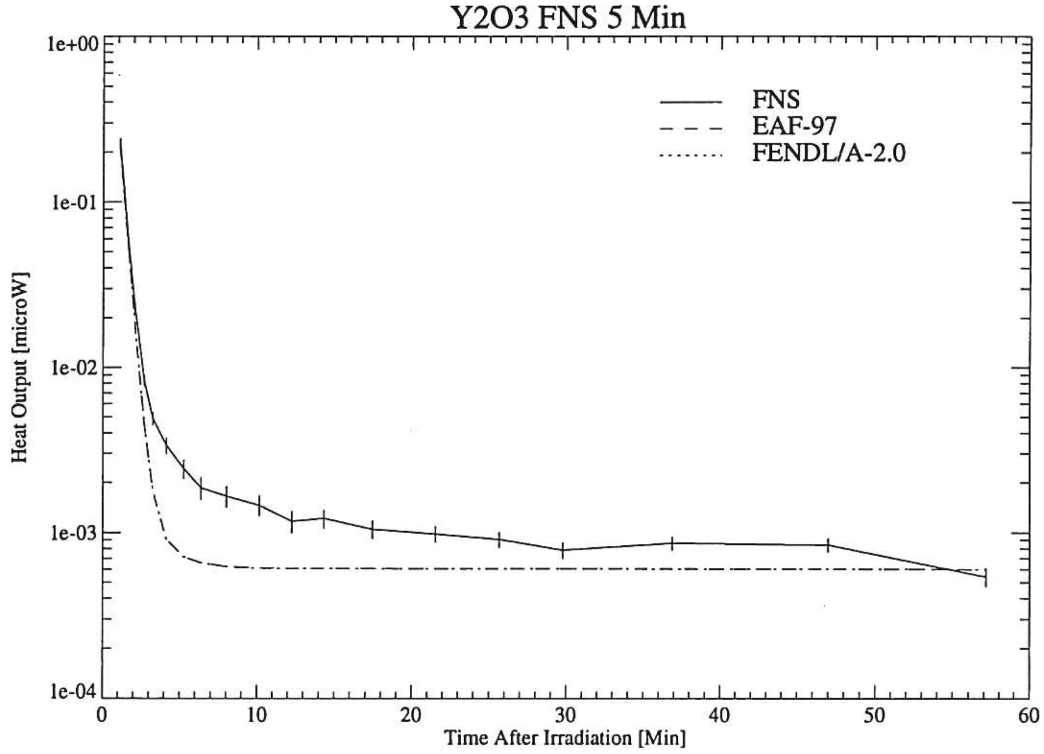
Times Min.	FNS EXP. 5 Min. microW/g	EAF-97 microW/g	(C-E)/E	FENDL/A-2 microW/g	(C-E)/E
1.12	8.22E-02+/- 29%	1.28E-01+/- 69%	55%	1.28E-01	55%
1.52	6.94E-02+/- 28%	1.09E-01+/- 69%	56%	1.09E-01	56%
1.78	6.23E-02+/- 28%	9.78E-02+/- 69%	57%	9.75E-02	56%
2.23	5.21E-02+/- 28%	8.16E-02+/- 68%	56%	8.13E-02	56%
2.83	4.06E-02+/- 28%	6.42E-02+/- 68%	57%	6.39E-02	57%
3.40	3.24E-02+/- 27%	5.12E-02+/- 67%	57%	5.10E-02	57%
4.28	2.30E-02+/- 26%	3.62E-02+/- 66%	57%	3.60E-02	56%
5.38	1.52E-02+/- 25%	2.38E-02+/- 63%	56%	2.36E-02	55%
6.50	1.02E-02+/- 23%	1.58E-02+/- 60%	54%	1.56E-02	53%
8.13	6.05E-03+/- 20%	9.03E-03+/- 54%	49%	8.87E-03	46%
10.25	3.36E-03+/- 15%	4.85E-03+/- 43%	44%	4.70E-03	40%
12.37	2.09E-03+/- 11%	3.01E-03+/- 34%	43%	2.88E-03	37%
14.43	1.50E-03+/- 9%	2.16E-03+/- 29%	44%	2.04E-03	36%
17.52	1.10E-03+/- 7%	1.59E-03+/- 28%	45%	1.49E-03	35%
21.57	8.37E-04+/- 7%	1.25E-03+/- 27%	49%	1.16E-03	38%
25.68	6.51E-04+/- 7%	1.05E-03+/- 26%	61%	9.70E-04	49%
29.80	5.36E-04+/- 9%	9.08E-04+/- 24%	69%	8.36E-04	55%
36.93	4.18E-04+/- 11%	7.37E-04+/- 21%	76%	6.75E-04	61%
47.02	2.91E-04+/- 15%	5.91E-04+/- 18%	102%	5.39E-04	84%
57.08	2.29E-04+/- 18%	5.07E-04+/- 17%	121%	4.63E-04	101%

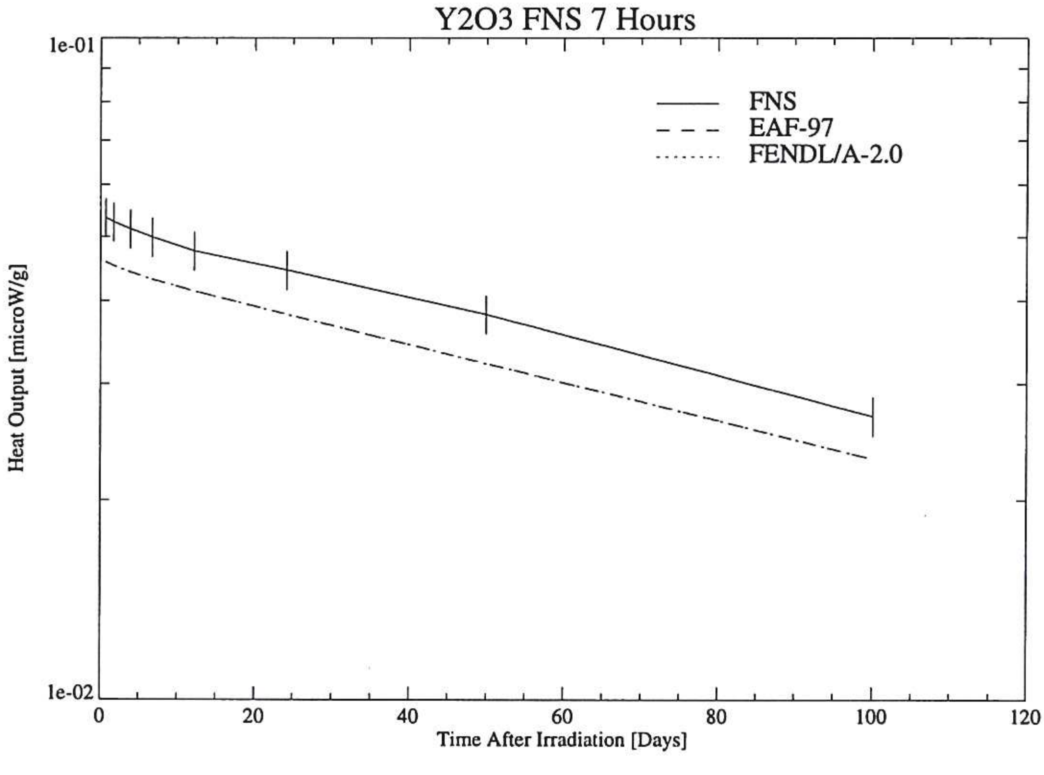
Times Days	FNS EXP. 7 Hrs. microW/g	EAF-97 microW/g	(C-E)/E	FENDL/A-2 microW/g	(C-E)/E
0.61	3.17E-03+/- 7%	4.19E-03+/- 26%	32%	4.20E-03	32%
1.33	2.02E-03+/- 9%	2.43E-03+/- 25%	20%	2.43E-03	20%
2.91	1.41E-03+/- 14%	1.58E-03+/- 32%	11%	1.58E-03	12%
6.88	1.08E-03+/- 14%	1.30E-03+/- 37%	20%	1.30E-03	20%
12.87	9.86E-04+/- 14%	1.20E-03+/- 38%	21%	1.20E-03	21%
23.87	8.59E-04+/- 14%	1.07E-03+/- 38%	24%	1.07E-03	24%
49.71	6.86E-04+/- 14%	8.58E-04+/- 38%	24%	8.58E-04	24%
99.90	3.48E-04+/- 14%	5.65E-04+/- 36%	62%	5.65E-04	62%

```
FNS 5 Min W
Nuclide  T1/2      Pathways
  W 183m 5.2 s    W182(n,g)W183m                     .6%  ??
                  W183(n,n')W183m                   2.2%  ??
                  W184(n,2n)W183m                  97.1%  ??
  W 185m 1.6 m    W186(n,2n)W185m                  99.9%  ??
  Ta185  49.0 m   W186(n,d)Ta185                   99.9%  ??
  Ta184  8.7 h    W184(n,p)Ta184                   98.3%  ??
                  W186(n,t)Ta184                    1.6%  ??
  Hf183  1.0 h    W186(n,a)Hf183                  100.0%  ??
  Ta186  10.5 m   W186(n,p)Ta186                  100.0%  ??
  W 187  23.8 h   W186(n,g)W187                   100.0%  ??
FNS 7 Hrs W
  W 183m 5.2 s    W183(n,n')W183m                   2.0%  ??
                  W184(n,2n)W183m                  97.8%  ??
  W 185m 1.6 m    W186(n,2n)W185m                  99.9%  ??
  Ta184  8.7 h    W184(n,p)Ta184                   98.8%  ??
                  W186(n,t)Ta184                    1.0%  ??
  W 187  23.8 h   W186(n,g)W187                   100.0%  ??
  W 185  75.1 d   W186(n,2n)W185                   56.7%  ??
                  W186(n,2n)W185m(IT)W185          43.0%  ??
  Ta183  5.0 d    W183(n,p)Ta183                   68.1%  ??
                  W184(n,d)Ta183                   17.9%  ??
```

		W186(n,a)Hf183(b-)Ta183	13.8%	??
W 181	120.9 d	W182(n,2n)W181	99.9%	??

This page is intentionally left blank

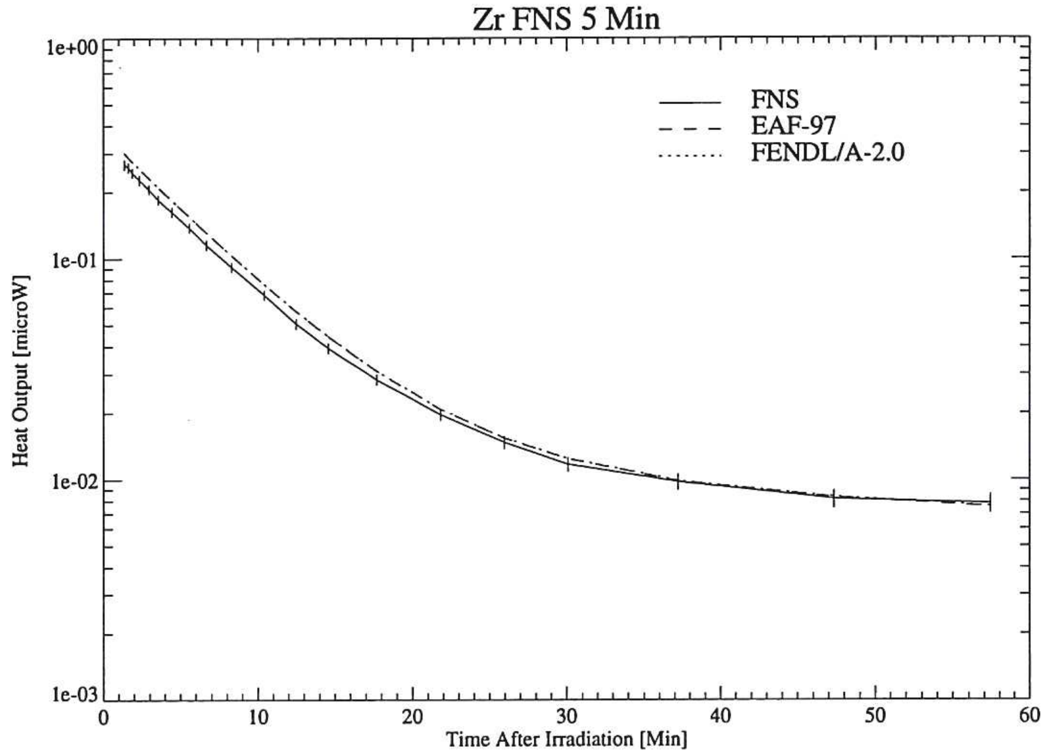


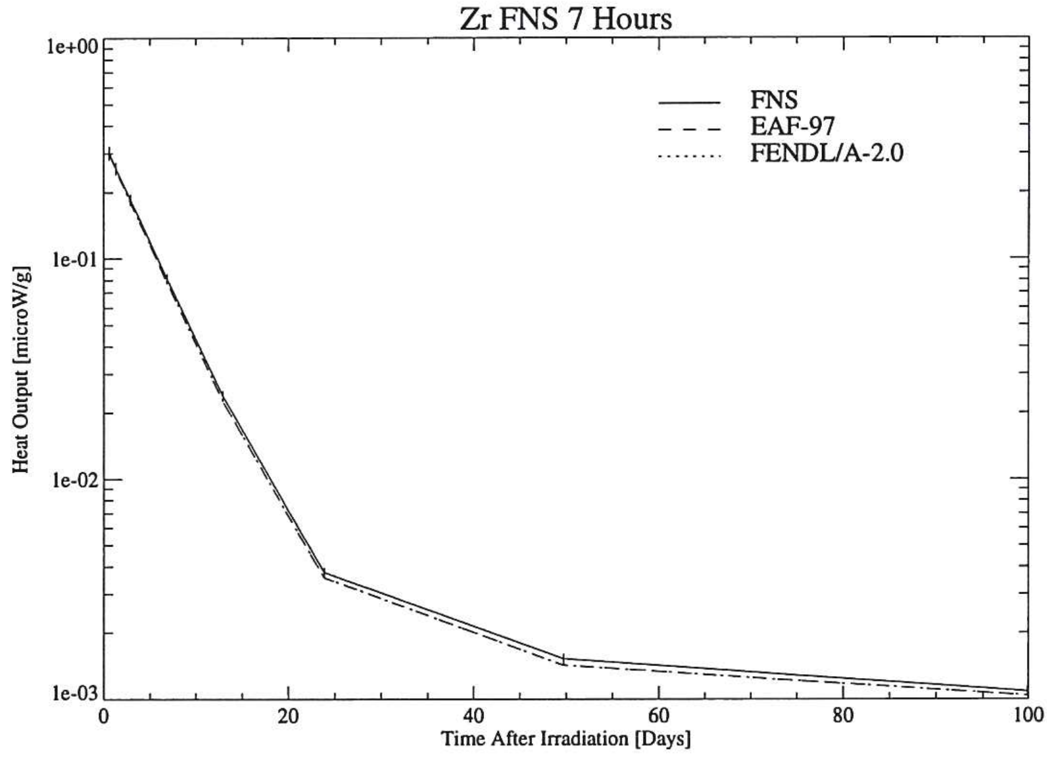


The pathway Y-89(n,a)Rb-86m seems to be the cause of the underprediction up to 10 minutes cooling. Amazingly for both graphs thereafter, Y-88 is the predominant isotope produced through the Y-89(n,2n) reaction, which may need to be revised upward although, once again, the decay data may be faulty as well.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.10	2.28E-01+/- 6%	2.15E-01+/- 75%	-5%	2.15E-01	-6%
1.37	1.17E-01+/- 6%	1.07E-01+/- 75%	-8%	1.07E-01	-8%
1.63	6.08E-02+/- 6%	5.40E-02+/- 75%	-11%	5.40E-02	-11%
2.08	2.32E-02+/- 6%	.1.77E-02+/- 71%	-23%	1.77E-02	-23%
2.70	8.30E-03+/- 7%	4.50E-03+/- 64%	-45%	4.49E-03	-45%
3.27	4.90E-03+/- 9%	1.78E-03+/- 80%	-63%	1.78E-03	-63%
4.15	3.36E-03+/- 11%	9.13E-04+/-141%	-72%	9.12E-04	-72%
5.27	2.42E-03+/- 13%	7.14E-04+/-179%	-70%	7.13E-04	-70%
6.38	1.85E-03+/- 15%	6.56E-04+/-195%	-64%	6.56E-04	-64%
8.03	1.65E-03+/- 14%	6.22E-04+/-205%	-62%	6.22E-04	-62%
10.15	1.46E-03+/- 14%	6.09E-04+/-209%	-58%	6.09E-04	-58%
12.27	1.17E-03+/- 15%	6.05E-04+/-211%	-48%	6.05E-04	-48%
14.33	1.21E-03+/- 12%	6.05E-04+/-211%	-50%	6.05E-04	-50%
17.47	1.04E-03+/- 12%	6.05E-04+/-211%	-42%	6.04E-04	-42%
21.55	9.76E-04+/- 11%	6.04E-04+/-211%	-38%	6.04E-04	-38%
25.67	9.06E-04+/- 10%	6.03E-04+/-212%	-33%	6.03E-04	-33%
29.78	7.81E-04+/- 11%	6.03E-04+/-212%	-22%	6.02E-04	-22%
36.87	8.59E-04+/- 9%	6.02E-04+/-212%	-29%	6.01E-04	-30%
47.00	8.39E-04+/- 9%	6.00E-04+/-213%	-28%	6.00E-04	-28%
57.12	5.41E-04+/- 12%	5.99E-04+/-213%	10%	5.99E-04	10%
Times	**FNS EXP. 7 Hrs.**	**EAF-97**	**(C-E)/E**	**FENDL/A-2**	**(C-E)/E**
Days	microW/g	microW/g		microW/g	
0.68	5.35E-02+/- 6%	4.58E-02+/-229%	-14%	4.58E-02	-14%
1.73	5.27E-02+/- 6%	4.52E-02+/-231%	-14%	4.52E-02	-14%
3.89	5.14E-02+/- 6%	4.42E-02+/-233%	-14%	4.42E-02	-14%
6.76	5.00E-02+/- 6%	4.31E-02+/-234%	-13%	4.31E-02	-13%
12.20	4.76E-02+/- 6%	4.14E-02+/-236%	-13%	4.14E-02	-13%
24.21	4.45E-02+/- 6%	3.81E-02+/-236%	-14%	3.81E-02	-14%
49.96	3.81E-02+/- 6%	3.22E-02+/-237%	-15%	3.21E-02	-15%
100.09	2.68E-02+/- 6%	2.31E-02+/-238%	-13%	2.31E-02	-13%

```
FNS 5 Min Y2O3
Nuclide  T1/2       Pathways
  N   16   7.1 s    O16(n,p)N16                        99.9%  VAL
  Y   89m 16.0 s    Y89(n,n')Y89m                     100.0%  ??
  Rb  86m  1.0 m    Y89(n,a)Rb86m                     100.0%  TBA
  Y   90m  3.1 h    Y89(n,g)Y90m                      100.0%  ??
  Y   88   106.6 d  Y89(n,2n)Y88                      100.0%  TBA
FNS 7 Hrs Y2O3
  N   16   7.1 s    O16(n,p)N16                        99.9%
  Y   89m 16.0 s    Y89(n,n')Y89m                     100.0%
  Y   88   106.6 d  Y89(n,2n)Y88                      100.0%  TBA
```





An excellent agreement can be seem for this element for which all the pathways of production tested by this benchmark seems to be well qualified.

Times	FNS EXP. 5 Min.	EAF-97	(C-E)/E	FENDL/A-2	(C-E)/E
Min.	microW/g	microW/g		microW/g	
1.37	2.67E-01+/- 5%	3.01E-01+/- 62%	12%	3.01E-01	12%
1.63	2.59E-01+/- 5%	2.86E-01+/- 62%	10%	2.87E-01	10%
1.88	2.45E-01+/- 5%	2.74E-01+/- 62%	12%	2.75E-01	12%
2.33	2.27E-01+/- 5%	2.55E-01+/- 62%	12%	2.55E-01	12%
2.95	2.06E-01+/- 5%	2.31E-01+/- 62%	12%	2.32E-01	12%
3.57	1.84E-01+/- 5%	2.10E-01+/- 61%	13%	2.10E-01	14%
4.45	1.62E-01+/- 5%	1.83E-01+/- 61%	12%	1.84E-01	13%
5.57	1.38E-01+/- 5%	1.55E-01+/- 60%	12%	1.55E-01	12%
6.68	1.15E-01+/- 5%	1.31E-01+/- 59%	13%	1.31E-01	13%
8.32	9.11E-02+/- 5%	1.03E-01+/- 57%	12%	1.03E-01	12%
10.43	6.82E-02+/- 5%	7.61E-02+/- 55%	11%	7.62E-02	11%
12.50	5.05E-02+/- 5%	5.75E-02+/- 52%	13%	5.76E-02	13%
14.57	3.92E-02+/- 5%	4.42E-02+/- 48%	12%	4.42E-02	12%
17.70	2.82E-02+/- 5%	3.08E-02+/- 42%	9%	3.08E-02	9%
21.82	1.96E-02+/- 6%	2.07E-02+/- 36%	5%	2.08E-02	5%
25.95	1.47E-02+/- 6%	1.54E-02+/- 32%	4%	1.54E-02	4%
30.07	1.17E-02+/- 7%	1.24E-02+/- 33%	5%	1.24E-02	6%
37.20	9.75E-03+/- 8%	9.85E-03+/- 37%	0%	9.89E-03	1%
47.33	8.17E-03+/- 9%	8.32E-03+/- 42%	1%	8.36E-03	2%
57.40	7.79E-03+/- 9%	7.54E-03+/- 46%	-3%	7.58E-03	-2%
Times	**FNS EXP. 7 Hrs.**	**EAF-97**	**(C-E)/E**	**FENDL/A-2**	**(C-E)/E**
Days	microW/g	microW/g		microW/g	
0.61	3.02E-01+/- 7%	3.01E-01+/- 40%	0%	3.02E-01	0%
1.33	2.57E-01+/- 6%	2.52E-01+/- 40%	-1%	2.53E-01	-1%
2.91	1.85E-01+/- 6%	1.80E-01+/- 41%	-3%	1.80E-01	-2%
6.88	8.12E-02+/- 5%	7.75E-02+/- 40%	-4%	7.77E-02	-4%
12.88	2.39E-02+/- 5%	2.26E-02+/- 39%	-5%	2.27E-02	-4%
23.85	3.77E-03+/- 5%	3.57E-03+/- 25%	-5%	3.57E-03	-5%
49.71	1.53E-03+/- 5%	1.43E-03+/- 16%	-6%	1.43E-03	-6%
99.90	1.09E-03+/- 5%	1.04E-03+/- 16%	-4%	1.04E-03	-4%

FNS 5 Min ZR

Nuclide	$T_{1/2}$	Pathways		
Zr 90m	830.0ms	Zr90(n,n')Zr90m	72.1%	??
		Zr91(n,2n)Zr90m	27.8%	??
Y 89m	16.0 s	Zr90(n,d)Y89m	98.3%	VAL
Zr 89m	4.1 m	Zr90(n,2n)Zr89m	100.0%	VAL
Y 94	19.1 m	Zr94(n,p)Y94	99.9%	VAL
Y 92	3.5 h	Zr92(n,p)Y92	99.8%	VAL
Y 90m	3.1 h	Zr90(n,p)Y90m	81.9%	VAL
		Zr91(n,d)Y90m	18.0%	VAL
Zr 89	3.2 d	Zr90(n,2n)Zr89	92.5%	VAL
		Zr90(n,2n)Zr89m(IT)Zr89	7.4%	VAL

FNS 7 Hrs Zr

Zr 90m	830.0ms	Zr90(n,n')Zr90m	73.1%	
		Zr91(n,2n)Zr90m	26.8%	
Y 89m	16.0 s	Zr90(n,d)Y89m	37.0%	
		Zr90(n,2n)Zr89(b+)Y89m	51.9%	
		Zr90(n,2n)Zr89m(IT)Zr89(b+)Y89m	11.0%	
Zr 89	3.2 d	Zr90(n,2n)Zr89	82.6%	
		Zr90(n,2n)Zr89m(IT)Zr89	17.6%	
Y 90	2.6 d	Zr90(n,p)Y90	67.8%	VAL
		Zr91(n,d)Y90	11.2%	VAL
		Zr90(n,p)Y90m(IT)Y90	17.4%	VAL

		Zr91(n,d)Y90m(IT)Y90	3.3%	??
Zr 95	64.0 d	Zr96(n,2n)Zr95	99.4%	VAL
Nb 95	34.9 d	Zr96(n,2n)Zr95(b-)Nb95	99.3%	VAL

5. ANALYSIS OF RESULTS

5.1 General comments

From such a validation exercise a lot of information can be extracted and conclusions drawn. However, its uniqueness and specificities require caution to be applied when drawing or projecting conclusions from the results. Table 1 has been designed with such an axiom in mind and reflects such an approach.

Table I Summary of FNS validation results

Material	Sample	1 min. to 1 hour cooling	1/2 day to 3 mths. cooling	Validation
Al	MF	Excellent	See comments	OK
B_4C	P	See comments	No exp.	Uncertain
$BaCO_3$	P	See comments	Excellent	Uncertain
Bi	P	Bad exp.	Bad exp.	Uncertain
CaO	P	See comments	See comments	TBA
CF_2	MF	Excellent	No exp.	OK
Co	MF	Excellent	Excellent	OK
Cr	P	Good	Good	TBA
Cu	MF	Excellent	Good	TBA
Fe	MF	Excellent	Excellent	OK
Inc	MF	Good	Excellent	TBA
K_2CO_3	P	Excellent	See comments	TBA
Mn	P	Good	Excellent	OK
Mo	MF	Excellent	Excellent	OK
Na_2CO_3	P	See comments	Good	TBA
Nb	MF	Good	Excellent	OK
Ni	MF	Good	Excellent	OK
NiCr	MF	Good	Excellent	OK
Pb	MF	See comments	Good	TBA
Re	P	Good	Excellent	OK
S	P	Good	Excellent	TBA
SiO_2	P	See comments	No exp.	Uncertain
SnO_2	P	See comments	Good	TBA
$SrCO_3$	P	See comments	Excellent	TBA
SS-304	MF	Excellent	Excellent	OK
SS-316	MF	Excellent	Excellent	OK
Ta	MF	See comments	Good	TBA
Ti	MF	Good	Excellent	OK
V	MF	Good	See comments	TBA
W	MF	See comments	See comments	Uncertain
Y_2O_3	P	See comments	Good	TBA
Zr	MF	Excellent	Excellent	OK
Excellent.: (C-E)/E values in the 0 to 10% range				
Good: (C-E)/E values in the 0 to 20% range				

MF = metallic foil sample   P = powder sample

The time dependence of the comparison has been clearly established and it was not surprising to see some fluctuations in the degree of agreement with time. This is due to the fact that the set of predominant radionuclides evolves with time in direct relation with their appropriate half-lives. A clear picture emerges in that the comparative results for short cooling times, less than one hour, tend to be worse than the results for cooling times greater than a day but shorter than 3 months. This was expected, since the nuclear data base (production cross-sections and decay data) tends to be less qualified for these nuclides. This is due to difficulties encountered when assessing short half-life isotopes. The overall results are surprisingly good, after making allowance for certain experimental difficulties. About 2/3 of the materials analysed have been flagged as excellent or good for the specified cooling times and irradiation conditions.

What has been clearly demonstrated by this validation exercise is that the calculational method (FISPACT code) used to predict the decay power of structural materials under a hard fusion neutron field is adequate. When the nuclear data are known with sufficient accuracy the code prediction are within the boundaries defined by the experimental uncertainty. The nuclear data bases (EAF-97 or FENDL-2.0) do tend to give different results because of differences in the data they contain for the cross-sections and decay of the radionuclides involved. The bulk of the results are satisfactory and gives credit to the work performed by the nuclear data community world-wide. However, the accuracy of the cross-sections and decay data tested by this validation exercise span from a few percent, that is acceptable, to orders of magnitude. When the latter case occurs then very specific and time consuming studies need to be performed before any action is taken to correct the nuclear data bases. Those remarks are in line with the results of an earlier international code comparison on decay heat performed on fission fuel material [7].

All the cross-section paths flagged TBA will be analysed in line with other validation studies, (FNG Frascati, SNEG-13 Dresden, D-Be Cyclotron Karlsruhe etc.) and compared with the experimental data base EXFOR. The decay data of the radionuclides produced needs to be checked in more detail, as well. If the results corroborate one another there will be more incentive and firm grounds to apply an appropriate correction.

5.2 Uncertainty and (C-E)/E

When concerned with uncertainties related to the activation calculations themselves, one has to acknowledge the complexity and magnitude of the necessary nuclear data libraries. The EAF-97 activation file [5] contains the neutron-induced reactions on stable and unstable targets including actinides. If a reaction can produce one or two isomers, the cross-sections for producing the ground and isomeric states are given separately. The file contains 766 target nuclides ranging from ^{1}H to ^{257}Fm with 12,469 reactions kinematically allowed below 20 MeV. A complementary and unique uncertainty file EAF_97_UN , in ENDF-6/MF33 format, has been generated for all reactions in a one-energy group structure for the threshold reactions and three-groups (10^{-5}<-->E_v<-->E_H<----->20MeV) for (n,γ) and (n,f) reactions. E_v represents the end of the 1/V region while E_H represents the end of the resolved resonance region. The error estimates for this file are adopted either from experimental information or from systematic fits of experimental data to simple equations.

For the first time experimental uncertainty, calculational uncertainty and (C-E)/E values have been systematically quoted and calculated in a way that allows their direct comparison to be made. The intuitive method for the generation of qualitative covariance information in EAF_97_UN is a significant achievement, since the calculational uncertainties quoted in the tables are of the same order of the (C-E)/E values. This demonstrates that the method chosen to calculate those uncertainties in the EASY code system is not only valid but nearly as precise as possible. Of course the same remarks as for the cross-section and decay data file apply: even if the bulk of the data seems to be satisfactory, certain specific data entries need to be revisited in line with the findings of this validation exercise and other studies.

5.2 Pertinence of the results to fusion next-step devices

In ITER, DEMO, or in a fusion power plant, the irradiation conditions will be very different from the ones encountered in this particular experimental assembly. These differences can have an impact on the conclusions that can be drawn from such a validation exercise and applied to these devices.

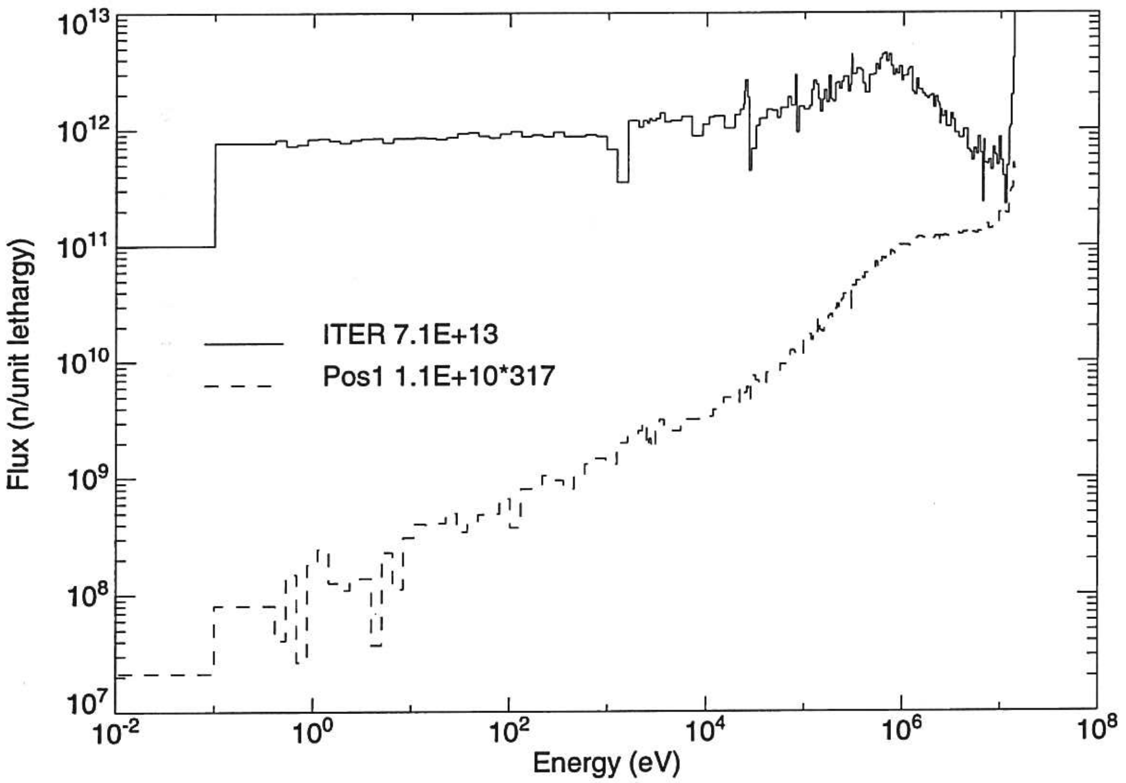


Figure 2 FNS and ITER neutron spectra, normalised to the same 14 MeV neutron flux

The profile of the neutron spectrum needs to be fully accounted for, in order for the validation test to be applied to all production channels and isotopes that will be produced in a tokamak fusion device [8]. Figure 2 shows the differences that occur in terms of spectral profiles between the FNS experiment (normalised to the ITER 14 MeV neutron flux) and an ITER divertor target plate [9]. There are vastly more scattered and thermalised neutrons in the ITER spectrum. The same remark would apply to DEMO or any other fusion tokamak device. This is mainly due to the lack of structure surrounding the experimental assembly. Regardless of the irradiation scenario and total flux encountered, such important differences have an impact on the reaction rate balance between low and high energy ranges.

As an examples of this effect, Table 2 describes such a balance for two important materials, Copper and SS-316, and three of their predominant radionuclides in terms of decay power. For the Cu-64 radionuclide the production pathways predicted by FISPACT change significantly due to such a spectral shift. The Cu-65(n,2n) channels that clearly dominate the FNS irradiation test, and for which the code predictions are in excellent agreement with the experimental measurement, only lead to the generation of 16% of the Cu-64 when an ITER spectrum is used. Nearly 84% of Cu-64 is produced through the Cu-63(n,γ) channel, that cannot be analysed nor validated in this experiment.

Table 2 FNS and ITER dominant pathways

Copper	Half-life	Pathways	FNS	ITER
Cu 64	12.7 h	Cu63(n,g)Cu64	0.8%	83.8%
		Cu65(n,2n)Cu64	99.2%	16.2%
SS-316				
Mn 56	2.5 h	Fe56(n,p)Mn56	99.3%	19.6%
		Fe57(n,d)Mn56	0.6%	<0.1%
		Mn55(n,g)Mn56	< 0.1%	80.4%
Mn 54	312.3 d	Mn55(n,2n)Mn54	49.3%	29.0%
		Fe54(n,p)Mn54	50.4%	71.0%

The same remarks apply to the Mn-56 production pathways, when SS-316 is irradiated under FNS or ITER spectral conditions. The Mn-54 production pathways, with two high threshold reaction channels, are even sensitive to the spectral differences at the high end of the energy scale: greater than a few MeV.

Under such circumstances and without detracting from the usefulness and necessity of such experimental measurements, the possibility of extrapolation of, for example, the uncertainties to fusion device predictions is very limited. As an example, the excellent agreement on the production of Cu-64 for the FNS experiment carries a meaning for only 16% of the Cu-64 production under ITER relevant conditions. The other production pathways remain unvalidated by this experimental set-up or other available experiments.

Such a validation exercise, although necessary and able to validate decay data and many high energy cross-sections, can only generate some very narrow overall parameters applicable to the decay power prediction of the next-step fusion devices. This is likely to remain the case, in the absence of a volumetric neutron source able to produce a fusion plant relevant neutron profile.

6 CONCLUSIONS

The experimental decay power measurement program at FNS, JAERI, combined with the code calculations performed in this study, provides a unique check of the calculational method and nuclear data bases associated with the prediction of decay power for the set of material samples analysed. The results of the comparison give confidence in most of the decay heat values calculated, although the predominantly 14 MeV neutron spectrum in FNS means that the low neutron energy reactions of importance in tokamak devices have not yet been adequately tested. This statement significantly limits the scope of possible extrapolation of the conclusions reached in this validation study to the decay power predicted by the same code system for the next generation of fusion devices.

For the first time, experimental uncertainty, calculational uncertainty and (C-E)/E values have been systematically produced. Their direct comparison demonstrates that the method chosen to calculate and propagate these uncertainties in the EASY-97 code system is valid and acceptable.

From the results, a set of inadequacies, not only in the cross-section but also in the decay libraries, has been revealed that will require some corrective actions to be taken. As expected, they impact both the production paths and/or decay data of some specific radionuclides without impairing the overall picture. A large proportion of the decay powers calculated in this validation exercise, is in good agreement (within 10-20%) with the experimental values for cooling times spanning from one minute up to three months.

Maintenance and testing of activation code systems and libraries is essential for fusion projects in order to present a sound and well validated safety assessment. Licensing authorities will require evidence of experimental validation. However, the relevance of the experimental irradiation conditions and set-up to those that are likely to exist in a tokamak device needs to be carefully considered in order for such an assessment and validation to be applicable to the data predicted for the next generation of fusion plants.

Acknowledgements

This work was funded jointly by the UK Department of Trade and Industry and Euratom. The author acknowledges the contributions of Dr Y Ikeda and F Maekawa, JAERI, in preparing the experimental set-up and data.

7. REFERENCES

1. F Maekawa, M Wada and Y Ikeda, Decay Heat Measurements, ITER Task Report T-339, JAERI report, 1998.

2. F Maekawa, private communication.

3. R A Forrest and J-Ch Sublet, EASY-97 a Multipurpose Activation and Transmutaion Code System, 17th IEE/NPSS SOFE, San Diego, October 6-9, 1997.

4. R A Forrest and J-Ch Sublet, FISPACT-97 - User manual, UKAEA Report, UKAEA FUS 358, 1997.

5. J-Ch Sublet, J Kopecky and R A Forrest, The European Activation File: EAF-97 - Cross-section library, UKAEA Report, FUS 351, 1997.

6. A B Pashchenko, H Wienke, J Kopecky, J-Ch Sublet and R A Forrest, FENDL/A-2.0: Neutron Activation Cross-section Data Library for Fusion Applications, IAEA report IAEA(NDS)-173, 1997.

7. B Duchemin and C Norborg, Decay Heat Calculation - an International Nuclear Code Comparison, NEACRP-319 L, NEANDC-275 U, 1988.

8. J-Ch Sublet and G J Butterworth, Fusion Activation of Ferrous Alloys - Dependence on Flux, Irradiation Time and Fluence, Fus. Eng. Des. 22(1993)279-321, 1992.

9. J-Ch Sublet, Three-Dimensional Heterogeneous Monte Carlo Neutronic and Activation Analysis for the ITER Divertor, UKAEA FUS 368, 1997.