Fission product after-heat in fast breeder reactors

by

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I. INTRODUCTION

Fission product decay power is required input for determining the shutdown cooling requirement of reactors as a function of time, providing an accurate source term for use in Loss-of-coolant Accident (LOCA) analysis and Emergency Core Cooling Systems (ECCS) safety analysis, and designing decay power removal systems optimally. Therefore, many studies have been performed to improve the accuracy of decay power prediction. On the experimental side, several measurements were performed to provide a data base for short time decay of U^{235} fission products[1-4] and for Pu^{239} [5-7]. At the same time, using the Evaluated Nuclear Data File IV (ENDF/B-IV) decay data file as a common basis, summation calculations, in which activities of fission products are computed as function of time after fission and the energy production rate is obtained by summing up the decay powers of these fission products as products of decay energy and activity, have been performed.

Based on the experimental data and the summation calculations, Schmittroth and Schenter[8] compiled and evaluated reliable decay power data which have been folded into the American Nuclear Society Standard of Committee ANS 5.1[9]. However, the summation calculations considerably underpredicted decay power at short times after fission (<100 seconds) and therefore were given very low weight at these times in arriving at the standard. Indeed, their uncertainties were evaluated to be quite large.

A new set of fission product yield and decay data, ENDF/B-V[10], is now available. Summation calculations with this set must therefore also be compared with high accuracy experiments on fission with thermal neutrons, to see whether the previous discrepancies have been resolved.

In a thermal reactor, only two major fissionable isotopes, U^{235} and Pu^{239}, are important. Fast fission effects of U^{238} on decay power are small. However, in a fast breeder reactor with plutonium-U^{238} fuel cycle where there is the highest breeding potential, not only is there significant fission in the fertile material U^{238} in both the core and the blanket, but with the plutonium there is a contribution from all the plutonium isotopes present, namely Pu^{239}, Pu^{240}, and Pu^{241}. The present paper is thus mostly concerned with estimating the shutdown decay powers of these nuclides irradiated by fast energy neutrons at constant fission rate and no neutron capture in fission products. The evaluation is performed by the summation method using the ENDF/B-V decay file. However, since summation calculations using the previous set (ENDF/B-IV) were a partial input to the ANS 5.1 standard, attention is also directed to examining discrepancies between predictions from ENDF/B-IV and ENDF/B-V data, especially for longer cooling times where ENDF/B-IV was a significant input to the standard. Therefore, comparisons of the summation calculations using the two data sets with respect to the ANS 5.1 standard are here performed and discussed. Also, using the ENDF/B-V library, a ratio method[11] is applied to the prediction of decay power. One particular aspect that provides incentive for the ratio method is

that, although the ENDF/B decay energies for high Q-value decays, which play an important role in the decay power of short cooling times, systematically have large uncertainties and seem too low, these uncertainties are strongly correlated between different types of fission and are largely canceled out in taking ratios between them. The ratio method is performed using the ROPEY1 computer program, converted from a CDC FORTRAN-EXTENDED version, ROPEY[12], to an IBM FORTRAN VS version, and the GOODY computer program written during this research. ROPEY1 has been extensively validated for summation calculations and has the feature that it calculates uncertainties in the result arising from uncertainties in the fission product yields and decay energies used in the summation calculations. However, its output is very voluminous and requires further processing, so GOODY was designed to produce several results simultaneously, including the comparison between the summation and the ratio methods, the results of ratio method, and the correlation coefficients between different types of fission.

Chapter II reviews the theory and properties related to decay power calculations. Chapters III and IV compare the decay powers which are obtained by the summation and the ratio method using both the ENDF/B-V and the ENDF/B-IV decay data.

In Chapter V, the weighted least-square method[13] is applied to the best estimated decay power data of the ANS 5.1 standard so that we can determine the best set of parameter values, A_i, of the model equation, with the same λ_i values, for thermal fission of U^{235} and Pu^{239} and fast

fission of U^{238}. These are to be used in the model equation, $H(t)=\sum_i A_i \exp(-\lambda_i t)$ ..... , etc. The parameters, A_i, and λ_i values for each fission type were well-evaluated for each fissioning nucleus in the ANS 5.1 standard. However, the decay power can be computed more conveniently by using a model equation having the same λ_i for U^{235}(thermal), Pu^{239}(thermal), and U^{238}(fast) fissions. We found a satisfactory common set of λ_i and corresponding A_i that vary for different fission types. The Statistical Analysis System (SAS) library is used to perform the weighted least square calculations that were required. Not only do these results provide a more compact data set for generating decay power predictions, but also they may make it possible to describe uncertainties and their correlation from one fission type to another by assigning appropriate uncertainties and correlations only to the A_i parameters.

II. BACKGROUND AND THEORY

A. Decay Power Measurement and Standard

In 1971, the American Nuclear Society (ANS) Standard Subcommittee 5 proposed the adoption of a standard entitled "Decay Energy Release Rate Following Shutdown for Uranium-Fueled Thermal Reactors" and minor revisions were made in October 1973. The proposed ANS standard was based on a single curve recommended by K. Shure[14] for long irradiation of uranium and for cooling time from 0 to 10^9 seconds. The single curve was taken to represent the decay power of uranium fueled thermal reactors and to have large uncertainties in order to include several kinds of operating situations. The Nuclear Regulatory Commission (NRC) has used the proposed ANS 5 standard in the regulatory process. This use is clearly stated in 10CFR part 50, Appendix K[15].

In 1974, new research programs were initiated and the ANS 5.1 working group was reestablished to quantify better the decay power and its uncertainties for short cooling times. The objectives of the ANS 5.1 working group were to create a revision and improvement of the ANS 5.1 standard for LOCA applications (cooling time up to 10^4 seconds) in LWRs and to extend the revised standard to address other thermal and fast reactor fuel cycles.

In 1978, the revised standard fission product decay powers and their uncertainties for thermal reactor neutron spectrum fission of U^{235} and Pu^{239} and for fast fission of U^{238} were adopted by the ANS standard

committee[9]. The standard values are represented at various times after shutdown following two limiting reactor operating periods, one for a fission pulse (H0 function) and one for a reactor operated at a constant fission rate for a long period of time (10^{13} seconds, H1 function) and then instantaneously shut down. The decay powers and uncertainties adopted for U^{235}(thermal) and Pu^{239}(thermal) are based on a statistical evaluation of new experimental data and summation calculations. The values for U^{238}(fast) are based solely on summation calculations because of the paucity of direct experimental data for the time range of interest. These standard representations do not account for neutron capture by fission products. Specifically, five experiments[1-4,16] provide a new data base for short time decay of U^{235} fission products. The decay power and its uncertainties for U^{235}(thermal) following a long irradiation are a concatenation of good experimental data and has a precision ranging from ±3.3 % at one second decay to better than ±2 % beyond 10 seconds of decay time. Therefore, this current version of the ANS 5.1 standard is considered to be the best estimate of decay power available. NRC is also concerned with the standard curve of the decay power and its uncertainties, since NRC uses a conservative curve approach for public protection regulation, and thus is at liberty to use the best estimate plus as many σ (one standard) values as they judge to be conservative.

This 1978 revision of the proposed ANS 5.1 standard has been used as the basis for comparison of the results of the summation calculations and the ratio technique in this study.

B. Summation Method

Since Way and Wigner's[17] theoretical treatment of decay power originally done in 1945, attention has been focused on theoretical calculations of decay power to augment and enhance experimental determinations. The summation method has been used to complete experimental measurements of decay power. Experiments can not be performed for every imaginable situation because of the great variety of operating histories of reactors. Therefore, summation calculations nave been used in order to make interpolations between experimental determinations, or to predict situations which are like, but not the same as, experimental situations. The summation method of calculating decay power has also been a major tool in reconciling individual nuclide data with experimental decay power measurements, and in providing detailed isotopic inventories important in radiation and shielding applications.

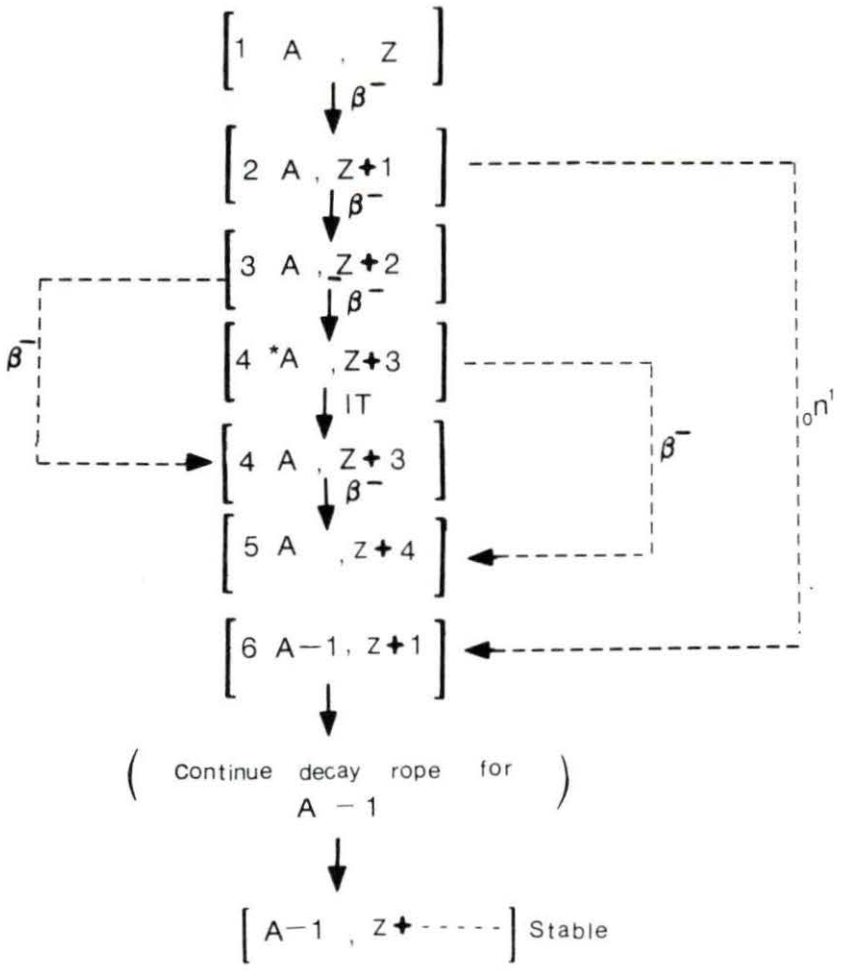
A fission product can result directly from fission, as a decay daughter of a fission product formed directly from fission, or both. In this study, three types of decays are considered. These are β^-, gamma, and delayed neutron emission. β^+ decay is not considered in the decay model because of the very small yield of β^+ decay. Also, the decays of shielded nuclides are not considered.

For the decays considered, there is a natural decay scheme which links a set of fission products together. A scheme starts with the nuclide having the lowest atomic number, of a particular mass, which has

an independent fission yield. This nuclide can only appear directly from fission and can be arbitrarily defined as the first nuclide in the scheme. Nuclides are added to the scheme until a stable nuclide is reached. Each of these nuclides potentially results from the decay of any parent nuclide or from a direct fission yield. The fractions of the decay to each daughter are determined by a branching ratio.

After the stable nuclide of one mass has been reached, the next nuclide in the scheme is the nuclide of the lowest atomic number (z) in the next lowest mass scheme to which one of the scheme members decays by neutron emission. Its daughters follow until a stable nuclide occurs. This process can continue for as many times as there are nuclides which decay by neutron emission. Figure 1 shows an example of this basic decay mechanism.

The decay of each fission product can thus be described by a first order differential equation which contains components accounting for both the production and depletion of the nuclide as a function of time. These equations are called the Bateman equations[18]. The decay power from a single fission product can be evaluated by multiplying the average energy per decay into the activity of that product. Summing over all the fission products gives total decay power. The concentration of each of the fission products as a function of time should be a solution of its Bateman equation, from which the activities are obtained by multiplying concentrations by decay constants. The following paragraphs define the equations which are of interest in decay power summation calculations.



Where

A ; mass number

Z ; atomic number

* ; excited state

IT ; Isomeric Transition

β^- ; β^- decay

$_0n^1$ delayed neutron

Figure 1. A Sample Decay Scheme

If a pulse irradiation of fission occurs in a reactor at time t=0, then the number of atoms of each fission product can be calculated as a function of time after the pulse irradiation. Let $N_{ij}(t)$ be the concentration of the ith fission product in the jth mass rope at time t after the pulse irradiation. The concentration of the fission products in each mass rope can be described by the equation:

$$dN_{ij}(t)/dt = \sum_{k=1}^{i-1} \lambda_{kj} B_{ijk} N_{kj}(t) - \lambda_{ij} N_{ij}(t) \qquad (2\text{-}1)$$

where

- t = time (seconds)
- λ_{ij} = the decay constant for fission product i, j
- B_{ijk} = the branching ratio from fission product i, j to fission product k, j

The initial conditions for this equation are

$$N_{ij}(t=0) = Y_j f_{ij} \qquad (2\text{-}2)$$

where

- Y_j : the cumulative rope yield of the jth mass rope. This is normalized such that the sum of all the cumulative yields is 2.
- f_{ij} : fractional independent yield of the ith fission product in the jth rope. This is normalized such that the sum

of the fractional independent yields in each rope is 1.

This set of equations can be solved for each rope either by performing a direct integration of each equation or by Laplace Transform of the system of equations. The solution is

$$N_{ij}(t) = Y_j \sum_{k=1}^{i} f_{kj} \sum_{\ell=k}^{i} A_{i\ell}^{j} \exp(-\lambda_{\ell j} t) \qquad (2\text{-}3)$$

where the coefficients $A_{i\ell}^{j}$ are defined by[19]

- $A_{11}^{\ell} = 1$
- $A_{mj}^{\ell} = \sum_{k=j}^{m-1} (\lambda_{k\ell} B_{mk\ell} A_{kj}^{\ell}) / (\lambda_{m\ell} - \lambda_{j\ell}), \quad m>1$
- $A_{mm}^{\ell} = -\sum_{j=1}^{m-1} A_{mj}^{\ell}, \quad m>1$
- $A_{nj}^{\ell} = 0, \quad j>n$ (2-4)

The reactor decay power, HO(t), per fission at time t after a fission is obtained by summing up the decay powers of the fission products as products of decay energy and activity and is given (in Mev/sec-fission) by

$$HO(t) = \sum_{j=1}^{N} \sum_{i=1}^{M_j} \lambda_{ij} N_{ij}(t) E_{ij} \qquad (2\text{-}5)$$

where

- N : number of mass ropes
- M_j : the number of nuclides in the jth rope
- E_{ij} : the average sensible decay energy for a disintegration of the ith nuclide in the jth rope.

Using the basic parameters, the decay power, H0(t), is

$$H0(t) = \sum_{j=1}^{N} Y_j \sum_{k=1}^{M_j} f_{kj} \sum_{\ell=k}^{M_j} C_{\ell j} \exp(-\lambda_{\ell j} t) \qquad (2\text{-}6)$$

where

$$C_{\ell j} = \sum_{i=\ell}^{M_j} \lambda_{ij} E_{ij} A^{j}_{i\ell} \qquad (2\text{-}7)$$

For a reactor which has operated from a long time ago, t=-T, to t=0 and then been shutdown for a time t>0, the shutdown decay power from a single fissionable material is (ignoring neutron capture effect[20])

$$H1(t,T) = \int_{T}^{0} R(\tau) H0(t-\tau) d\tau \qquad (2\text{-}8)$$

where

- H1(t,T) : the decay power at time t after shutdown following operation for a time T.
- $R(\tau)$: the fission rate at a time τ during reactor operation for a single fissionable nuclide.

Substituting Eq. (2-6) into (2-8), the shutdown decay power, H1(t,T), for $R(\tau)=1$ at all times during reactor operations becomes

$$H1(t,T)=\sum_{j=1}^{N} Y_j \sum_{k=1}^{M_j} f_{kj} G(\ell,j,t) \qquad (2\text{-}9)$$

where

$$G(\ell,j,t)=\sum_{\ell=k}^{M_j} C_{\ell j} \exp(-\lambda_{\ell j} t)(1-\exp(-\lambda_{\ell j} T)/\lambda_{\ell j} \qquad (2\text{-}10)$$

This is thus the decay power at time t after shutdown due to reactor operation at a constant fission rate for a time T.

It is also sometimes useful to define the energy which has been released from shutdown, t=0, until some time t after shutdown. For a constant fission rate, this energy is designed as the H2(t,T) and can be expressed as

$$H2(t,T)=\int_0^t H1(t,T)dt \qquad (2\text{-}11)$$

Substituting Eq. (2-9) into (2-11), the energy, H2(t,T), can be expressed as

$$H2(t,T)=\sum_{j=1}^{N} Y_j \sum_{k=1}^{M_j} f_{kj} D(\ell,j,t) \qquad (2\text{-}12)$$

where

$$D(\ell,j,t)=\sum_{\ell=k}^{M_j} C_{\ell j}(1-\exp(-\lambda_{\ell j}t))(1-\exp(-\lambda_{\ell j}T))/\lambda_{\ell j}^2 \qquad (2\text{-}13)$$

This energy has units of Mev shutdown energy per fission/second of operating power. Thus, the H2 function represents the amount of energy available to increase fuel temperature in a Loss of Coolant Accident (LOCA).

A number of computer programs comprising the summation model have been written. Programs in use include CINDER[21], RIBD[22], ORIGEN[23], FISP[24] and ROPEY. These programs are capable of solving the fission product equation under various external assumptions. For example, the later versions of CINDER can include effects of time variation of reactor power, depletion and formation of fissile nuclides, and capture by fission products in a multigroup spectrum. RIBD and ORIGEN have similar capabilities with somewhat less flexibility of problem specification. However, a chief objective of this study is to include data uncertainty propagation. The ROPEY summation code was therefore chosen in this study, since only ROPEY allows direct computation of uncertainty propagation.

C. Ratio Methods and Statistical Properties of Uncertainties

Schmittroth and Schenter[25] proposed that the main sources of uncertainty in decay power summation calculation come from the decay energy and fission product yield uncertainties. Specifically, decay energy uncertainties are the dominant source of error for total decay

power uncertainties for U^{235}(thermal), particularly shortly after reactor shutdown, as demonstrated by Spinrad et al.[26]. Also, this qualitative trend has been extensively studied and proved[19]. In addition to this, it was proven that uncertainties of decay power, arising from uncertainties of the half-lives and the branching ratio, are quite small[27] compared with estimates of the total decay power uncertainties.

The ratio technique developed by Trapp[11] is primarily due to the strong correlation between the well-known decay power from thermal neutron fission of U^{235} and that from fast or thermal spectrum neutron fission of the other fissioning species (U^{238}, Pu^{239}, Pu^{240}, Pu^{241}, U^{235}, etc.) in the summation calculation. Any uncertainties in decay energy, half-lives, or branching ratio of a fission product will produce uncertainties in the decay power computed for one fissioning species which are actually the same, and in the same direction, as from a similar computation for the well-defined decay power of thermal neutron fission of U^{235}. Uncertainty in the fission product yield is, however, not correlated from one type of fission to another. These results clearly imply that fission product decay energy uncertainties not only are strongly correlated between thermal fission of U^{235} and the other type of fissioning species but also contribute dominantly to the total decay power uncertainties.

The basic mechanism of the ratio technique is to predict ratios of decay power from fast or thermal spectrum neutron fission of some

fissioning nuclide to the well-defined decay power from thermal neutron fission of U^{235} and to multiply the thermal U^{235} decay power that has been well-evaluated in the ANS 5.1 standard (see section A) by this computed ratio. If $H^i(t,T)$ is the computed decay power t seconds after shutdown, following a constant fission rate irradiation of T seconds of nuclide i and $H^{25}(t,T)$ is the computed decay power of thermal neutron fission of U^{235}, then the ratio is given by

$$R(t,T) = H^i(t,T)/H^{25}(t,T) \qquad (2\text{-}14)$$

By combining this ratio with the well-evaluated thermal U^{235} decay power, $H^{25}_s(t,T)$, in the ANS 5.1 standard, an estimate of ith nuclide decay power is obtained by

$$H^i(t,T) = R(t,T)H^{25}_s(t,T) \qquad (2\text{-}15)$$

The next step is to evaluate the uncertainty of the ratio in order to obtain the uncertainty of the ith nuclide decay power. For any lognormal distribution function constrained to be positive, the expected value, μ, the variance, σ^2, and the standard deviation of the lognormal distribution, S, are related by[11]

$$S^2 = \ln(1+\sigma^2/\mu^2) \qquad (2\text{-}16)$$

The probability $P_i(R)$ that the ratio, R^i, will have a value R is given by

$$P_i(R)dR=(1/\sqrt{2\pi}S_R^2)\exp((-\ln^2(R/R_o))/2S_R^2)(dR/R) \quad , \quad R>0 \tag{2-17}$$

where R_o is the median and S_R^2 is the variance of the ratio in lognormal distribution. These parameters are given as

$$R_o = H_o^i/H_o^{25} \tag{2-18}$$

$$S_R^2=S_i^2 + S_{25}^2 -2\rho S_i S_{25} \tag{2-19}$$

where ρ is a correlation coefficient between ith nuclide and U^{235} uncertainties.

The correlation coefficient is defined by[28]

$$\rho = COV_e(H^{25},H^i)/\sqrt{VAR(H^{25})VAR(H^i)} \tag{2-20}$$

The covariance term accounts for correlation in decay energy uncertainties. This covariance can be evaluated by evaluating decay power from $H^i = \Sigma_j A_j^i E_j$ where A_j^i is the activities of the fission products, and is given by

$$COV_e = VARC + VARU \tag{2-21}$$

where

$$VARC=\sum_k \sum_j A^{25}_k A^i_j \sqrt{VAR_c(E_k)VAR_c(E_j)}$$

$$VARU=\sum_k \sum_j A^{25}_k A^i_j \sqrt{VAR_u(E_k)VAR_u(E_j)}\delta \qquad (2\text{-}22)$$

$$\delta = 1 \text{ (if } k=j) \text{ or } 0 \text{ (if } k=j)$$

and $VAR_c(E)$ and $VAR_u(E)$ are correlated and uncorrelated variances of decay energies respectively. The correlated variances are due to the nuclides for which decay energy data are predicted from theoretical models. It is possible for a theoretical model to give decay energy prediction which are biased away from the true value with a high degree of correlation. The effect of this possible bias on the decay energy data is estimated by postulating an additional correlated uncertainty for each nuclide of which decay energy data are predicted from theoretical models. The uncorrelated decay energy variances are, of course, derived in the nuclides for which decay energy data are predicted from experimental method as well as theoretical models. Thus, using Eq. (2-15), the variance of the ith nuclide decay power was well-derived[11] as follows

$$V(H^i)=R^2V(H^{25})+(H^2)^2V(R)+V(R)V(H^{25}) \qquad (2\text{-}23)$$

where V denotes variance.

In justifying the ratio technique, complete independence between the ratio R and the well-evaluated thermal U^{235} decay power should exist. Then, the uncertainty in $H^i(t,T)$ can be estimated from Eq. (2-23). If there is correlation between the factors, we cannot combine the two value to obtain the ith nuclide decay power by using Eq. (2-15) directly. Also, Eq. (2-23) does not contain correlation components. Fortunately, the summation calculations carry small weight in the averaging process for the standard. The standard decay power of U^{235} is virtually the same as the experimental data[29], particularily for short cooling time. Thus, the well-evaluated thermal U^{235} decay power in the ANS 5.1 standard is sensibly independent of the ratio R and the independence enables us to apply Eqs. (2-15) and (2-23) in order to estimate ith nuclide decay power.

In our endeavor where the purpose is confidence in a value of fission product decay power, uncertainties of the predicted decay powers arising from uncertainties in the nuclear data - yields, half-lives, decay energies, and branching ratio - are evaluated in the summation and ratio calculation. However, uncertainties of the predicted decay powers in the ratio method are evaluated on the basis of a somewhat different statistical interpretation from the summation calculation; uncertainties of the ratios of other fission type decay powers to that from thermal fission of U^{235} were evaluated by using the two decay powers and their uncertainties in the lognormal distribution, while the uncertainties in the basic data represent one standard deviation in a normal

distribution. In addition, uncertainties of the average β and γ decay energies in the ENDF/B-IV data file were evaluated in a statistical sense by using a beta distribution[30]. Thus, it is necessary to understand what the statistical properties of the ratio uncertainties and the β and γ decay energy uncertainties in ENDF/B-IV data file are.

In the ratio method, the nominal values (means and variances computed by ROPEY1) were used to represent the variance of one fissioning nuclide decay power in a lognormal distribution and the variance S^2 was given by Eq. (2-16). Now, we may relate the lognormal distribution to the Normal Convergence Theorem (Central Limit Theorem) by considering a variate X that is the result of a large number of independent influences each of which produces a small effect proportional to X. Each influence, then, produces an effect such that

$$\Delta X/X = k = \Delta(\ln X) \tag{2-24}$$

The distribution resulting from a large number of independent influences, each producing a small constant effect, is normal, that is, lnX is normally distributed and X is lognormal. Using this concept, we can understand the statistical properties of Eq. (2-16), Eq. (2-19), and Eq. (2-23). Namely, the logarithm of a random variable $(1+\sigma^2/\mu^2)$ of Eq. (2-16) is normally distributed, that is, S^2 is in the normal distribution. The ratio uncertainties, S_R, in Eq. (2-19) are thus in the normal distribution.

On the other hand, a beta distribution function was used in deriving density functions for average beta and gamma decay energies by Baker[30] because of large relative uncertainties of the data supplied. However, he found that the spectral data with large uncertainties have small yields, that is, the nonnormal spectral data contribute little to average decay energy and have correspondingly little effect on the derived density function. So, the derived density functions turned out to be in very nearly normal distribution.

Therefore, uncertainties of the predicted decay powers in the ratio or summation method are based on the normal distribution probability function.

III. COMPARISION OF ENDF/B-V WITH ENDF/B-IV DECAY DATA

A. Introduction

There are several nuclear decay data libraries that can be used for decay power summation calculations. These include ENDF/B-IV, Japanese data as published by Yashida and Nakasima[31], French[32], and England[33]. However, a new set of fission product yield and decay data, ENDF/B-V, has been recently released. Since the successive ENDF/B set are to some extent the standard U.S data, it is important to see whether this new data set is reliable for practical application to decay power calculation. In order to obtain a feeling for this, we compared decay power summation calculations based on this new decay data set with the results obtained using the previous, ENDF/B-IV decay data. Since the most reliable data on fission product decay power have been incorporated into the evaluation that led to the ANS 5.1 standard, and the data considered included summation calculations using the previous (ENDF/B-IV), comparisons with the ENDF/B-IV results are appropriate. These new decay data set contains the complete set of basic data (yields, decay energies and their uncertainties) needed in the summation calculations. These are for more than 800 fission product nuclides.

B. Comparison of Decay Power Predictions

All decay power results for comparison were obtained with the ROPEY1 program which calculates the H0 (decay power from fission burst)

and H1 (decay power at time t after shutdown due to the long irradiation time T) function with its uncertainties. In order to simplify the decay rope and the calculations, ROPEY1 ignores the effect of neutron capture in fission products on decay power. It has been shown[20,26,34,35] that the neutron capture effect changes the results of decay power by only a few percent for cooling time less than 10^5 seconds.

The ENDF/B-V decay data was received on tape from the Hanford Engineering Development Laboratory (HEDL), interpreted, and the data format was changed to the ROPEY1 data library format. Appendix XI describes the detailed procedure for moving the ENDF/B-V decay data to the ROPEY1 data library. ENDF/B-IV data had been already included in the ROPEY1 data library as part of the ROPEY1 package available to us.

The decay power H0(t) functions for fission by fast neutrons on U^{238}, Pu^{239}, and U^{235} were calculated using ENDF/B-IV data sets, and are shown in Figures 2 through 4. The value tH0(t) is plotted rather than H0(t), because of its convenient interpretation. The decay power H1(t,T) is just the area under the curve H0(t) between the times t and (t+T). Because of the relation d(ln(t))=dt/t, the distortion of the area under H0(t) caused by use of semilog paper is removed by graphing the quantity tH0(t) rather than H0(t). At short cooling times <100 seconds, large uncertainties are apparent. The uncertainty band decreases as the cooling times increase. In addition, the decay power H1(t,T) functions are shown in Figures 5, 6, 7 and 8 for fast fission of Pu^{239}, Pu^{240}, Pu^{241}, and U^{235}. As before, the large uncertainties occurred at short cooling times.

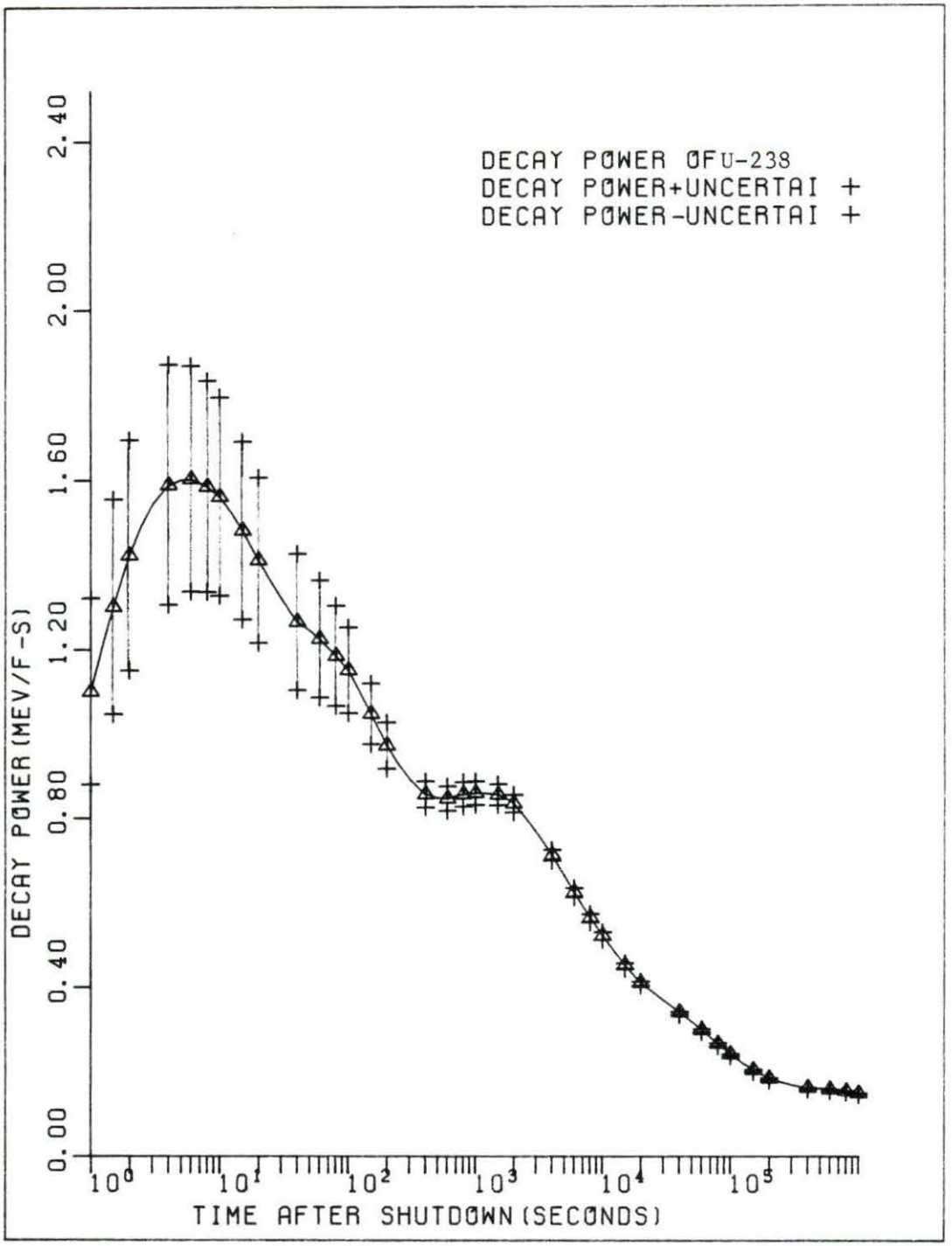


Figure 2. The Decay Power After a U^{238} Fast Fission Burst, H0(t) Function

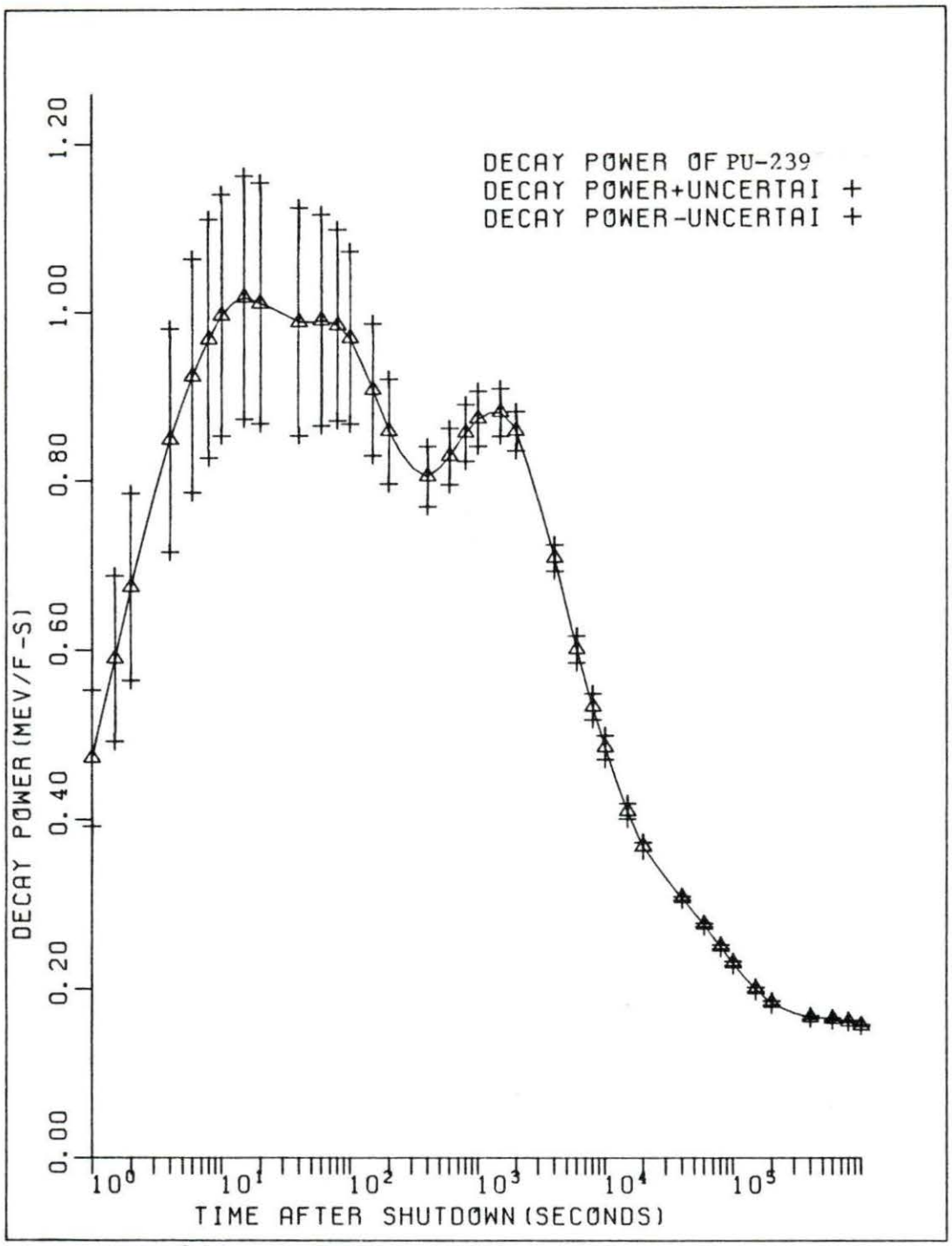


Figure 3. The Decay Power After a Pu^{239} Fast Fission Burst, HO(t) Function

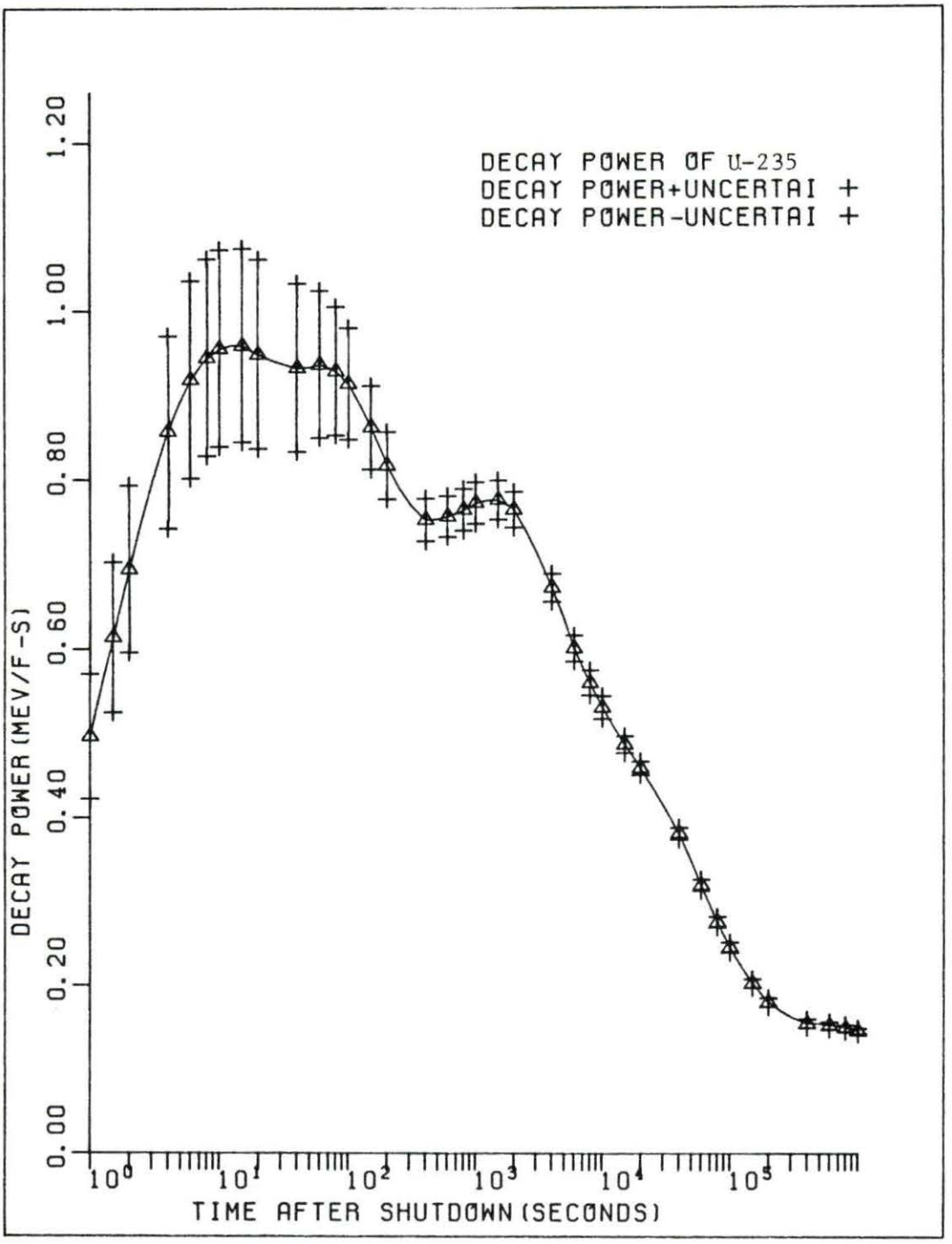


Figure 4. The Decay Power After a U^{235} Fast Fission Burst, H0(t) Function

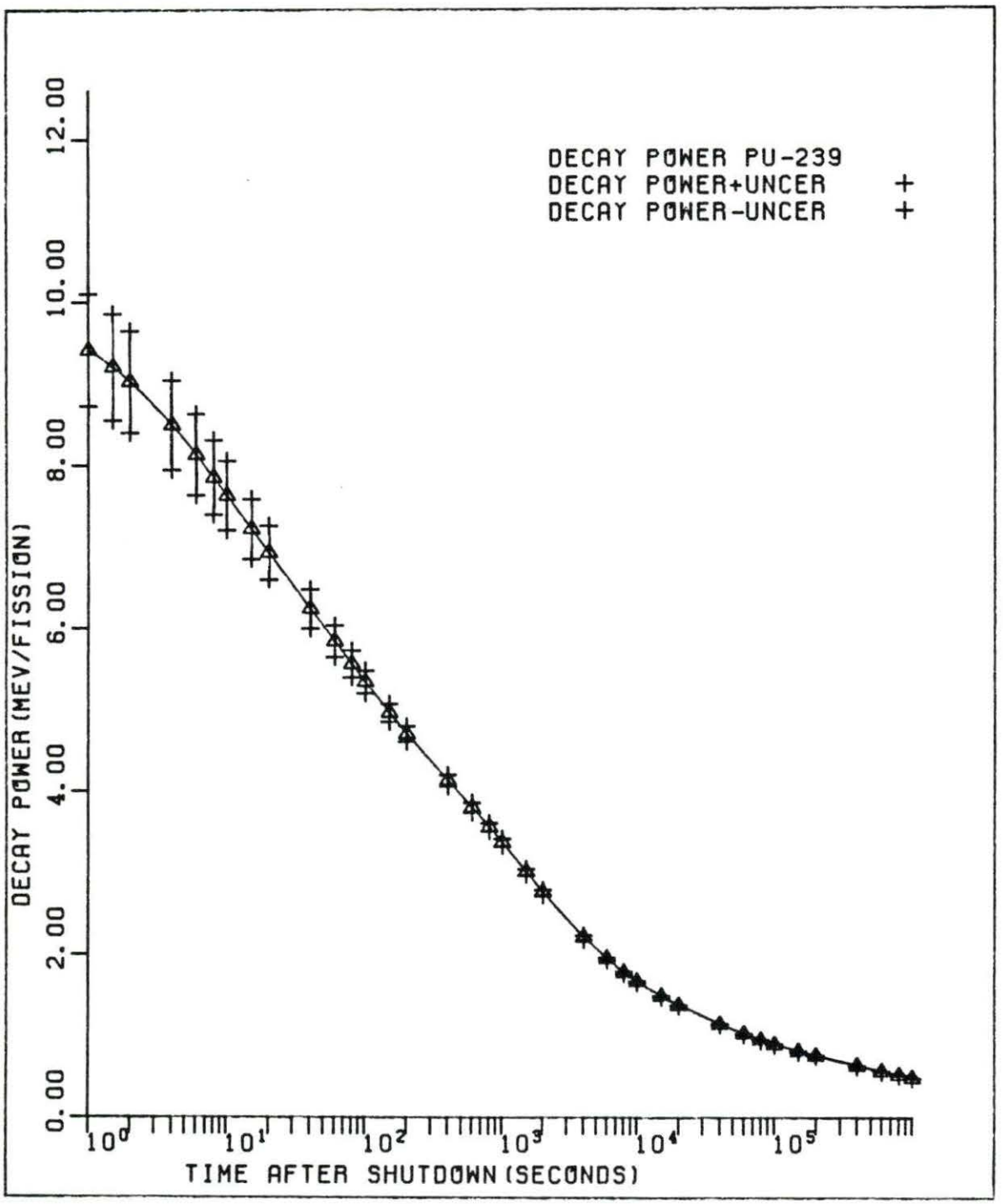


Figure 5. The Decay Power from Pu^{239} Fast Fission After Long Irradiation (10^{13} seconds) at a Constant Fission Rate, H1(t,T) Function

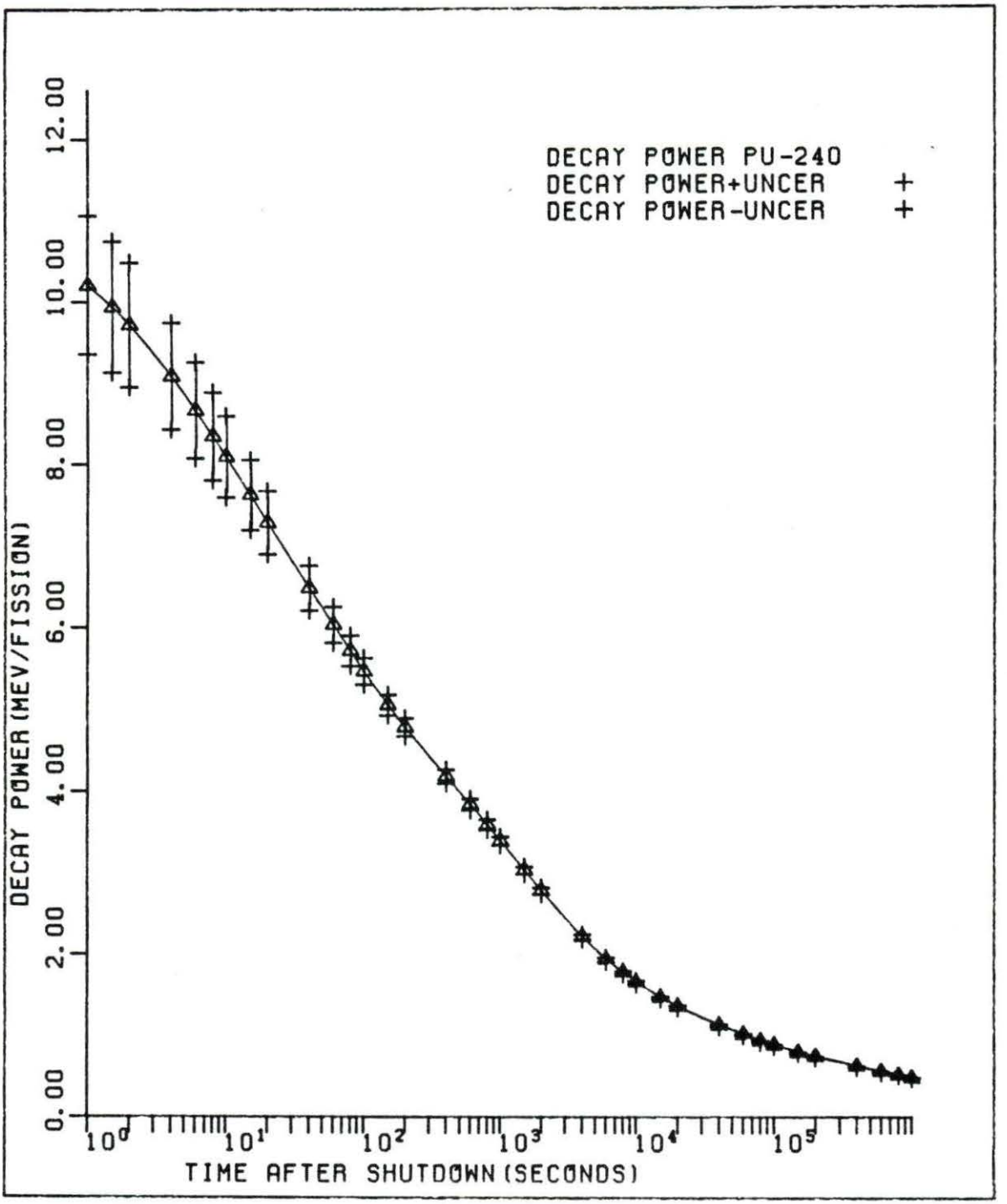


Figure 6. The Decay Power from Pu^{240} Fast Fission After Long Irradiation (10^{13} seconds) at a Constant Fission Rate, H1(t,T) Function

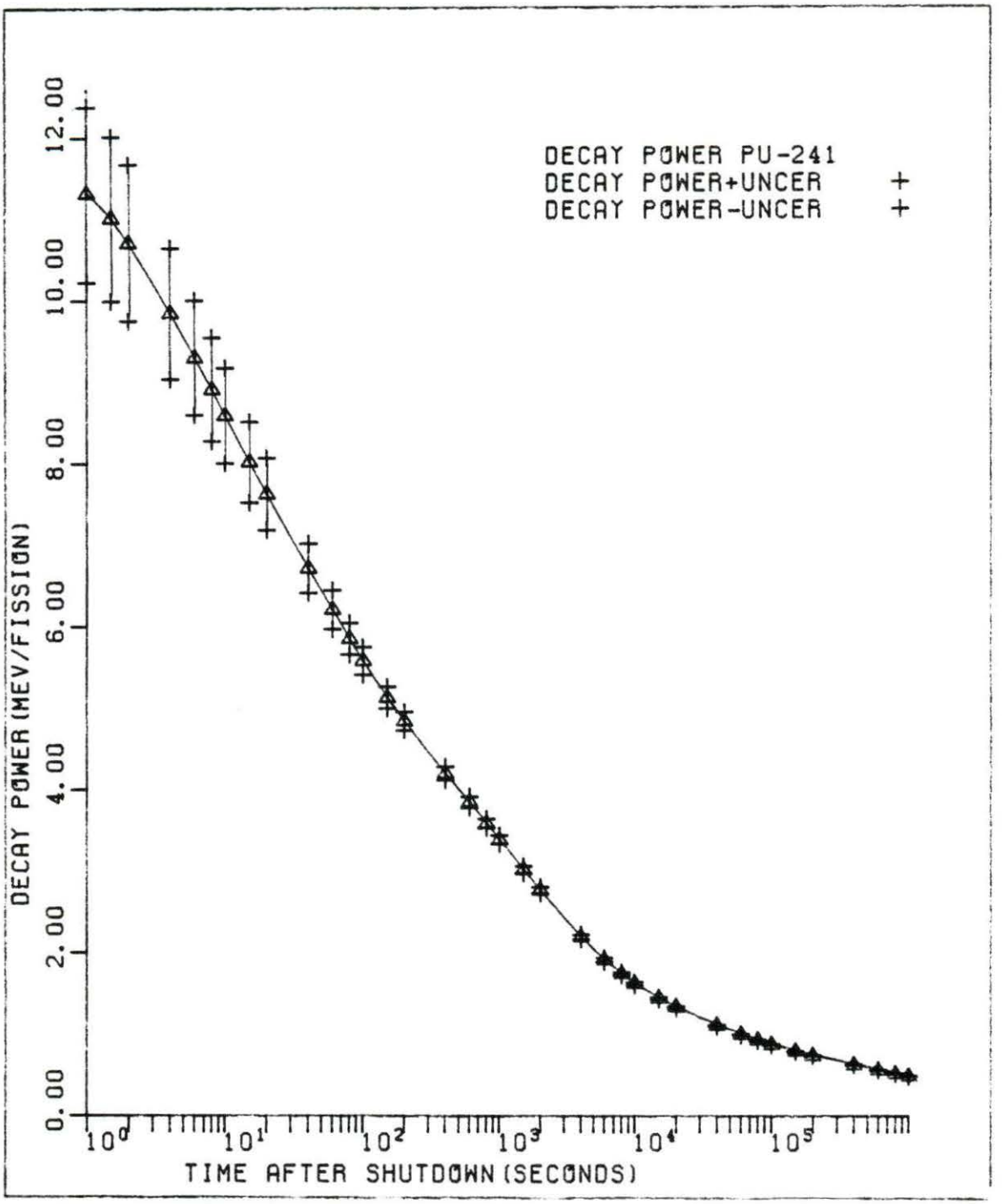


Figure 7. The Decay Power from Pu^{241} Fast Fission After Long Irradiation (10^{13} seconds) at a Constant Fission Rate, H1(t,T) Function

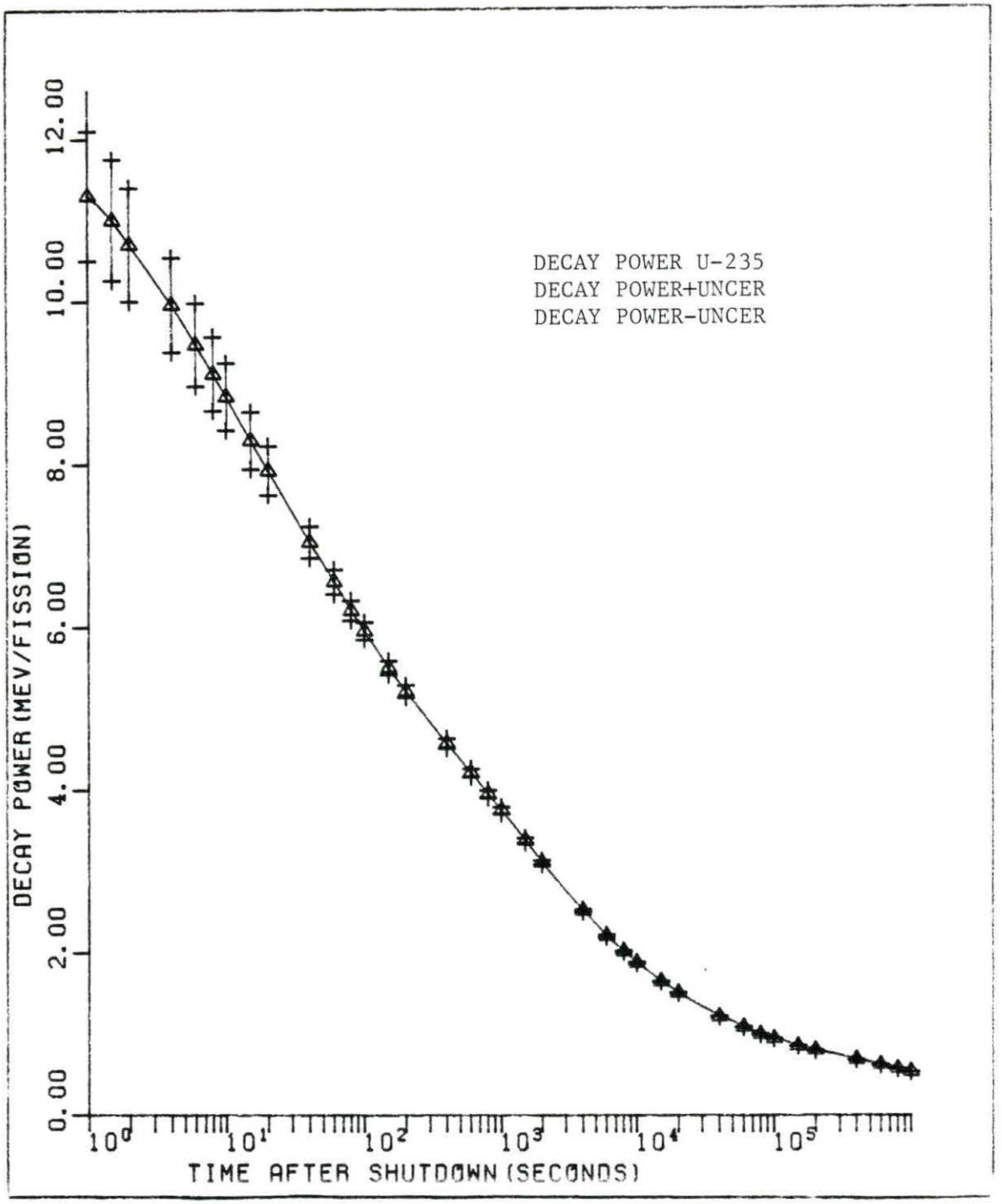


Figure 8. The Decay Power from U^{235} Fast Fission After Long Irradiation (10^{13} seconds) at a Constant Fission Rate, H1(t,T) Function

As a first comparison, the summation calculation results, based on both ENDF/B-V and ENDF/B-IV data libraries, after a long irradiation by thermal neutrons on U^{235}, are shown in Figure 9. The curve labeled "Direct" represents the ratio of ENDF/B-V to ENDF/B-IV direct summation calculation. At short cooling times <200 seconds, as can be seen from the graph, the new data yields results reduced by < 3 % from the previous one. This reduction increases to a maximum value of about 3.9 % (at 8 seconds after shutdown). As the cooling time increases, the differences between the curves become insignificant. Of more interest is the comparison of the decay power following a long irradiation of fast fission of U^{238}, which is an important isotope in Fast Breeder Reactor decay power. The discrepancy between calculations using the two data sets is shown in Figure 10 and is listed in Table 1. The new ENDF/B-V data give much lower values than the previous set (ENDF/B-IV) for short cooling times <200 seconds. The reduction increases to a maximum value of about 6.9 % at around 10 seconds after reactor shutdown, after which the two curves approach each other quickly. We can also see this trend in other data. Figures 11, 12, and 13 clearly show this trend for Pu^{239}(thermal), Pu^{241}(thermal), and U^{235}(fast) respectively.

In addition, decay power summation calculations for U^{235}(thermal), Pu^{239}(thermal), and U^{238}(fast) obtained from the two decay data sets were compared with respect to the ANS 5.1 standard values. This is shown in Figures 14, 15, and 16. The graph displays

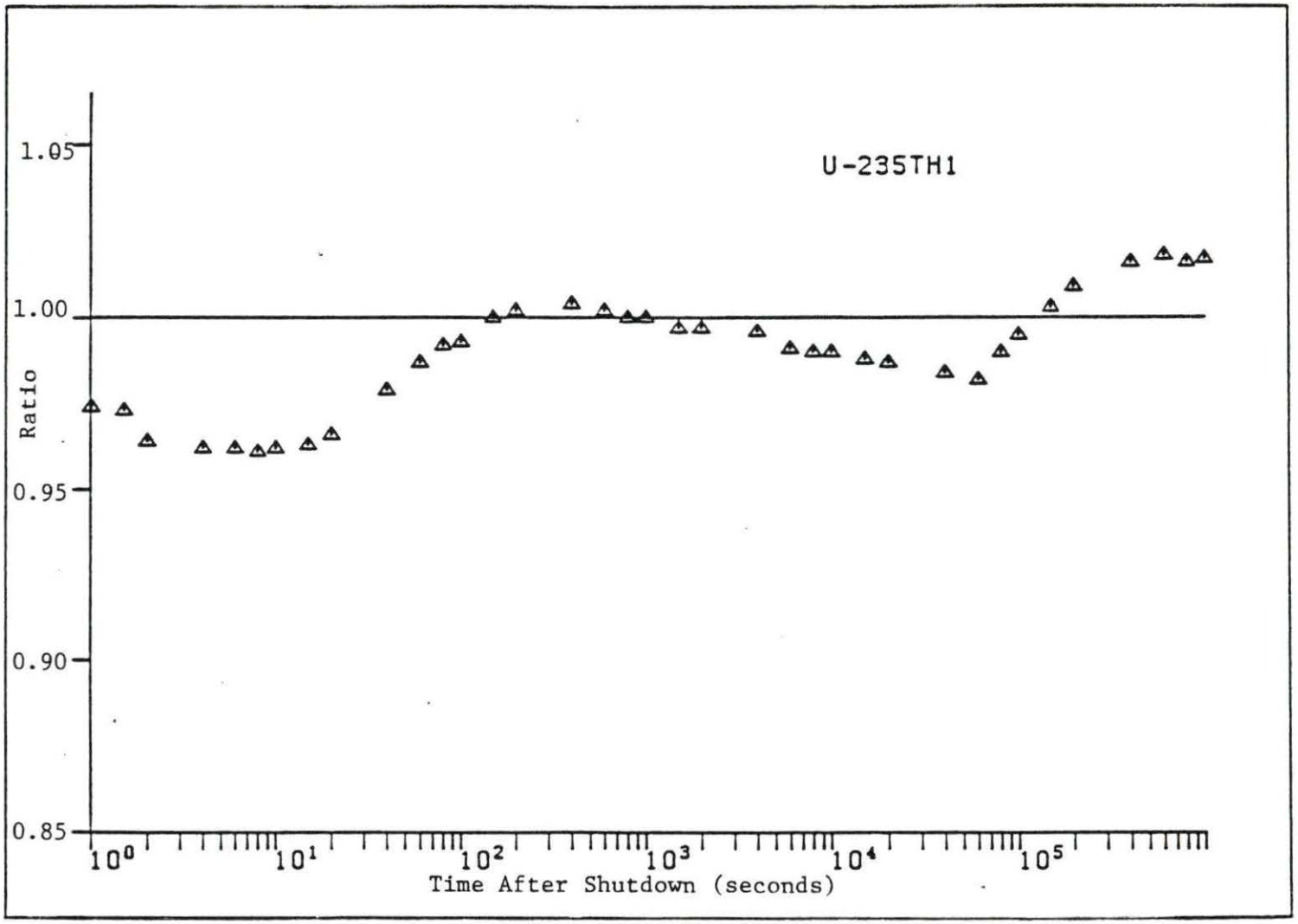


Figure 9. Ratio of Predictions, ENDF/B-V:ENDF/B-IV, U^{235}(thermal)
Long Irradiation, Direct Summation Method

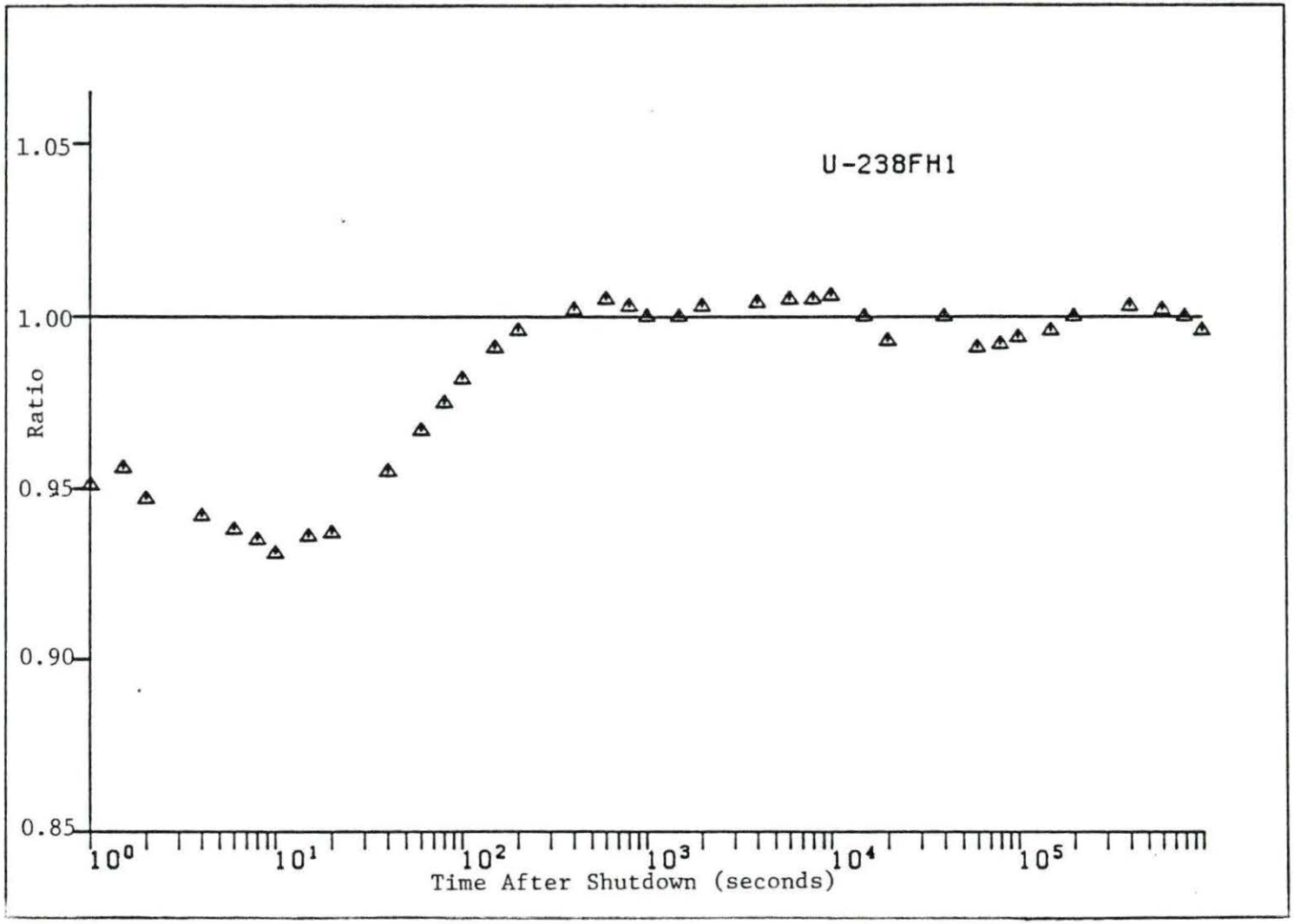


Figure 10. Ratio of Predictions, ENDF/B-V:ENDF/B-IV, U^{238}(fast)
Long Irradiation, Direct Summation Method

Table 1. Ratio of Decay Powers After Long Irradiation, ENDF/B-V:ENDF/B-IV Input, Direct Summation Method

Decay Time (second)	Ratio (U-235T)	Ratio (U-235F)	Ratio (PU-241T)
1.00	0.974	0.974	0.974
1.50	0.973	0.973	0.973
2.00	0.964	0.973	0.964
4.00	0.962	0.967	0.962
6.00	0.962	0.960	0.962
8.00	0.961	0.960	0.961
10.00	0.962	0.961	0.962
15.00	0.963	0.962	0.963
20.00	0.966	0.966	0.966
40.00	0.979	0.978	0.979
60.00	0.987	0.986	0.987
80.00	0.992	0.990	0.992
100.00	0.993	0.995	0.993
150.00	1.000	0.998	1.000
200.00	1.002	1.002	1.002
400.00	1.004	1.004	1.004
600.00	1.002	1.005	1.002
800.00	1.000	1.003	1.000
1000.00	1.000	1.003	1.000
1500.00	0.997	1.003	0.997
2000.00	0.997	1.003	0.997
4000.00	0.996	1.004	0.996
6000.00	0.991	1.000	0.991
8000.00	0.990	1.000	0.990
10000.00	0.990	1.000	0.990
15000.00	0.988	0.994	0.988
20000.00	0.987	0.993	0.987
40000.00	0.984	0.992	0.984
60000.00	0.982	1.000	0.982
80000.00	0.990	0.990	0.990
100000.00	0.995	0.998	0.995
150000.00	1.003	1.005	1.003
200000.00	1.009	1.009	1.009
400000.00	1.016	1.015	1.016
600000.00	1.018	1.016	1.018
800000.00	1.016	1.016	1.016
1000000.00	1.017	1.015	1.017

Decay Time (second)	Ratio (U-238F)	Ratio (PU-239T)
1.00	0.951	0.981
1.50	0.956	0.980
2.00	0.947	0.977
4.00	0.942	0.972
6.00	0.938	0.969
8.00	0.935	0.968
10.00	0.931	0.968
15.00	0.936	0.969
20.00	0.937	0.972
40.00	0.955	0.983
60.00	0.967	0.990
80.00	0.975	0.995
100.00	0.982	1.000
150.00	0.991	1.006
200.00	0.996	1.011
400.00	1.002	1.012
600.00	1.005	1.011
800.00	1.003	1.011
1000.00	1.000	1.006
1500.00	1.000	1.007
2000.00	1.003	1.004
4000.00	1.004	1.004
6000.00	1.005	1.000
8000.00	1.005	1.000
10000.00	1.006	1.000
15000.00	1.000	0.993
20000.00	0.993	0.993
40000.00	1.000	0.992
60000.00	0.991	0.991
80000.00	0.992	0.990
100000.00	0.994	0.991
150000.00	0.996	0.996
200000.00	1.000	0.999
400000.00	1.003	1.003
600000.00	1.002	1.003
800000.00	1.000	1.002
1000000.00	0.996	1.000

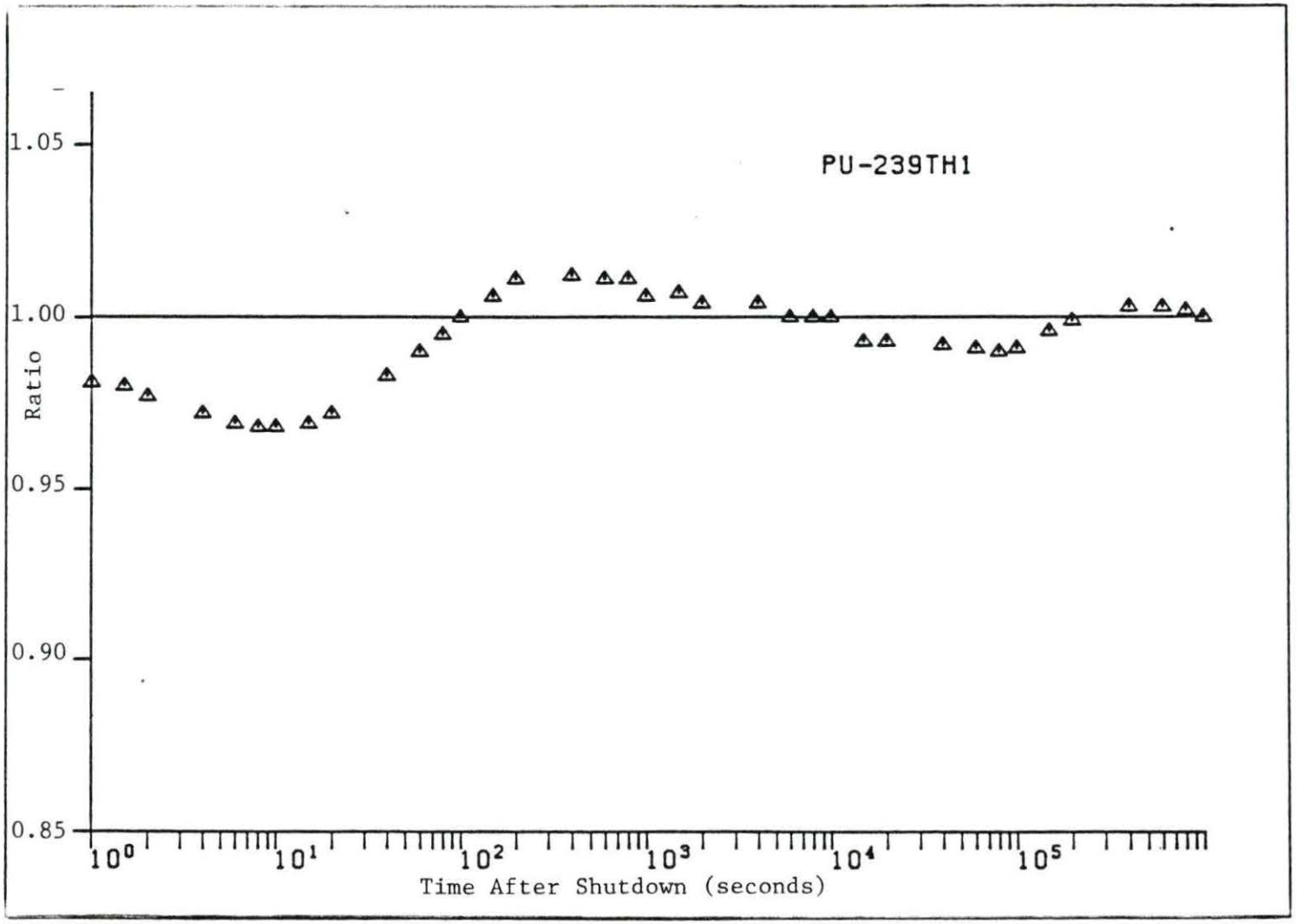


Figure 11. Ratio of Predictions, ENDF/B-V:ENDF/B-IV, Pu^{239}(thermal)
Long Irradiation, Direct Summation Method

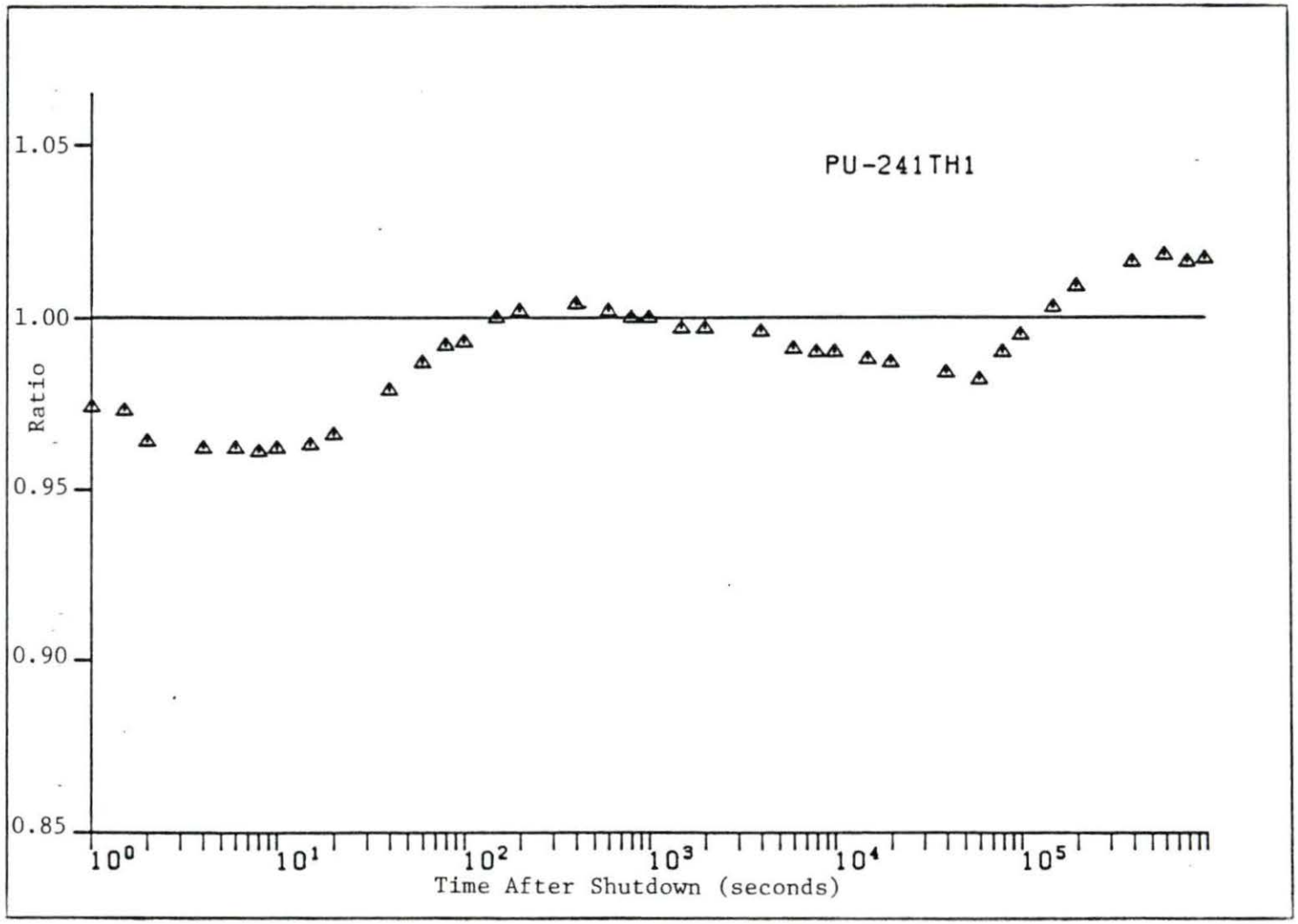


Figure 12. Ratio of Predictions, ENDF/B-V:ENDF/B-IV, Pu^{241} (thermal)
Long Irradiation, Direct Summation Method

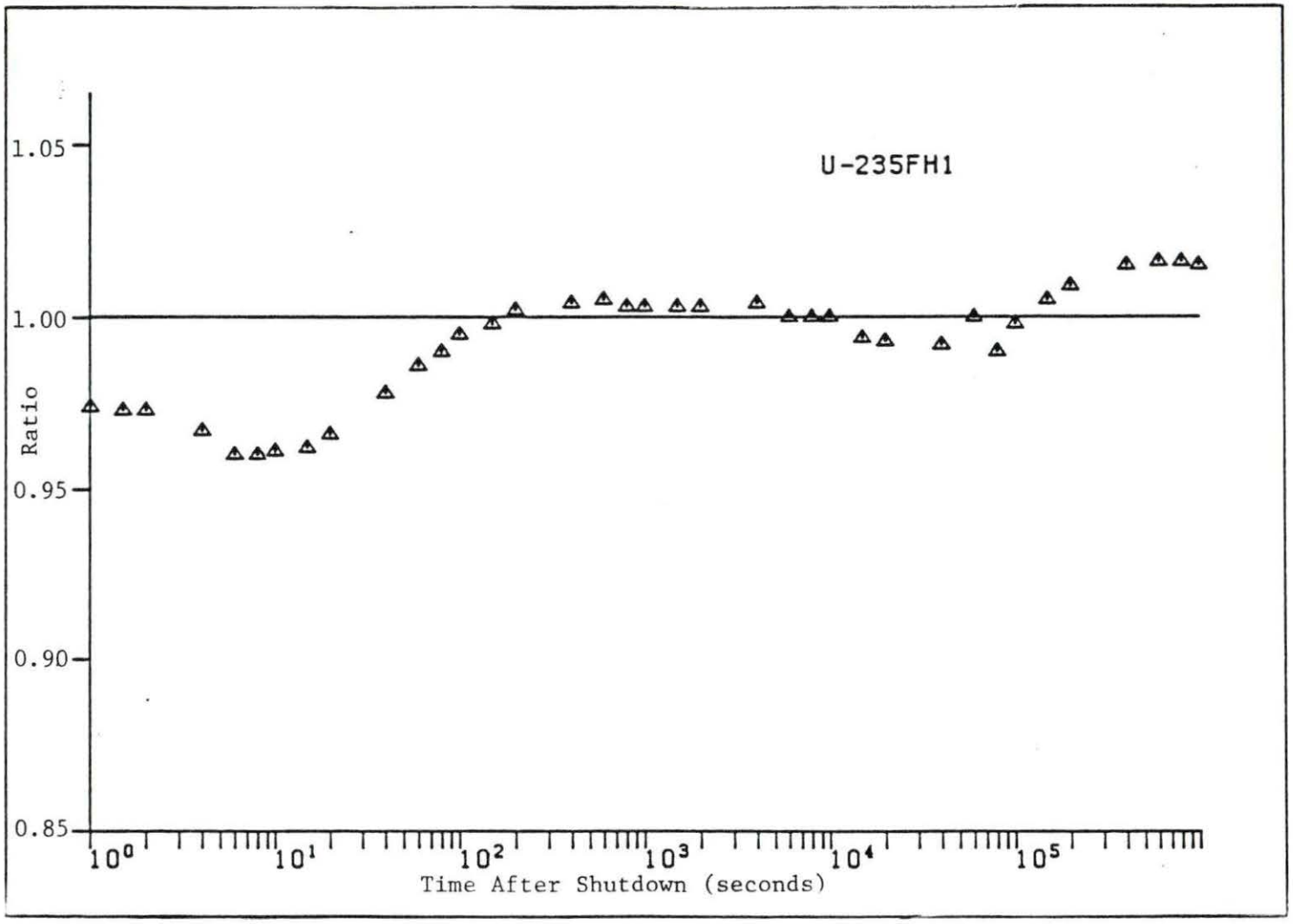


Figure 13. Ratio of Predictions, ENDF/B-V:ENDF/B-IV, U^{235}(fast)
Long Irradiation, Direct Summation Method

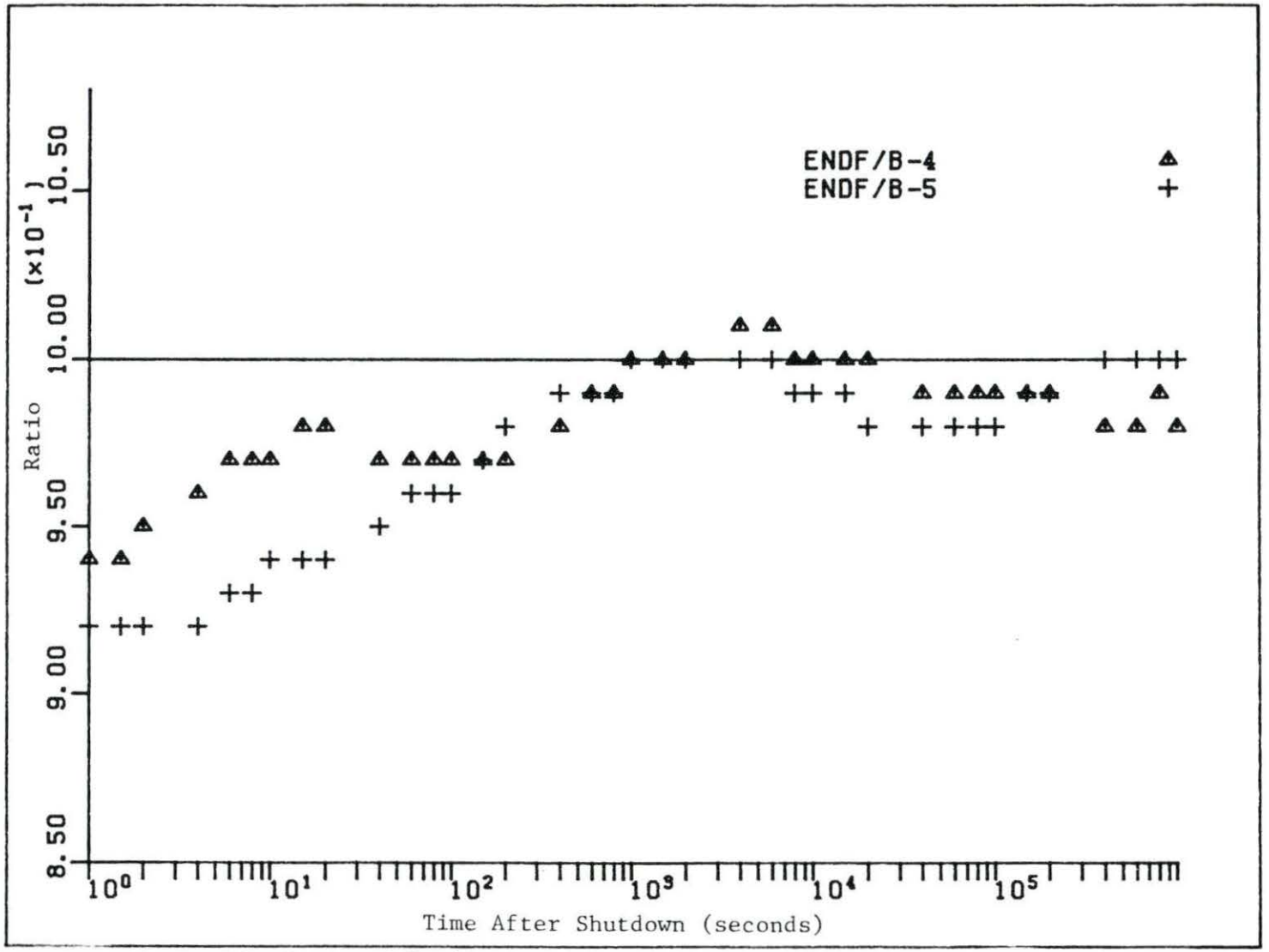


Figure 14. Ratio of Predictions, ENDF/B-V and ENDF/B-IV:ANS 5.1 Standard U^{235}(thermal), Long Irradiation Summation Method

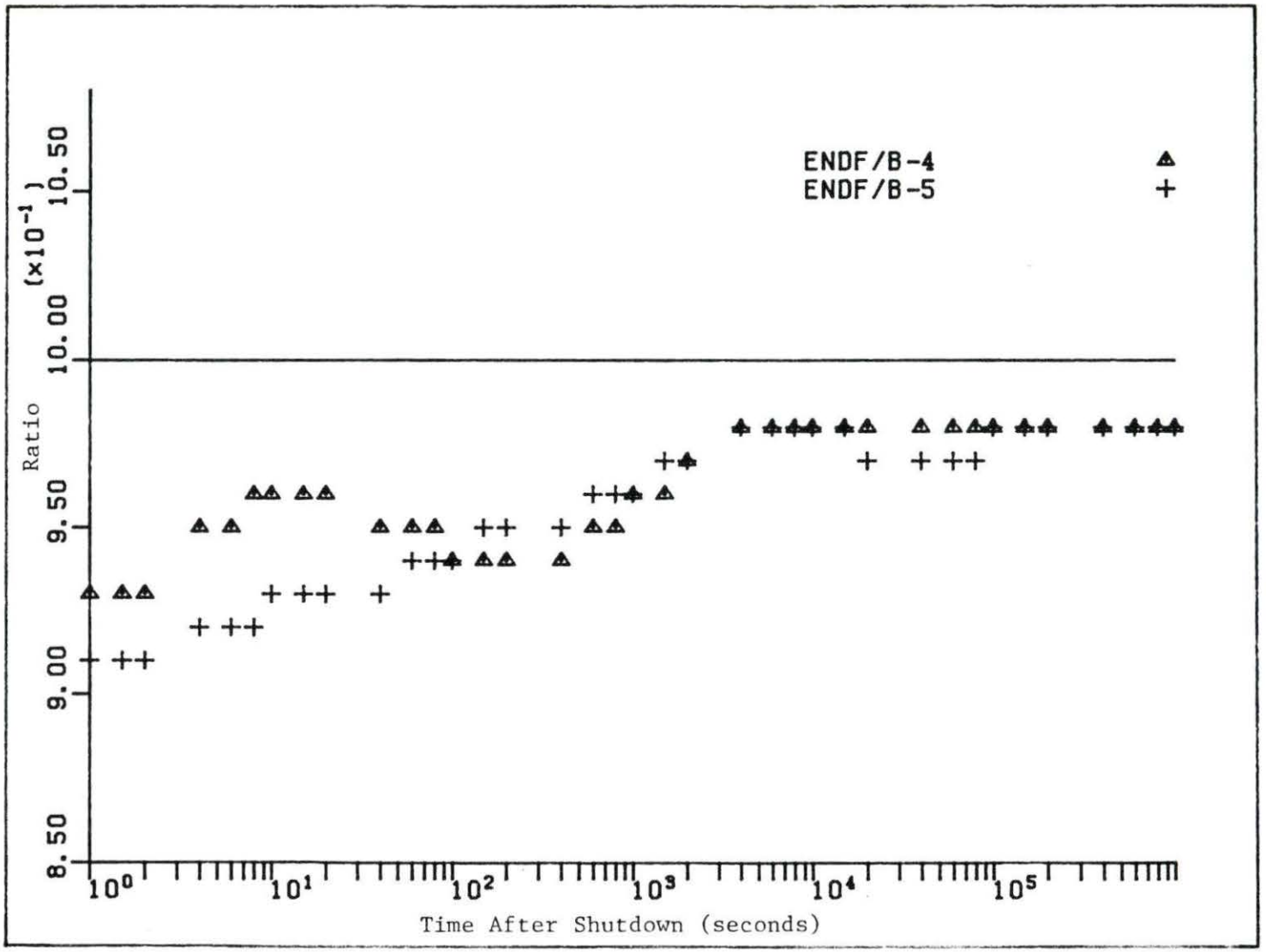


Figure 15. Ratio of Predictions, ENDF/B-V and ENDF/B-IV:ANS 5.1 Standard Pu^{239}(thermal), Long Irradiation, Summation Method

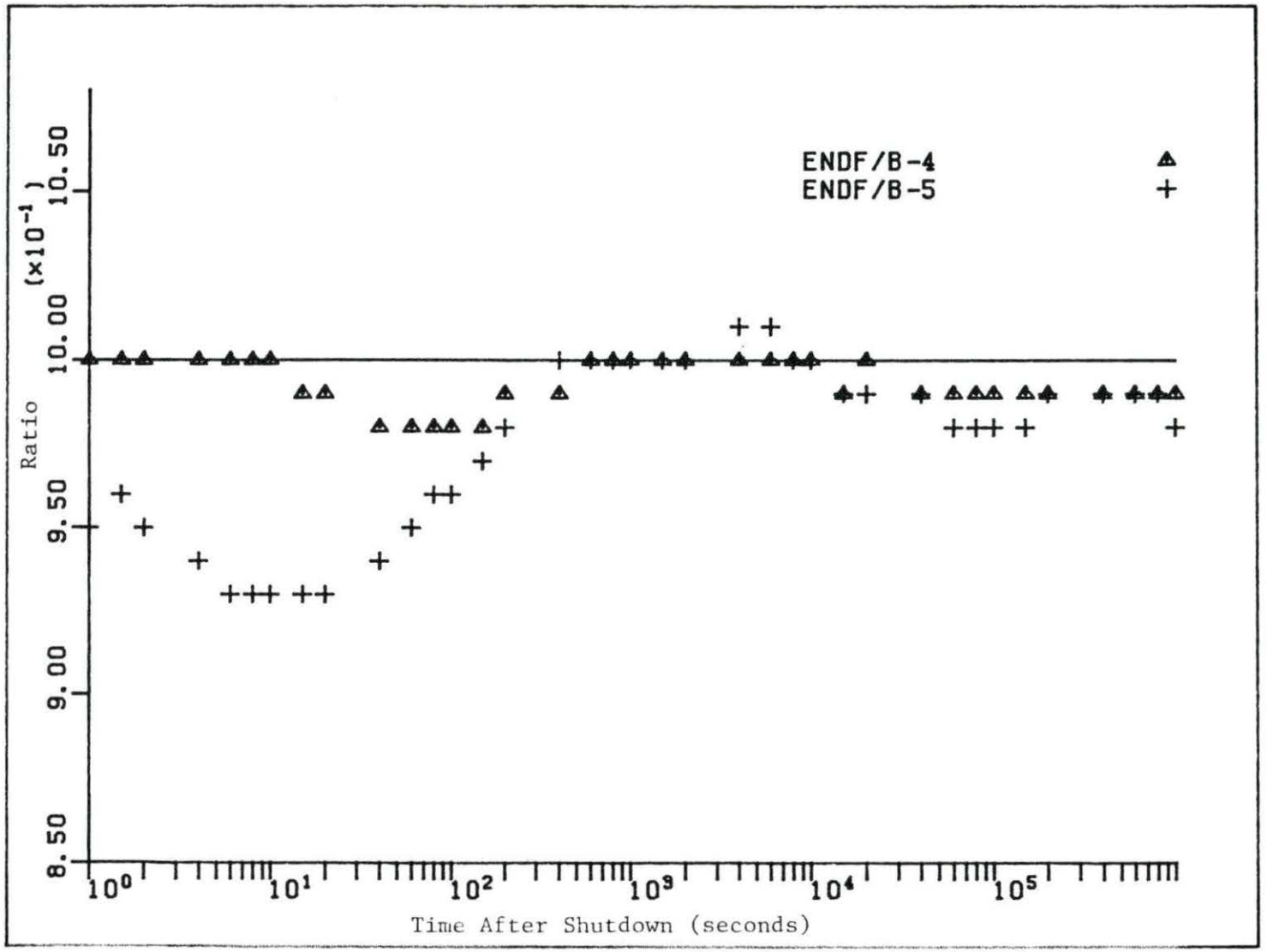


Figure 16. Ratio of Predictions, ENDF/B-V and ENDF/B-IV:ANS 5.1 Standard U^{238}(fast), Long Irradiation, Summation Method

the ratio of ENDF/B-V and ENDF/B-IV to the ANS 5.1 standard respectively and indicates that both data sets predict much lower decay powers, for short cooling times <200 seconds, than the ANS 5.1 standard values for the three nuclides. Moreover, the new data, ENDF/B-V, underpredicts decay power for short cooling times <200 seconds even more than the previous one, ENDF/B-IV. These results show that there is considerable discrepancy between the direct summation calculation results and the ANS 5.1 standard for short cooling times. This trend is also seen more transparently in the comparison of H0 functions for the two ENDF data sets. Figures 17, 18, and 19 show this trend very well by plotting H0 functions.

In decay power summation calculations, about one-third of the computed decay power immediately following a reactor scram arises from short-lived fission products. Although the fractional contribution of these fission products decreases rapidly with increasing cooling time, they still contribute nearly 10 % at 100 seconds cooling time. However, such a short time is very important to reactor Loss of Coolant Accident (LOCA). Thus, the underpredictions in the direct decay power summation calculation based on the new set of ENDF/B-V decay data, especially for short cooling times, are disappointing. The change to ENDF/B-V makes matters worse, rather than better. The problem seems to lie with the relatively poor state of knowledge of decay characteristics of fission products with short half-lives. Apparently, the ENDF decay schemes systematically overpredict beta decays that lead to low-lying energy state of daughter nuclides and correspondingly underestimate

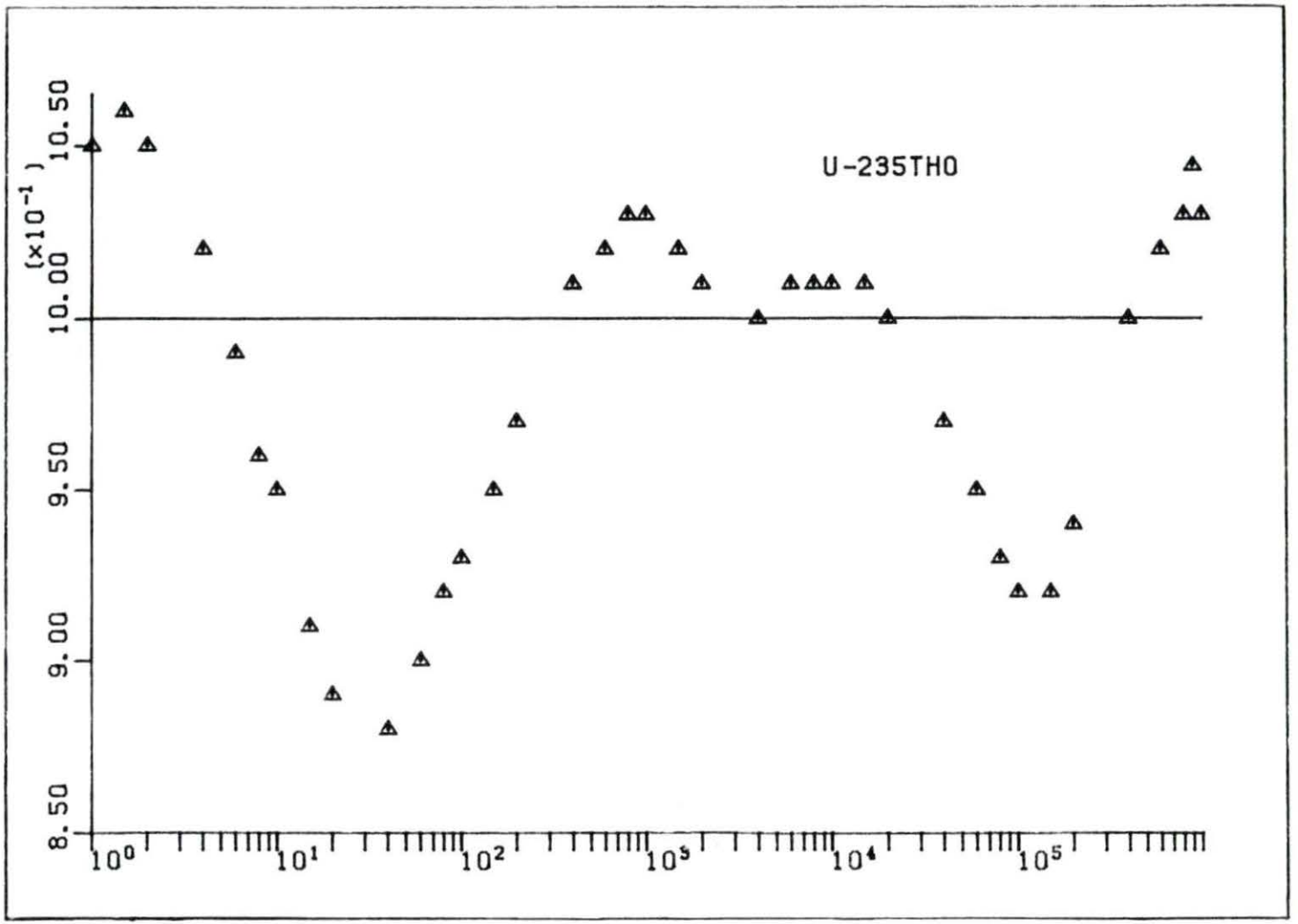


Figure 17. Ratio of Predictions, ENDF/B-V:ENDF/B-IV, U^{235}(thermal) Fission Burst, H0(t) Function, Summation Method

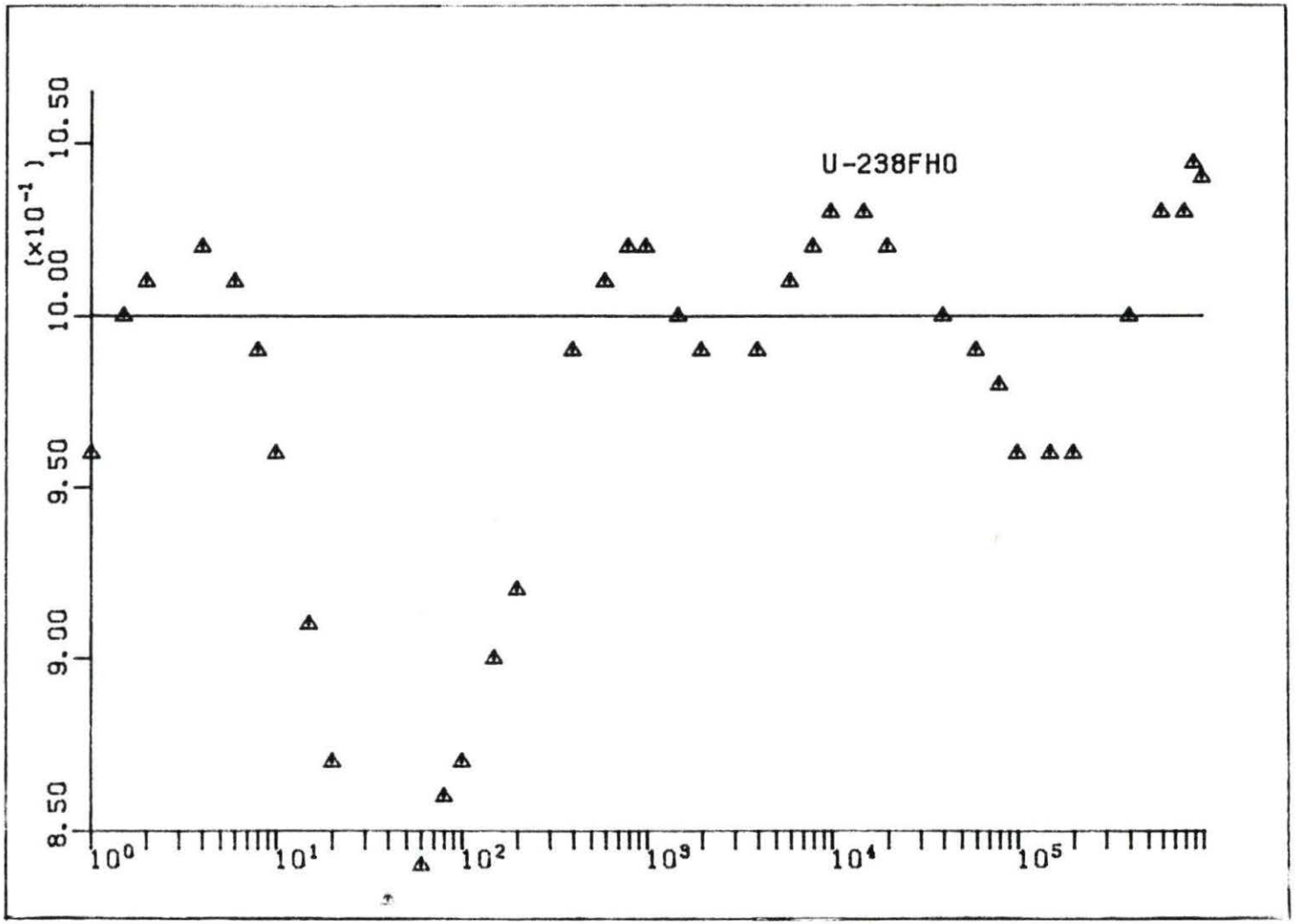


Figure 18. Ratio of Predictions, ENDF/B-V:ENDF/B-IV, U^{238}(fast) Fission Burst, H0(t) Function, Summation Method

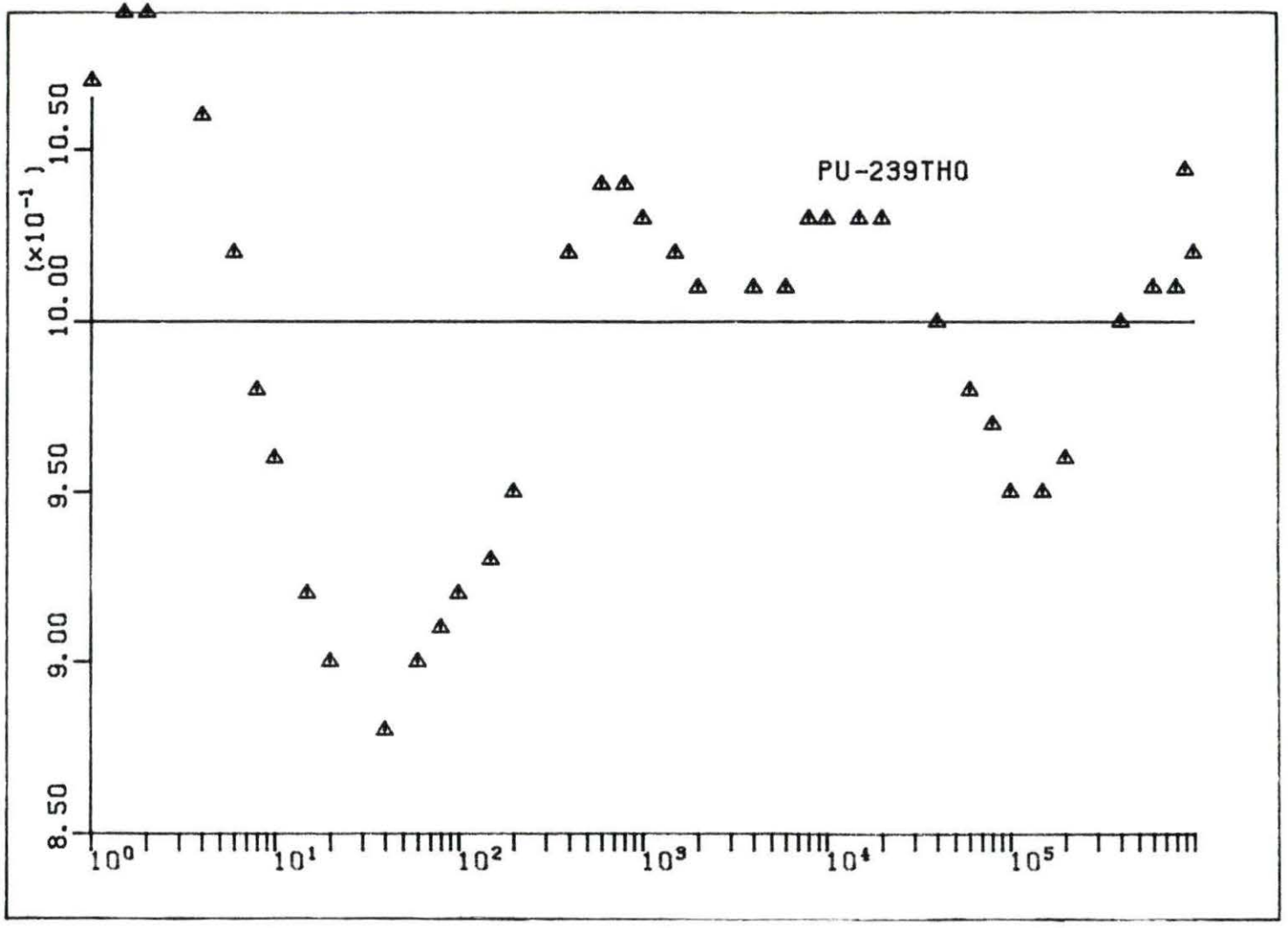


Figure 19. Ratio of Predictions, ENDF/B-V:ENDF/B-IV, Pu^{239} (thermal) Fission Burst, H0(t) Function, Summation Method

the fraction of high Q-value beta decays going to excited states of the daughter nuclides. Wu[36] has tentatively pointed out this trend of the ENDF data by use of two nuclear models (Defirmed Shell Model and Collective Model) for nuclear decay systematics. Also, the Japanese library, which uses somewhat different nuclear decay systematics[31] supports this trend.

We, thus, attribute these results to a conclusion that ENDF/B-V decay energies for fission products of short half-lives are systematically underpredicted, even more so than ENDF/B-IV values that are also belived to be too low. There is no significant differences between the summation calculation results obtained from the two data sets for cooling times longer than 200 seconds. Therefore, the most important next step is to put the analytical method for predicting decay power on a more satisfactory basis, or to use theoretically well-evaluated decay energy data for short lived fission products so that we can obtain more reliable decay power for the important short cooling times.

IV. ESTIMATION OF DECAY POWER BY RATIO METHOD

A. Advantages of the Ratio Method

The comparisons of the summation results from ENDF/B decay data with the ANS 5.1 standards make us clearly see that the summation results are quite underpredicted at short cooling times (<100 second), times important to LOCA, as shown in Chapter II.B. To remedy this problem, much effort has been devoted to compilation and evaluation of data for short-lived fission product nuclides based on theoretical approaches. C. H. Wu[36] constructed energy level diagrams based on nuclear systematics to calculate average beta and gamma decay energies for all the fission products. His predictions showed a random scatter in a normal distribution for those nuclides whose decay spectra had been measured. Schmittroth[37] carried out theoretical estimates of decay data for short lived nuclides, specifically decay energy data, by using β strength functions. Yoshida and Nakasima[31] introduced theoretical values of average β and ɣ decay energies for high Q-value decays based on the gross theory of beta decay developed by Takahashi, Yamada, and Koyama et al.[38]. These theoretical approaches, of course, are due to the lack of good experimental decay data for these nuclides. Although the methods of Wu and of Yoshida et al. significantly improved the agreement between summation calculations and integral experiments when ENDF/B-IV yield data were used, their results were not, however, considered in preparing ENDF/B-V decay energy data. Specifically,

Yoshida and Nakasima do not consider the uncertainties of the decay power, which give confidence in predicting decay power values.

The main source of uncertainty in the decay powers is due to the uncertainty in the fission product decay energy and this uncertainty is strongly correlated between the thermal fission of U^{235} and the other fissioning nuclides, as described in Chapter II.C. Figure 20 represents the decay energy correlation between the thermal fission of U^{235} and the fast fission of Pu^{239} as a function of time, for the H1 function. The correlation coefficients for the H1 and H0 functions are also listed on Table 2. There are strong correlations at all times, particularly at short cooling times (<200 seconds). The correlation coefficients decrease a little bit (about 2-3 %) at around $4*10^2$ and $2*10^4$ seconds. However, they still show strong correlation. Figures 21 through 26 and Tables 3 through 6 also show the strong correlation trend between the other fissioning nuclides (U^{238}(fast), Pu^{240}(fast), U^{235}(fast), and Pu^{241}(fast)) and the thermal fission of U^{235}. The ratio method, using ratios of decay power prediction from summation calculations to predict the decay power of nuclides other than U^{235}(thermal), can thus reduce these decay energy uncertainties. Decay energy uncertainties are strongly correlated between different types of fission, and are therefore suppressed as sources of uncertainty in the ratios. Without compiling and evaluating short lived fission product decay energies, the ratio technique can produce more reliable decay powers by suppressing errors due to fission product decay energies in the ratios, particularly at the short cooling times.

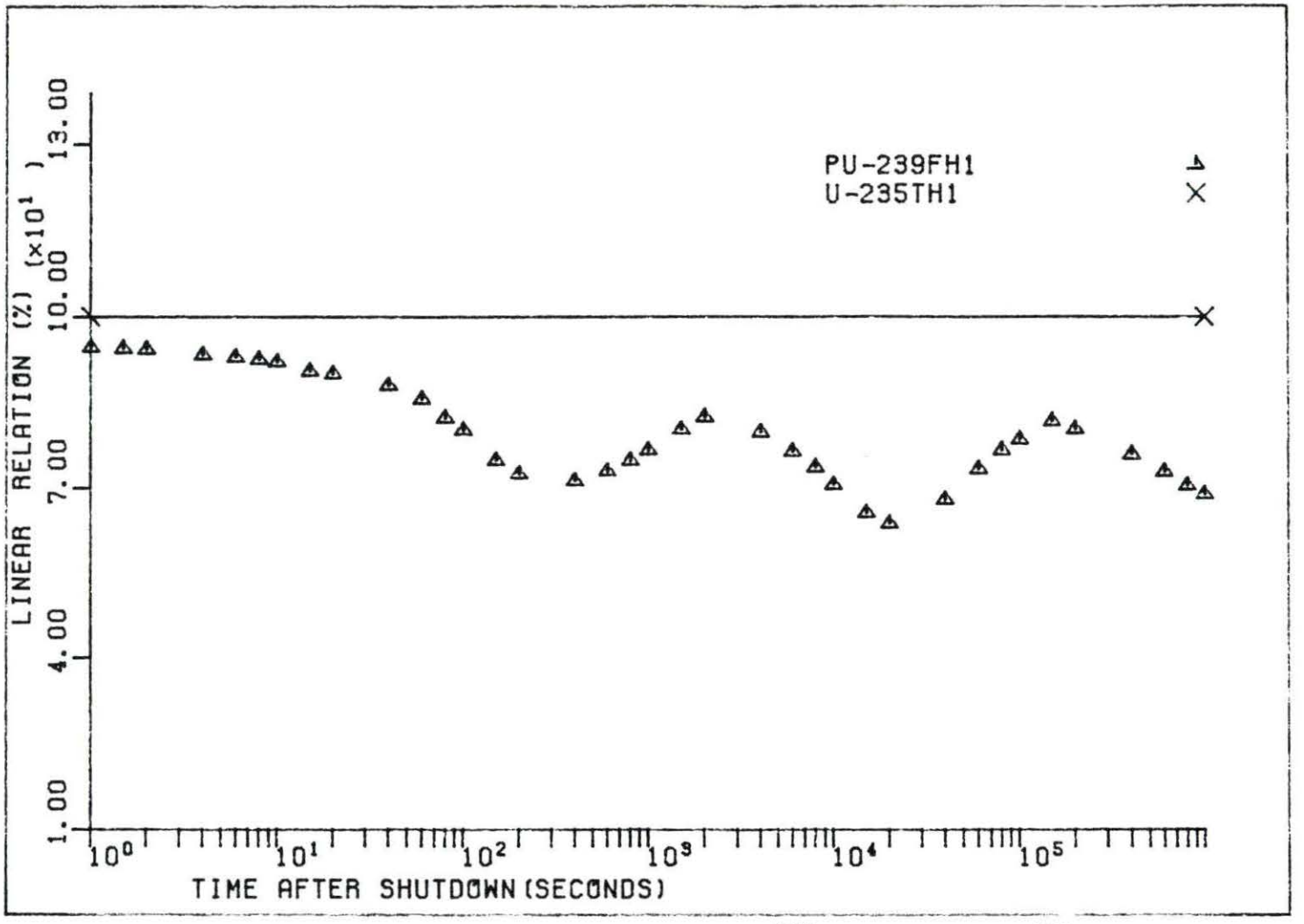


Figure 20. Correlation Coefficients between U^{235} Thermal and Pu^{239} Fast Fission Decay Power Uncertainties After Long Irradiation, H1 Function, at a Constant Fission Rate

Table 2. Correlation Coefficients between U^{235} Thermal and Pu^{239} Fast Fission Decay Power Uncertainties for H0 and H1 Functions

DECAY Time (Seconds)	CORRELATION COEFFICIENT Burst	Infinite Irradiation
0.10E+01	0.990	0.973
0.15E+01	0.988	0.972
0.20E+01	0.988	0.971
0.40E+01	0.988	0.966
0.60E+01	0.987	0.964
0.80E+01	0.989	0.962
0.10E+02	0.990	0.960
0.15E+02	0.983	0.951
0.20E+02	0.983	0.949
0.40E+02	0.969	0.938
0.60E+02	0.958	0.925
0.80E+02	0.955	0.907
0.10E+03	0.952	0.895
0.15E+03	0.948	0.865
0.20E+03	0.943	0.851
0.40E+03	0.842	0.844
0.60E+03	0.812	0.854
0.80E+03	0.816	0.865
0.10E+04	0.827	0.875
0.15E+04	0.859	0.896
0.20E+04	0.888	0.908
0.40E+04	0.920	0.893
0.60E+04	0.925	0.874
0.80E+04	0.926	0.858
0.10E+05	0.918	0.840
0.15E+05	0.893	0.810
0.20E+05	0.864	0.798
0.40E+05	0.800	0.824
0.60E+05	0.779	0.856
0.80E+05	0.769	0.875
0.10E+06	0.764	0.886
0.15E+06	0.811	0.904
0.20E+06	0.869	0.896
0.40E+06	0.953	0.871
0.60E+06	0.979	0.853
0.80E+06	0.980	0.839
0.10E+07	0.964	0.830

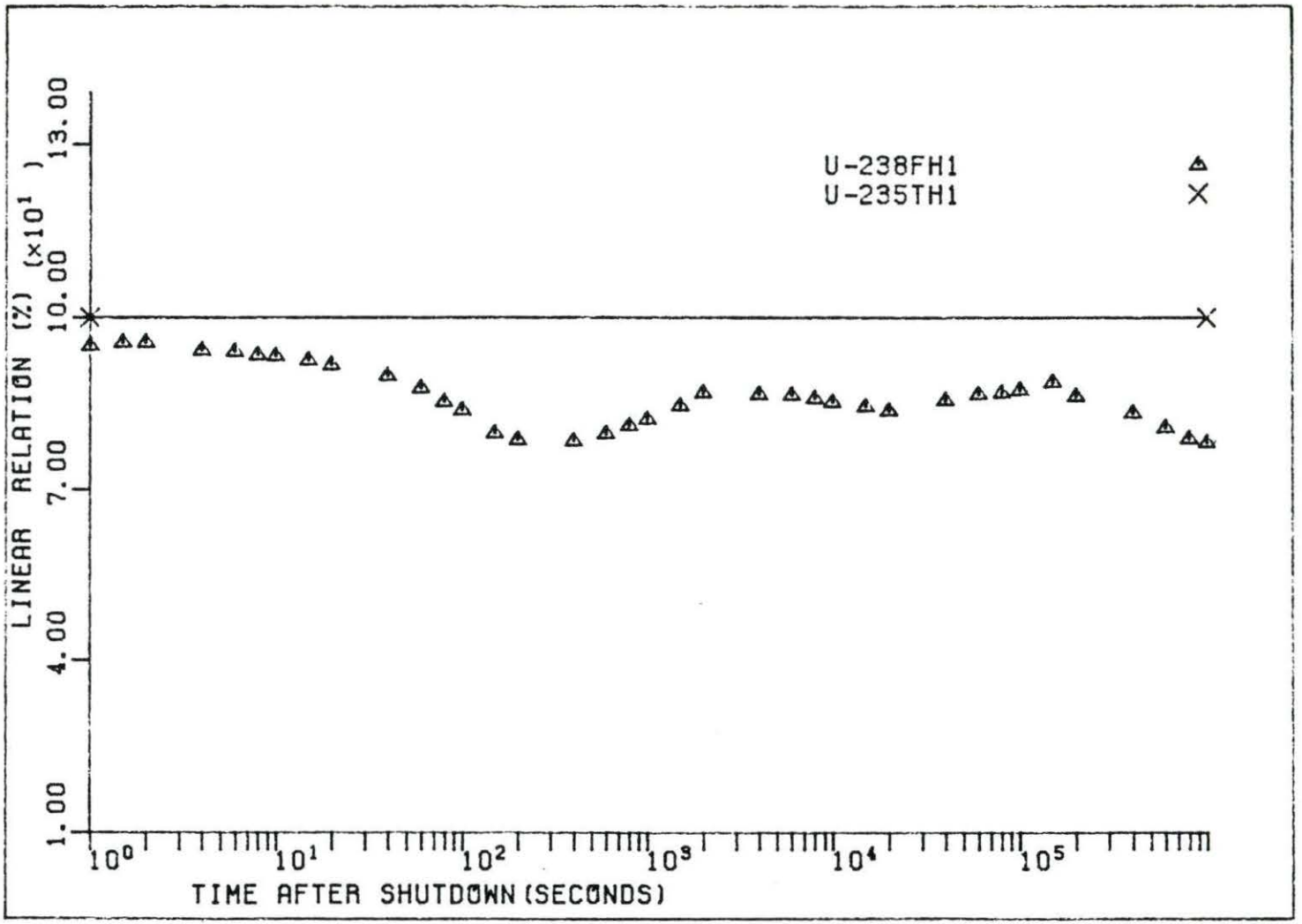


Figure 21. Correlation Coefficients between U^{235} Thermal and U^{238} Fast Fission Decay Power Uncertainties After Long Irradiation, H1 Function, at a Constant Fission Rate

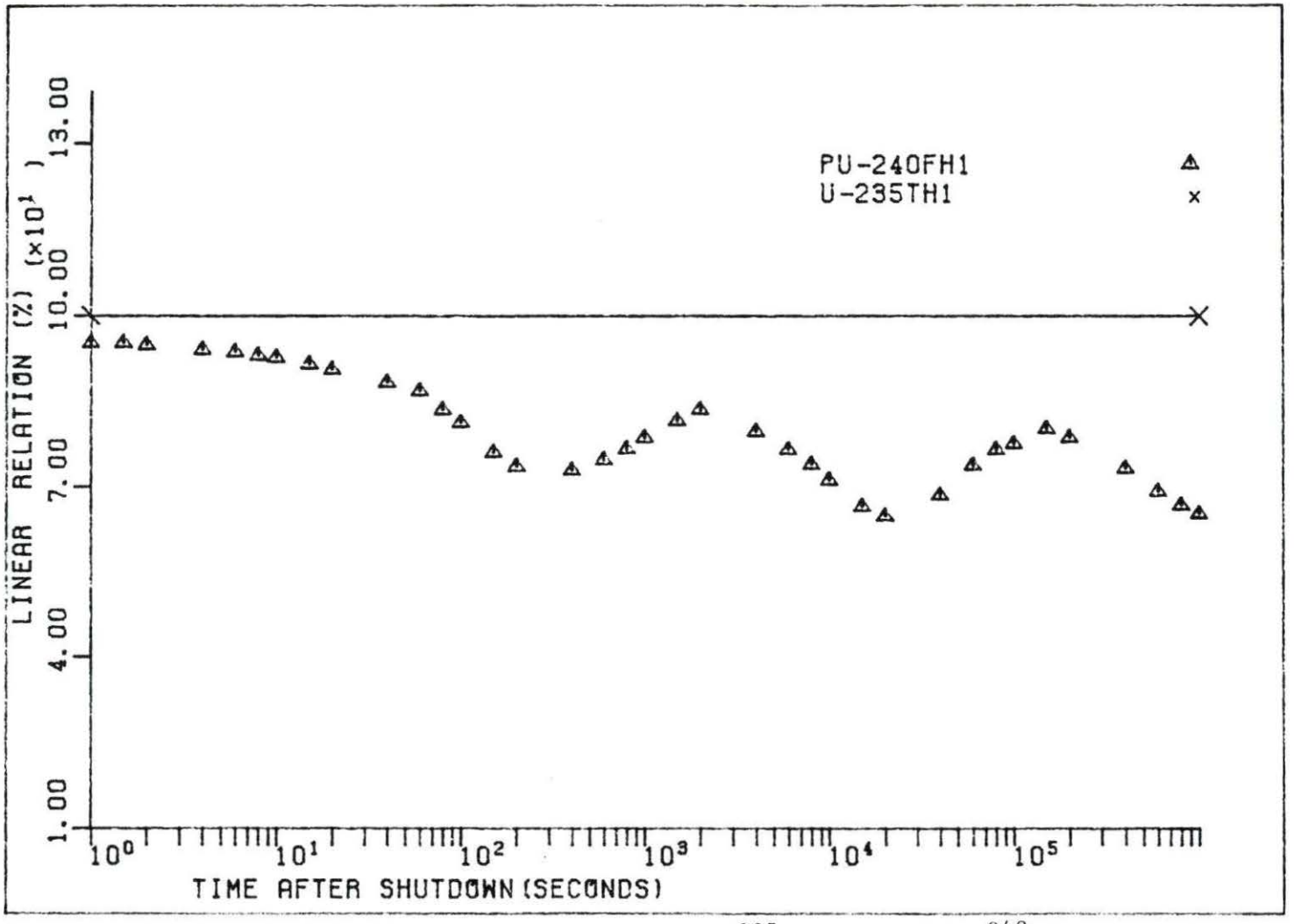


Figure 22. Correlation Coefficients between U^{235} Thermal and Pu^{240} Fast Fission Decay Power Uncertainties After Long Irradiation, H1 Function, at a Constant Fission Rate

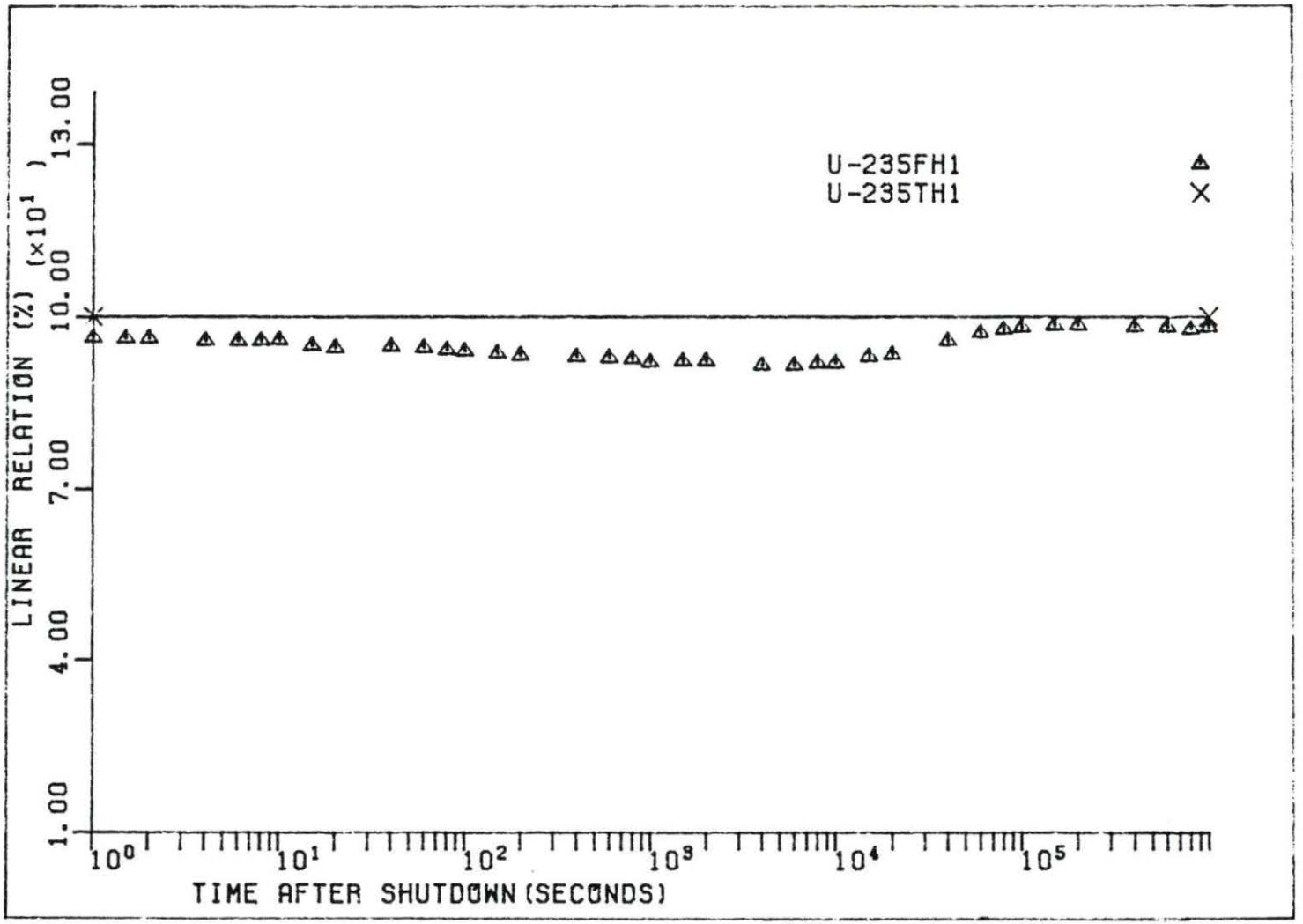


Figure 23. Correlation Coefficients between U^{235} Thermal and U^{235} Fast Fission Decay Power Uncertainties After Long Irradiation, H1 Function, at a Constant Fission Rate

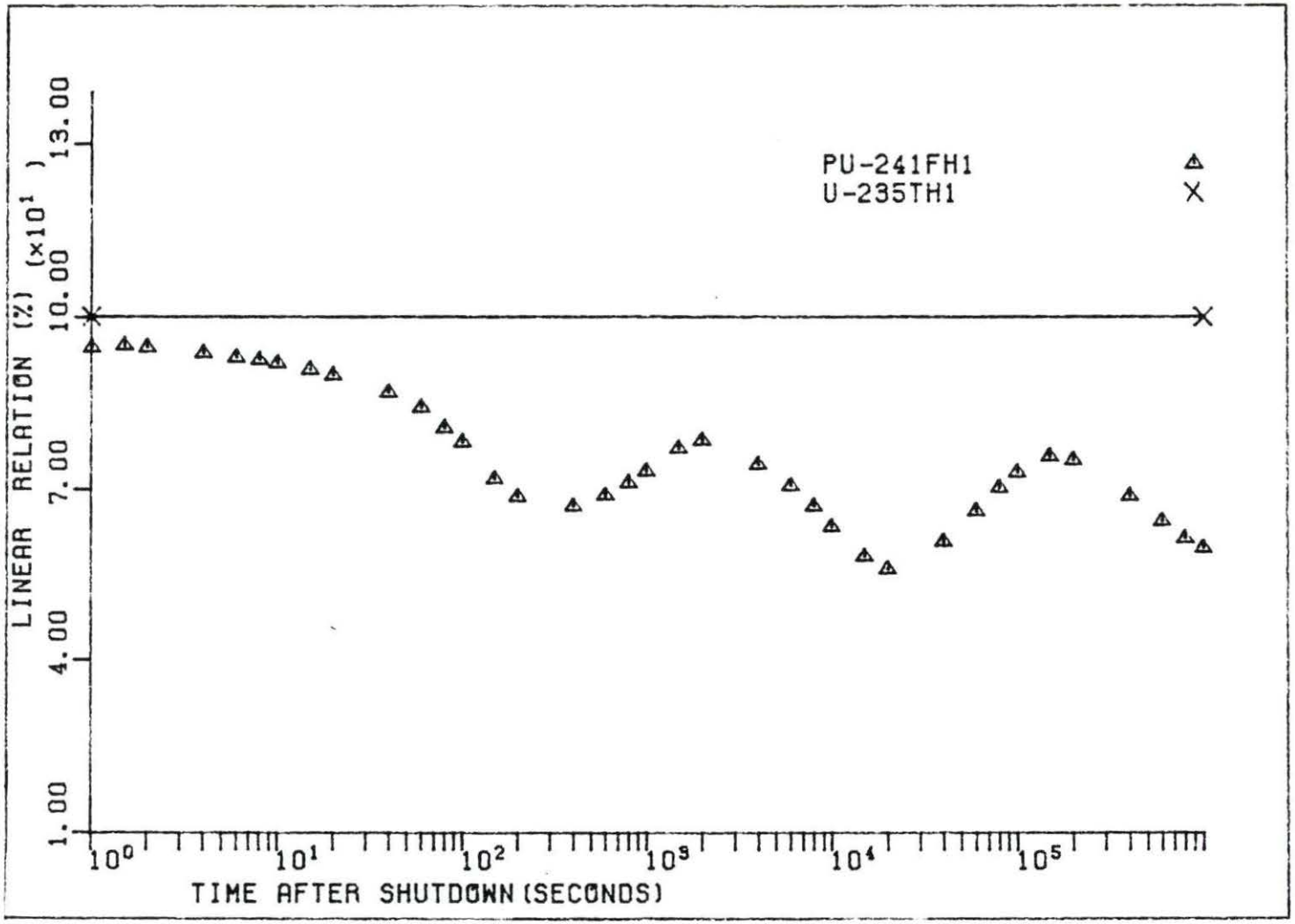


Figure 24. Correlation Coefficients between U^{235} Thermal and Pu^{241} Fast Fission Decay Power Uncertainties After Long Irradiation, H1 Function, at a Constant Fission Rate

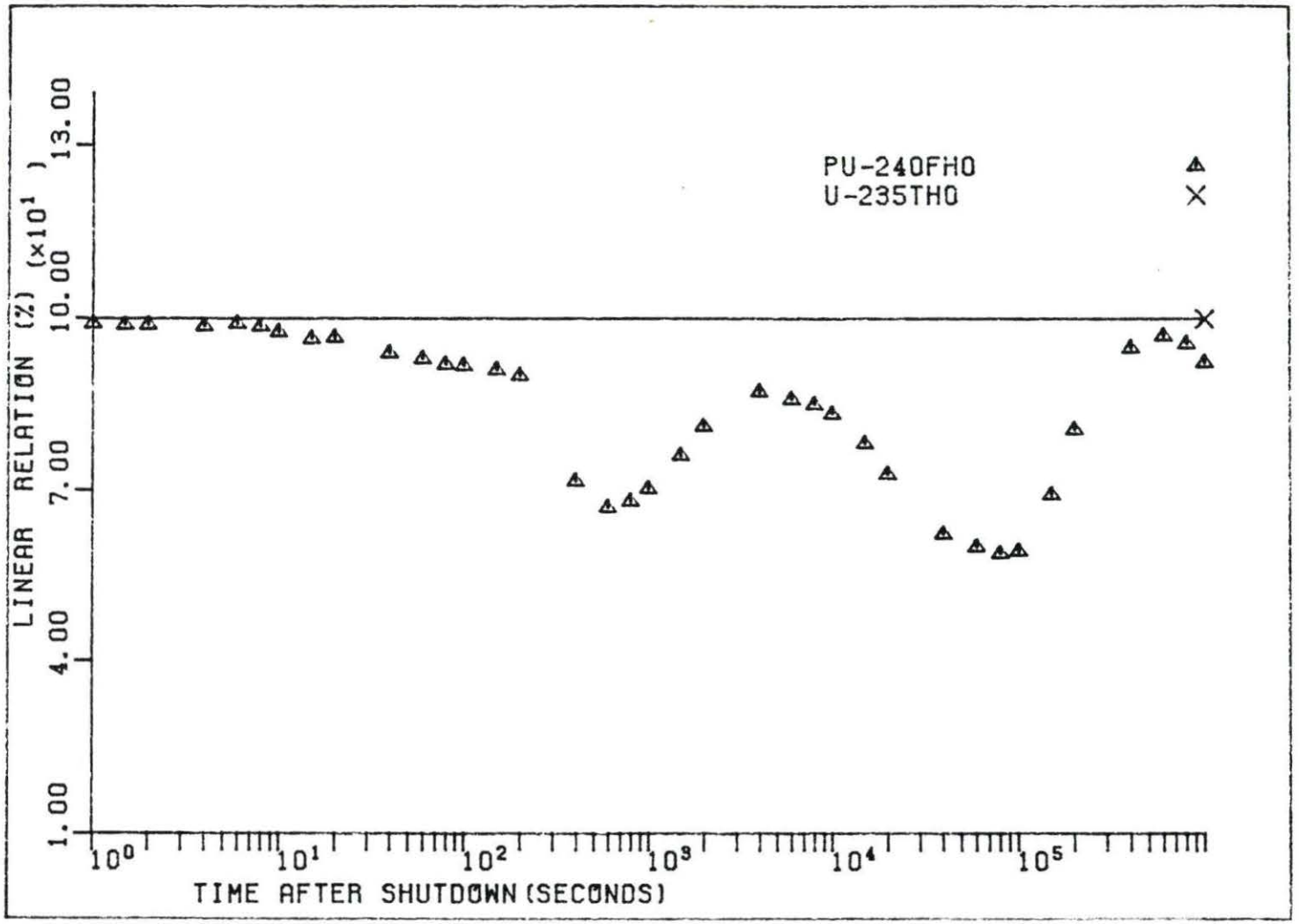


Figure 25. Correlation Coefficients between U^{235} Thermal and Pu^{240} Fast Fission Decay Power Uncertainties After Fission Burst, H0 Function

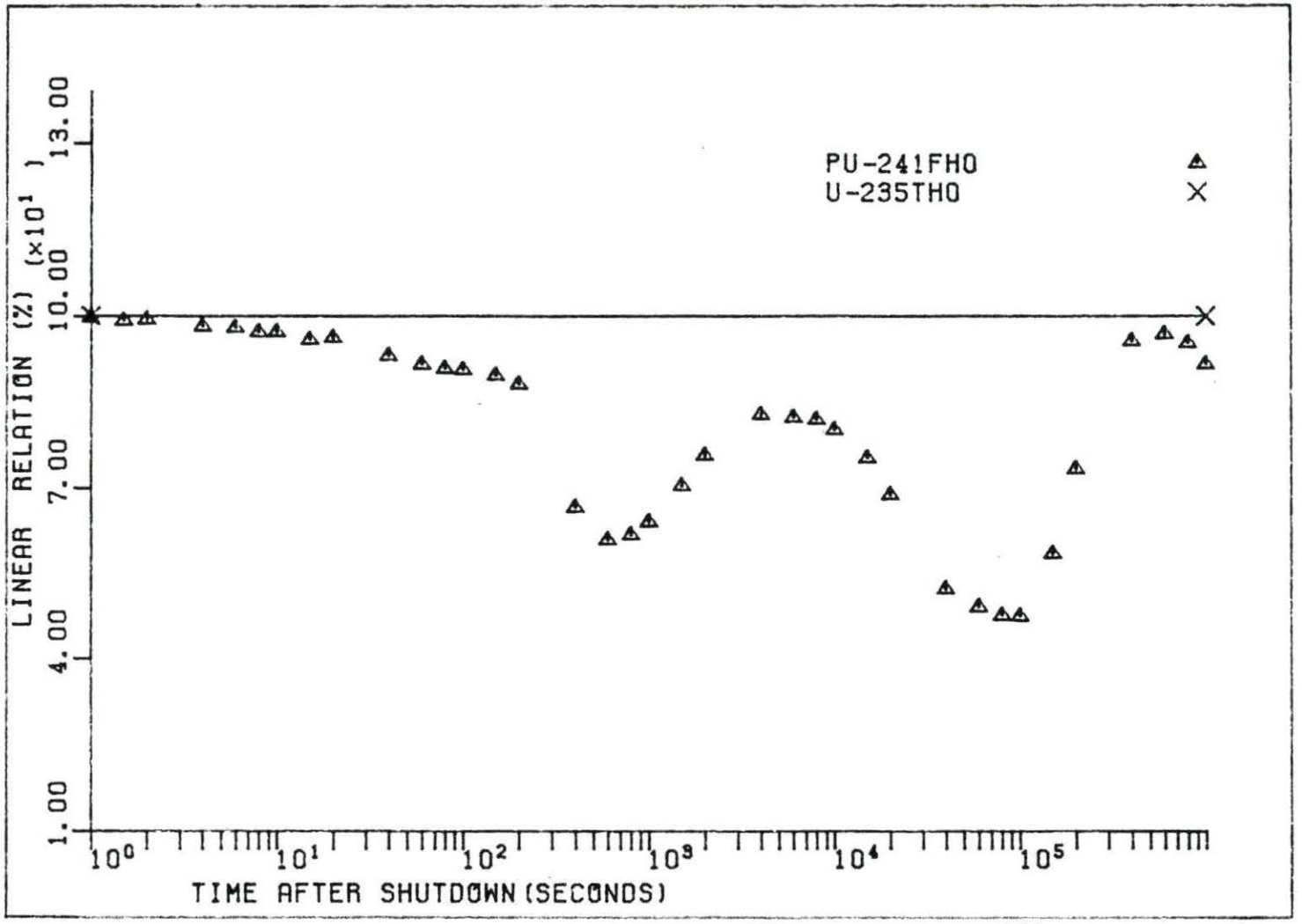


Figure 26. Correlation Coefficients between U^{235} Thermal and Pu^{241} Fast Fission Decay Power Uncertainties After Fission Burst, H0 Function

Table 3. Correlation Coefficients between U^{235} Thermal and U^{238} Fast Fission Decay Power Uncertainties for H0 and H1 Functions

DECAY Time (Seconds)	CORRELATION COEFFICIENT Burst	Infinite Irradiation
0.10E+01	0.999	0.975
0.15E+01	0.996	0.978
0.20E+01	0.995	0.978
0.40E+01	0.992	0.971
0.60E+01	0.993	0.970
0.80E+01	0.989	0.967
0.10E+02	0.987	0.966
0.15E+02	0.986	0.962
0.20E+02	0.983	0.958
0.40E+02	0.980	0.948
0.60E+02	0.976	0.937
0.80E+02	0.970	0.924
0.10E+03	0.972	0.916
0.15E+03	0.965	0.894
0.20E+03	0.960	0.887
0.40E+03	0.886	0.886
0.60E+03	0.868	0.893
0.80E+03	0.869	0.901
0.10E+04	0.878	0.907
0.15E+04	0.900	0.920
0.20E+04	0.915	0.932
0.40E+04	0.929	0.931
0.60E+04	0.928	0.930
0.80E+04	0.925	0.927
0.10E+05	0.921	0.923
0.15E+05	0.902	0.919
0.20E+05	0.895	0.915
0.40E+05	0.898	0.925
0.60E+05	0.923	0.931
0.80E+05	0.940	0.932
0.10E+06	0.947	0.935
0.15E+06	0.953	0.942
0.20E+06	0.964	0.929
0.40E+06	0.981	0.913
0.60E+06	0.985	0.899
0.80E+06	0.983	0.888
0.10E+07	0.973	0.884

Table 4. Correlation Coefficients between U^{235} Thermal and Pu^{240} Fast Fission Decay Power Uncertainties for H0 and H1 Functions

DECAY Time (Seconds)	CORRELATION COEFFICIENT Burst	Infinite Irradiation
0.10E+01	0.995	0.976
0.15E+01	0.994	0.976
0.20E+01	0.994	0.974
0.40E+01	0.993	0.970
0.60E+01	0.995	0.968
0.80E+01	0.993	0.965
0.10E+02	0.988	0.963
0.15E+02	0.982	0.957
0.20E+02	0.983	0.952
0.40E+02	0.969	0.940
0.60E+02	0.964	0.932
0.80E+02	0.959	0.914
0.10E+03	0.958	0.902
0.15E+03	0.954	0.872
0.20E+03	0.949	0.858
0.40E+03	0.846	0.854
0.60E+03	0.818	0.865
0.80E+03	0.825	0.876
0.10E+04	0.838	0.887
0.15E+04	0.872	0.904
0.20E+04	0.901	0.914
0.40E+04	0.934	0.893
0.60E+04	0.927	0.875
0.80E+04	0.922	0.860
0.10E+05	0.913	0.844
0.15E+05	0.884	0.816
0.20E+05	0.853	0.805
0.40E+05	0.789	0.828
0.60E+05	0.775	0.859
0.80E+05	0.767	0.875
0.10E+06	0.770	0.881
0.15E+06	0.832	0.896
0.20E+06	0.898	0.887
0.40E+06	0.974	0.856
0.60E+06	0.985	0.832
0.80E+06	0.978	0.817
0.10E+07	0.961	0.808

Table 5. Correlation Coefficients between U^{235} Thermal and U^{235} Fast Fission Decay Power Uncertainties for H0 and H1 Functions

DECAY Time (Seconds)	CORRELATION COEFFICIENT Burst	Infinite Irradiation
0.10E+01	1.001	0.982
0.15E+01	0.998	0.981
0.20E+01	0.997	0.981
0.40E+01	0.996	0.979
0.60E+01	0.996	0.979
0.80E+01	0.996	0.979
0.10E+02	0.993	0.980
0.15E+02	0.993	0.975
0.20E+02	0.995	0.973
0.40E+02	0.991	0.974
0.60E+02	0.994	0.973
0.80E+02	0.992	0.971
0.10E+03	0.989	0.970
0.15E+03	0.985	0.968
0.20E+03	0.987	0.966
0.40E+03	0.979	0.965
0.60E+03	0.977	0.964
0.80E+03	0.974	0.963
0.10E+04	0.975	0.960
0.15E+04	0.976	0.961
0.20E+04	0.971	0.961
0.40E+04	0.962	0.957
0.60E+04	0.952	0.957
0.80E+04	0.943	0.959
0.10E+05	0.935	0.959
0.15E+05	0.922	0.965
0.20E+05	0.911	0.967
0.40E+05	0.927	0.979
0.60E+05	0.951	0.986
0.80E+05	0.972	0.989
0.10E+06	0.979	0.991
0.15E+06	0.988	0.993
0.20E+06	0.993	0.993
0.40E+06	0.999	0.991
0.60E+06	0.996	0.991
0.80E+06	0.997	0.989
0.10E+07	0.995	0.991

Table 6. Correlation Coefficients between U^{235} Thermal and Pu^{241} Fast Fission Decay Power Uncertainties for H0 and H1 Functions

DECAY Time (Seconds)	CORRELATION COEFFICIENT Burst	Infinite Irradiation
0.10E+01	0.999	0.973
0.15E+01	0.996	0.975
0.20E+01	0.997	0.973
0.40E+01	0.991	0.968
0.60E+01	0.990	0.964
0.80E+01	0.986	0.962
0.10E+02	0.986	0.959
0.15E+02	0.979	0.953
0.20E+02	0.981	0.948
0.40E+02	0.965	0.932
0.60E+02	0.957	0.918
0.80E+02	0.953	0.898
0.10E+03	0.952	0.884
0.15E+03	0.947	0.847
0.20E+03	0.939	0.828
0.40E+03	0.816	0.818
0.60E+03	0.780	0.830
0.80E+03	0.786	0.843
0.10E+04	0.800	0.855
0.15E+04	0.839	0.878
0.20E+04	0.870	0.886
0.40E+04	0.910	0.862
0.60E+04	0.907	0.840
0.80E+04	0.905	0.818
0.10E+05	0.895	0.796
0.15E+05	0.867	0.762
0.20E+05	0.829	0.747
0.40E+05	0.722	0.779
0.60E+05	0.700	0.813
0.80E+05	0.689	0.838
0.10E+06	0.688	0.854
0.15E+06	0.764	0.870
0.20E+06	0.856	0.866
0.40E+06	0.978	0.829
0.60E+06	0.984	0.802
0.80E+06	0.976	0.783
0.10E+07	0.957	0.772

The ratio method calculation can be easily performed. The method directly uses the summation results and adds the ANS 5.1 standard values as input data. One computer program, GOODY, was written in this study to perform the ratio method calculations. GOODY, which is connected with the summation code, ROPEY1 and is composed of the statistical model described in Chapter II.C, produces H0 and H1 functions and their uncertainties as well as a comparison between the direct summation calculation and the ratio results, and correlation coefficients of the two different types of fission. Since GOODY automatically performs these calculations with input data, there are no difficulties in obtaining the results, even though several large data sets are generated during the calculations. The detailed data control logic, source program, and its results are attached at Appendix X.

B. Comparisons of Ratio Method Results with Summation Method

Decay powers and their uncertainties of U^{238}(fast), Pu^{239}(fast) ,Pu^{240}(fast), Pu^{241}(fast), U^{235}(fast), Pu^{239}(thermal), and Pu^{241}(thermal) for H0, H1 functions are evaluated by the ratio method and listed on Tables 7 through 20. However, to see the effectiveness of the ratio method, it is necessary to compare different decay powers; one from direct summation calculations and another from ratio method. Table 21 represents the comparisons of both H1 functions for Pu^{239}(fast), where the relative uncertainties denote the ratio of uncertainties to decay powers. For short cooling times <200 seconds,

Table 7. Decay Power of Fast Fission of U^{238} After Long Irradiation (10^{13} seconds), H1 Function, Ratio Method Results

DECAY Time (Seconds)	DECAY Power (Mev/fission)	UNCERTAINTY
0.10E+01	0.147E+02	0.673E+00
0.15E+01	0.142E+02	0.564E+00
0.20E+01	0.137E+02	0.504E+00
0.40E+01	0.122E+02	0.404E+00
0.60E+01	0.113E+02	0.350E+00
0.80E+01	0.107E+02	0.317E+00
0.10E+02	0.102E+02	0.291E+00
0.15E+02	0.942E+01	0.255E+00
0.20E+02	0.887E+01	0.233E+00
0.40E+02	0.766E+01	0.185E+00
0.60E+02	0.699E+01	0.161E+00
0.80E+02	0.653E+01	0.146E+00
0.10E+03	0.621E+01	0.135E+00
0.15E+03	0.563E+01	0.119E+00
0.20E+03	0.528E+01	0.109E+00
0.40E+03	0.451E+01	0.897E-01
0.60E+03	0.412E+01	0.806E-01
0.80E+03	0.384E+01	0.743E-01
0.10E+04	0.362E+01	0.695E-01
0.15E+04	0.323E+01	0.618E-01
0.20E+04	0.296E+01	0.567E-01
0.40E+04	0.237E+01	0.469E-01
0.60E+04	0.209E+01	0.410E-01
0.80E+04	0.192E+01	0.380E-01
0.10E+05	0.180E+01	0.351E-01
0.15E+05	0.159E+01	0.321E-01
0.20E+05	0.146E+01	0.293E-01
0.40E+05	0.122E+01	0.253E-01
0.60E+05	0.109E+01	0.232E-01
0.80E+05	0.996E+00	0.218E-01
0.10E+06	0.939E+00	0.211E-01
0.15E+06	0.842E+00	0.189E-01
0.20E+06	0.782E+00	0.175E-01
0.40E+06	0.660E+00	0.149E-01
0.60E+06	0.592E+00	0.133E-01
0.80E+06	0.545E+00	0.122E-01
0.10E+07	0.508E+00	0.113E-01

Table 8. Decay Power of Fast Fission of U^{238} After Fission Burst, H0 Function, Ratio Method Results

DECAY Time (Seconds)	DECAY Power (Mev/fis-sec)	UNCERTAINTY
0.10E+01	0.131E+01	0.522E+00
0.15E+01	0.112E+01	0.202E+00
0.20E+01	0.961E+00	0.836E-01
0.40E+01	0.563E+00	0.291E-01
0.60E+01	0.376E+00	0.168E-01
0.80E+01	0.275E+00	0.111E-01
0.10E+02	0.213E+00	0.858E-02
0.15E+02	0.132E+00	0.449E-02
0.20E+02	0.942E-01	0.314E-02
0.40E+02	0.422E-01	0.139E-02
0.60E+02	0.270E-01	0.916E-03
0.80E+02	0.193E-01	0.671E-03
0.10E+03	0.148E-01	0.475E-03
0.15E+03	0.885E-02	0.275E-03
0.20E+03	0.606E-02	0.177E-03
0.40E+03	0.253E-02	0.633E-04
0.60E+03	0.165E-02	0.407E-04
0.80E+03	0.123E-02	0.313E-04
0.10E+04	0.981E-03	0.237E-04
0.15E+04	0.638E-03	0.143E-04
0.20E+04	0.460E-03	0.948E-05
0.40E+04	0.188E-03	0.377E-05
0.60E+04	0.107E-03	0.215E-05
0.80E+04	0.718E-04	0.141E-05
0.10E+05	0.532E-04	0.104E-05
0.15E+05	0.304E-04	0.534E-06
0.20E+05	0.204E-04	0.327E-06
0.40E+05	0.857E-05	0.141E-06
0.60E+05	0.511E-05	0.841E-07
0.80E+05	0.347E-05	0.572E-07
0.10E+06	0.256E-05	0.429E-07
0.15E+06	0.147E-05	0.332E-07
0.20E+06	0.981E-06	0.219E-07
0.40E+06	0.419E-06	0.942E-08
0.60E+06	0.277E-06	0.621E-08
0.80E+06	0.205E-06	0.464E-08
0.10E+07	0.161E-06	0.366E-08

Table 9. Decay Power of Fast Fission of Pu^{239} After Long Irradiation (10^{13} seconds), H1 Function, Ratio Method Results

DECAY Time (Seconds)	DECAY Power (Mev/fission)	UNCERTAINTY
0.10E+01	0.103E+02	0.393E+00
0.15E+01	0.100E+02	0.335E+00
0.20E+01	0.985E+01	0.307E+00
0.40E+01	0.919E+01	0.270E+00
0.60E+01	0.875E+01	0.251E+00
0.80E+01	0.841E+01	0.239E+00
0.10E+02	0.815E+01	0.229E+00
0.15E+02	0.768E+01	0.214E+00
0.20E+02	0.735E+01	0.201E+00
0.40E+02	0.656E+01	0.171E+00
0.60E+02	0.610E+01	0.153E+00
0.80E+02	0.578E+01	0.142E+00
0.10E+03	0.553E+01	0.132E+00
0.15E+03	0.510E+01	0.116E+00
0.20E+03	0.482E+01	0.106E+00
0.40E+03	0.419E+01	0.865E-01
0.60E+03	0.384E+01	0.770E-01
0.80E+03	0.359E+01	0.705E-01
0.10E+04	0.338E+01	0.656E-01
0.15E+04	0.302E+01	0.577E-01
0.20E+04	0.276E+01	0.528E-01
0.40E+04	0.220E+01	0.430E-01
0.60E+04	0.195E+01	0.367E-01
0.80E+04	0.179E+01	0.333E-01
0.10E+05	0.169E+01	0.303E-01
0.15E+05	0.151E+01	0.276E-01
0.20E+05	0.140E+01	0.252E-01
0.40E+05	0.118E+01	0.221E-01
0.60E+05	0.106E+01	0.204E-01
0.80E+05	0.973E+00	0.194E-01
0.10E+06	0.917E+00	0.188E-01
0.15E+06	0.823E+00	0.168E-01
0.20E+06	0.763E+00	0.155E-01
0.40E+06	0.639E+00	0.129E-01
0.60E+06	0.571E+00	0.115E-01
0.80E+06	0.525E+00	0.105E-01
0.10E+07	0.490E+00	0.982E-02

Table 10. Decay Power of Fast Fission of Pu^{239} After Fission Burst, H0 Function, Ratio Method Results

DECAY Time (Seconds)	DECAY Power (Mev/fis-sec)	UNCERTAINTY
0.10E+01	0.489E+00	0.194E+00
0.15E+01	0.436E+00	0.794E-01
0.20E+01	0.390E+00	0.350E-01
0.40E+01	0.258E+00	0.137E-01
0.60E+01	0.186E+00	0.881E-02
0.80E+01	0.144E+00	0.614E-02
0.10E+02	0.116E+00	0.496E-02
0.15E+02	0.766E-01	0.341E-02
0.20E+02	0.566E-01	0.250E-02
0.40E+02	0.283E-01	0.146E-02
0.60E+02	0.190E-01	0.107E-02
0.80E+02	0.140E-01	0.805E-03
0.10E+03	0.109E-01	0.625E-03
0.15E+03	0.673E-02	0.367E-03
0.20E+03	0.474E-02	0.236E-03
0.40E+03	0.216E-02	0.756E-04
0.60E+03	0.147E-02	0.473E-04
0.80E+03	0.113E-02	0.352E-04
0.10E+04	0.915E-03	0.265E-04
0.15E+04	0.605E-03	0.152E-04
0.20E+04	0.437E-03	0.966E-05
0.40E+04	0.174E-03	0.404E-05
0.60E+04	0.960E-04	0.282E-05
0.80E+04	0.636E-04	0.207E-05
0.10E+05	0.465E-04	0.154E-05
0.15E+05	0.265E-04	0.682E-06
0.20E+05	0.180E-04	0.328E-06
0.40E+05	0.784E-05	0.119E-06
0.60E+05	0.479E-05	0.713E-07
0.80E+05	0.331E-05	0.499E-07
0.10E+06	0.248E-05	0.387E-07
0.15E+06	0.146E-05	0.323E-07
0.20E+06	0.988E-06	0.219E-07
0.40E+06	0.421E-06	0.917E-08
0.60E+06	0.273E-06	0.574E-08
0.80E+06	0.201E-06	0.412E-08
0.10E+07	0.155E-06	0.314E-08

Table 11. Decay Power of Fast Fission of Pu^{240} After Long Irradiation (10^{13} seconds), H1 Function, Ratio Method Results

DECAY Time (Seconds)	DECAY Power (Mev/fission)	UNCERTAINTY
0.10E+01	0.111E+02	0.450E+00
0.15E+01	0.108E+02	0.389E+00
0.20E+01	0.106E+02	0.360E+00
0.40E+01	0.983E+01	0.315E+00
0.60E+01	0.932E+01	0.292E+00
0.80E+01	0.894E+01	0.278E+00
0.10E+02	0.864E+01	0.264E+00
0.15E+02	0.811E+01	0.242E+00
0.20E+02	0.772E+01	0.227E+00
0.40E+02	0.682E+01	0.190E+00
0.60E+02	0.630E+01	0.167E+00
0.80E+02	0.593E+01	0.153E+00
0.10E+03	0.566E+01	0.142E+00
0.15E+03	0.519E+01	0.124E+00
0.20E+03	0.490E+01	0.114E+00
0.40E+03	0.424E+01	0.926E-01
0.60E+03	0.388E+01	0.825E-01
0.80E+03	0.362E+01	0.756E-01
0.10E+04	0.340E+01	0.705E-01
0.15E+04	0.304E+01	0.627E-01
0.20E+04	0.278E+01	0.577E-01
0.40E+04	0.221E+01	0.477E-01
0.60E+04	0.194E+01	0.411E-01
0.80E+04	0.179E+01	0.375E-01
0.10E+05	0.168E+01	0.343E-01
0.15E+05	0.149E+01	0.311E-01
0.20E+05	0.138E+01	0.284E-01
0.40E+05	0.116E+01	0.244E-01
0.60E+05	0.105E+01	0.225E-01
0.80E+05	0.960E+00	0.211E-01
0.10E+06	0.904E+00	0.203E-01
0.15E+06	0.811E+00	0.182E-01
0.20E+06	0.753E+00	0.169E-01
0.40E+06	0.633E+00	0.142E-01
0.60E+06	0.567E+00	0.128E-01
0.80E+06	0.523E+00	0.117E-01
0.10E+07	0.489E+00	0.109E-01

Table 12. Decay Power of Fast Fission of Pu^{240} After Fission Burst, H0 Function, Ratio Method Results

DECAY Time (Seconds)	DECAY Power (Mev/fis-sec)	UNCERTAINTY
0.10E+01	0.588E+00	0.233E+00
0.15E+01	0.522E+00	0.941E-01
0.20E+01	0.465E+00	0.406E-01
0.40E+01	0.303E+00	0.160E-01
0.60E+01	0.218E+00	0.993E-02
0.80E+01	0.166E+00	0.737E-02
0.10E+02	0.134E+00	0.637E-02
0.15E+02	0.885E-01	0.416E-02
0.20E+02	0.655E-01	0.295E-02
0.40E+02	0.324E-01	0.162E-02
0.60E+02	0.215E-01	0.110E-02
0.80E+02	0.157E-01	0.822E-03
0.10E+03	0.120E-01	0.623E-03
0.15E+03	0.728E-02	0.366E-03
0.20E+03	0.506E-02	0.234E-03
0.40E+03	0.224E-02	0.777E-04
0.60E+03	0.152E-02	0.489E-04
0.80E+03	0.115E-02	0.364E-04
0.10E+04	0.927E-03	0.272E-04
0.15E+04	0.610E-03	0.156E-04
0.20E+04	0.441E-03	0.985E-05
0.40E+04	0.179E-03	0.407E-05
0.60E+04	0.998E-04	0.269E-05
0.80E+04	0.659E-04	0.191E-05
0.10E+05	0.480E-04	0.142E-05
0.15E+05	0.269E-04	0.676E-06
0.20E+05	0.180E-04	0.364E-06
0.40E+05	0.771E-05	0.148E-06
0.60E+05	0.474E-05	0.905E-07
0.80E+05	0.328E-05	0.612E-07
0.10E+06	0.246E-05	0.450E-07
0.15E+06	0.143E-05	0.329E-07
0.20E+06	0.966E-06	0.217E-07
0.40E+06	0.405E-06	0.910E-08
0.60E+06	0.261E-06	0.585E-08
0.80E+06	0.192E-06	0.428E-08
0.10E+07	0.149E-06	0.334E-08

Table 13. Decay Power of Fast Fission of Pu^{241} After Long Irradiation (10^{13} seconds), H1 Function, Ratio Method Results

DECAY Time (Seconds)	DECAY Power (Mev/fission)	UNCERTAINTY
0.10E+01	0.123E+02	0.564E+00
0.15E+01	0.120E+02	0.489E+00
0.20E+01	0.117E+02	0.454E+00
0.40E+01	0.107E+02	0.392E+00
0.60E+01	0.100E+02	0.357E+00
0.80E+01	0.955E+01	0.332E+00
0.10E+02	0.917E+01	0.314E+00
0.15E+02	0.853E+01	0.282E+00
0.20E+02	0.809E+01	0.261E+00
0.40E+02	0.707E+01	0.212E+00
0.60E+02	0.649E+01	0.182E+00
0.80E+02	0.608E+01	0.164E+00
0.10E+03	0.578E+01	0.151E+00
0.15E+03	0.527E+01	0.131E+00
0.20E+03	0.496E+01	0.119E+00
0.40E+03	0.426E+01	0.955E-01
0.60E+03	0.389E+01	0.841E-01
0.80E+03	0.362E+01	0.764E-01
0.10E+04	0.340E+01	0.708E-01
0.15E+04	0.303E+01	0.621E-01
0.20E+04	0.277E+01	0.569E-01
0.40E+04	0.219E+01	0.466E-01
0.60E+04	0.192E+01	0.399E-01
0.80E+04	0.176E+01	0.363E-01
0.10E+05	0.165E+01	0.330E-01
0.15E+05	0.147E+01	0.299E-01
0.20E+05	0.136E+01	0.272E-01
0.40E+05	0.115E+01	0.236E-01
0.60E+05	0.104E+01	0.218E-01
0.80E+05	0.957E+00	0.206E-01
0.10E+06	0.903E+00	0.199E-01
0.15E+06	0.813E+00	0.178E-01
0.20E+06	0.756E+00	0.166E-01
0.40E+06	0.639E+00	0.141E-01
0.60E+06	0.575E+00	0.126E-01
0.80E+06	0.532E+00	0.116E-01
0.10E+07	0.498E+00	0.109E-01

Table 14. Decay Power of Fast Fission of Pu^{241} After Fission Burst, H0 Function, Ratio Method Results

DECAY Time (Seconds)	DECAY Power (Mev/fis-sec)	UNCERTAINTY
0.10E+01	0.796E+00	0.316E+00
0.15E+01	0.700E+00	0.126E+00
0.20E+01	0.616E+00	0.542E-01
0.40E+01	0.391E+00	0.217E-01
0.60E+01	0.275E+00	0.138E-01
0.80E+01	0.207E+00	0.997E-02
0.10E+02	0.164E+00	0.788E-02
0.15E+02	0.105E+00	0.488E-02
0.20E+02	0.762E-01	0.345E-02
0.40E+02	0.364E-01	0.187E-02
0.60E+02	0.239E-01	0.127E-02
0.80E+02	0.173E-01	0.931E-03
0.10E+03	0.132E-01	0.693E-03
0.15E+03	0.787E-02	0.388E-03
0.20E+03	0.541E-02	0.244E-03
0.40E+03	0.235E-02	0.842E-04
0.60E+03	0.157E-02	0.537E-04
0.80E+03	0.118E-02	0.400E-04
0.10E+04	0.951E-03	0.298E-04
0.15E+04	0.623E-03	0.167E-04
0.20E+04	0.451E-03	0.104E-04
0.40E+04	0.182E-03	0.411E-05
0.60E+04	0.101E-03	0.271E-05
0.80E+04	0.662E-04	0.193E-05
0.10E+05	0.479E-04	0.143E-05
0.15E+05	0.264E-04	0.669E-06
0.20E+05	0.173E-04	0.348E-06
0.40E+05	0.736E-05	0.132E-06
0.60E+05	0.454E-05	0.807E-07
0.80E+05	0.317E-05	0.556E-07
0.10E+06	0.237E-05	0.418E-07
0.15E+06	0.138E-05	0.316E-07
0.20E+06	0.935E-06	0.210E-07
0.40E+06	0.397E-06	0.877E-08
0.60E+06	0.258E-06	0.565E-08
0.80E+06	0.191E-06	0.416E-08
0.10E+07	0.149E-06	0.326E-08

Table 15. Decay Power of Fast Fission of U^{235} After Long Irradiation (10^{13} seconds), H1 Function, Ratio Method Results

DECAY Time (Seconds)	DECAY Power (Mev/fission)	UNCERTAINTY
0.10E+01	0.123E+02	0.433E+00
0.15E+01	0.120E+02	0.356E+00
0.20E+01	0.117E+02	0.318E+00
0.40E+01	0.108E+02	0.263E+00
0.60E+01	0.102E+02	0.237E+00
0.80E+01	0.977E+01	0.221E+00
0.10E+02	0.943E+01	0.206E+00
0.15E+02	0.882E+01	0.188E+00
0.20E+02	0.840E+01	0.174E+00
0.40E+02	0.741E+01	0.144E+00
0.60E+02	0.685E+01	0.129E+00
0.80E+02	0.644E+01	0.121E+00
0.10E+03	0.617E+01	0.115E+00
0.15E+03	0.565E+01	0.105E+00
0.20E+03	0.534E+01	0.984E-01
0.40E+03	0.464E+01	0.839E-01
0.60E+03	0.425E+01	0.767E-01
0.80E+03	0.398E+01	0.715E-01
0.10E+04	0.377E+01	0.675E-01
0.15E+04	0.339E+01	0.605E-01
0.20E+04	0.311E+01	0.553E-01
0.40E+04	0.251E+01	0.453E-01
0.60E+04	0.221E+01	0.391E-01
0.80E+04	0.203E+01	0.361E-01
0.10E+05	0.190E+01	0.330E-01
0.15E+05	0.167E+01	0.299E-01
0.20E+05	0.153E+01	0.269E-01
0.40E+05	0.125E+01	0.229E-01
0.60E+05	0.112E+01	0.210E-01
0.80E+05	0.102E+01	0.198E-01
0.10E+06	0.963E+00	0.193E-01
0.15E+06	0.866E+00	0.174E-01
0.20E+06	0.807E+00	0.161E-01
0.40E+06	0.688E+00	0.138E-01
0.60E+06	0.622E+00	0.125E-01
0.80E+06	0.576E+00	0.115E-01
0.10E+07	0.540E+00	0.108E-01

Table 16. Decay Power of Fast Fission of U^{235} After Fission Burst, H0 Function, Ratio Method Results

DECAY Time (Seconds)	DECAY Power (Mev/fis-sec)	UNCERTAINTY
0.10E+01	0.744E+00	0.294E+00
0.15E+01	0.644E+00	0.115E+00
0.20E+01	0.562E+00	0.469E-01
0.40E+01	0.352E+00	0.157E-01
0.60E+01	0.248E+00	0.942E-02
0.80E+01	0.189E+00	0.644E-02
0.10E+02	0.151E+00	0.542E-02
0.15E+02	0.991E-01	0.296E-02
0.20E+02	0.730E-01	0.203E-02
0.40E+02	0.352E-01	0.895E-03
0.60E+02	0.231E-01	0.514E-03
0.80E+02	0.167E-01	0.373E-03
0.10E+03	0.128E-01	0.265E-03
0.15E+03	0.780E-02	0.163E-03
0.20E+03	0.542E-02	0.110E-03
0.40E+03	0.237E-02	0.457E-04
0.60E+03	0.158E-02	0.304E-04
0.80E+03	0.120E-02	0.242E-04
0.10E+04	0.959E-03	0.186E-04
0.15E+04	0.635E-03	0.122E-04
0.20E+04	0.464E-03	0.864E-05
0.40E+04	0.196E-03	0.385E-05
0.60E+04	0.113E-03	0.231E-05
0.80E+04	0.775E-04	0.157E-05
0.10E+05	0.578E-04	0.116E-05
0.15E+05	0.336E-04	0.574E-06
0.20E+05	0.227E-04	0.339E-06
0.40E+05	0.934E-05	0.136E-06
0.60E+05	0.539E-05	0.749E-07
0.80E+05	0.359E-05	0.489E-07
0.10E+06	0.261E-05	0.359E-07
0.15E+06	0.146E-05	0.298E-07
0.20E+06	0.959E-06	0.194E-07
0.40E+06	0.403E-06	0.814E-08
0.60E+06	0.269E-06	0.536E-08
0.80E+06	0.202E-06	0.402E-08
0.10E+07	0.161E-06	0.320E-08

Table 17. Decay Power of Thermal Fission of Pu^{239} After Long Irradiation (10^{13} seconds), H1 Function, Ratio Method Results

DECAY Time (Seconds)	DECAY Power (Mev/fission)	UNCERTAINTY
0.10E+01	0.102E+02	0.389E+00
0.15E+01	0.995E+01	0.330E+00
0.20E+01	0.979E+01	0.302E+00
0.40E+01	0.916E+01	0.266E+00
0.60E+01	0.873E+01	0.248E+00
0.80E+01	0.841E+01	0.237E+00
0.10E+02	0.816E+01	0.225E+00
0.15E+02	0.770E+01	0.211E+00
0.20E+02	0.738E+01	0.198E+00
0.40E+02	0.660E+01	0.168E+00
0.60E+02	0.614E+01	0.150E+00
0.80E+02	0.580E+01	0.138E+00
0.10E+03	0.557E+01	0.128E+00
0.15E+03	0.512E+01	0.113E+00
0.20E+03	0.485E+01	0.103E+00
0.40E+03	0.421E+01	0.839E-01
0.60E+03	0.386E+01	0.745E-01
0.80E+03	0.361E+01	0.680E-01
0.10E+04	0.339E+01	0.629E-01
0.15E+04	0.304E+01	0.550E-01
0.20E+04	0.278E+01	0.498E-01
0.40E+04	0.223E+01	0.405E-01
0.60E+04	0.197E+01	0.351E-01
0.80E+04	0.182E+01	0.325E-01
0.10E+05	0.172E+01	0.300E-01
0.15E+05	0.153E+01	0.276E-01
0.20E+05	0.142E+01	0.251E-01
0.40E+05	0.120E+01	0.221E-01
0.60E+05	0.108E+01	0.205E-01
0.80E+05	0.992E+00	0.195E-01
0.10E+06	0.936E+00	0.189E-01
0.15E+06	0.840E+00	0.170E-01
0.20E+06	0.779E+00	0.157E-01
0.40E+06	0.653E+00	0.132E-01
0.60E+06	0.584E+00	0.118E-01
0.80E+06	0.537E+00	0.107E-01
0.10E+07	0.500E+00	0.100E-01

Table 18. Decay Power of Thermal Fission of Pu^{239} After Fission Burst, H0 Function, Ratio Method Results

DECAY Time (Seconds)	DECAY Power (Mev/fis-sec)	UNCERTAINTY
0.10E+01	0.463E+00	0.184E+00
0.15E+01	0.415E+00	0.755E-01
0.20E+01	0.371E+00	0.333E-01
0.40E+01	0.247E+00	0.128E-01
0.60E+01	0.179E+00	0.769E-02
0.80E+01	0.138E+00	0.577E-02
0.10E+02	0.112E+00	0.507E-02
0.15E+02	0.748E-01	0.338E-02
0.20E+02	0.558E-01	0.251E-02
0.40E+02	0.283E-01	0.147E-02
0.60E+02	0.191E-01	0.102E-02
0.80E+02	0.141E-01	0.789E-03
0.10E+03	0.109E-01	0.606E-03
0.15E+03	0.677E-02	0.357E-03
0.20E+03	0.478E-02	0.229E-03
0.40E+03	0.218E-02	0.732E-04
0.60E+03	0.148E-02	0.457E-04
0.80E+03	0.113E-02	0.342E-04
0.10E+04	0.911E-03	0.256E-04
0.15E+04	0.597E-03	0.147E-04
0.20E+04	0.431E-03	0.930E-05
0.40E+04	0.173E-03	0.341E-05
0.60E+04	0.960E-04	0.197E-05
0.80E+04	0.640E-04	0.135E-05
0.10E+05	0.470E-04	0.101E-05
0.15E+05	0.268E-04	0.495E-06
0.20E+05	0.181E-04	0.283E-06
0.40E+05	0.791E-05	0.117E-06
0.60E+05	0.484E-05	0.689E-07
0.80E+05	0.336E-05	0.471E-07
0.10E+06	0.251E-05	0.357E-07
0.15E+06	0.148E-05	0.307E-07
0.20E+06	0.100E-05	0.207E-07
0.40E+06	0.430E-06	0.893E-08
0.60E+06	0.278E-06	0.570E-08
0.80E+06	0.204E-06	0.414E-08
0.10E+07	0.159E-06	0.320E-08

Table 19. Decay Power of Thermal Fission of Pu^{241} After Long Irradiation (10^{13} seconds), H1 Function, Ratio Method Results

DECAY Time (Seconds)	DECAY Power (Mev/fission)	UNCERTAINTY
0.10E+01	0.124E+02	0.571E+00
0.15E+01	0.121E+02	0.498E+00
0.20E+01	0.118E+02	0.462E+00
0.40E+01	0.108E+02	0.397E+00
0.60E+01	0.101E+02	0.360E+00
0.80E+01	0.966E+01	0.334E+00
0.10E+02	0.928E+01	0.314E+00
0.15E+02	0.864E+01	0.282E+00
0.20E+02	0.818E+01	0.260E+00
0.40E+02	0.713E+01	0.208E+00
0.60E+02	0.654E+01	0.178E+00
0.80E+02	0.613E+01	0.160E+00
0.10E+03	0.584E+01	0.147E+00
0.15E+03	0.532E+01	0.127E+00
0.20E+03	0.499E+01	0.116E+00
0.40E+03	0.429E+01	0.930E-01
0.60E+03	0.391E+01	0.819E-01
0.80E+03	0.364E+01	0.744E-01
0.10E+04	0.342E+01	0.688E-01
0.15E+04	0.305E+01	0.602E-01
0.20E+04	0.278E+01	0.548E-01
0.40E+04	0.220E+01	0.449E-01
0.60E+04	0.193E+01	0.387E-01
0.80E+04	0.177E+01	0.354E-01
0.10E+05	0.167E+01	0.326E-01
0.15E+05	0.148E+01	0.296E-01
0.20E+05	0.137E+01	0.270E-01
0.40E+05	0.117E+01	0.237E-01
0.60E+05	0.106E+01	0.219E-01
0.80E+05	0.978E+00	0.208E-01
0.10E+06	0.925E+00	0.202E-01
0.15E+06	0.837E+00	0.182E-01
0.20E+06	0.781E+00	0.170E-01
0.40E+06	0.664E+00	0.145E-01
0.60E+06	0.599E+00	0.131E-01
0.80E+06	0.555E+00	0.120E-01
0.10E+07	0.519E+00	0.113E-01

Table 20. Decay Power of Thermal Fission of Pu^{241} After Fission Burst, H0 Function, Ratio Method Results

DECAY Time (Seconds)	DECAY Power (Mev/fis-sec)	UNCERTAINTY
0.10E+01	0.810E+00	0.321E+00
0.15E+01	0.711E+00	0.129E+00
0.20E+01	0.626E+00	0.565E-01
0.40E+01	0.395E+00	0.223E-01
0.60E+01	0.277E+00	0.142E-01
0.80E+01	0.209E+00	0.103E-01
0.10E+02	0.165E+00	0.817E-02
0.15E+02	0.107E+00	0.512E-02
0.20E+02	0.778E-01	0.365E-02
0.40E+02	0.373E-01	0.189E-02
0.60E+02	0.244E-01	0.126E-02
0.80E+02	0.176E-01	0.912E-03
0.10E+03	0.134E-01	0.680E-03
0.15E+03	0.798E-02	0.372E-03
0.20E+03	0.548E-02	0.232E-03
0.40E+03	0.237E-02	0.807E-04
0.60E+03	0.158E-02	0.519E-04
0.80E+03	0.120E-02	0.386E-04
0.10E+04	0.956E-03	0.288E-04
0.15E+04	0.623E-03	0.162E-04
0.20E+04	0.450E-03	0.101E-04
0.40E+04	0.182E-03	0.386E-05
0.60E+04	0.101E-03	0.237E-05
0.80E+04	0.663E-04	0.164E-05
0.10E+05	0.480E-04	0.121E-05
0.15E+05	0.263E-04	0.582E-06
0.20E+05	0.172E-04	0.318E-06
0.40E+05	0.721E-05	0.124E-06
0.60E+05	0.444E-05	0.754E-07
0.80E+05	0.309E-05	0.520E-07
0.10E+06	0.232E-05	0.392E-07
0.15E+06	0.136E-05	0.305E-07
0.20E+06	0.924E-06	0.203E-07
0.40E+06	0.398E-06	0.867E-08
0.60E+06	0.264E-06	0.571E-08
0.80E+06	0.198E-06	0.428E-08
0.10E+07	0.156E-06	0.339E-08

Table 21. A Comparison of the Ratio Method Results for Pu^{239} Fast Fission After Long Irradiation, H1 Function, with Values Calculated Using Summation Method

SHUTDOWN Time Seconds	DIRECT CALCULATION Decay Power Mev/fission	Relative Uncertainty %	RATIO METHOD Decay Power Mev/fission	Relative Uncertainty %
1.0	0.941E+01	7.31	0.103E+02	3.83
1.5	0.920E+01	7.11	0.100E+02	3.35
2.0	0.902E+01	6.93	0.985E+01	3.12
4.0	0.849E+01	6.42	0.919E+01	2.94
6.0	0.813E+01	6.06	0.875E+01	2.87
8.0	0.785E+01	5.80	0.841E+01	2.84
10.0	0.763E+01	5.57	0.815E+01	2.81
15.0	0.722E+01	5.14	0.768E+01	2.79
20.0	0.693E+01	4.79	0.735E+01	2.73
40.0	0.624E+01	3.88	0.656E+01	2.61
60.0	0.584E+01	3.32	0.610E+01	2.51
80.0	0.556E+01	2.93	0.578E+01	2.45
100.0	0.534E+01	2.66	0.553E+01	2.38
150.0	0.496E+01	2.24	0.510E+01	2.27
200.0	0.470E+01	2.03	0.482E+01	2.20
400.0	0.413E+01	1.70	0.419E+01	2.06
600.0	0.380E+01	1.55	0.384E+01	2.01
800.0	0.356E+01	1.44	0.359E+01	1.97
1000.0	0.337E+01	1.35	0.338E+01	1.94
1500.0	0.301E+01	1.22	0.302E+01	1.91
2000.0	0.276E+01	1.16	0.276E+01	1.91
4000.0	0.221E+01	1.03	0.220E+01	1.95
6000.0	0.195E+01	0.89	0.195E+01	1.88
8000.0	0.178E+01	0.76	0.179E+01	1.86
10000.0	0.167E+01	0.66	0.169E+01	1.80
15000.0	0.149E+01	0.55	0.151E+01	1.83
20000.0	0.138E+01	0.54	0.140E+01	1.80
40000.0	0.115E+01	0.58	0.118E+01	1.88
60000.0	0.103E+01	0.59	0.106E+01	1.93
80000.0	0.954E+00	0.58	0.973E+00	1.99
100000.0	0.901E+00	0.57	0.917E+00	2.05
150000.0	0.814E+00	0.53	0.823E+00	2.04
200000.0	0.759E+00	0.49	0.763E+00	2.03
400000.0	0.639E+00	0.38	0.639E+00	2.03
600000.0	0.572E+00	0.32	0.571E+00	2.02
800000.0	0.525E+00	0.29	0.525E+00	2.00
1000000.0	0.490E+00	0.28	0.490E+00	2.01

the ratio predictions result in higher decay powers and smaller uncertainties than those of direct summation calculations. The error band stays about 3 % or less at short cooling times <200 seconds. As the cooling time increases, the error band is within about 2 %, even though there is a little variation. The one sigma uncertainties of the Pu^{239}(thermal) ANS 5.1 standard H1 function[9] is about 5 % at all cooling times, while the uncertainty of this ratio method for Pu^{239}(thermal) H1 function remains about 3 to 2 % or less at all cooling times as shown in Table 22. These comparisons show that the ratio method predicts quite reliable decay powers because of its small uncertainties. Figure 27 shows the comparison of the H1 function for Pu^{239}(fast) and the effectiveness of the ratio predictions. Figures 28 through 30 and Tables 23 through 26 also show the effectiveness of the ratio method for the other fissioning nuclides (U^{235}(fast), Pu^{240}(fast), Pu^{241}(fast), U^{238}(fast)).

Comparisons of the H0 function for these fissioning nuclides are also shown in Tables 27 through 31. The ratio method clearly reduces uncertainties, particularly at short cooling times <200 seconds. However, for very short cooling time, < 1.5 seconds, the uncertainty of the ratio prediction is larger than that of the direct summation calculation. The main sources of uncertainties in the ratio method are the uncertainties in the ratio of the H0 functions and in the ANS 5.1 standard U^{235}(thermal) H0 function as described in chapter II.C. The uncertainty of the ANS 5.1 U^{235} (thermal) H0 function is, however, 39.6 %[9] at very short cooling times <1.5 seconds.

Table 22. A Comparison of the Ratio Method Results for Pu^{239} Thermal Fission After Long Irradiation, H1 Function, with Values Calculated Using Summation Method

SHUTDOWN Time Seconds	DIRECT CALCULATION Decay Power Mev/fission	Relative Uncertainty %	RATIO METHOD Decay Power Mev/fission	Relative Uncertainty %
1.0	0.934E+01	7.23	0.102E+02	3.82
1.5	0.914E+01	7.02	0.995E+01	3.31
2.0	0.896E+01	6.86	0.979E+01	3.08
4.0	0.846E+01	6.35	0.916E+01	2.90
6.0	0.811E+01	6.00	0.873E+01	2.84
8.0	0.785E+01	5.73	0.841E+01	2.81
10.0	0.764E+01	5.51	0.816E+01	2.75
15.0	0.724E+01	5.08	0.770E+01	2.74
20.0	0.696E+01	4.74	0.738E+01	2.69
40.0	0.627E+01	3.81	0.660E+01	2.55
60.0	0.587E+01	3.24	0.614E+01	2.45
80.0	0.558E+01	2.85	0.580E+01	2.39
100.0	0.537E+01	2.55	0.557E+01	2.30
150.0	0.498E+01	2.13	0.512E+01	2.20
200.0	0.473E+01	1.90	0.485E+01	2.13
400.0	0.415E+01	1.53	0.421E+01	1.99
600.0	0.382E+01	1.35	0.386E+01	1.93
800.0	0.358E+01	1.20	0.361E+01	1.89
1000.0	0.338E+01	1.08	0.339E+01	1.85
1500.0	0.303E+01	0.88	0.304E+01	1.81
2000.0	0.278E+01	0.77	0.278E+01	1.79
4000.0	0.224E+01	0.63	0.223E+01	1.81
6000.0	0.197E+01	0.56	0.197E+01	1.78
8000.0	0.181E+01	0.50	0.182E+01	1.79
10000.0	0.170E+01	0.45	0.172E+01	1.75
15000.0	0.151E+01	0.40	0.153E+01	1.80
20000.0	0.140E+01	0.39	0.142E+01	1.77
40000.0	0.117E+01	0.42	0.120E+01	1.85
60000.0	0.105E+01	0.43	0.108E+01	1.90
80000.0	0.973E+00	0.43	0.992E+00	1.96
100000.0	0.919E+00	0.43	0.936E+00	2.02
150000.0	0.831E+00	0.42	0.840E+00	2.02
200000.0	0.775E+00	0.40	0.779E+00	2.01
400000.0	0.653E+00	0.33	0.653E+00	2.02
600000.0	0.585E+00	0.29	0.584E+00	2.01
800000.0	0.537E+00	0.27	0.537E+00	2.00
1000000.0	0.500E+00	0.26	0.500E+00	2.00

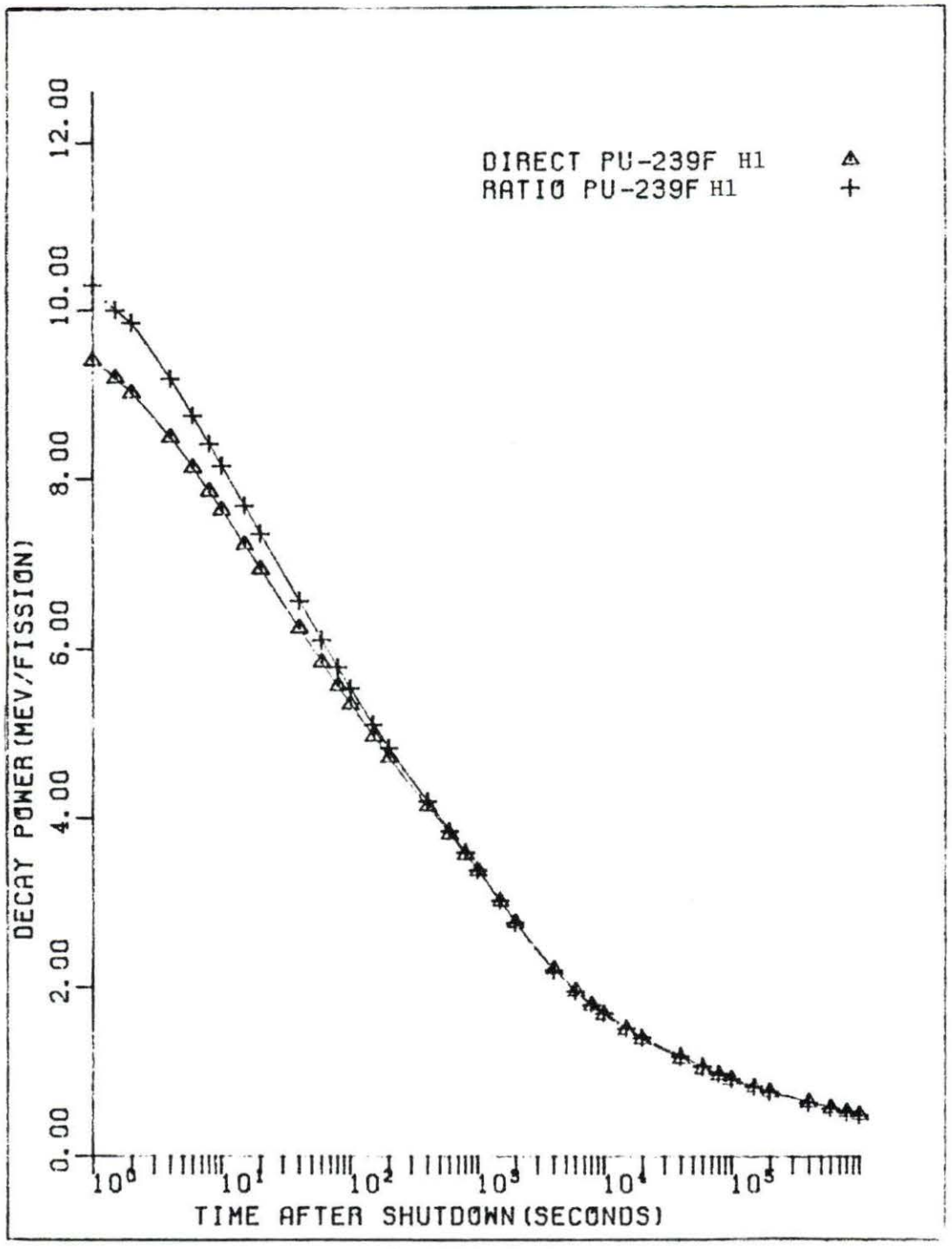


Figure 27. A Comparison of the Summation with the Ratio Results for Pu^{239} Fast Fission After Long Irradiation at a Constant Fission Rate

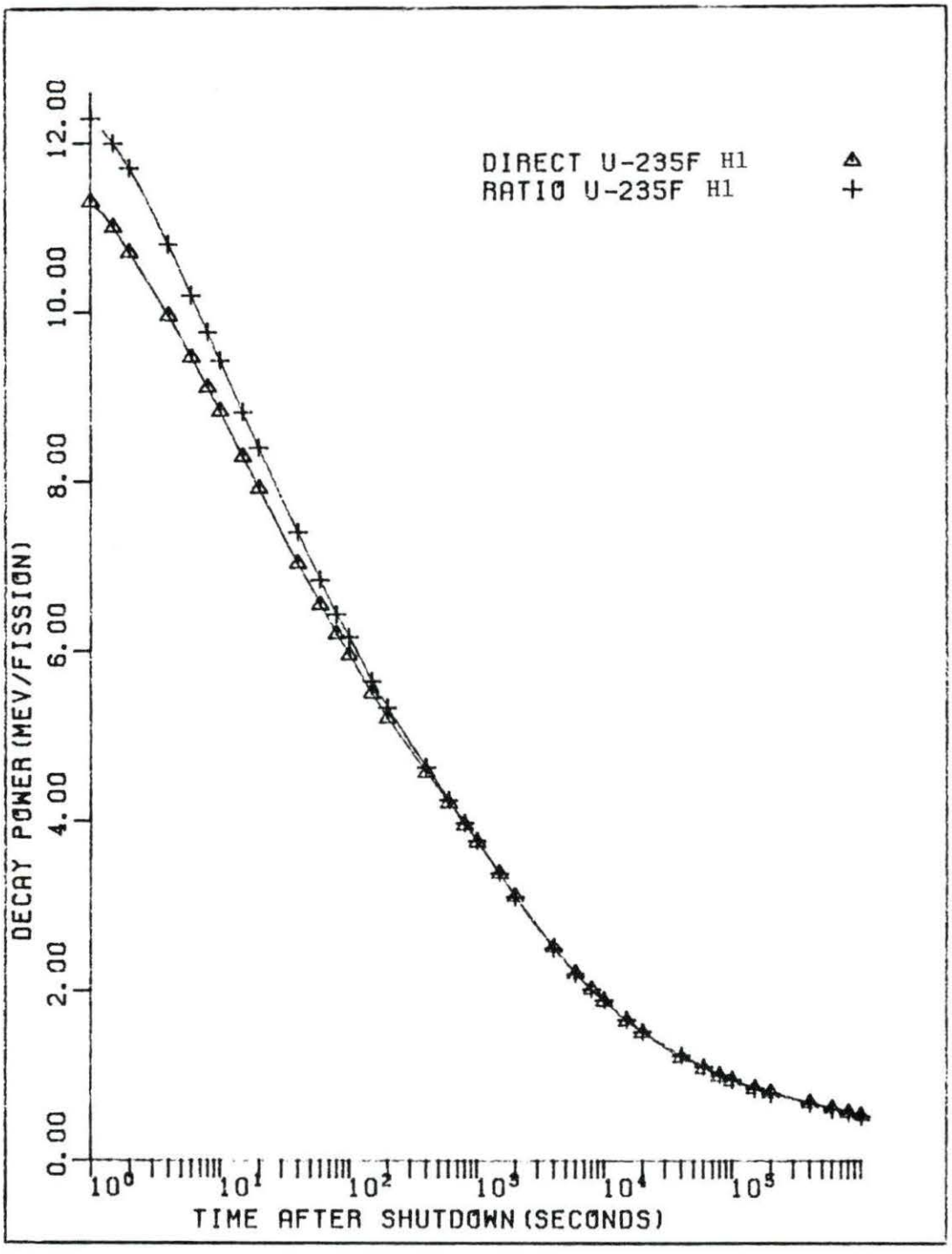


Figure 28. A Comparison of the Summation with the Ratio Results for U^{235} Fast Fission After Long Irradiation at a Constant Fission Rate

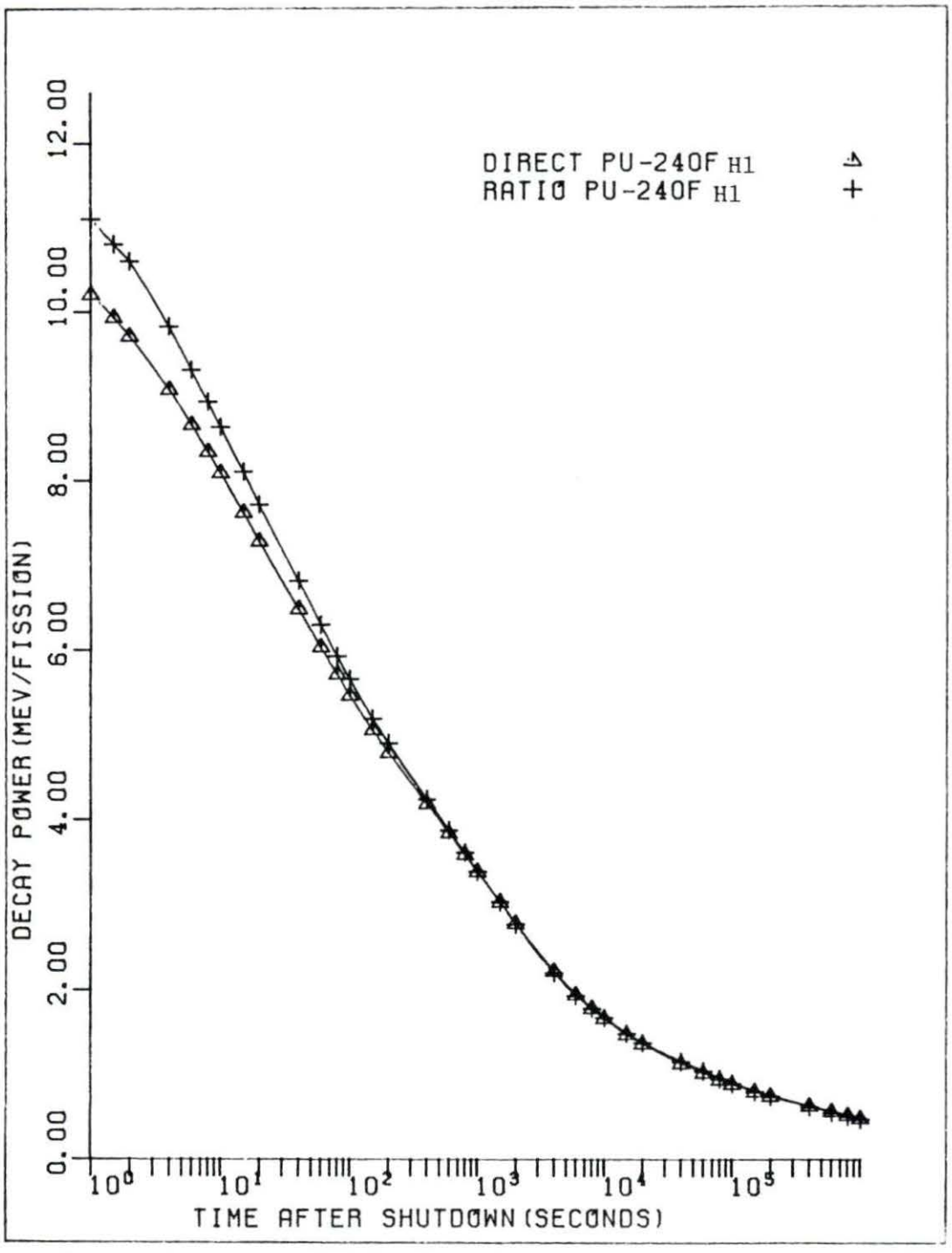


Figure 29. A Comparison of the Summation with the Ratio Results for Pu^{240} Fast Fission After Long Irradiation at a Constant Fission Rate

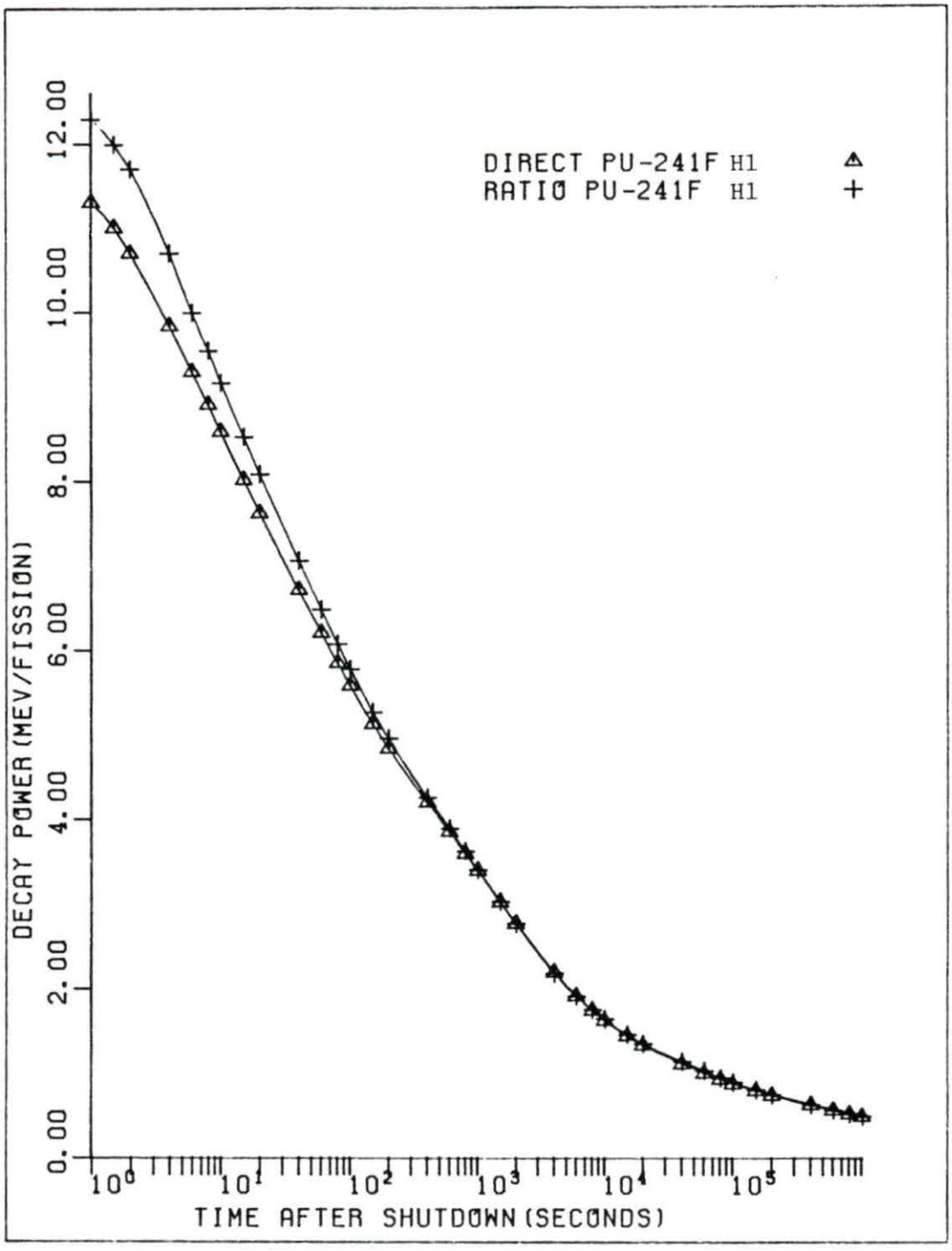


Figure 30. A Comparison of the Summation with the Ratio Results for Pu^{241} Fast Fission After Long Irradiation at a Constant Fission Rate

Table 23. A Comparison of the Ratio Method Results for U^{235} Fast Fission After Long Irradiation, H1 Function, with Values Calculated Using Summation Method

SHUTDOWN Time Seconds	DIRECT CALCULATION Decay Power Mev/fission	Relative Uncertainty %	RATIO METHOD Decay Power Mev/fission	Relative Uncertainty %
1.0	0.113E+02	7.08	0.123E+02	3.52
1.5	0.110E+02	6.77	0.120E+02	2.97
2.0	0.107E+02	6.54	0.117E+02	2.72
4.0	0.996E+01	5.83	0.108E+02	2.44
6.0	0.947E+01	5.36	0.102E+02	2.33
8.0	0.911E+01	5.01	0.977E+01	2.26
10.0	0.883E+01	4.72	0.943E+01	2.18
15.0	0.829E+01	4.20	0.882E+01	2.13
20.0	0.792E+01	3.79	0.840E+01	2.08
40.0	0.704E+01	2.80	0.741E+01	1.94
60.0	0.655E+01	2.26	0.685E+01	1.89
80.0	0.620E+01	1.95	0.644E+01	1.88
100.0	0.595E+01	1.75	0.617E+01	1.86
150.0	0.550E+01	1.51	0.565E+01	1.85
200.0	0.521E+01	1.41	0.534E+01	1.84
400.0	0.457E+01	1.27	0.464E+01	1.81
600.0	0.421E+01	1.19	0.425E+01	1.80
800.0	0.395E+01	1.11	0.398E+01	1.80
1000.0	0.375E+01	1.04	0.377E+01	1.79
1500.0	0.338E+01	0.90	0.339E+01	1.79
2000.0	0.311E+01	0.81	0.311E+01	1.78
4000.0	0.252E+01	0.66	0.251E+01	1.80
6000.0	0.221E+01	0.57	0.221E+01	1.76
8000.0	0.202E+01	0.50	0.203E+01	1.77
10000.0	0.188E+01	0.43	0.190E+01	1.74
15000.0	0.165E+01	0.35	0.167E+01	1.78
20000.0	0.151E+01	0.33	0.153E+01	1.75
40000.0	0.122E+01	0.31	0.125E+01	1.83
60000.0	0.109E+01	0.31	0.112E+01	1.88
80000.0	0.100E+01	0.30	0.102E+01	1.94
100000.0	0.946E+00	0.29	0.963E+00	2.00
150000.0	0.857E+00	0.27	0.866E+00	2.00
200000.0	0.803E+00	0.26	0.807E+00	2.00
400000.0	0.688E+00	0.24	0.688E+00	2.01
600000.0	0.623E+00	0.24	0.622E+00	2.01
800000.0	0.576E+00	0.24	0.576E+00	2.00
1000000.0	0.540E+00	0.25	0.540E+00	2.00

Table 24. A Comparison of the Ratio Method Results for Pu^{240} Fast Fission After Long Irradiation, H1 Function, with Values Calculated Using Summation Method

SHUTDOWN Time Seconds	DIRECT CALCULATION Decay Power Mev/fission	Relative Uncertainty %	RATIO METHOD Decay Power Mev/fission	Relative Uncertainty %
1.0	0.102E+02	8.34	0.111E+02	4.05
1.5	0.993E+01	8.11	0.108E+02	3.60
2.0	0.971E+01	7.89	0.106E+02	3.39
4.0	0.908E+01	7.24	0.983E+01	3.21
6.0	0.866E+01	6.79	0.932E+01	3.13
8.0	0.834E+01	6.46	0.894E+01	3.11
10.0	0.809E+01	6.19	0.864E+01	3.06
15.0	0.762E+01	5.67	0.811E+01	2.99
20.0	0.728E+01	5.27	0.772E+01	2.94
40.0	0.648E+01	4.24	0.682E+01	2.79
60.0	0.603E+01	3.62	0.630E+01	2.65
80.0	0.571E+01	3.20	0.593E+01	2.58
100.0	0.546E+01	2.91	0.566E+01	2 50
150.0	0.505E+01	2.50	0.519E+01	2.39
200.0	0.478E+01	2.28	0.490E+01	2.32
400.0	0.418E+01	1.99	0.424E+01	2.18
600.0	0.384E+01	1.85	0.388E+01	2.13
800.0	0.359E+01	1.75	0.362E+01	2.09
1000.0	0.339E+01	1.67	0.340E+01	2.07
1500.0	0.303E+01	1.55	0.304E+01	2.06
2000.0	0.278E+01	1.49	0.278E+01	2.08
4000.0	0.222E+01	1.40	0.221E+01	2.15
6000.0	0.194E+01	1.34	0.194E+01	2.11
8000.0	0.178E+01	1.26	0.179E+01	2.09
10000.0	0.166E+01	1.21	0.168E+01	2.05
15000.0	0.147E+01	1.16	0.149E+01	2.08
20000.0	0.136E+01	1.15	0.138E+01	2.06
40000.0	0.113E+01	1.15	0.116E+01	2.11
60000.0	0.102E+01	1.14	0.105E+01	2.15
80000.0	0.941E+00	1.13	0.960E+00	2.20
100000.0	0.888E+00	1.12	0.904E+00	2.25
150000.0	0.802E+00	1.11	0.811E+00	2.24
200000.0	0.749E+00	1.10	0.753E+00	2.24
400000.0	0.633E+00	1.07	0.633E+00	2.25
600000.0	0.568E+00	1.05	0.567E+00	2.25
800000.0	0.523E+00	1.03	0.523E+00	2.23
1000000.0	0.489E+00	1.02	0.489E+00	2.23

Table 25. A Comparison of the Ratio Method Results for Pu^{241} Fast Fission After Long Irradiation, H1 Function, with Values Calculated Using Summation Method

SHUTDOWN Time Seconds	DIRECT CALCULATION Decay Power Mev/fission	Relative Uncertainty %	RATIO METHOD Decay Power Mev/fission	Relative Uncertainty %
1.0	0.113E+02	9.56	0.123E+02	4.59
1.5	0.110E+02	9.18	0.120E+02	4.08
2.0	0.107E+02	8.93	0.117E+02	3.88
4.0	0.984E+01	8.12	0.107E+02	3.68
6.0	0.930E+01	7.55	0.100E+02	3.56
8.0	0.891E+01	7.13	0.955E+01	3.47
10.0	0.859E+01	6.81	0.917E+01	3.42
15.0	0.802E+01	6.20	0.853E+01	3.31
20.0	0.763E+01	5.74	0.809E+01	3.22
40.0	0.672E+01	4.55	0.707E+01	3.00
60.0	0.621E+01	3.83	0.649E+01	2.81
80.0	0.585E+01	3.37	0.608E+01	2.71
100.0	0.558E+01	3.05	0.578E+01	2.61
150.0	0.513E+01	2.59	0.527E+01	2.48
200.0	0.484E+01	2.36	0.496E+01	2.40
400.0	0.420E+01	2.01	0.426E+01	2.24
600.0	0.385E+01	1.85	0.389E+01	2.16
800.0	0.359E+01	1.73	0.362E+01	2.11
1000.0	0.339E+01	1.63	0.340E+01	2.08
1500.0	0.302E+01	1.49	0.303E+01	2.05
2000.0	0.277E+01	1.42	0.277E+01	2.06
4000.0	0.220E+01	1.33	0.219E+01	2.12
6000.0	0.192E+01	1.24	0.192E+01	2.08
8000.0	0.175E+01	1.17	0.176E+01	2.06
10000.0	0.163E+01	1.10	0.165E+01	2.01
15000.0	0.145E+01	1.03	0.147E+01	2.03
20000.0	0.134E+01	1.02	0.136E+01	2.00
40000.0	0.112E+01	1.03	0.115E+01	2.06
60000.0	0.101E+01	1.03	0.104E+01	2.11
80000.0	0.938E+00	1.02	0.957E+00	2.15
100000.0	0.887E+00	1.01	0.903E+00	2.20
150000.0	0.804E+00	1.00	0.813E+00	2.20
200000.0	0.752E+00	0.99	0.756E+00	2.19
400000.0	0.639E+00	0.97	0.639E+00	2.20
600000.0	0.576E+00	0.95	0.575E+00	2.20
800000.0	0.532E+00	0.93	0.532E+00	2.18
1000000.0	0.498E+00	0.93	0.498E+00	2.18

Table 26. A Comparison of the Ratio Method Results for U^{238} Fast Fission After Long Irradiation, H1 Function, with Values Calculated Using Summation Method

SHUTDOWN Time Seconds	DIRECT CALCULATION Decay Power Mev/fission	Relative Uncertainty %	RATIO METHOD Decay Power Mev/fission	Relative Uncertainty %
1.0	0.135E+02	10.30	0.147E+02	4.58
1.5	0.130E+02	9.69	0.142E+02	3.98
2.0	0.125E+02	9.28	0.137E+02	3.69
4.0	0.113E+02	8.06	0.122E+02	3.30
6.0	0.105E+02	7.31	0.113E+02	3.10
8.0	0.100E+02	6.76	0.107E+02	2.96
10.0	0.959E+01	6.35	0.102E+02	2.85
15.0	0.886E+01	5.65	0.942E+01	2.71
20.0	0.836E+01	5.17	0.887E+01	2.63
40.0	0.728E+01	3.94	0.766E+01	2.42
60.0	0.669E+01	3.26	0.699E+01	2.30
80.0	0.629E+01	2.83	0.653E+01	2.24
100.0	0.599E+01	2.54	0.621E+01	2.17
150.0	0.548E+01	2.15	0.563E+01	2.11
200.0	0.515E+01	1.96	0.528E+01	2.07
400.0	0.445E+01	1.71	0.451E+01	1.99
600.0	0.408E+01	1.60	0.412E+01	1.96
800.0	0.381E+01	1.50	0.384E+01	1.94
1000.0	0.360E+01	1.43	0.362E+01	1.92
1500.0	0.322E+01	1.30	0.323E+01	1.91
2000.0	0.296E+01	1.24	0.296E+01	1.92
4000.0	0.238E+01	1.16	0.237E+01	1.98
6000.0	0.209E+01	1.15	0.209E+01	1.96
8000.0	0.191E+01	1.13	0.192E+01	1.97
10000.0	0.178E+01	1.13	0.180E+01	1.95
15000.0	0.157E+01	1.13	0.159E+01	2.02
20000.0	0.144E+01	1.14	0.146E+01	2.00
40000.0	0.119E+01	1.15	0.122E+01	2.07
60000.0	0.106E+01	1.17	0.109E+01	2.14
80000.0	0.977E+00	1.17	0.996E+00	2.19
100000.0	0.922E+00	1.17	0.939E+00	2.25
150000.0	0.833E+00	1.16	0.842E+00	2.25
200000.0	0.778E+00	1.15	0.782E+00	2.24
400000.0	0.660E+00	1.13	0.660E+00	2.25
600000.0	0.593E+00	1.10	0.592E+00	2.25
800000.0	0.545E+00	1.08	0.545E+00	2.23
1000000.0	0.508E+00	1.07	0.508E+00	2.23

Table 27. A Comparison of the Ratio Method Results for Pu^{239} Fast Fission After Fission Burst, H0 Function, with Values Calculated Using Summation Method

SHUTDOWN Time Seconds	DIRECT CALCULATION Decay Power Mev/fis-sec	Relative Uncertainty %	RATIO METHOD Decay Power Mev/fis-sec	Relative Uncertainty %
1.0	0.472E+00	16.95	0.489E+00	39.77
1.5	0.393E+00	16.64	0.436E+00	18.21
2.0	0.337E+00	16.38	0.390E+00	8.99
4.0	0.212E+00	15.61	0.258E+00	5.30
6.0	0.154E+00	15.00	0.186E+00	4.73
8.0	0.121E+00	14.63	0.144E+00	4.27
10.0	0.996E-01	14.36	0.116E+00	4.28
15.0	0.678E-01	14.16	0.766E-01	4.45
20.0	0.505E-01	14.10	0.566E-01	4.42
40.0	0.247E-01	13.64	0.283E-01	5.18
60.0	0.165E-01	12.61	0.190E-01	5.66
80.0	0.123E-01	11.46	0.140E-01	5.75
100.0	0.969E-02	10.53	0.109E-01	5.73
150.0	0.605E-02	8.63	0.673E-02	5.46
200.0	0.429E-02	7.27	0.474E-02	4.99
400.0	0.201E-02	4.44	0.216E-02	3.51
600.0	0.138E-02	4.06	0.147E-02	3.21
800.0	0.107E-02	3.95	0.113E-02	3.11
1000.0	0.873E-03	3.79	0.915E-03	2.90
1500.0	0.587E-03	3.22	0.605E-03	2.52
2000.0	0.429E-03	2.73	0.437E-03	2.21
4000.0	0.177E-03	2.21	0.174E-03	2.32
6000.0	0.100E-03	2.63	0.960E-04	2.94
8000.0	0.665E-04	2.90	0.636E-04	3.25
10000.0	0.484E-04	2.91	0.465E-04	3.30
15000.0	0.273E-04	2.23	0.265E-04	2.57
20000.0	0.184E-04	1.41	0.180E-04	1.82
40000.0	0.767E-05	0.67	0.784E-05	1.51
60000.0	0.459E-05	0.77	0.479E-05	1.49
80000.0	0.312E-05	0.89	0.331E-05	1.51
100000.0	0.230E-05	1.00	0.248E-05	1.56
150000.0	0.133E-05	1.20	0.146E-05	2.22
200000.0	0.918E-06	1.31	0.988E-06	2.21
400000.0	0.416E-06	1.23	0.421E-06	2.18
600000.0	0.274E-06	1.02	0.273E-06	2.10
800000.0	0.202E-06	0.83	0.201E-06	2.06
1000000.0	0.157E-06	0.67	0.155E-06	2.03

Table 28. A Comparison of the Ratio Method Results for U^{238} Fast Fission After Fission Burst, H0 Function, with Values Calculated Using Summation Method

SHUTDOWN Time Seconds	DIRECT CALCULATION Decay Power Mev/fis-sec	Relative Uncertainty %	RATIO METHOD Decay Power Mev/fis-sec	Relative Uncertainty %
1.0	0.127E+01	22.83	0.131E+01	39.67
1.5	0.101E+01	22.08	0.112E+01	18.00
2.0	0.831E+00	21.54	0.961E+00	8.70
4.0	0.463E+00	19.98	0.563E+00	5.16
6.0	0.311E+00	18.33	0.376E+00	4.46
8.0	0.232E+00	16.90	0.275E+00	4.03
10.0	0.183E+00	16.01	0.213E+00	4.03
15.0	0.117E+00	14.79	0.132E+00	3.39
20.0	0.840E-01	14.29	0.942E-01	3.33
40.0	0.369E-01	13.36	0.422E-01	3.29
60.0	0.235E-01	11.87	0.270E-01	3.39
80.0	0.170E-01	10.41	0.193E-01	3.47
100.0	0.131E-01	9.16	0.148E-01	3.22
150.0	0.795E-02	7.07	0.885E-02	3.11
200.0	0.549E-02	5.76	0.606E-02	2.92
400.0	0.236E-02	3.58	0.253E-02	2.50
600.0	0.154E-02	3.42	0.165E-02	2.48
800.0	0.116E-02	3.46	0.123E-02	2.55
1000.0	0.936E-03	3.39	0.981E-03	2.42
1500.0	0.619E-03	3.02	0.638E-03	2.25
2000.0	0.451E-03	2.62	0.460E-03	2.06
4000.0	0.191E-03	1.63	0.188E-03	2.00
6000.0	0.111E-03	1.47	0.107E-03	2.01
8000.0	0.751E-04	1.46	0.718E-04	1.97
10000.0	0.554E-04	1.44	0.532E-04	1.96
15000.0	0.313E-04	1.30	0.304E-04	1.76
20000.0	0.208E-04	1.19	0.204E-04	1.60
40000.0	0.839E-05	1.17	0.857E-05	1.65
60000.0	0.490E-05	1.25	0.511E-05	1.64
80000.0	0.327E-05	1.31	0.347E-05	1.65
100000.0	0.237E-05	1.35	0.256E-05	1.68
150000.0	0.134E-05	1.39	0.147E-05	2.26
200000.0	0.911E-06	1.41	0.981E-06	2.24
400000.0	0.414E-06	1.42	0.419E-06	2.25
600000.0	0.278E-06	1.40	0.277E-06	2.24
800000.0	0.207E-06	1.40	0.205E-06	2.26
1000000.0	0.163E-06	1.39	0.161E-06	2.28

Table 29. A Comparison of the Ratio Method Results for Pu^{240} Fast Fission After Fission Burst, H0 Function, with Values Calculated Using Summation Method

SHUTDOWN Time Seconds	DIRECT CALCULATION Decay Power Mev/fis-sec	DIRECT CALCULATION Relative Uncertainty %	RATIO METHOD Decay Power Mev/fis-sec	RATIO METHOD Relative Uncertainty %
1.0	0.568E+00	19.01	0.588E+00	39.65
1.5	0.471E+00	18.68	0.522E+00	18.01
2.0	0.402E+00	18.41	0.465E+00	8.73
4.0	0.249E+00	17.51	0.303E+00	5.27
6.0	0.180E+00	16.67	0.218E+00	4.56
8.0	0.140E+00	16.07	0.166E+00	4.43
10.0	0.115E+00	15.65	0.134E+00	4.76
15.0	0.783E-01	15.20	0.885E-01	4.70
20.0	0.584E-01	14.97	0.655E-01	4.51
40.0	0.283E-01	14.17	0.324E-01	4.99
60.0	0.187E-01	12.89	0.215E-01	5.13
80.0	0.138E-01	11.59	0.157E-01	5.23
100.0	0.107E-01	10.56	0.120E-01	5.17
150.0	0.654E-02	8.61	0.728E-02	5.02
200.0	0.458E-02	7.21	0.506E-02	4.62
400.0	0.209E-02	4.53	0.224E-02	3.46
600.0	0.142E-02	4.20	0.152E-02	3.22
800.0	0.109E-02	4.14	0.115E-02	3.16
1000.0	0.885E-03	3.99	0.927E-03	2.94
1500.0	0.592E-03	3.46	0.610E-03	2.55
2000.0	0.433E-03	2.96	0.441E-03	2.23
4000.0	0.182E-03	2.21	0.179E-03	2.28
6000.0	0.104E-03	2.42	0.998E-04	2.69
8000.0	0.689E-04	2.63	0.659E-04	2.91
10000.0	0.500E-04	2.64	0.480E-04	2.96
15000.0	0.277E-04	2.18	0.269E-04	2.51
20000.0	0.184E-04	1.65	0.180E-04	2.02
40000.0	0.755E-05	1.40	0.771E-05	1.92
60000.0	0.454E-05	1.48	0.474E-05	1.91
80000.0	0.309E-05	1.49	0.328E-05	1.87
100000.0	0.228E-05	1.45	0.246E-05	1.83
150000.0	0.131E-05	1.38	0.143E-05	2.30
200000.0	0.897E-06	1.37	0.966E-06	2.24
400000.0	0.400E-06	1.38	0.405E-06	2.25
600000.0	0.262E-06	1.34	0.261E-06	2.24
800000.0	0.193E-06	1.28	0.192E-06	2.24
1000000.0	0.151E-06	1.23	0.149E-06	2.24

Table 30. A Comparison of the Ratio Method Results for Pu^{241} Fast Fission After Fission Burst, H0 Function, with Values Calculated Using Summation Method

SHUTDOWN Time Seconds	DIRECT CALCULATION Decay Power Mev/fis-sec	Relative Uncertainty %	RATIO METHOD Decay Power Mev/fis-sec	Relative Uncertainty %
1.0	0.769E+00	20.81	0.796E+00	39.67
1.5	0.631E+00	20.44	0.700E+00	18.05
2.0	0.533E+00	20.08	0.616E+00	8.80
4.0	0.321E+00	19.07	0.391E+00	5.56
6.0	0.227E+00	17.93	0.275E+00	5.02
8.0	0.174E+00	17.07	0.207E+00	4.83
10.0	0.141E+00	16.45	0.164E+00	4.80
15.0	0.931E-01	15.79	0.105E+00	4.64
20.0	0.680E-01	15.59	0.762E-01	4.53
40.0	0.318E-01	14.87	0.364E-01	5.14
60.0	0.208E-01	13.51	0.239E-01	5.31
80.0	0.152E-01	12.17	0.173E-01	5.38
100.0	0.117E-01	11.03	0.132E-01	5.26
150.0	0.707E-02	8.81	0.787E-02	4.93
200.0	0.490E-02	7.31	0.541E-02	4.52
400.0	0.219E-02	4.70	0.235E-02	3.58
600.0	0.147E-02	4.41	0.157E-02	3.42
800.0	0.112E-02	4.34	0.118E-02	3.37
1000.0	0.908E-03	4.15	0.951E-03	3.13
1500.0	0.605E-03	3.52	0.623E-03	2.68
2000.0	0.442E-03	2.94	0.451E-03	2.32
4000.0	0.185E-03	2.15	0.182E-03	2.26
6000.0	0.105E-03	2.41	0.101E-03	2.69
8000.0	0.692E-04	2.63	0.662E-04	2.92
10000.0	0.499E-04	2.65	0.479E-04	2.99
15000.0	0.272E-04	2.15	0.264E-04	2.53
20000.0	0.177E-04	1.56	0.173E-04	2.00
40000.0	0.720E-05	1.14	0.736E-05	1.79
60000.0	0.435E-05	1.21	0.454E-05	1.78
80000.0	0.298E-05	1.25	0.317E-05	1.76
100000.0	0.220E-05	1.27	0.237E-05	1.76
150000.0	0.126E-05	1.30	0.138E-05	2.29
200000.0	0.868E-06	1.31	0.935E-06	2.24
400000.0	0.392E-06	1.27	0.397E-06	2.21
600000.0	0.259E-06	1.21	0.258E-06	2.19
800000.0	0.192E-06	1.16	0.191E-06	2.18
1000000.0	0.151E-06	1.12	0.149E-06	2.19

Table 31. A Comparison of the Ratio Method Results for U^{235} Fast Fission After Fission Burst, H0 Function, with Values Calculated Using Summation Method

SHUTDOWN Time Seconds	DIRECT CALCULATION Decay Power Mev/fis-sec	Relative Uncertainty %	RATIO METHOD Decay Power Mev/fis-sec	Relative Uncertainty %
1.0	0.719E+00	17.94	0.744E+00	39.55
1.5	0.581E+00	17.38	0.644E+00	17.82
2.0	0.486E+00	16.95	0.562E+00	8.34
4.0	0.289E+00	15.88	0.352E+00	4.46
6.0	0.205E+00	14.93	0.248E+00	3.80
8.0	0.159E+00	14.28	0.189E+00	3.41
10.0	0.130E+00	13.77	0.151E+00	3.58
15.0	0.877E-01	13.23	0.991E-01	2.98
20.0	0.651E-01	12.93	0.730E-01	2.78
40.0	0.308E-01	11.56	0.352E-01	2.54
60.0	0.201E-01	9.75	0.231E-01	2.22
80.0	0.147E-01	8.23	0.167E-01	2.23
100.0	0.114E-01	6.98	0.128E-01	2.06
150.0	0.701E-02	5.01	0.780E-02	2.09
200.0	0.491E-02	3.93	0.542E-02	2.03
400.0	0.221E-02	2.63	0.237E-02	1.93
600.0	0.148E-02	2.72	0.158E-02	1.92
800.0	0.113E-02	2.85	0.120E-02	2.03
1000.0	0.915E-03	2.91	0.959E-03	1.94
1500.0	0.616E-03	2.78	0.635E-03	1.93
2000.0	0.455E-03	2.51	0.464E-03	1.86
4000.0	0.199E-03	1.65	0.196E-03	1.97
6000.0	0.118E-03	1.62	0.113E-03	2.04
8000.0	0.810E-04	1.68	0.775E-04	2.02
10000.0	0.602E-04	1.63	0.578E-04	2.00
15000.0	0.346E-04	1.28	0.336E-04	1.71
20000.0	0.232E-04	0.94	0.227E-04	1.49
40000.0	0.914E-05	0.57	0.934E-05	1.45
60000.0	0.517E-05	0.55	0.539E-05	1.39
80000.0	0.338E-05	0.58	0.359E-05	1.36
100000.0	0.242E-05	0.61	0.261E-05	1.38
150000.0	0.133E-05	0.69	0.146E-05	2.05
200000.0	0.891E-06	0.71	0.959E-06	2.02
400000.0	0.398E-06	0.55	0.403E-06	2.02
600000.0	0.270E-06	0.41	0.269E-06	1.99
800000.0	0.204E-06	0.35	0.202E-06	1.99
1000000.0	0.163E-06	0.31	0.161E-06	1.99

So, this large uncertainty source at the very short cooling time contributes to produce large uncertainty in the ratio prediction. The uncertainty of the H0 function of Pu^{239}(thermal) ANS 5.1 standard at the very short cooling time <1.5 second is evaluated as 54 %[9], while the ratio method in this study yields about 40 % as shown in Table 32.

In addition, we can see the effectiveness of the ratio method in predicting decay powers of the H1 function for short cooling times < 200 seconds by comparing the decay power from the ENDF/B-V data file with that from the ENDF/B-IV data file. Figures 31 through 33 and Table 33 represent the ratios of the H1 function from the ENDF/B-V to that from ENDF/B-IV data file for U^{235}(fast), Pu^{239}(thermal), Pu^{241} (thermal) when the ratio method is used. There is no significant difference in these comparisons at all cooling times. However, the ratios of the H1 function, when the summation method is used as shown at Figures 8 through 11, show large underprediction at short cooling times < 200 seconds when ENDF/B-V data are used. Figure 34 and Table 33 represent the ratios of H1 function from the ENDF/B-V to that from the ENDF/B-IV data file for U^{238}(fast) when the ratio method is used. The ratios are less than unity at the short cooling times < 200 seconds. This probably means that even the ratio method underpredicts U^{238}(fast) H1 function at the short cooling times < 200 seconds when the ENDF/B-V decay data is used. Because U^{238} has high neutron to proton ratios, its fission products are well above the stability range and decay power from U^{238}(fast) is relatively high.

Table 32. A Comparison of the Ratio Method Results for Pu^{239} Thermal Fission After Fission Burst, H0 Function, with Values Calculated Using Summation Method

SHUTDOWN Time Seconds	DIRECT CALCULATION Decay Power Mev/fis-sec	Relative Uncertainty %	RATIO METHOD Decay Power Mev/fis-sec	Relative Uncertainty %
1.0	0.447E+00	17.11	0.463E+00	39.76
1.5	0.374E+00	16.74	0.415E+00	18.20
2.0	0.321E+00	16.48	0.371E+00	8.97
4.0	0.203E+00	15.67	0.247E+00	5.19
6.0	0.148E+00	15.07	0.179E+00	4.30
8.0	0.116E+00	14.74	0.138E+00	4.19
10.0	0.960E-01	14.48	0.112E+00	4.54
15.0	0.662E-01	14.26	0.748E-01	4.52
20.0	0.498E-01	14.20	0.558E-01	4.50
40.0	0.247E-01	13.68	0.283E-01	5.19
60.0	0.166E-01	12.53	0.191E-01	5.35
80.0	0.124E-01	11.37	0.141E-01	5.59
100.0	0.970E-02	10.41	0.109E-01	5.55
150.0	0.608E-02	8.49	0.677E-02	5.27
200.0	0.433E-02	7.11	0.478E-02	4.78
400.0	0.203E-02	4.30	0.218E-02	3.36
600.0	0.139E-02	3.91	0.148E-02	3.08
800.0	0.107E-02	3.84	0.113E-02	3.02
1000.0	0.869E-03	3.69	0.911E-03	2.81
1500.0	0.580E-03	3.14	0.597E-03	2.46
2000.0	0.423E-03	2.60	0.431E-03	2.16
4000.0	0.176E-03	1.44	0.173E-03	1.97
6000.0	0.100E-03	1.47	0.960E-04	2.05
8000.0	0.669E-04	1.63	0.640E-04	2.11
10000.0	0.489E-04	1.67	0.470E-04	2.15
15000.0	0.276E-04	1.36	0.268E-04	1.85
20000.0	0.185E-04	0.96	0.181E-04	1.56
40000.0	0.774E-05	0.53	0.791E-05	1.48
60000.0	0.464E-05	0.55	0.484E-05	1.42
80000.0	0.316E-05	0.59	0.336E-05	1.40
100000.0	0.233E-05	0.64	0.251E-05	1.42
150000.0	0.135E-05	0.74	0.148E-05	2.07
200000.0	0.933E-06	0.82	0.100E-05	2.06
400000.0	0.424E-06	0.92	0.430E-06	2.08
600000.0	0.279E-06	0.83	0.278E-06	2.05
800000.0	0.206E-06	0.70	0.204E-06	2.02
1000000.0	0.161E-06	0.57	0.159E-06	2.01

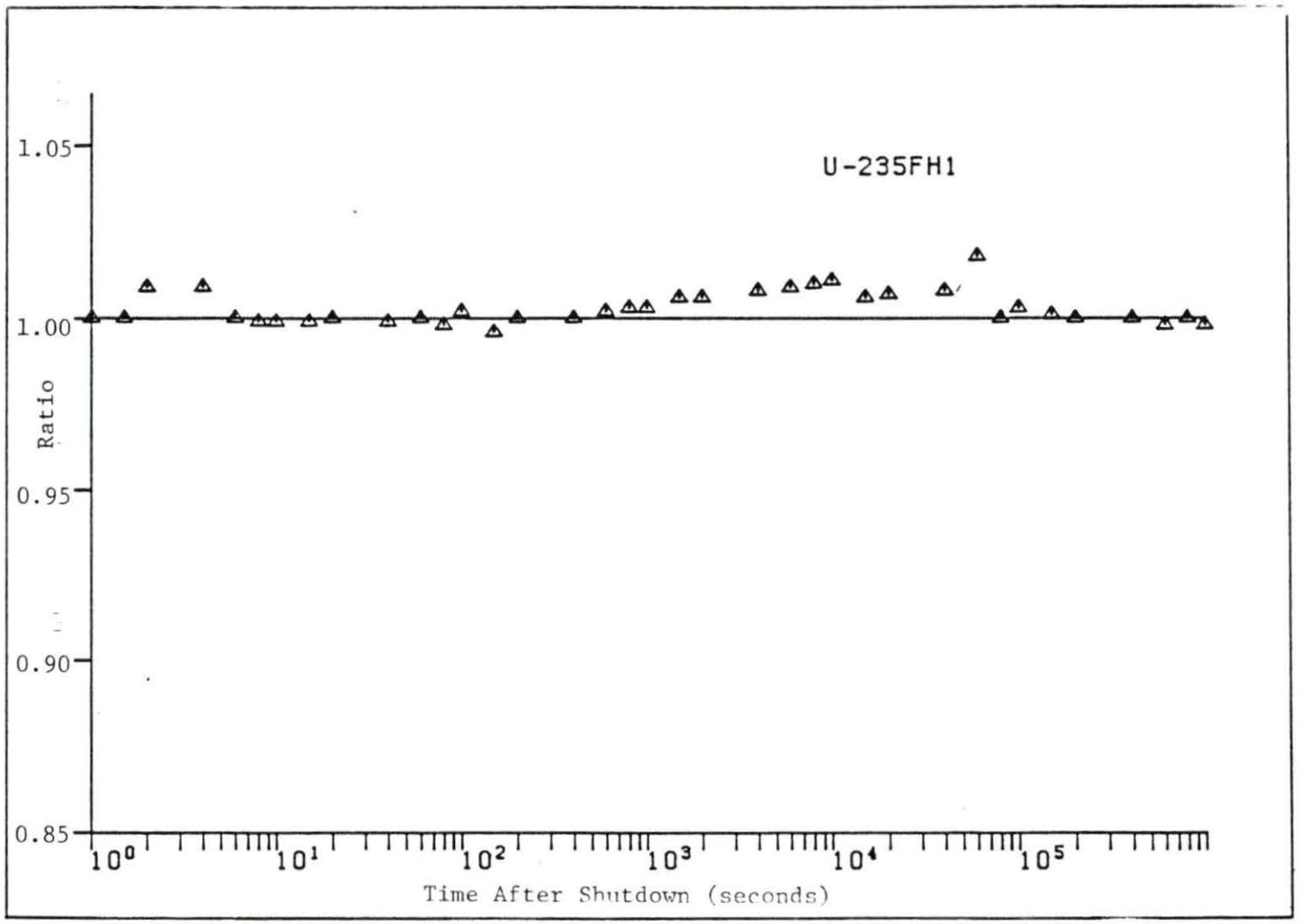


Figure 31. Ratio of Predictions, ENDF/B-V:ENDF/B-IV U^{235}(fast)
Long Irradiation, H1 Function, Ratio Method

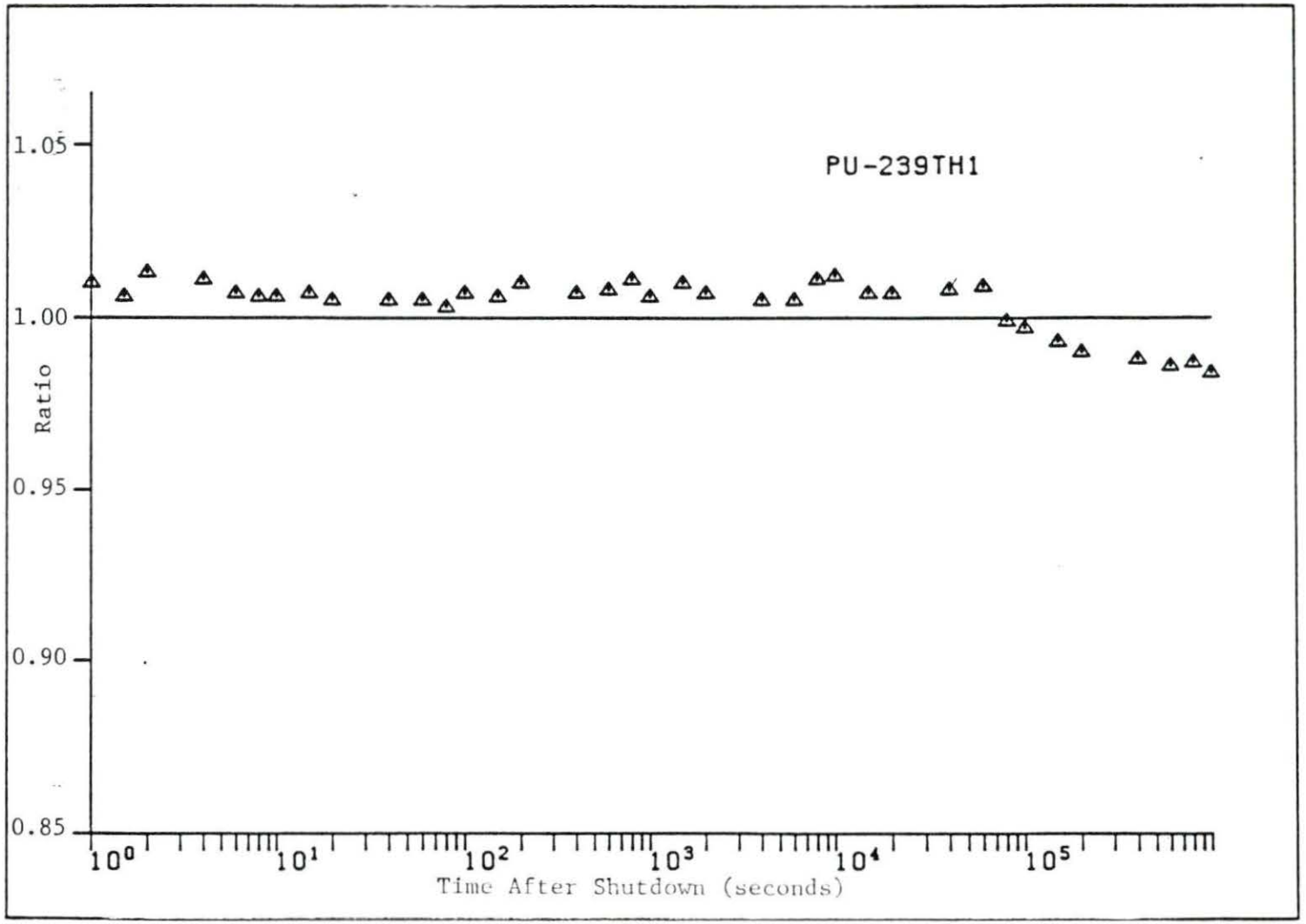


Figure 32. Ratio of Predictions, ENDF/B-V:ENDF/B-IV Pu^{239} (thermal)
Long Irradiation, H1 Function, Ratio Method

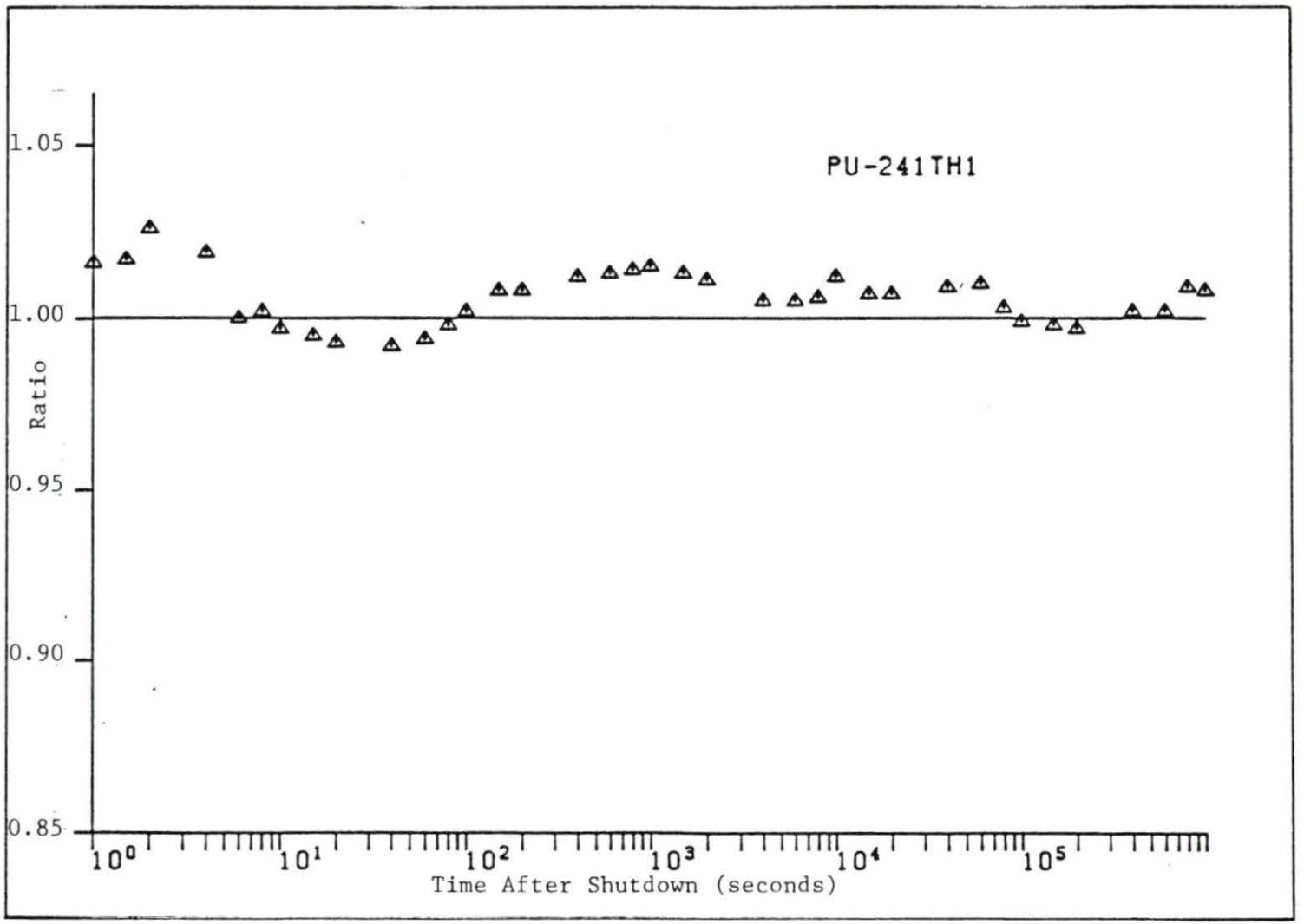


Figure 33. Ratio of Predictions, ENDF/B-V:ENDF/B-IV Pu^{241} (thermal)
Long Irradiation, H1 Function, Ratio Method

Table 33. Ratio of Decay Powers After Long Irradiation
ENDF/B-V:ENDF/B-IV Input, Ratio Method

Decay Time (second)	Ratio (U-235F)	Ratio (U-238F)
1.00	1.000	0.974
1.50	1.000	0.986
2.00	1.009	0.986
4.00	1.009	0.976
6.00	1.000	0.974
8.00	0.999	0.973
10.00	0.999	0.962
15.00	0.999	0.971
20.00	1.000	0.970
40.00	0.999	0.976
60.00	1.000	0.979
80.00	0.998	0.982
100.00	1.002	0.989
150.00	0.996	0.989
200.00	1.000	0.994
400.00	1.000	0.998
600.00	1.002	1.002
800.00	1.003	1.003
1000.00	1.003	1.000
1500.00	1.006	1.003
2000.00	1.006	1.007
4000.00	1.008	1.004
6000.00	1.009	1.010
8000.00	1.010	1.016
10000.00	1.011	1.017
15000.00	1.006	1.013
20000.00	1.007	1.007
40000.00	1.008	1.017
60000.00	1.018	1.009
80000.00	1.000	1.001
100000.00	1.003	0.999
150000.00	1.001	0.993
200000.00	1.000	0.991
400000.00	1.000	0.988
600000.00	0.998	0.983
800000.00	1.000	0.986
1000000.00	0.998	0.981

Decay Time (second)	Ratio (PU-239T)	Ratio (PU-241T)
1.00	1.010	1.016
1.50	1.006	1.017
2.00	1.013	1.026
4.00	1.011	1.019
6.00	1.007	1.000
8.00	1.006	1.002
10.00	1.006	0.997
15.00	1.007	0.995
20.00	1.005	0.993
40.00	1.005	0.992
60.00	1.005	0.994
80.00	1.003	0.998
100.00	1.007	1.002
150.00	1.006	1.008
200.00	1.010	1.008
400.00	1.007	1.012
600.00	1.008	1.013
800.00	1.011	1.014
1000.00	1.006	1.015
1500.00	1.010	1.013
2000.00	1.007	1.011
4000.00	1.005	1.005
6000.00	1.005	1.005
8000.00	1.011	1.006
10000.00	1.012	1.012
15000.00	1.007	1.007
20000.00	1.007	1.007
40000.00	1.008	1.009
60000.00	1.009	1.010
80000.00	0.999	1.003
100000.00	0.997	0.999
150000.00	0.993	0.998
200000.00	0.990	0.997
400000.00	0.988	1.002
600000.00	0.986	1.002
800000.00	0.987	1.009
1000000.00	0.984	1.008

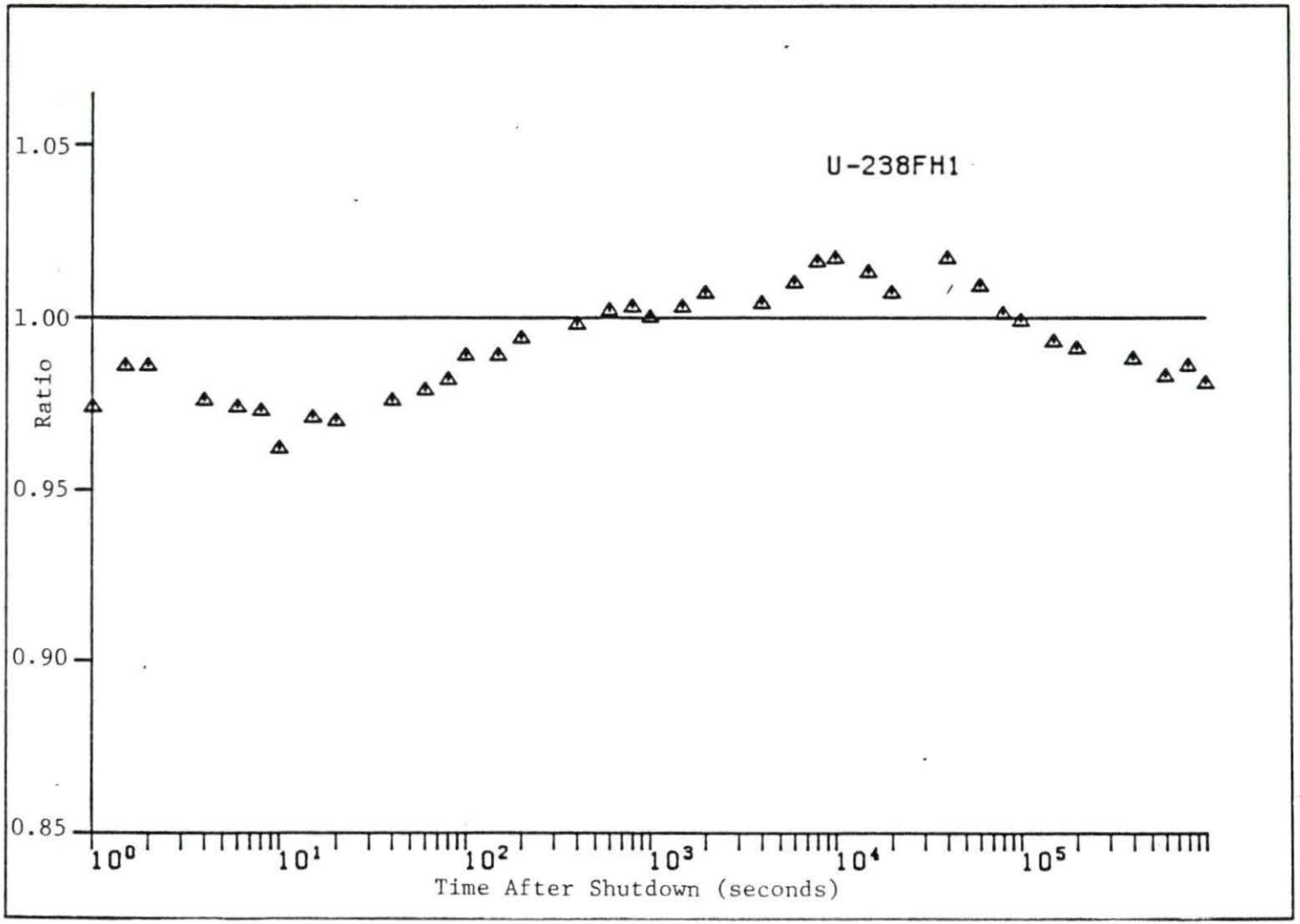


Figure 34. Ratio of Predictions, ENDF/B-V:ENDF/B-IV U^{238}(fast)
Long Irradiation, H1 Function, Ratio Method

Specifically, for U^{238}(fast), not only is the fission yield of the short-lived fission products higher compared to that of U^{235}(thermal), but also the decay energy data for the short-lived fission products in U^{238}(fast) are not well known. As described in Chapter II.A, the summation results from the ENDF/B-IV are directly used for the ANS 5.1 U^{238}(fast) standard because of the absence of good experimental data. So we attribute these results to a conclusion that the ratio method is much less sensitive to ENDF/B decay data except for U^{238}(fast). The decay powers from the ENDF/B-V data file for U^{235}(fast), Pu^{239}(thermal), and Pu^{241}(thermal) are not significantly different from those from the ENDF/B-IV data file for the same fissioning nuclides.

Finally, the comparison of the ratio method results with the ANS 5.1 standard for Pu^{239}(thermal), H1 function, is performed. Figure 35 shows the ratio of the ratio method results to the ANS 5.1 standard for Pu^{239}(thermal). All values are close to unity. There is no significant difference in this comparisons at all cooling times. The ratio method is thus capable of predicting the best estimate of the decay power directly using the summation method results.

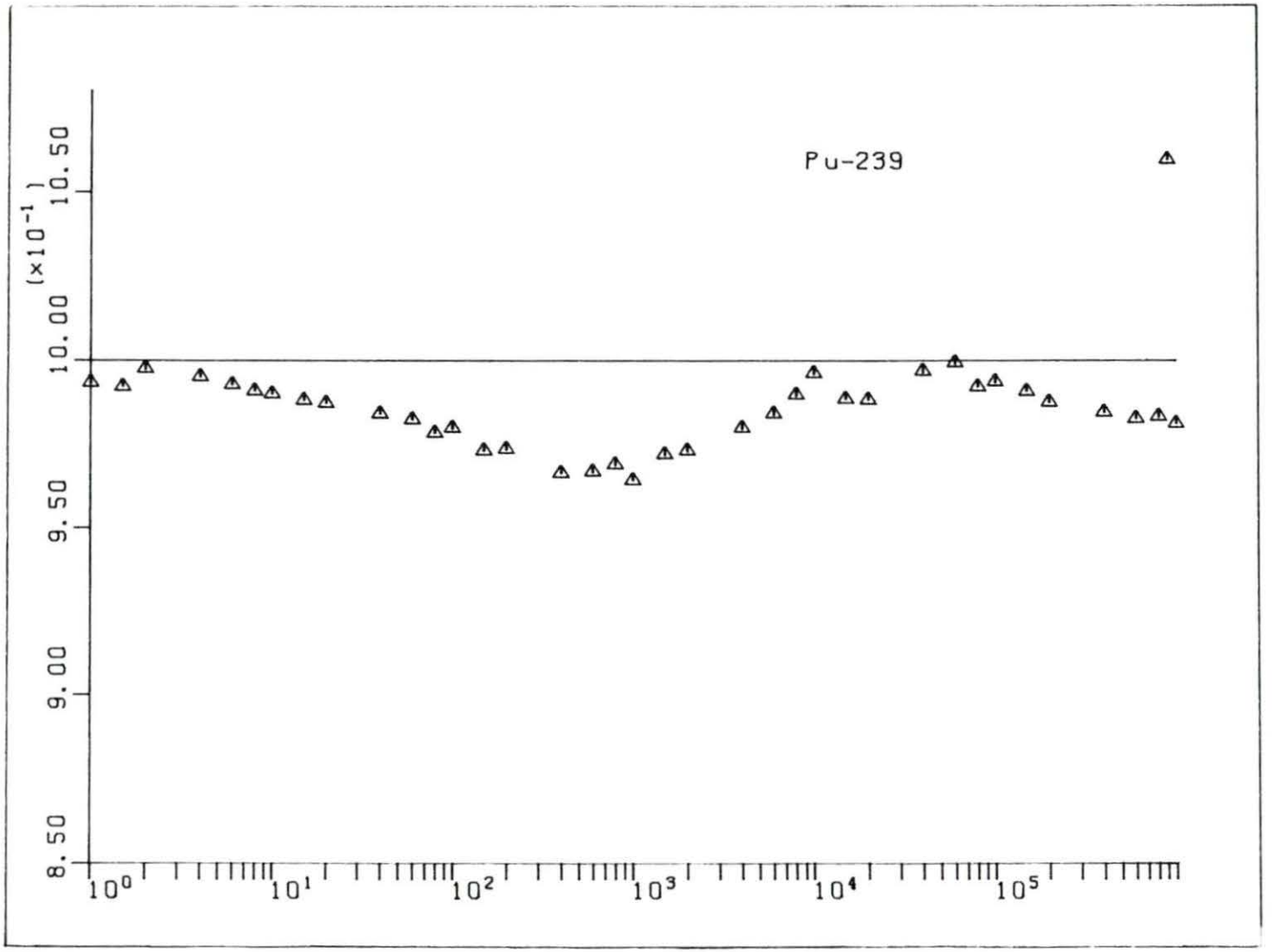


Figure 35. A Comparison of the Ratio Method Results with the ANS 5.1 Standard for Pu^{239} Thermal Fission After Long Irradiation at a Constant Fission Rate

V. APPLICATION OF LEAST SQUARE METHOD TO DECAY POWER

A. Least Square Model Equation for Decay Power

Schmittroth and Schenter[8] have developed and applied a generalized least square method to obtain a best estimate of the decay power from the experimental data[1-5] and summation calculation results[35] based on ENDF/B-IV. This best estimate of the decay power is the basis of the decay power data for the ANS 5.1 standard data for U^{235}, Pu^{239} thermal fission and U^{238} fast fission, as described in chapter II.A. Fitting the best estimate of the decay powers of H0(t) and H1(t,T) functions to the following exponential representations repective by,

$$H0(t) = \sum_{i=1}^{23} A_i \exp(-\lambda_i t) \qquad (5\text{-}1)$$

$$H1(t,T) = \sum_{i=1}^{23} A_i \exp(-\lambda_i t)(1-\exp(-\lambda_i T))/\lambda_i \qquad (5\text{-}2)$$

they obtained the parameters, A_i and λ_i. The parameters, A_i and λ_i, are separately chosen for each fissioning nuclides (U^{235}(thermal), Pu^{239}(thermal) ,and U^{238}(fast)) in such a way that the model equations, Eq (5-1) and Eq (5-2), provide the least square residuals of the decay powers of H0(t) and H1(t,T) functions for the fissioning nuclide. The three sets of A_i and λ_i values for U^{235}(thermal), Pu^{239}(thermal), and U^{238}(fast) have been listed in the ANS 5.1 standard. However, it is desirable to find more convenient parameter sets of A_i and λ_i. In

particular, we have reasoned that, since the λ_i in a sense represent the decay constants of fission products that are the same for all fissions, a common set of λ_i for the three fissioning nuclides should be sought. Corresponding A_i that vary for different fissioning nuclides are acceptable.

To find out the new parameter sets, A_i, for the three fissioning nuclides that are acceptable under a common set of λ_i, the model equations Eqs. (5-1) and (5-2) are used in this study with the ANS 5.1 standard decay power values represented by 55 data points as a function of time after shutdown. However, the first thing to do is to determine a common set of λ_i. There are three sets of λ_i and of A_i in the ANS 5.1 standard. Since the λ_i in a sense represent the decay constants of fission products from the three fissioning nuclides, the most appropriate common values of the λ_i, to cover the three fissioning nuclides, would be the average ones. By averaging the three sets of λ_i values in the ANS 5.1 standard, a common set of λ_i is determined.

There are several ways to predict the parameter sets A_i by applying the least square technique to the model equations, Eqs. (5-1) and (5-2). However, the model equation would produce a correlation among the decay power values at various times after operation, while the shutdown cooling time t is uncorrelated in the model equations. Since this kind of correlation sometimes makes the design matrix of the least square method approach a near-singular condition, much caution is thus needed in performing the least square method. Considering this correlation, we used the weighted least square method[39].

The weighted least square method is to minimize the weighted sum of squares of the errors. Using the model equation, the H0 function of the decay power, H_j, at time t_j after shutdown can be written as

$$H_j = \sum_{i=1}^{r} A_j \exp(-\lambda_i t_j) + \varepsilon_j \quad ,j=1,2.....n \qquad (5\text{-}3)$$

where

- A_i : parameters of the model equation
- ε_j : errors

and defining

$$X_{ij} = \exp(-\lambda_i t_j) \qquad (5\text{-}4)$$

With this definition the decay power is

$$H_j = \sum_{i=1}^{r} A_j X_{ij} + \varepsilon_j \qquad (5\text{-}5)$$

and the n equations representing H_j as a function of Xs, As, and εs can be defined as following matrix form,

$$H = XA + \varepsilon \qquad (5\text{-}6)$$

In the general case (correlated errors of different weights), the weighted sum of squares of the errors, S, is written by[39]

$$S = (H - XA)^T W (H - XA) \qquad (5\text{-}7)$$

where

- W = diagonal matrix of weights represented by the reciprocal of the variance for each experimental decay power
- T = transpose of the matrix

Eq. (5-7) can be rewritten as

$$S = H^T WH - 2A^T X^T + A^T X^T WXA \qquad (5\text{-}8)$$

Differentiating Eq. (5-8) with respect to A and setting the derivative to zero, the least square estimate <A> that minimizes S can be defined

$$\langle A \rangle = (X^T WX)^{-1} X^T WH \qquad (5\text{-}9)$$

The statistical Analysis System (SAS) on AS/6 was used to find the new parameter set A_i. The weighted least square model produces 20 non-zero parameter values. It is thus necessary to compare the results from this method with the ANS 5.1 standard values so that we can see the effectiveness of the weighted least square method.

B. Comparison of This Study Result with the ANS 5.1 Standard

Comparisons of decay powers of H1 function between the ANS 5.1 standard values and the values from our model equation are listed in Tables 35 through 37. The H1 functions for U^{235}(thermal), Pu^{239}(thermal), and U^{238}(fast) are calculated by using Eq. (5-2) with the common set of λ_i and the new parameters A_i evaluated in this study. Table 38 lists the common set of λ_i and new parameters A_i for each fissioning nuclide from the weighted least square method, while Table 39 displays the parameter sets in the ANS 5.1 standard. Table 35 gives the comparisons of the U^{235}(thermal) decay power between the standard and the predicted values. "Method" denotes the weighted least square results. The results are almost the same as the standard decay power indicating very good fits. The maximum relative error in the method is about 0.07 % at cooling time $4*10^5$ seconds and the weighted sum of squares of errors are listed in Table 34. At all cooling times, the relative error is surely negligible.

Table 34. Weighted Sum of Square of the Errors

	U^{235}(Th)	Pu^{239}(Th)	U^{238}(F)
Method	$3.179*10^{-6}$	$1.072*10^{-5}$	$3.406*10^{-4}$

Table 35. Comparison of This Study Results with the ANS 5.1 Standard for U^{235} Thermal Fission After Long Irradiation, H1 Function

Decay Time (seconds)	ANS Standard Mev/fiss	Method Mev/fiss	Relative error(%)
0.10E+01	0.1231E+02	0.1231E+02	0.0091
0.15E+01	0.1198E+02	0.1198E+02	0.0226
0.20E+01	0.1169E+02	0.1169E+02	0.0069
0.40E+01	0.1083E+02	0.1084E+02	0.0502
0.60E+01	0.1026E+02	0.1026E+02	0.0213
0.80E+01	0.9830E+01	0.9829E+01	0.0113
0.10E+02	0.9494E+01	0.9492E+01	0.0215
0.15E+02	0.8882E+01	0.8883E+01	0.0065
0.20E+02	0.8455E+01	0.8457E+01	0.0269
0.40E+02	0.7459E+01	0.7457E+01	0.0203
0.60E+02	0.6888E+01	0.6887E+01	0.0086
0.80E+02	0.6493E+01	0.6494E+01	0.0089
0.10E+03	0.6198E+01	0.6199E+01	0.0115
0.15E+03	0.5696E+01	0.5696E+01	0.0020
0.20E+03	0.5369E+01	0.5368E+01	0.0105
0.40E+03	0.4667E+01	0.4667E+01	0.0047
0.60E+03	0.4282E+01	0.4282E+01	0.0027
0.80E+03	0.4009E+01	0.4009E+01	0.0047
0.10E+04	0.3796E+01	0.3796E+01	0.0095
0.15E+04	0.3408E+01	0.3408E+01	0.0006
0.20E+04	0.3137E+01	0.3136E+01	0.0329
0.40E+04	0.2534E+01	0.2535E+01	0.0286
0.60E+04	0.2234E+01	0.2234E+01	0.0071
0.80E+04	0.2044E+01	0.2044E+01	0.0103
0.10E+05	0.1908E+01	0.1908E+01	0.0125
0.15E+05	0.1685E+01	0.1685E+01	0.0156
0.20E+05	0.1545E+01	0.1545E+01	0.0067
0.40E+05	0.1258E+01	0.1259E+01	0.0459
0.60E+05	0.1117E+01	0.1117E+01	0.0171
0.80E+05	0.1030E+01	0.1029E+01	0.0615
0.10E+06	0.9691E+00	0.9690E+00	0.0072
0.15E+06	0.8734E+00	0.8738E+00	0.0492
0.20E+06	0.8154E+00	0.8158E+00	0.0476
0.40E+06	0.6975E+00	0.6970E+00	0.0711
0.60E+06	0.6331E+00	0.6327E+00	0.0674
0.80E+06	0.5868E+00	0.5869E+00	0.0147
0.10E+07	0.5509E+00	0.5512E+00	0.0547

Table 36. Comparison of This Study Results with the ANS 5.1 Standard for Pu^{239} Thermal Fission After Long Irradiation, H1 Function

Decay Time (seconds)	ANS Standard Mev/fiss	Method Mev/fiss	Relative error(%)
0.10E+01	0.1027E+02	0.1027E+02	0.0089
0.15E+01	0.1003E+02	0.1003E+02	0.0283
0.20E+01	0.9816E+01	0.9818E+01	0.0242
0.40E+01	0.9206E+01	0.9206E+01	0.0051
0.60E+01	0.8795E+01	0.8795E+01	0.0046
0.80E+01	0.8488E+01	0.8487E+01	0.0114
0.10E+02	0.8243E+01	0.8243E+01	0.0024
0.15E+02	0.7794E+01	0.7795E+01	0.0162
0.20E+02	0.7476E+01	0.7476E+01	0.0066
0.40E+02	0.6707E+01	0.6705E+01	0.0250
0.60E+02	0.6251E+01	0.6251E+01	0.0049
0.80E+02	0.5929E+01	0.5930E+01	0.0154
0.10E+03	0.5685E+01	0.5686E+01	0.0177
0.15E+03	0.5262E+01	0.5262E+01	0.0087
0.20E+03	0.4982E+01	0.4981E+01	0.0181
0.40E+03	0.4357E+01	0.4356E+01	0.0297
0.60E+03	0.3993E+01	0.3993E+01	0.0089
0.80E+03	0.3726E+01	0.3727E+01	0.0402
0.10E+04	0.3516E+01	0.3516E+01	0.0110
0.15E+04	0.3128E+01	0.3127E+01	0.0167
0.20E+04	0.2857E+01	0.2856E+01	0.0281
0.40E+04	0.2276E+01	0.2275E+01	0.0353
0.60E+04	0.2002E+01	0.2003E+01	0.0647
0.80E+04	0.1839E+01	0.1840E+01	0.0480
0.10E+05	0.1727E+01	0.1727E+01	0.0004
0.15E+05	0.1548E+01	0.1547E+01	0.0623
0.20E+05	0.1437E+01	0.1436E+01	0.0554
0.40E+05	0.1204E+01	0.1205E+01	0.0577
0.60E+05	0.1081E+01	0.1081E+01	0.0265
0.80E+05	0.1000E+01	0.1000E+01	0.0240
0.10E+06	0.9421E+00	0.9421E+00	0.0037
0.15E+06	0.8480E+00	0.8475E+00	0.0607
0.20E+06	0.7890E+00	0.7886E+00	0.0488
0.40E+06	0.6634E+00	0.6640E+00	0.0945
0.60E+06	0.5944E+00	0.5947E+00	0.0565
0.80E+06	0.5462E+00	0.5462E+00	0.0005
0.10E+07	0.5097E+00	0.5094E+00	0.0545

Table 37. Comparison of This Study Results with the ANS 5.1 Standard for U^{238} Thermal Fission After Long Irradiation, H1 Function

Decay Time (seconds)	ANS Standard Mev/fiss	Method Mev/fiss	Relative error(%)
0.10E+01	0.1419E+02	0.1418E+02	0.0379
0.15E+01	0.1361E+02	0.1362E+02	0.0646
0.20E+01	0.1316E+02	0.1316E+02	0.0039
0.40E+01	0.1196E+02	0.1195E+02	0.0600
0.60E+01	0.1123E+02	0.1123E+02	0.0304
0.80E+01	0.1070E+02	0.1071E+02	0.0503
0.10E+02	0.1029E+02	0.1030E+02	0.0553
0.15E+02	0.9546E+01	0.9543E+01	0.0336
0.20E+02	0.9012E+01	0.9009E+01	0.0306
0.40E+02	0.7755E+01	0.7756E+01	0.0156
0.60E+02	0.7052E+01	0.7053E+01	0.0079
0.80E+02	0.6572E+01	0.6572E+01	0.0063
0.10E+03	0.6217E+01	0.6217E+01	0.0042
0.15E+03	0.5621E+01	0.5620E+01	0.0181
0.20E+03	0.5241E+01	0.5240E+01	0.0108
0.40E+03	0.4464E+01	0.4467E+01	0.0621
0.60E+03	0.4072E+01	0.4072E+01	0.0033
0.80E+03	0.3804E+01	0.3802E+01	0.0436
0.10E+04	0.3598E+01	0.3596E+01	0.0565
0.15E+04	0.3220E+01	0.3221E+01	0.0345
0.20E+04	0.2954E+01	0.2956E+01	0.0715
0.40E+04	0.2366E+01	0.2365E+01	0.0328
0.60E+04	0.2078E+01	0.2077E+01	0.0422
0.80E+04	0.1901E+01	0.1901E+01	0.0203
0.10E+05	0.1777E+01	0.1777E+01	0.0149
0.15E+05	0.1578E+01	0.1579E+01	0.0387
0.20E+05	0.1455E+01	0.1456E+01	0.0477
0.40E+05	0.1204E+01	0.1204E+01	0.0291
0.60E+05	0.1077E+01	0.1076E+01	0.0788
0.80E+05	0.9955E+00	0.9955E+00	0.0037
0.10E+06	0.9383E+00	0.9386E+00	0.0292
0.15E+06	0.8459E+00	0.8464E+00	0.0650
0.20E+06	0.7884E+00	0.7887E+00	0.0347
0.40E+06	0.6673E+00	0.6667E+00	0.0971
0.60E+06	0.6002E+00	0.5999E+00	0.0472
0.80E+06	0.5530E+00	0.5531E+00	0.0224
0.10E+07	0.5171E+00	0.5173E+00	0.0467

Table 38. Common Set of λ_i and the New Parameters A_i in the Weighted Least Square Method

	A_i coefficients		
λ_i	U-235(Th)	Pu-239(Th)	U-238(F)
0.6991E+00	0.3998E+00	0.3375E+00	0.1400E+01
0.2618E+00	0.3777E+00	0.2495E+00	0.3463E+00
0.1049E+00	0.1668E+00	0.1187E+00	0.2193E+00
0.3569E-01	0.5265E-01	0.3772E-01	0.6767E-01
0.1310E-01	0.2450E-01	0.2056E-01	0.3014E-01
0.4383E-02	0.4478E-02	0.3361E-02	0.5798E-02
0.1362E-02	0.1262E-02	0.1269E-02	0.9606E-03
0.5712E-03	0.6844E-03	0.7559E-03	0.7644E-03
0.1803E-03	0.1823E-03	0.1584E-03	0.1680E-03
0.5094E-04	0.3028E-04	0.1854E-04	0.2496E-04
0.1936E-04	0.7256E-05	0.7634E-05	0.6520E-05
0.8458E-05	0.1848E-05	0.1532E-05	0.1769E-05
0.2407E-05	0.4377E-06	0.5792E-06	0.5168E-06
0.6511E-06	0.1810E-06	0.1691E-06	0.1700E-06
0.1257E-06	0.2628E-07	0.2106E-07	0.2303E-07
0.2581E-07	0.2568E-08	0.2891E-08	0.2826E-08
0.7409E-08	-.1711E-09	0.1583E-09	0.4415E-10
0.7514E-09	0.2208E-09	-.2071E-10	0.5624E-10
0.2441E-09	-.9140E-10	0.5313E-10	0.5563E-11
0.2241E-12	0.5318E-13	-.2905E-13	-.2502E-14

Table 39. Coefficients of the ANS 5.1 Standard for an Exponential Representation of the Decay Power from U^{235}(thermal), Pu^{239}(thermal), and U^{238}(fast)

U-235(Th)		Pu-239(Th)		U-238(F)	
λ_i	A_i	λ_i	A_i	λ_i	A_i
2.2138E+01	6.5057E-01	1.002E+01	2.083E-01	3.2881E+0	1.2311E+0
5.1587E-01	5.1264E-01	6.433E-01	3.853E-01	9.3805E-1	1.1486E+0
1.9594E-01	2.4384E-01	2.186E-01	2.213E-01	3.7073E-1	7.0701E-1
1.0314E-01	1.3850E-01	1.004E-01	9.460E-02	1.1118E-1	2.5209E-1
3.3656E-02	5.5440E-02	3.728E-02	3.531E-02	3.6143E-2	7.1870E-2
1.1681E-02	2.2225E-02	1.435E-02	2.292E-02	1.3272E-2	2.8291E-2
3.5870E-03	3.3088E-03	4.549E-03	3.946E-03	5.0133E-3	6.8382E-3
1.3930E-03	9.3015E-04	1.328E-03	1.317E-03	1.3655E-3	1.2322E-3
6.2630E-04	8.0943E-04	5.356E-04	7.052E-04	5.5158E-4	1.6975E-4
1.8906E-04	1.9567E-04	1.730E-04	1.432E-04	1.7873E-4	1.6975E-4
5.4988E-05	3.2535E-05	4.881E-05	1.765E-05	4.9032E-5	2.4182E-5
2.0958E-05	7.5595E-06	2.006E-05	7.347E-06	1.7058E-5	6.6356E-6
1.0010E-05	2.5232E-06	8.319E-06	1.747E-06	7.0465E-6	1.0075E-6
2.5438E-06	4.9948E-07	2.358E-06	5.481E-07	2.3190E-6	4.9894E-7
6.6361E-07	1.8531E-07	6.450E-07	1.671E-07	6.4480E-7	1.6352E-7
1.2290E-07	2.6608E-08	1.278E-07	2.112E-08	1.2649E-7	2.3355E-8
2.7213E-08	2.2398E-09	2.466E-08	2.996E-09	2.5548E-8	2.8094E-9
4.3714E-09	8.1641E-09	9.378E-09	5.107E-11	8.4782E-9	3.6236E-11
7.5780E-10	8.7797E-11	7.450E-10	5.370E-11	7.5130E-10	6.4577E-11
2.4786E-10	2.5131E-14	2.426E-10	4.138E-14	2.4188E-10	4.4963E-14
2.2384E-13	3.2176E-16	2.210E-13	1.088E-15	2.2739E-13	3.6654E-16
2.4600E-14	4.5038E-17	2.640E-14	2.454E-17	9.0536E-14	5.6293E-17
1.5699E-14	7.4791E-17	1.380E-14	7.557E-17	5.6098E-15	7.1602E-17

Model Equations for H0 and H1 function

$$H0(t)=\sum_i A_i \exp(-\lambda_i t) \qquad \text{MeV/fission-sec}$$

$$H1(t,T)=\sum_i ((A_i/\lambda_i)\exp(-\lambda_i t)(1-\exp(-\lambda_i T)) \qquad \text{MeV/fission}$$

Tables 36 and 37 represent the comparisons of Pu^{239}(thermal) and U^{238}(fast) with the ANS 5.1 standards. They also produce negligible relative errors at all cooling times and fit very well. The uncertainty of the ANS 5.1 standards for U^{235}(thermal) and Pu^{239}(thermal) H1 function is about 2 % and 5 % at all cooling times respectively, while that for U^{238}(fast) is about 12-10 % at short cooling times (< 15 seconds) and is about 8-4 % after the short cooling times. However, all errors in the predicted values are below 0.1 %.

A nonlinear least square analysis was performed at Los Alamos National Laboratory and Hanford Engineering Development Laboratory (HEDL) to determine the best set of A_i and λ_i values for a 23 term fit to the decay power because of both the A_i and λ_i parameters are unknown. This evaluation was the basis of the A_i and λ_i parameters in the ANS 5.1 standard. Trapp[11] used standard linear least square method to obtain the set of the A_i with the λ_i values for U^{235} from the HEDL study. His results were not, however, considered in preparing the ANS 5.1 standard values and he did not exhibit any comparisons with the experimental decay power from HEDL. However, he chose and used a common set of λ_i values.

However, a common set of 20 λ_i and corresponding A_i values obtained in this study, as listed in Table 38, that vary for different fissioning nuclides produce the best estimate of the decay power without yielding any sensible error, while the ANS 5.1 standard has 23 λ_i and A_i values that vary for different fissioning nuclides, as listed in Table

39. Therefore, our model for the decay power with this common set of 20 λ_i and A_i values for each fissioning nuclide is more compact and convenient. However, there are 1 or 2 negative values of the A_i parameter at small λ_i values (< 0.7409E-08) in our model. If we consider a Batemann equation described in Chapter II, all A_i values would be positive. The ANS 5.1 standard has all positive A_i values. More studies are thus required to explain the negative A_i values occurred in this study.

VI. SUMMARY

The qualitative outlines of the problem of short term decay power are now emerging clearly. For short cooling times < 200 seconds, the summation results using a new version of ENDF/B-V nuclear data underpredict the decay power, even more than the previous ENDF/B-IV nuclear data do. Thus, the change to ENDF/B-V makes matters worse, rather than better. This new version of ENDF/B-V nuclear data used as a summation method input data is thus not good enough to specify fast neutron fission decay power with acceptable precision at short cooling times < 200 seconds. However, for decay times longer than 200 seconds, there is not any significant difference between the decay power results obtained from the two decay data sets (ENDF/B-IV and ENDF/B-V). Since the ANS 5.1 standard significantly weighted the summation results into the total for longer times, the effects of the data change from ENDF/B-IV to ENDF/B-V on the standard values should be trivial.

The use of the ratio method makes the decay power predictions much less sensitive to ENDF/B nuclear decay data, except for the case of fast fission of U^{238}. The ENDF/B-V predictions by the ratio method were not significantly different from the ENDF/B-IV predictions for U^{235}(fast), Pu^{239}(thermal), and Pu^{241}(thermal) at all cooling times. Specifically, the lower values of ENDF/B-V prediction at short cooling times < 200 seconds disappear when the ratio method is used.

Since the ratios suppress errors due to fission product decay energies, these results suggest that ENDF/B-V fission product decay

energies are systematically lower than they should be, more so than ENDF/B-IV values that are also believed to be too low, for fission product nuclides of short half life.

It is thus concluded that ENDF/B fission product decay data still have problems in specifying fast or thermal neutron fission decay powers with acceptable precision by direct summation calculation, particularly at short times after shutdown. However, the ratio technique overcomes the problem that ENDF/B nuclear data have, and predicts a better estimate of decay power. This is shown in the comparisons of the ratio method results with the ANS 5.1 standard (Chapter IV).

The weighted least square method predicts new parameter sets A_i under a common set of λ_i values. The new parameter sets A_i (i=1,2,3 ....20) and the common set of λ_i (i=1,2,3.....20) obtained by direct solution of the weighted least square method with the model Eqs. (5-1) and (5-2) provide excellent estimates of the decay power without adding any sensible uncertainty to that already existing in the standard. Therefore, we are able to estimate the decay power from a simple model by using Eqs. (5-1) and (5-2) with these new parameter sets. The common set of λ_i might permit us also to quickly reproduce both the uncertainties in the standard and the correlation of ratios by assigning suitable uncertainties to the A_i. Such work, however, has not been performed in this research.

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IX. APPENDIX A

A. Conversion of the ROPEY program from CDC to IBM system

The major modification to ROPEY was the change of the several statements which apply only to the CDC FORTRAN EXTENDED compiler and the addition of the one subprogram, BLOCK DATA, to ROPEY accompanied by the deletion of the three subprograms (IOUNIT, BELL, and CORE) from ROPEY.

The CDC FORTRAN EXTENDED systems provide the capability of checking for an end of file following a read operation via EOF function. Specifically, any of the following conditions encountered during a read returns an end of file status via the EOF function.

- End of section (only input file)
- End of information
- Terminating end of file label

The IBM FORTRAN VS compiler does not have the same EOF function as the CDC FORTRAN EXTENDED does to check for an end of file following read operation. Instead, the IBM FORTRAN VS has the END FILE statement which defines the end of a data set. After execution of a sequential END FILE statement, no record exists in the data set following the last record transferred by that statement. The EOF function of the CDC FORTRAN EXTENDED is thus similar to the END FILE statement of IBM FORTRAN VS in character and execution. Therefore, the EOF function in the CDC FORTRAN EXTENDED can be replaced by the END FILE statement of IBM FORTRAN VS.

To initialize variables in a labeled (named) common block, a separate subprogram, BLOCK DATA, had to be written in the IBM FORTRAN VS. This subprogram is not called; its presence suffices to provide initial data values for references in main and subprograms to labeled common blocks. The CDC FORTRAN EXTENDED has the ability to initialize variables in a labeled common block without a subprogram. This difference requires adding the BLOCK DATA subprogram to ROPEY.

Another problem with ROPEY as received is that the dimension number of variables in the dimension specification statement is different from that in the executable statements. The dimension number of these variables is changed by making use of the statement function, which is a user defined, single statement computation and applies only to the program unit containing the definition. There are two ways to solve this problem, one is to modify the statement function which computes the location of the next element in a two dimensional array and another is to make the dimension number of variables equal to those used in the program. The latter method was chosen, since the former could result in confusion in the control of dummy arguments of the statement functions and the actual arguments are substituted for the dummy arguments in the definition.

Variable format statements using the DATA statements, intrinsic library function MAX, named common block and variables in common statements are similarly changed for ROPEY to work on the IBM system. A user-supplied subprogram, MAX, with the same name as a library function,

overrides the library subprogram MAX only in the CDC FORTRAN EXTENDED system. When a subprogram is defined with the same name as that of an intrinsic library function in the IBM FORTRAN VS, the user definition can override the intrinsic library definition only if, in the calling program unit, the name of the function appears either in an EXTERNAL statement or in an explicit type statement that overrides the type associated with the intrinsic library function.

Two subprograms, IOUNIT and BELL, permit ROPEY to be run interactively in the CDC system. Both of them were written in FORTRAN EXTENDED. It is not necessary for ROPEY1 to have IOUNIT and BELL in IBM because of the differences in job execution method between the IBM and the CDC system. Also, since subprogram CORE is only a system program of CDC to increase the size of job memory in the unit program, the IBM FORTRAN VS compiler can not control this subprogram. Therefore, these three subprograms are not required to run the ROPEY1 on the IBM system, and have been deleted. Subprogram PRYNT to print the output interactively in the CDC system is properly modified to work on the IBM output system. The following paragraphs contain a detailed description of the conversion of the ROPEY to the ROPEY1 at each unit program.

1. Main Program

Subject:
a. Job control language for CDC system
b. Print statements to run the ROPEY interactively
c. Call statement to run ROPEY interactively
d. Logical unit file number.

Action :
a. Deleting all statements to run ROPEY interactively and the job control language for CDC system
b. Changing the logical unit file numbers

c. Increasing the dimension number of array D

2. Subprogram IOUNIT

This subprogram is deleted since it is used only to run ROPEY interactively.

3. Subprogram BELL

This program is also deleted.

4. Subprogram BLOCK DATA

Since the IBM FORTRAN VS compiler does not allow the use of the DATA statement to initialize values of variables in labeled COMMON ares, and does not allow initialization on any COMMON area, a subprogram called BLOCK DATA is used for this purpose.
The BLOCK DATA subprogram contains only IMPLICIT, LEVEL TYPE, DIMENSION, COMMON, EQUIVALENCE, DATA AND END statements.
A valid BLOCK DATA subprogram must contain at least one COMMON statement and one DATA statement. Any executable statements are ignored and a warning is issued.
To enter data into labeled COMMON prior to program execution, two labeled COMMON, CHARACTER, INTEGER and these DATA statements are thus used as follow

```
BLOCK DATA
COMMON/IO/INPT,OUTPT,MLIB,MSCR,WRIB,LTIME,ISPC,IPTAPE
COMMON/SDG/IN(15),F(14)
CHARACTER*10 IN,F
INTEGER OUTPT,WLIB
DATA INPT,OUTPT,LTIME,WLIB,MLIB,MSCR/5,6,9,1,8,2/
DATA ISPC,IPTAPE/10,11/
DATA IN/'-10','-9','-8','-7','-6','-5','-4','-3','-2'
        '-1','0','1','2','3','4'/
END
```

5. Subprogram ROPEYD

Subject : Call statement,call CORE(D,MTOP),through which the size of memory is increased.

Action : Deleted.

6. Subprogram ROPDAT

The following subjects are only executable on the CDC FORTRAN EXTENDED compiler. These statements should be thus substituted by other statements or structures that work on the IBM FORTRAN VS compiler. The only differences between the version of the statements on the two computers are that the capability of overriding the intrinsic function of the system and controlling the array for dimension numbers that are not constant does not exist on the IBM computer.

Subject : a. A subprogram MAX in the ROPEY is defined with the same name as that of an intrinsic function MAX of the IBM FORTRAN VS compiler.

```
CALL MAX(ICHANM,ICHAIN,NLOT)
```

b. EOF function statement which is used to test for an end of file condition on file following a formatted,listed-directed or unformatted read

```
READ(MLIB,2005)NLOT,NOFA,NA
IF(EOF(MLIB).NE.0)GO TO 400
```

C. Difference of the number of dimension between the array declarator and the I/O statements.

```
INTO(3,1),BRAN(3,1)
READ(MLIB,2003)IB,(INTO(I),BRAN(I),I=1,IB)
```

Action : a. The IBM FORTRAN VS compiler can not distinguish a subprogram MAX from an intrinsic function MAX without special declaration. To avoid confusion, an EXTERNAL declaration is used in the calling program ROPDAT to indicate that the subprogram name MAX used in the argument is external to that program.

```
EXTERNAL MAX
```

b. The EOF function does not exist on the IBM FORTRAN VS compiler. However, the IBM compiler has the END FILE statement in the read statement which is used to test for an end of file condition following a formatted read statement. Thus, the EOF function is replaced by the END FILE statement to avoid the input errors.

```
READ(MLIB,2005,END=400)NLOT,NOFA,NA
```

c. The CDC compiler works even if the dimension number of a variable is different between the array declaration

and the I/O statement. To work on the IBM system, the dimension number of all variables should be equal throughout a program.

```
INTO(500),BRAN(500)
READ(MLIB,2003)IB,(INTO(I),BRAN(I),I=1,IB)
```

7. Subprogram MATCH

No modification to MATCH was made

8. Subprogram PARLAM

No modification to PARLAM was made

9. Subprogram BUMPT

Subject : EOF function in the I/O and IF statements

```
READ(MSCR)NAME(IPTR),ALAM(IPTR),EB(IPTR)...
IF(EOF(MSCR).NE.0)GO TO 110
```

Action : EOF function is replaced by the END FILE I/O statement to define the end of a data set

```
READ(MSCR,END=110)NAME(IPTR),ALAM(IPTR)
```

10. Subprogram PARBR

No modification to PARBR was made

11. Subprogram MAX

Since the EXTERNAL MAX is declared in the calling program ROPDAT to indicate that a FORTRAN VS supplied in-line function MAX is not expanded in-line, it is not necessary for the subprogram MAX to be modified.

12. Subprogram ROPEYH

Only a calling statement CALL CORE(D,MTOP) through which the size of the job memory is increased is deleted. CORE is a system program used to increase the memory size in the CDC system.

Subject : IF(MTOP.GT.LIMIT)CALL CORE(D,MTOP)

Action : Deleted.

13. Subprogram TIMEIN

Subject : a. Data initialization statement to run the program interactively.

```
DATA YES,NO/'YES','NO'/
```

b. EOF function in the IF and I/O statements

```
READ(LTIME,1000)T(1,NTIME),T(2,NTIME)
IF(EOF(LTIME).NE.0)GO TO 200
```

Action : a. Data initialization statement is changed to have the initial integer values, 0 and 1 in place of YES and NO.

```
DATA YES,NO/0,1/
```

b. EOF function is also substituted by the END FILE I/O statement to define the end of file LTIME.

```
READ(LTIME,1000,END=200)T(1,NTIME),T(2,NTIME)
```

14. Subprogram ROPEH

Subject : a. Some variables have dimension number in the dimension specification statement that are different from those in the executable statement

```
HN(NFUN,1),HNB(NFUN,1),HE(NFUN,1),HE1(NFUN,1),
HE2(NFUN,1),HE3(NFUN,1),H(NFUN,1),HN1(NFUN,1),
HN2(NFUN,1),HT1(NFUN,1),HT2(NFUN,1),HT3(NFUN,1),
UNC(NFUN,1),ACT(NFUN,1),HNG(NFUN,1),SPACT(NFUN,1),
HCO(25),CO(25),TIN(25),ALIB(7)
```

b. Variable data statements

```
DATA(FORMT(I),I=1,57)/......../
```

c. Dimension and data statements that define the variable format and unit

```
DIMENSION HEAD(7),FORMAT(57),ITHERE(3)
DIMENSION HMEV(3),HWATT(3)
DATA HMEV/........../
```

```
DATA HWATT/...../
DATA ITHERE/...../
```

Action : a. Making the dimension number of both the dimension specification statement and the executable statement equal

```
HN(500),HNB(500),HE(500),HE1(500)
HE2(500),HE3(500),H(500),HN1(500)
HN2(500),HT1(500),HT2(500),HT3(500)
UNC(500),ACT(500),HNG(500),SPACT(500)
HCO(500),CO(500),TIN(500),ALIB(107)
```

b. Replacing the variable data statements by the formatted output statements

c. Deleting those statements

d. A character statement is inserted

```
CHARACTER*10 HEAD
```

15. Subprogram HESS

No modification to HESS was made

16. Subprogram ZERO

No modification to ZERO was made

17. Subprogram CORE

Completely deleted.

18. Subprogram PRYNT

This program is to print the output by the local printer in the CDC system. To make use of this program, several statements should be changed first to work on the IBM system. Specifically, the common statement and variable format statement should be converted carefully.

Subject : Use of the DATA statement to initialize value of variable in labeled COMMON areas

```
COMMON/SDG/A(9),F(14),IN(15)
DATA IN/...../
```

Variable format statements F(i) for the teletype machine printer

Action : Data statement, DATA IN, is moved to BLOCK DATA subprogram. New labeled common statement COMMON/AO/A(10), is inserted.

```
COMMON/SDG/IN(15),F(14)
COMMON/AO/A(10)
```

Variable format statements F(i) are modified to be suited to the IBM system

A character statement is inserted.

```
CHARACTER*10 IN,F
```

Real specification statement, REAL IN, is deleted.

19. Subprogram SIGDIG

Common statements of this program should be equal to those in the subprogram PRYNT since the SIGDIG is called by the PRYNT. The specification statement of SIGDIG is also converted as in PRYNT

Subject : Common statement

```
COMMON/SDG/A(9),F(14),IN(15)
```

Action : Common statement is separated and new labeled common statement is inserted.

```
COMMON/SDG/A(9),F(14)
COMMON/AO/A(10)
```

A character statement is inserted

```
CHARACTER*10 IN,F
```

Real specification statement, REAL IN, is deleted.

B. Input File Description

Five basic cards are required to run the ROPEY1 program. Each card information and format to be designed is described as follows :

Table 40. ROPEY1 Input Data Format

Card	Column	Input Name	Format	Description
1	1	INUCO	i1	The number of nuclides for which user evaluates decay power. ex) 1=U^{235}(Th) 4=U^{238}(F)
2	1-2	ANSWER	i2	Determine whether an uncertainty analysis is performed or not. 0=ok, 1=no
3	1-2	ANSWER	i2	Determine whether a separated β and γ uncertainty analysis is performed or not. 0=ok, 1=no
4	1-7	HEAD	A7	The name of nuclide for which user wants to evaluate the decay power.
5	1-2	ANSWER	i2	Unit of decay power. 0=default number

C. ROPEY1 Source Program

```
C   ***                  PROGRAM  ROPEY1                        ***
C
C
C     THIS IS THE ROPEY PROGRAM. MODIFIED  AND
C     IMPLEMENTED BY B.I. SPINRAD, S.K.CHUNG
C     AT IOWA STATE UNIVERSITY,1983.
C     THE ROPEY SYSTEM CALCULATES THE H,H1,AND
C     H2 FUNCTIONS FOR ARBITRARY IRRADIATION
C     AND DECAY TIMES. THE UNCERTAINTY IN EACH
C     OF THESE FUNCTIONS DUE TO THE YIELDS,
C     CORRELATED ENERGY UNCERTAINTIES, AND
C     UNCORRELATED ENERGY UNCERTAINTIES CAN
C     ALSO BE EVALUATED.
C   ***              ROPEY LOGICAL UNITS                      ***
C   ***      LOGICAL UNIT            PURPOSE                  ***
C   ***            8           ROPEY MASTER LIBRARY           ***
C   ***            2           ROPEY SCRATCH FILE             ***
C   ***            1           ROPEY WORKING LIBRARY          ***
C   ***            6           ROPEG OUTPUT                   ***
C   ***            9           IRRADIATION - DECAY TIMES      ***
C   ***           10           SPECIAL I/O TAPE (NOT USED)    ***
C   ***           11           TAPE WITH PLOT INFORMATION     ***
C   ***           5            BATCH INPUT                ***
C  ***             12          DATA FILE TO PLOT THE DATA *****
C
      COMMON D(20000)
      COMMON/IO/INPT,OUTPT,MLIB,MSCR,WLIB,LTIME,ISPC,IPTAPE
      INTEGER OUTPT,WLIB
      MAXMOD = 4
      LIMIT = 20000
      IERR =00
      IOPER=0
   10 CONTINUE
      REWIND WLIB
      REWIND LTIME
      IF(IOPER.EQ.1) GO TO 220
      CALL ROPEYD(D,LIMIT)
      IOPER=IOPER+1
      GO TO 10
  220 CALL ROPEYH(D,LIMIT)
      STOP
      END
```

```
C
      BLOCK DATA
      COMMON/IO/INPT,OUTPT,MLIB,MSCR,WLIB,LTIME,ISPC,IPTAPE
      COMMON/SDG/IN(15),F(14)
      CHARACTER*10 IN,F
      INTEGER OUTPT,WLIB
      DATA INPT,OUTPT,LTIME,WLIB,MLIB,MSCR/5,6,9,1,8,2/
      DATA ISPC,IPTAPE/10,11/
      DATA IN/'-10','-9','-8','-7','-6','-5','-4','-3','-2'
     +,'-1','0','1','2','3','4'/
      END
```

```
C
      SUBROUTINE ROPEYD(D,LIMIT)
      DIMENSION D(1)
C
C     THIS PROGRAM SETS UP THE POINTERS FOR THE DATA
C     PROCESSING MODULE.
C
      NCHN = 23
      IBUMP = 30
      MNAME = 1
      MALAM = MNAME + IBUMP
      MEB = MALAM + IBUMP
      MEG = MEB + IBUMP
      MEBU = MEG + IBUMP
      MEGU = MEBU + IBUMP
      MEBC = MEGU + IBUMP
      MEGC = MEBC + IBUMP
      MINTO = MEGC + IBUMP
      MBRAN = MINTO + 3*IBUMP
      MYLD = MBRAN + 3*IBUMP
      MYLDE = MYLD + IBUMP
      MICHN = MYLDE + IBUMP
      MBRTO = MICHN + NCHN
      MALMCH = MBRTO + NCHN*NCHN
      MA = MALMCH + NCHN
      MHCO = MA + NCHN*NCHN
      MCO = MHCO + NCHN
      MCOO = MCO + NCHN
      MENRGY = MCOO + NCHN*NCHN
      MTOP = MENRGY + NCHN
      CALL ZERO(D, MTOP)
      CALL ROPDAT(D(MNAME), D(MALAM), D(MEB), D(MEG),
     1 D(MEBU), D(MEGU), D(MEBC), D(MEGC), D(MINTO),
     2 D(MBRAN), D(MYLD), D(MYLDE), D(MICHN), D(MBRTO),
     3 D(MALMCH), D(MA), D(MHCO), D(MCO), D(MCOO),
     4 D(MENRGY), IBUMP, NCHN )
      RETURN
      END
```

```
C
      SUBROUTINE ROPDAT(NAME, ALAM, EB, EG, EBU, EGU,
     1 EBC, EGC, INTO, BRAN, YLD, YLDE, ICHAIN, BRTO,
     2 ALAMCH, A, HCO, CO, COO ,ENERGY, IBUMP, NCHN )
      EXTERNAL MAX
      COMMON/IO/INPT,OUTPT,MLIB,MSCR,WLIB,LTIME,ISPC,IPTAPE
      INTEGER OUTPT,WLIB
      DIMENSION NAME(1), ALAM(1), EG(1), EB(1), EBU(1),
     1 EGU(1), EGC(1), EBC(1), INTO(500), BRAN(500),
     2 YLD(1), YLDE(1), ICHAIN(1), BRTO(NCHN,1), ALAMCH(1),
     3 STOR(10), A(NCHN,1), COO(NCHN,1),HCO(1),CO(1)
     4, ENERGY(1), EFISS(10), EFISUN(10), STOR1(10)
      REWIND MSCR
      REWIND MLIB
      REWIND WLIB
      IPT = 0
C
C     FIRST PUT THE NUCLIDE DATA ON A SCRATCH FILE.
C
      READ(MLIB,2008) ILIB, INUC, (STOR(I),I=1,7)
 2008 FORMAT(2I5,7A10)
      WRITE(WLIB) (STOR(I),I=1,7)
      READ(MLIB,2000) (STOR(J),EFISS(J),EFISUN(J),J=1,INUC)
 2000 FORMAT(A10,2E10.4)
      READ(INPT,2001)INUCO
      WRITE(WLIB) ILIB,STOR(INUCO),EFISS(INUCO),EFISUN(INUCO)
C
C     NOW DO THE COPY TO A BINARY SCRATCH FILE.
C
  100 READ(MLIB,2002) NAME(1),(STOR(I),I=1,7)
      IF(NAME(1).LT.0) GO TO 110
      READ(MLIB,2003) IB,(INTO(I),BRAN(I),I=1,IB)
      READ(MLIB,2004) (YLD(I),YLDE(I),I=1,INUC)
      WRITE(MSCR) NAME(1), (STOR(I),I=1,7),
     1 IB, (INTO(I),BRAN(I),I=1,IB),YLD(INUCO),YLDE(INUCO)
      GO TO 100
  110 CONTINUE
      NAME(1) = 0.
      CALL ZERO(YLD, INUC)
      CALL ZERO(YLDE, INUC)
      ALAM(1) = 0.
      EB(1) = 0.
```

```
      EG(1) = .0
      ENDFILE MSCR
      REWIND MSCR
C
C     NOW LETS PROCESS THE MASS CHAINS
C
  120 CONTINUE
      CALL ZERO(ALAMCH, NCHN)
      CALL ZERO(BRTO,NCHN*NCHN)
      READ(MLIB,2005, END=400) NLOT, NOFA, NA
      READ(MLIB,2004) (STOR(I),STOR1(I),I=1,INUC)
      CHYLD = STOR(INUCO)
      CHYLDE = STOR1(INUCO)
      READ(MLIB,2007) (ICHAIN(I),I=1,NLOT)
      WRITE(WLIB) NLOT,NOFA,NA,CHYLD,CHYLDE
      CALL MAX(ICHANM,ICHAIN,NLOT)
C
C     NOW SET UP THE BUMP TABLES
C
      CALL BUMPT(IBUMP, IPT, NAME, ALAM, EB, EBU, EBC,
     1 EG, EGU, EGC, INTO, BRAN, YLD, YLDE, ICHANM)
C
C     NOW SET UP THE TABLES
C
      DO 300 I=1,NLOT
      CALL PARLAM(IBUMP, IPT, NAME, ALAM, ALAMCH(I),ENERGY(I),
     1 EB, EG, ICHAIN(I) )
C
      CALL PARBR(IBUMP, IPT, NAME, INTO, BRAN, BRTO(1,I), ICHAIN, I)
  300 CONTINUE
C
C     ADD THE COEFFICIENTS SECTION..
C
      CALL ZERO(COO,NCHN*NCHN)
      DO 56 NUM=1,NOFA
C     BEGIN COMPUTING H R FUNCTION COEFFICIENTS
      CALL ZERO(HCO, NCHN)
      CALL ZERO(CO,NCHN)
      CALL ZERO(A,NCHN*NCHN)
C     COEFFICIENT BOXES CLEARED
      A(NUM,NUM)=1.
      IF (NUM.EQ.NLOT) GO TO 45
```

```
      N=NUM+1
      DO 42 I=N,NLOT
      II=I-1
      DO 36 J=NUM,II
       DO 36 K=J,II
      IF (ALAMCH(I).EQ.0..AND.ALAMCH(J).EQ.0.) GO TO 36
      IF (ABS(ALAMCH(I)-ALAMCH(J)).LT.1.E-11) ALAMCH(I) = ALAMCH(I)*1.
     $001
      IF (ABS(ALAMCH(I)-ALAMCH(J)).LT.1.E-11) GO TO 36
      A(I,J) = A(I,J)+ALAMCH(K)*BRTO(K,I)*A(K,J)/(ALAMCH(I)-ALAMCH(J))
 36   CONTINUE
      DO 42 K=NUM,II
 42   A(I,I) = A(I,I)-A(I,K)
C     CONCENTRATION COEFFICIENTS CALCULATED
45       DO 44 J=NUM,NLOT
            DO 44 I=J,NLOT
 44      HCO(J) = HCO(J)+ALAMCH(I)*ENERGY(I)*A(I,J)
      CALL MATCH(ICHAIN(NUM),NAME,ITLE,IBUMP,IPT)
      YLD1 = YLD(ITLE)/CHYLD
      YLDE1 = YLDE(ITLE)/CHYLD
      DO 46 J=1,NOFA
         DO 46 I=1,NOFA
            COO(I,J)=COO(I,J)+YLD1*A(I,J)
46    CONTINUE
      WRITE(WLIB)NUM, NLOT, NAME(ITLE),EB(ITLE),EG(ITLE),YLD1,YLDE1
     $ ,EBU(ITLE),EGU(ITLE),EBC(ITLE),EGC(ITLE)
     $ , (HCO(L),ALAMCH(L),L=NUM,NLOT)
     $ , (COO(NUM,K),ALAMCH(K),K=1,NUM)
56    CONTINUE
      GO TO 120
  400 CONTINUE
      ENDFILE WLIB
      REWIND WLIB
C
      RETURN
 1004 FORMAT(' DATA ERROR',2I7,2E10.4,I3)
 2001 FORMAT(I1)
 2002 FORMAT(I10,7E10.4)
 2003 FORMAT(I10,3(I10,E10.4))
 2004 FORMAT(8E10.4)
 2005 FORMAT(3I10)
 2007 FORMAT(8I10)
```

```
C
      SUBROUTINE MATCH(ICHAIN,NAME,ITLE,IBUMP,IPT)
      DIMENSION NAME(1)
      DO 100 I=1,IBUMP
      ITLE = MOD(IPT-I+1,IBUMP) + 1
      IF(NAME(ITLE).EQ.ICHAIN) RETURN
  100 CONTINUE
      ITLE = 1
      RETURN
      END
```

```
C
      SUBROUTINE PARLAM(IBUMP, IPT, NAME, ALAM, ALAMCH, ENERGY,
     1 EB, EG, ICHAIN )
      COMMON/IO/MSCR,MLIB
      DIMENSION NAME(1), ALAM(1)
      DIMENSION EB(1), EG(1)
      DO 100 I=1,IBUMP
      IPTR = MOD(IPT-I+1,IBUMP) + 1
      IF(ICHAIN.NE.NAME(IPTR)) GO TO 100
      ALAMCH = ALAM(IPTR)
      ENERGY = EB(IPTR) + EG(IPTR)
      RETURN
  100 CONTINUE
      RETURN
      END
```

```
C
      SUBROUTINE BUMPT(IBUMP, IPT, NAME, ALAM, EB, EBU,
     1 EBC, EG, EGU, EGC, INTO, BRAN, YLD, YLDE, NAMETP )
      COMMON/IO/INPT,OUTPT,MLIB,MSCR,WLIB,LTIME,ISPC,IPTAPE
      INTEGER OUTPT,WLIB
C
C     THIS ROUTINE BUILDS AND ADDS TO THE BUMP TABLE.
C
      DIMENSION NAME(1), ALAM(1), EB(1), EBU(1), EBC(1),
     1 EG(1), EGU(1), EGC(1), INTO(3,1), BRAN(3,1)
     2 , YLD(1), YLDE(1)
      LOGICAL IPRINT
      DATA IPRINT/.FALSE./
      IBOT = IPT + 1
      IPTR = MOD(IPT,IBUMP) + 1
  100 IF(NAME(IPTR).GT.NAMETP)  GO TO 110
C
      IPT = IPT + 1
      IPTR = MOD(IPT,IBUMP) + 1
      INTO(2,IPTR) = 0
      BRAN(2,IPTR) = 0.0
      READ(MSCR,END=110) NAME(IPTR),ALAM(IPTR), EB(IPTR),EBU(IPTR),
     1 EBC(IPTR), EG(IPTR), EGU(IPTR), EGC(IPTR),IB,
     2(INTO(I,IPTR),BRAN(I,IPTR),I=1,IB),YLD(IPTR),
     3 YLDE(IPTR)
      GO TO 100
  110 CONTINUE
      IF(.NOT.IPRINT) RETURN
      DO 200 J=IBOT,IPT
      IND = MOD(J, IBUMP) + 1
      WRITE(OUTPT,1000)J, NAME(IND), ALAM(IND), EB(IND),
     1 EBU(IND), EBC(IND), EG(IND), EGU(IND),
     2 EGC(IND), (INTO(I,IND),BRAN(I,IND),I=1,3)
 1000 FORMAT(1X,2I10,7E10.4,/,1X,3(I10,E10.4))
  200 CONTINUE
      RETURN
      END
```

```
C
      SUBROUTINE PARBR(IBUMP, IPT, NAME, INTO, BRAN,
     1 BRTO, ICHAIN, ITOP )
      DIMENSION NAME(1), INTO(3,1), BRAN(3,1), BRTO(1),
     1 ICHAIN(1)
      DO 100 I=1,ITOP
      DO 200 J=1,IBUMP
      IPTR = MOD(IPT-J+1,IBUMP) + 1
      IF(NAME(IPTR).NE.ICHAIN(I)) GO TO 200
      DO 300 K=1,3
      IF(INTO(K,IPTR).EQ.ICHAIN(ITOP)) BRTO(I) = BRAN(K,IPTR)
  300 CONTINUE
      GO TO 100
  200 CONTINUE
  100 CONTINUE
      BRTO(ITOP) = 1.0
      RETURN
      END
```

```
C
      SUBROUTINE MAX(IMAX, IA, N )
      DIMENSION IA(1)
      IMAX = 0
      DO 100 I=1,N
      IF(IMAX.LT.IA(I)) IMAX = IA(I)
  100 CONTINUE
      RETURN
      END
```

```
C
      SUBROUTINE ROPEYH(D,LIMIT)
      DIMENSION D(1)
      LOGICAL IUNCER, IBETGM
C
C     THIS SUBROUTINE SETS UP THE POINTERS FOR THE
C     CALCULATION OF THE DECAY HEAT AND THE UNCERTAINTIES
C     IN THE DECAY HEAT
C
      CALL TIMEIN(D, LIMIT, NO, IUNCER, IBETGM )
      NFUN = 3
      NOY = 0
      NOE = 0
      IF(IUNCER) NOY = NO
      IF(IBETGM) NOE = NO
      MT = 1
      MHN = MT + 2*NO
      MH = MHN + NFUN * NO
      MHNB = MH + NFUN
      MHNG = MHNB + NFUN * NOE
      MHE = MHNG + NFUN * NOE
      MHE1 = MHE + NFUN * NOE
      MHE2 = MHE1 + NFUN * NOY
      MHE3 = MHE2 + NFUN * NOE
      MHN1 = MHE3 + NFUN * NOY
      MHN2 = MHN1 + NFUN * NOY
      MHT1 = MHN2 + NFUN * NOY
      MHT2 = MHT1 + NFUN * NOY
      MHT3 = MHT2 + NFUN * NOY
      MACT = MHT3 + NFUN * NOY
      MUNC = MACT + NFUN * NOE
      MSPACT = MUNC + NOY
      MTOP = MSPACT + NOY * NFUN
      CALL ZERO(D(MHN), MTOP-MHN+1)
      CALL ROPEH( D(MT), D(MHN), D(MH), D(MHNB), D(MHNG), D(MHE),
     1 D(MHE1), D(MHE2), D(MHE3), D(MHN1), D(MHN2), D(MHT1),
     2 D(MHT2), D(MHT3), D(MACT),D(MUNC), D(MSPACT), NO, IUNCER,
     3 IBETGM, NFUN )
      RETURN
      END
```

```
C
      SUBROUTINE TIMEIN(T, LIMIT, NTIME, IUNCER, IBETGM )
      DIMENSION T(2,1)
      COMMON/IO/INPT,OUTPT,MLIB,MSCR,WLIB,LTIME,ISPC,IPTAPE
      INTEGER OUTPT,WLIB
      LOGICAL IUNCER, IBETGM
      INTEGER ANSWER,YES
      DATA YES,NO/0,1/
      DATA AYEAR/3.1536E+7/
C
C     THIS ROUTINE SETS UP THE TIME STEPS AND THE
C     TYPE OF PROBLEM TO BE EXECUTED.
C
      NTIME = 0
      IUNCER = .FALSE.
      IBETGM = .FALSE.
      READ(INPT,1001) ANSWER
      IF(ANSWER.EQ.NO) GO TO 100
      IUNCER = .TRUE.
      READ(INPT,1001) ANSWER
      IF(ANSWER.EQ.YES) IBETGM = .TRUE.
  100 NTIME = NTIME + 1
      READ(LTIME,1000,END=200) T(1,NTIME), T(2,NTIME)
      IF(T(1,NTIME).LT.0) GO TO 200
      IF(T(2,NTIME).LT.0.) T(2,NTIME) = -T(2,NTIME)*AYEAR
      IF(T(2,NTIME).EQ.0) T(2,NTIME) = T(2,NTIME-1)
      GO TO 100
  200 CONTINUE
      NTIME = NTIME - 1
      IF(NTIME.EQ.0) GO TO 300
      RETURN
  300 CONTINUE
  310 NTIME = NTIME + 1
      READ(LTIME,1000)T(1,NTIME), T(2,NTIME)
      IF(T(1,NTIME).LT.0) GO TO 200
      GO TO 310
 1000 FORMAT(2E9.2)
 1001 FORMAT(I2)
      END
```

```
C
      SUBROUTINE ROPEH(T, HN, H, HNB, HNG, HE, HE1, HE2, HE3,
     1 HN1, HN2, HT1, HT2, HT3, ACT,UNC, SPACT , NTIME, IUNCER,
     2 IBETGM, NFUN )
      CHARACTER*10 HEAD
      DIMENSION T(2,1), HN(500), HNB(500), HE(500),
     1 HE1(500),HE2(500),HE3(500),H(500),
     2 HN1(500), HN2(500), HT1(500), HT2(500),HY(500),
     3 HT3(500), UNC(500), ACT(500), HNG(500), SPACT(500),SSACT(3,100)
      DIMENSION HCO(225), CO(225), TIN(225), ALIB(107)
      INTEGER YES, ANSWER
      LOGICAL IUNCER, IBETGM, LEFIS, LPLOT, ISEP
      COMMON/IO/INPT,OUTPT,MLIB,MSCR,WLIB,LTIME,ISPC,IPTAPE
      INTEGER OUTPT,WLIB
      DATA ISEP/.FALSE./
      DATA YES, NO/0,1/
      INDEX(I,J)=I+NFUN*(J-1)
C
C     INDEX IS A STATEMENT FUNCTION WHICH COMPUTES THE
C     LOCATION OF THE NEXT ELEMENT IN A TWO DIMENSIONAL
C     ARRAY.  IT WAS USED TO SAVE ON REPETITIVE CALCULATIONS
C     OF ARRAY POINTERS
C
C
C     THE FOLLOWING ARRAYS ARE USED IN THE ROPEY
C     CALCULATIONS.
C     H             DUMMY ARRAY TO HOLD ACTIVITIES
C     HN            HOLDS THE FUNCTIONAL VALUES
C     HNG           HOLDS THE GAMMA CONTRIBUTIONS
C                   FOR THE SEPERATE EVALUATION.
C     HNB           THE BETA CONTRIBUTION TO THE FUNCTIONS
C     HE            CORRELATED BETA UNCERTAINITY
C     HE1           CORRELATED GAMMA UNCERTAINTY
C                   OR TOTAL CORRELATED UNCERTAINTY
C     HE2           UNCORRELATED BETA UNCERTAINTY
C     HE3           UNCORRELATED GAMMA UNCERTAINTY
C                   OR TOTAL UNCORRELATED ENERGY UNCERTAINTY
C     HN1           INDEP. YIELD SUM OF UNCERTAINTY
C     HN2           INDEP. YIELD SUM OF SQUARES OF
C                   UNCERTAINTY
C     HT1           CUMMULATIVE YIELD SUM OF UNCERTAINTY
C     HT2           CUMULATIVE YIELD SUM OF SQUARES OF
```

```
C                    UNCERTAINTY
C     HYT            YIELD UNCERTAINTY
C     T              HOLDS THE DECAY AND IRRADIATION
C                    TIMES FOR EACH EVALUATION POINT
C     UNCT           TOTAL UNCERTAINTY
C     ACT            ACTIVITY VALUES
C     SPACT          SEPARATE ACTIVITIES FOR EACH FISSION PRODUCT
C
C     IUNCER IS A LOGICAL VARIABLE WHICH IS
C     TRUE IF AN UNCERTAINTY ANALYSIS IS TO
C     BE PERFORMED.
C     IBETGM IS A LOGICAL VARIABLE WHICH IS TRUE
C     IF A SEPERATE BETA AND GAMMA ANALYSIS IS
C     NEEDED.
C     ISEP IS A LOGICAL VARIABLE USED TO WRITE OUT
C     THE INDIVIDUAL ACTIVITIES OF EACH FISSION
C     PRODUCT ON UNIT IPTAPE
C     NTIME IS THE NUMBER OF TIME STEPS
C     NFUN IS THE NUMBER OF DECAY HEAT FUNCTIONS
C
      REWIND WLIB
      READ(WLIB) ALIB
      READ(WLIB) ILIB, ANUCL, EFISS, EFISUN
      READ(INPT,2000) HEAD
C     THIS HARDWIRES ISEP OFF.
      ISEP = .FALSE.
      LEFIS = .FALSE.
      IF(IBETGM) GO TO 100
C
C     FIND OUT IF IT IS PER FISSION
C
      READ(INPT,1003)ANSWER
      IF(ANSWER.EQ.YES) LEFIS = .TRUE.
  100 CONTINUE
      REWIND IPTAPE
      SCHN=0.
3     READ(WLIB,END=7) NLOT,NOFA,NA,CHYLD,CHYLDE
      CHYLD=CHYLD/100.
      CHYLDE=CHYLDE/100.
      SCHN=SCHN+CHYLDE*CHYLDE
      CALL ZERO(HN1(1), NFUN * NTIME)
      CALL ZERO(HN2(1), NFUN * NTIME)
```

```
      SUMN=0.
C
C     THIS LOOP DOES THE NUCLIDES IN THE CHAIN
C
      DO 5 I=1,NOFA
      READ(WLIB,END=5)I1,I2, NAME,EB,EG,YLD,YLDE,
     1 EBU, EGU ,EBC, EGC,
     2 (HCO(J),TIN(J),J=I1,I2)
     3, (CO(J),TIN(J),J=1,I1)
         SUMN=SUMN+YLDE*YLDE
      X = TIN(I) * CHYLD
      BU2 = (EBU*X)**2
      GU2 = (EGU*X)**2
      ETU = BU2 + GU2
      BC = EBC * X
      GC = EGC * X
      EGT = EG * X
      EBT = EB * X
      ETC = BC + GC
C
C     THIS LOOP EVALUATES THE FUNCTION AT EACH
C     TIME STEP FOR ONE NUCLIDE.
C
      YLDE2 = YLDE**2
      YLDCHD = YLD * CHYLD
         DO 8 N=1,NTIME
      CALL ZERO(H, NFUN )
C
C
C     GET THE ACTIVITIES FOR THE FUNCTIONS
C
      DO 250 J=I,NLOT
      CALL HESS(H, T(1,N), T(2,N), HCO(J), TIN(J), NFUN )
  250 CONTINUE
C
C       NOW DO THE TOTALS AND YIELD UNCERTAINTIES IF WE
C      ARE DOING AN UNCERTAINTY ANALYSIS
C
      IND=INDEX(1,N)
      DO 200 J=1,NFUN
      HN(IND) = HN(IND) + H(J) * YLDCHD
      IND = IND + 1
```

```
  200 CONTINUE
      IF(.NOT.IUNCER) GO TO 8
      IND=INDEX(1,N)
      DO 210 J=1,NFUN
      HN1(IND) = HN1(IND) + (H(J)**2) * YLDE2
      HN2(IND) = HN2(IND) + H(J) * YLDE2
      IND = IND + 1
  210 CONTINUE
C
C     NOW DO IT ALL BACKWARDS FOR THE ENERGY UNCERTAINTIES
C
      CALL ZERO(H, NFUN)
      DO 350 J=1,I
      CALL HESS(H, T(1,N), T(2,N), CO(J), TIN(J), NFUN )
  350 CONTINUE
      IND=INDEX(1,N)
      DO 300 J=1,NFUN
      HI2 = H(J)**2
      IF(IBETGM) GO TO 302
C
C     THIS DOES THE TOTAL ENERGY UNCERTAINTIES
C
      HE1(IND) = HE1(IND) + H(J) * ETC
      HE2(IND) = HE2(IND) + HI2 * ETU
      SPACT(IND) = H(J) * X
      SSACT(J,N)=SPACT(IND)
      GO TO 300
  302 CONTINUE
C
C     OF THIS DOES ALL THE PARTS
C
      HNB(IND) = HNB(IND) + H(J) * EBT
      HNG(IND) = HNG(IND) + H(J) * EGT
      HE(IND) = HE(IND) + H(J) * BC
      HE1(IND) = HE1(IND) + H(J) * GC
      HE2(IND) = HE2(IND) + HI2 * BU2
      HE3(IND) = HE3(IND) + HI2 * GU2
      ACT(IND) = ACT(IND) + H(J) * X
  300 IND = IND + 1
    8 CONTINUE
      IF(.NOT.IBETGM)
     +WRITE(IPTAPE)NAME,((SSACT(1,J),SSACT(2,J)),J=1,NTIME),EBU,
```

```
     +EGU,EBC,EGC,EB,EG
    5 CONTINUE
      IF(.NOT.IUNCER) GO TO 3
C
C     THIS DOES THE CONSTRAINED YIELD ANALYSIS
C
      CHYE2 = CHYLDE**2
      CHY2 = CHYLD**2
      DO 10 N=1,NTIME
      IND=INDEX(1,N)
      DO 400 I=1,NFUN
      HNN = HN(IND)
      X = HN1(IND) - HN2(IND) * HN2(IND) / SUMN
      IF(X.LT.0) X = 0.
      HT1(IND) = HT1(IND) + CHYE2 * (HNN**2)
      HT2(IND) = HT2(IND) + CHYE2 * HNN
      HT3(IND) = HT3(IND) + X * CHY2
      IND = IND + 1
  400 CONTINUE
   10 CONTINUE
C
C     NOW GO AND DO THE NEXT CHAIN
C
      GO TO 3
    7 CONTINUE
C
C     DO THE IMPORTANT WORK NOW, WRITE THE ANSWERS..
C
      LPLOT = .FALSE.
      IOUT = 3
      IF(IUNCER) IOUT = 7
      IF(IBETGM) IOUT = 9
      DO 600 I=1,NFUN
C
C     FIRST DO THE HEADINGS
      WRITE(OUTPT,2999)
      WRITE(OUTPT,3000)HEAD,I-1
C
      IF(I-2)500,501,503
 500  WRITE(OUTPT,3001)
      GOTO 3005
 501  WRITE(OUTPT,3002)
```

```
      GOTO 3005
 503  WRITE(OUTPT,3003)
C
 3005 CONTINUE
C
 2999 FORMAT(1H1)
 3000 FORMAT(////////,39X,A7,1X,'ROPEY',1X,'DECAY HEAT WITH THE'
     1,1X,'SEPARATE',1X,'EVALUATION',1X,'H',I1 /)
 3001 FORMAT(/,6X,'DECAY',7X,'IRRADIATION',4X,'BETA VALUE',
     13X,'GAMMA VALUE',6X,'YIELD',7X,'COR.ENERGY',4X,'COR.ENERGY',
     24X,'UNC.ENERGY',4X,'UNC.ENERGY'/6X,'TIME(SEC)',5X,'TIME(SEC)',
     35X,'MEV/F-SEC',5X,'MEV/F-SEC',3X,'UNCERTAINTY',3X,'UNCERTAINTY'
     4,3X,'UNCERTAINTY',3X,'UNCERTAINTY',3X,'UNCERTAINTY'/)
C
 3002 FORMAT(/,6X,'DECAY',7X,'IRRADIATION',4X,'BETA VALUE',
     13X,'GAMMA VALUE',6X,'YIELD',7X,'COR.ENERGY',4X,'COR.ENERGY',
     24X,'UNC.ENERGY',4X,'UNC.ENERGY'/6X,'TIME(SEC)',5X,'TIME(SEC)',
     35X,'MEV/FISSI',5X,'MEV/FISSI',3X,'UNCERTAINTY',3X,'UNCERTAINTY'
     4,3X,'UNCERTAINTY',3X,'UNCERTAINTY',3X,'UNCERTAINTY'/)
C      NOW DO THE NUMBERS
C
 3003 FORMAT(/,6X,'DECAY',7X,'IRRADIATION',4X,'BETA VALUE',
     13X,'GAMMA VALUE',6X,'YIELD',7X,'COR.ENERGY',4X,'COR.ENERGY',
     24X,'UNC.ENERGY',4X,'UNC.ENERGY'/6X,'TIME(SEC)',5X,'TIME(SEC)',
     35X,'MEV-SEC/F',5X,'MEV-SEC/F',3X,'UNCERTAINTY',3X,'UNCERTAINTY'
     4,3X,'UNCERTAINTY',3X,'UNCERTAINTY',3X,'UNCERTAINTY'/)
C
      DO 12 N=1,NTIME
      IND=INDEX(I,N)
C
C      BE CAREFUL TO CONVERT VARIANCES TO S.D.
C
      IF(.NOT.IUNCER) GO TO 17
       HYT = HT1(IND) + HT3(IND)
     1 - HT2(IND) * HT2(IND) / SCHN
      UNCT = SQRT(HE1(IND)**2 + HE3(IND) + HYT )
      IF(IBETGM) HE2(IND) = SQRT(HE2(IND))
      HE3(IND) = SQRT(HE3(IND))
       HYT = SQRT(HYT)
   17 CONTINUE
      IF(.NOT.LEFIS.OR.I.EQ.1) GO TO 104
      IF(HN(IND).NE.0)
```

```
     1UNCT = SQRT((UNCT/EFISS)**2 + (HN(IND)*EFISUN/EFISS**2)**2)
      HN(IND) = HN(IND)/EFISS
      HYT = HYT/EFISS
      HE1(IND) = HE1(IND)/EFISS
      HE3(IND) = HE3(IND)/EFISS
  104 CONTINUE
      UNC(IND) = UNCT
      HY(IND)=HYT
C
C     NOW PRINT THE GOODIES.
C
      IND=INDEX(I,N)
      IF(HNB(IND)+HNG(IND).NE.0.)
     1  HNORM = HN(IND)/(HNB(IND) + HNG(IND))
      HNB(IND) = HNORM * HNB(IND)
      HNG(IND) = HNORM * HNG(IND)
      HE(IND) = HE(IND) * HNORM
      HE1(IND) = HE1(IND) * HNORM
      HE2(IND) = HE2(IND) * HNORM
      HE3(IND) = HE3(IND) * HNORM
       CALL PRYNT(T(1,N),T(2,N),HNB(IND)
     1 ,HNG(IND), HYT, HE(IND), HE1(IND), HE2(IND),
     2 HE3(IND),9)
   12 CONTINUE
  600 CONTINUE
C
C
C     NOW CALCULATE THE AVERAGE ENERGIES
C
      IF(.NOT.IBETGM)RETURN
      REWIND 12
C FILE 12 IS TO MAKE THE DATA FILE TO PLOT THE DATA
      DO 900 I=1,NFUN
      WRITE(OUTPT,2999)
      WRITE(OUTPT,1007)HEAD,I-1
      IF(I-2)801,802,803
 801  WRITE(OUTPT,1008)
      GOTO 807
 802  WRITE(OUTPT,1009)
      GOTO 807
 803  WRITE(OUTPT,1010)
C
```

```
 807  CONTINUE
C
      DO 900 J=1,NTIME
      IND=INDEX(I,J)
      HE3(IND)=SQRT(HE2(IND)**2+HE3(IND)**2)
      UNC(IND)=SQRT(HE1(IND)**2+HY(IND)**2+HE3(IND)**2)
      EGAMMA = 0.
      EBETA = 0.
      IF(ACT(IND).EQ.0.) GO TO 901
      EBETA = HNB(IND)/ACT(IND)
      EGAMMA = HNG(IND) / ACT(IND)
  901 CONTINUE
      WRITE(OUTPT,1006)T(1,J),T(2,J),HN(IND),UNC(IND),HE1(IND),HE3(IND)
     +,ACT(IND),EBETA,EGAMMA
      WRITE(12,999)T(1,J),HN(IND),UNC(IND),HE1(IND),HE3(IND),HY(IND)
  900 CONTINUE
      ENDFILE 12
  999  FORMAT(E10.4,5(2X,E10.3))
 1006 FORMAT(2X,7E14.3,4X,F6.3,8X,F6.3)
 1007 FORMAT(/////////,18X,A7,1X,'ROPEY',1X,'DECAY HEAT WITH UNCERTAIN',
     1'TY',1X,'ACTIVITIES AND AVERAGE ENERGIES EVALUATION',1X,'H',I1,//)
 1008 FORMAT(7X,'DECAY',6X,'IRRADIATION',6X,'VALUE',9X,'TOTAL',7X,
     1'COR.ENERGY',4X,'UNC.ENERGY',5X,'ACTIVITY',4X,'AVE.BETA',6X,
     2'AVE.GAMMA'/7X,'TIME(SEC)',4X,'TIME(SEC)',5X,'MEV/F-SEC',4X,
     3'UNCERTAINTY',4X,'UNCERTAINTY',3X,'UNCERTAINTY',18X,'(MEV)',
     411X,'(MEV)' /)
C
 1009 FORMAT(7X,'DECAY',6X,'IRRADIATION',6X,'VALUE',9X,'TOTAL',7X,
     1'COR.ENERGY',4X,'UNC.ENERGY',5X,'ACTIVITY',4X,'AVE.BETA',6X,
     2'AVE.GAMMA'/7X,'TIME(SEC)',4X,'TIME(SEC)',5X,'MEV/FISSI',4X,
     3'UNCERTAINTY',4X,'UNCERTAINTY',3X,'UNCERTAINTY',18X,'(MEV)',
     411X,'(MEV)' /)
C
 1010 FORMAT(7X,'DECAY',6X,'IRRADIATION',6X,'VALUE',9X,'TOTAL',7X,
     1'COR.ENERGY',4X,'UNC.ENERGY',5X,'ACTIVITY',4X,'AVE.BETA',6X,
     2'AVE.GAMMA'/7X,'TIME(SEC)',4X,'TIME(SEC)',5X,'MEV-SEC/F',4X,
     3'UNCERTAINTY',4X,'UNCERTAINTY',3X,'UNCERTAINTY',18X,'(MEV)',
     411X,'(MEV)' /)
C
      RETURN
 2006 FORMAT(14X,7E14.3)
 2008 FORMAT(9E14.3)
```

```
910   FORMAT(' PLEASE INPUT THE CASE TITLE (LESS THAN 70 CHARACTERS)')
2000  FORMAT(A7)
 1003 FORMAT(I2)
      END
```

```
C
      SUBROUTINE HESS(H, T, TIR, Y, TIN, NFUN )
      DIMENSION H(NFUN)
      DATA EMAX/50./
      IF(TIN.LT.1.0E-10) RETURN
      X = T * TIN
      X1 = TIR * TIN
      U = 0.
      V = 0.
      IF(X.LT.EMAX) U = EXP(-X)
      IF(X1.LT.EMAX) V = EXP(-X1)
      H(1) = H(1) + U * Y
      HINNER = (1-V) * Y / TIN
      H(2) = H(2) + U * HINNER
      H(3) = H(3) + (1-U) * HINNER / TIN
      RETURN
      END
```

```
C
      SUBROUTINE ZERO(D, N)
      DIMENSION D(1)
      DO 100 I=1,N
      D(I) = 0.
  100 CONTINUE
      RETURN
      END
```

```
C
      SUBROUTINE PRYNT(A1,A2,A3,A4,A5,A6,A7,A8,A9,IOUT)
      COMMON/IO/INPT,OUTPT,MLIB,MSCR,WLIB,LTIME,ISPC,IPTAPE
      COMMON/SDG/IN(15),F(14)
      COMMON/AO/A(10)
      CHARACTER*10 IN,F
      INTEGER OUTPT,WLIB
      A(1)=A1
      A(2)=A2
      A(3)=A3
      A(4)=A4
      A(5)=A5
      A(6)=A6
      A(7)=A7
      A(8)=A8
      A(9)=A9
      F(1)='(1X,3(E1'
      IF(IOUT.EQ.3) F(1) = '(43X3(E1'
      IF(IOUT.EQ.7) F(1) = '(15X3(E1'
      F(2)='4.3),'
      DO 20 I=4,12,2
         F(I)='E14.3,'
   20 CONTINUE
      F(14)='E14.3)'
      DO 30 I=3,13,2
         F(I)=IN(11)
   30 CONTINUE
      IF(IOUT.NE.3.AND.IOUT.NE.7.AND.IOUT.NE.9)
     1 PRINT*,'   FORMAT PROBLEM WITH PRYNT'
      IF(IOUT-7) 230,200,300
  200 H=0.
      IF(A(3).GT.0.) H = ALOG10(A(3))
      DO 220 I=4,IOUT
         J=2*I-5
         CALL SIGDIG(I,J,H)
  220 CONTINUE
  230 CONTINUE
      WRITE(OUTPT,F) (A(I),I=1,IOUT)
      RETURN
  300 F(3)=IN(12)
      HB=0.
      HG=0.
```

```
IF(A(3).GT.0.) HB=ALOG10(A(3))
IF(A(4).GT.0.) HG=ALOG10(A(4))
H=A(3)+A(4)
IF(H.GT.0.) H=ALOG10(H)
CALL SIGDIG(5,5,H)
CALL SIGDIG(6,7,HB)
CALL SIGDIG(7,9,HG)
CALL SIGDIG(8,11,HB)
CALL SIGDIG(9,13,HG)
GO TO 230
END
```

```
C
      SUBROUTINE SIGDIG(I,J,H)
      COMMON/SDG/IN(15),F(14)
      COMMON/AO/A(10)
      CHARACTER*10 IN,F
      DATA ALITLE/5.0E-4/
      ND=0
      IF(A(I).LE.0.) GO TO 30
      NH=H
      IF(H.LT.0.) NH=NH-1
      U=ALOG10(A(I))
      NU=U
      IF(U.LT.0.) NU=NU-1
      ALOW = 10**NU * (1-ALITLE)
      AHI = 10**NU
      IF(A(I).GT.ALOW.AND.A(I).LE.AHI) NU = NU + 1
      ND=NU+1-NH
      IF(ND.LT.-10) ND=-10
      IF(ND.GT.4) ND=4
   30 F(J)=IN(ND+11)
      RETURN
      END
```

D. Sample Outputs

PU-239T ROPEY DECAY HEAT WITH THE SEPARATE EVALUATION HO

DECAY TIME(SEC)	IRRADIATION TIME(SEC)	BETA VALUE MEV/F-SEC	GAMMA VALUE MEV/F-SEC	YIELD UNCERTAINTY	COR.ENERGY UNCERTAINTY	COR.ENERGY UNCERTAINTY	UNC.ENERGY UNCERTAINTY	UNC.ENERGY UNCERTAINTY
0.100E+01	0.100E+14	0.269E+00	0.179E+00	0.184E-01	0.000E+00	0.718E-01	0.112E-01	0.150E-01
0.150E+01	0.100E+14	0.227E+00	0.147E+00	0.141E-01	0.000E+00	0.590E-01	0.935E-02	0.125E-01
0.200E+01	0.100E+14	0.196E+00	0.125E+00	0.113E-01	0.000E+00	0.499E-01	0.797E-02	0.106E-01
0.400E+01	0.100E+14	0.127E+00	0.760E-01	0.645E-02	0.000E+00	0.300E-01	0.496E-02	0.651E-02
0.600E+01	0.100E+14	0.933E-01	0.545E-01	0.482E-02	0.000E+00	0.208E-01	0.376E-02	0.490E-02
0.800E+01	0.100E+14	0.738E-01	0.426E-01	0.397E-02	0.000E+00	0.158E-01	0.309E-02	0.402E-02
0.100E+02	0.100E+14	0.610E-01	0.351E-01	0.337E-02	0.000E+00	0.128E-01	0.261E-02	0.339E-02
0.150E+02	0.100E+14	0.418E-01	0.243E-01	0.225E-02	0.000E+00	0.870E-02	0.178E-02	0.229E-02
0.200E+02	0.100E+14	0.312E-01	0.186E-01	0.149E-02	0.000E+00	0.660E-02	0.127E-02	0.163E-02
0.400E+02	0.100E+14	0.149E-01	0.983E-02	0.425E-03	0.000E+00	0.320E-02	0.640E-03	0.787E-03
0.600E+02	0.100E+14	0.968E-02	0.690E-02	0.251E-03	0.000E+00	0.193E-02	0.472E-03	0.554E-03
0.800E+02	0.100E+14	0.707E-02	0.528E-02	0.179E-03	0.000E+00	0.128E-02	0.373E-03	0.415E-03
0.100E+03	0.100E+14	0.548E-02	0.422E-02	0.136E-03	0.000E+00	0.894E-03	0.305E-03	0.322E-03
0.150E+03	0.100E+14	0.337E-02	0.270E-02	0.782E-04	0.000E+00	0.427E-03	0.202E-03	0.192E-03
0.200E+03	0.100E+14	0.238E-02	0.194E-02	0.497E-04	0.000E+00	0.238E-03	0.140E-03	0.126E-03
0.400E+03	0.100E+14	0.110E-02	0.937E-03	0.140E-04	0.000E+00	0.591E-04	0.456E-04	0.431E-04
0.600E+03	0.100E+14	0.727E-03	0.662E-03	0.787E-05	0.000E+00	0.332E-04	0.300E-04	0.299E-04
0.800E+03	0.100E+14	0.544E-03	0.526E-03	0.574E-05	0.000E+00	0.241E-04	0.231E-04	0.232E-04
0.100E+04	0.100E+14	0.431E-03	0.438E-03	0.452E-05	0.000E+00	0.186E-04	0.182E-04	0.182E-04
0.150E+04	0.100E+14	0.274E-03	0.306E-03	0.296E-05	0.000E+00	0.104E-04	0.103E-04	0.105E-04
0.200E+04	0.100E+14	0.192E-03	0.231E-03	0.234E-05	0.000E+00	0.601E-05	0.614E-05	0.637E-05
0.400E+04	0.100E+14	0.710E-04	0.105E-03	0.164E-05	0.000E+00	0.885E-06	0.104E-05	0.138E-05
0.600E+04	0.100E+14	0.378E-04	0.624E-04	0.129E-05	0.000E+00	0.181E-06	0.274E-06	0.622E-06
0.800E+04	0.100E+14	0.247E-04	0.421E-04	0.987E-06	0.000E+00	0.538E-07	0.136E-06	0.437E-06
0.100E+05	0.100E+14	0.183E-04	0.306E-04	0.736E-06	0.000E+00	0.269E-07	0.928E-07	0.335E-06
0.150E+05	0.100E+14	0.111E-04	0.165E-04	0.324E-06	0.000E+00	0.157E-07	0.474E-07	0.184E-06
0.200E+05	0.100E+14	0.803E-05	0.105E-04	0.139E-06	0.000E+00	0.122E-07	0.286E-07	0.107E-06
0.400E+05	0.100E+14	0.363E-05	0.411E-05	0.279E-07	0.000E+00	0.541E-08	0.939E-08	0.275E-07
0.600E+05	0.100E+14	0.212E-05	0.252E-05	0.193E-07	0.000E+00	0.293E-08	0.527E-08	0.155E-07
0.800E+05	0.100E+14	0.140E-05	0.176E-05	0.149E-07	0.000E+00	0.191E-08	0.359E-08	0.107E-07
0.100E+06	0.100E+14	0.101E-05	0.132E-05	0.120E-07	0.000E+00	0.137E-08	0.271E-08	0.819E-08
0.150E+06	0.100E+14	0.561E-06	0.791E-06	0.825E-08	0.000E+00	0.696E-09	0.158E-08	0.536E-08
0.200E+06	0.100E+14	0.372E-06	0.561E-06	0.649E-08	0.000E+00	0.389E-09	0.103E-08	0.396E-08
0.400E+06	0.100E+14	0.150E-06	0.273E-06	0.353E-08	0.000E+00	0.595E-10	0.369E-09	0.163E-08
0.600E+06	0.100E+14	0.951E-07	0.184E-06	0.214E-08	0.000E+00	0.146E-10	0.218E-09	0.890E-09
0.800E+06	0.100E+14	0.693E-07	0.137E-06	0.132E-08	0.000E+00	0.626E-11	0.144E-09	0.553E-09
0.100E+07	0.100E+14	0.541E-07	0.107E-06	0.835E-09	0.000E+00	0.424E-11	0.102E-09	0.369E-09

PU-239T ROPEY DECAY HEAT WITH THE SEPARATE EVALUATION H1

DECAY TIME(SEC)	IRRADIATION TIME(SEC)	BETA VALUE MEV/FISSI	GAMMA VALUE MEV/FISSI	YIELD UNCERTAINTY	COR.ENERGY UNCERTAINTY	COR.ENERGY UNCERTAINTY	UNC.ENERGY UNCERTAINTY	UNC.ENERGY UNCERTAINTY
0.100E+01	0.100E+14	0.498E+01	0.436E+01	0.990E-01	0.000E+00	0.644E+00	0.116E+00	0.133E+00
0.150E+01	0.100E+14	0.485E+01	0.428E+01	0.944E-01	0.000E+00	0.611E+00	0.113E+00	0.130E+00
0.200E+01	0.100E+14	0.475E+01	0.422E+01	0.907E-01	0.000E+00	0.584E+00	0.112E+00	0.128E+00
0.400E+01	0.100E+14	0.444E+01	0.402E+01	0.798E-01	0.000E+00	0.507E+00	0.106E+00	0.119E+00
0.600E+01	0.100E+14	0.422E+01	0.389E+01	0.717E-01	0.000E+00	0.457E+00	0.102E+00	0.113E+00
0.800E+01	0.100E+14	0.405E+01	0.380E+01	0.651E-01	0.000E+00	0.421E+00	0.985E-01	0.108E+00
0.100E+02	0.100E+14	0.392E+01	0.372E+01	0.597E-01	0.000E+00	0.392E+00	0.956E-01	0.104E+00
0.150E+02	0.100E+14	0.367E+01	0.358E+01	0.501E-01	0.000E+00	0.340E+00	0.903E-01	0.964E-01
0.200E+02	0.100E+14	0.349E+01	0.347E+01	0.444E-01	0.000E+00	0.302E+00	0.864E-01	0.909E-01
0.400E+02	0.100E+14	0.306E+01	0.321E+01	0.351E-01	0.000E+00	0.210E+00	0.759E-01	0.769E-01
0.600E+02	0.100E+14	0.283E+01	0.304E+01	0.309E-01	0.000E+00	0.161E+00	0.685E-01	0.680E-01
0.800E+02	0.100E+14	0.266E+01	0.292E+01	0.282E-01	0.000E+00	0.129E+00	0.627E-01	0.617E-01
0.100E+03	0.100E+14	0.254E+01	0.283E+01	0.263E-01	0.000E+00	0.107E+00	0.581E-01	0.570E-01
0.150E+03	0.100E+14	0.232E+01	0.266E+01	0.235E-01	0.000E+00	0.762E-01	0.497E-01	0.493E-01
0.200E+03	0.100E+14	0.218E+01	0.255E+01	0.220E-01	0.000E+00	0.601E-01	0.442E-01	0.446E-01
0.400E+03	0.100E+14	0.187E+01	0.229E+01	0.198E-01	0.000E+00	0.368E-01	0.331E-01	0.347E-01
0.600E+03	0.100E+14	0.169E+01	0.213E+01	0.188E-01	0.000E+00	0.281E-01	0.265E-01	0.284E-01
0.800E+03	0.100E+14	0.156E+01	0.201E+01	0.181E-01	0.000E+00	0.224E-01	0.214E-01	0.237E-01
0.100E+04	0.100E+14	0.147E+01	0.192E+01	0.175E-01	0.000E+00	0.182E-01	0.175E-01	0.200E-01
0.150E+04	0.100E+14	0.129E+01	0.174E+01	0.163E-01	0.000E+00	0.111E-01	0.109E-01	0.141E-01
0.200E+04	0.100E+14	0.118E+01	0.160E+01	0.153E-01	0.000E+00	0.712E-02	0.709E-02	0.109E-01
0.400E+04	0.100E+14	0.946E+00	0.129E+01	0.120E-01	0.000E+00	0.191E-02	0.226E-02	0.675E-02
0.600E+04	0.100E+14	0.842E+00	0.113E+01	0.942E-02	0.000E+00	0.104E-02	0.157E-02	0.549E-02
0.800E+04	0.100E+14	0.782E+00	0.103E+01	0.752E-02	0.000E+00	0.842E-03	0.132E-02	0.469E-02
0.100E+05	0.100E+14	0.739E+00	0.958E+00	0.623E-02	0.000E+00	0.767E-03	0.118E-02	0.412E-02
0.150E+05	0.100E+14	0.668E+00	0.846E+00	0.484E-02	0.000E+00	0.670E-03	0.966E-03	0.330E-02
0.200E+05	0.100E+14	0.621E+00	0.781E+00	0.453E-02	0.000E+00	0.601E-03	0.857E-03	0.291E-02
0.400E+05	0.100E+14	0.515E+00	0.654E+00	0.424E-02	0.000E+00	0.438E-03	0.665E-03	0.236E-02
0.600E+05	0.100E+14	0.459E+00	0.590E+00	0.394E-02	0.000E+00	0.359E-03	0.576E-03	0.211E-02
0.800E+05	0.100E+14	0.425E+00	0.548E+00	0.368E-02	0.000E+00	0.312E-03	0.520E-03	0.195E-02
0.100E+06	0.100E+14	0.401E+00	0.518E+00	0.346E-02	0.000E+00	0.280E-03	0.480E-03	0.182E-02
0.150E+06	0.100E+14	0.364E+00	0.467E+00	0.303E-02	0.000E+00	0.231E-03	0.418E-03	0.159E-02
0.200E+06	0.100E+14	0.341E+00	0.434E+00	0.270E-02	0.000E+00	0.205E-03	0.381E-03	0.143E-02
0.400E+06	0.100E+14	0.295E+00	0.358E+00	0.183E-02	0.000E+00	0.171E-03	0.315E-03	0.111E-02
0.600E+06	0.100E+14	0.272E+00	0.313E+00	0.136E-02	0.000E+00	0.165E-03	0.284E-03	0.976E-03
0.800E+06	0.100E+14	0.255E+00	0.281E+00	0.111E-02	0.000E+00	0.163E-03	0.267E-03	0.901E-03
0.100E+07	0.100E+14	0.243E+00	0.257E+00	0.964E-03	0.000E+00	0.162E-03	0.254E-03	0.850E-03

PU-239T ROPEY DECAY HEAT WITH THE SEPARATE EVALUATION H2

DECAY TIME(SEC)	IRRADIATION TIME(SEC)	BETA VALUE MEV-SEC/F	GAMMA VALUE MEV-SEC/F	YIELD UNCERTAINTY	COR.ENERGY UNCERTAINTY	COR.ENERGY UNCERTAINTY	UNC.ENERGY UNCERTAINTY	UNC.ENERGY UNCERTAINTY
0.100E+01	0.100E+14	0.498E+01	0.440E+01	0.105E+00	0.000E+00	0.686E+00	0.118E+00	0.137E+00
0.150E+01	0.100E+14	0.763E+01	0.658E+01	0.153E+00	0.000E+00	0.100E+01	0.175E+00	0.203E+00
0.200E+01	0.100E+14	0.996E+01	0.867E+01	0.199E+00	0.000E+00	0.130E+01	0.231E+00	0.267E+00
0.400E+01	0.100E+14	0.189E+02	0.168E+02	0.367E+00	0.000E+00	0.238E+01	0.447E+00	0.512E+00
0.600E+01	0.100E+14	0.275E+02	0.247E+02	0.515E+00	0.000E+00	0.334E+01	0.654E+00	0.742E+00
0.800E+01	0.100E+14	0.358E+02	0.323E+02	0.648E+00	0.000E+00	0.422E+01	0.852E+00	0.960E+00
0.100E+02	0.100E+14	0.437E+02	0.397E+02	0.769E+00	0.000E+00	0.503E+01	0.104E+01	0.117E+01
0.150E+02	0.100E+14	0.623E+02	0.577E+02	0.103E+01	0.000E+00	0.685E+01	0.150E+01	0.166E+01
0.200E+02	0.100E+14	0.799E+02	0.751E+02	0.125E+01	0.000E+00	0.845E+01	0.193E+01	0.211E+01
0.400E+02	0.100E+14	0.144E+03	0.141E+03	0.195E+01	0.000E+00	0.135E+02	0.351E+01	0.372E+01
0.600E+02	0.100E+14	0.205E+03	0.206E+03	0.254E+01	0.000E+00	0.171E+02	0.491E+01	0.511E+01
0.800E+02	0.100E+14	0.259E+03	0.265E+03	0.307E+01	0.000E+00	0.200E+02	0.618E+01	0.635E+01
0.100E+03	0.100E+14	0.310E+03	0.321E+03	0.357E+01	0.000E+00	0.223E+02	0.735E+01	0.747E+01
0.150E+03	0.100E+14	0.433E+03	0.459E+03	0.470E+01	0.000E+00	0.269E+02	0.990E+01	0.993E+01
0.200E+03	0.100E+14	0.543E+03	0.588E+03	0.572E+01	0.000E+00	0.302E+02	0.121E+02	0.121E+02
0.400E+03	0.100E+14	0.945E+03	0.107E+04	0.951E+01	0.000E+00	0.394E+02	0.190E+02	0.192E+02
0.600E+03	0.100E+14	0.130E+04	0.151E+04	0.131E+02	0.000E+00	0.458E+02	0.244E+02	0.250E+02
0.800E+03	0.100E+14	0.162E+04	0.192E+04	0.166E+02	0.000E+00	0.508E+02	0.288E+02	0.298E+02
0.100E+04	0.100E+14	0.193E+04	0.232E+04	0.200E+02	0.000E+00	0.549E+02	0.325E+02	0.339E+02
0.150E+04	0.100E+14	0.261E+04	0.323E+04	0.282E+02	0.000E+00	0.620E+02	0.390E+02	0.416E+02
0.200E+04	0.100E+14	0.323E+04	0.406E+04	0.359E+02	0.000E+00	0.665E+02	0.430E+02	0.470E+02
0.400E+04	0.100E+14	0.532E+04	0.692E+04	0.625E+02	0.000E+00	0.740E+02	0.493E+02	0.595E+02
0.600E+04	0.100E+14	0.709E+04	0.933E+04	0.834E+02	0.000E+00	0.767E+02	0.510E+02	0.676E+02
0.800E+04	0.100E+14	0.871E+04	0.115E+05	0.997E+02	0.000E+00	0.786E+02	0.520E+02	0.746E+02
0.100E+05	0.100E+14	0.102E+05	0.135E+05	0.113E+03	0.000E+00	0.802E+02	0.528E+02	0.810E+02
0.150E+05	0.100E+14	0.137E+05	0.180E+05	0.136E+03	0.000E+00	0.838E+02	0.545E+02	0.945E+02
0.200E+05	0.100E+14	0.170E+05	0.220E+05	0.153E+03	0.000E+00	0.869E+02	0.562E+02	0.106E+03
0.400E+05	0.100E+14	0.282E+05	0.362E+05	0.220E+03	0.000E+00	0.970E+02	0.631E+02	0.145E+03
0.600E+05	0.100E+14	0.379E+05	0.485E+05	0.289E+03	0.000E+00	0.105E+03	0.701E+02	0.181E+03
0.800E+05	0.100E+14	0.467E+05	0.599E+05	0.358E+03	0.000E+00	0.111E+03	0.772E+02	0.215E+03
0.100E+06	0.100E+14	0.549E+05	0.705E+05	0.424E+03	0.000E+00	0.117E+03	0.841E+02	0.248E+03
0.150E+06	0.100E+14	0.740E+05	0.950E+05	0.578E+03	0.000E+00	0.130E+03	0.101E+03	0.324E+03
0.200E+06	0.100E+14	0.916E+05	0.118E+06	0.715E+03	0.000E+00	0.141E+03	0.117E+03	0.393E+03
0.400E+06	0.100E+14	0.155E+06	0.196E+06	0.115E+04	0.000E+00	0.177E+03	0.174E+03	0.620E+03
0.600E+06	0.100E+14	0.211E+06	0.263E+06	0.145E+04	0.000E+00	0.210E+03	0.226E+03	0.806E+03
0.800E+06	0.100E+14	0.264E+06	0.322E+06	0.168E+04	0.000E+00	0.243E+03	0.275E+03	0.973E+03
0.100E+07	0.100E+14	0.313E+06	0.376E+06	0.187E+04	0.000E+00	0.276E+03	0.322E+03	0.113E+04

PU-239T ROPEY DECAY HEAT WITH UNCERTAINTY ACTIVITIES AND AVERAGE ENERGIES EVALUATION HO

DECAY TIME(SEC)	IRRADIATION TIME(SEC)	VALUE MEV/F-SEC	TOTAL UNCERTAINTY	COR. ENERGY UNCERTAINTY	UNC. ENERGY UNCERTAINTY	ACTIVITY	AVE. BETA (MEV)	AVE. GAMMA (MEV)
0.100E+01	0.100E+14	0.447E+00	0.765E-01	0.718E-01	0.187E-01	0.132E+00	2.031	1.353
0.150E+01	0.100E+14	0.374E+00	0.626E-01	0.590E-01	0.156E-01	0.113E+00	2.003	1.300
0.200E+01	0.100E+14	0.321E+00	0.529E-01	0.499E-01	0.133E-01	0.991E-01	1.980	1.256
0.400E+01	0.100E+14	0.203E+00	0.318E-01	0.300E-01	0.819E-02	0.662E-01	1.913	1.147
0.600E+01	0.100E+14	0.148E+00	0.223E-01	0.208E-01	0.617E-02	0.500E-01	1.865	1.089
0.800E+01	0.100E+14	0.116E+00	0.171E-01	0.158E-01	0.507E-02	0.405E-01	1.825	1.054
0.100E+02	0.100E+14	0.960E-01	0.139E-01	0.128E-01	0.428E-02	0.341E-01	1.788	1.029
0.150E+02	0.100E+14	0.662E-01	0.944E-02	0.870E-02	0.290E-02	0.245E-01	1.708	0.992
0.200E+02	0.100E+14	0.498E-01	0.707E-02	0.660E-02	0.207E-02	0.191E-01	1.639	0.974
0.400E+02	0.100E+14	0.247E-01	0.338E-02	0.320E-02	0.101E-02	0.101E-01	1.470	0.973
0.600E+02	0.100E+14	0.166E-01	0.208E-02	0.193E-02	0.728E-03	0.701E-02	1.382	0.984
0.800E+02	0.100E+14	0.124E-01	0.141E-02	0.128E-02	0.557E-03	0.537E-02	1.318	0.984
0.100E+03	0.100E+14	0.970E-02	0.101E-02	0.894E-03	0.443E-03	0.433E-02	1.267	0.975
0.150E+03	0.100E+14	0.608E-02	0.516E-03	0.427E-03	0.278E-03	0.286E-02	1.179	0.945
0.200E+03	0.100E+14	0.433E-02	0.308E-03	0.238E-03	0.188E-03	0.211E-02	1.130	0.922
0.400E+03	0.100E+14	0.203E-02	0.873E-04	0.591E-04	0.627E-04	0.103E-02	1.062	0.908
0.600E+03	0.100E+14	0.139E-02	0.544E-04	0.332E-04	0.424E-04	0.710E-03	1.024	0.933
0.800E+03	0.100E+14	0.107E-02	0.411E-04	0.241E-04	0.328E-04	0.550E-03	0.990	0.956
0.100E+04	0.100E+14	0.869E-03	0.321E-04	0.186E-04	0.257E-04	0.448E-03	0.962	0.976
0.150E+04	0.100E+14	0.580E-03	0.182E-04	0.104E-04	0.147E-04	0.300E-03	0.913	1.017
0.200E+04	0.100E+14	0.423E-03	0.110E-04	0.601E-05	0.885E-05	0.219E-03	0.880	1.054
0.400E+04	0.100E+14	0.176E-03	0.254E-05	0.885E-06	0.173E-05	0.892E-04	0.796	1.180
0.600E+04	0.100E+14	0.100E-03	0.147E-05	0.181E-06	0.680E-06	0.511E-04	0.740	1.223
0.800E+04	0.100E+14	0.669E-04	0.109E-05	0.538E-07	0.458E-06	0.354E-04	0.699	1.190
0.100E+05	0.100E+14	0.489E-04	0.815E-06	0.269E-07	0.348E-06	0.273E-04	0.670	1.119
0.150E+05	0.100E+14	0.276E-04	0.376E-06	0.157E-07	0.190E-06	0.178E-04	0.625	0.922
0.200E+05	0.100E+14	0.185E-04	0.178E-06	0.122E-07	0.110E-06	0.135E-04	0.594	0.777
0.400E+05	0.100E+14	0.774E-05	0.407E-07	0.541E-08	0.291E-07	0.720E-05	0.504	0.571
0.600E+05	0.100E+14	0.464E-05	0.255E-07	0.293E-08	0.164E-07	0.485E-05	0.438	0.520
0.800E+05	0.100E+14	0.316E-05	0.188E-07	0.191E-08	0.113E-07	0.358E-05	0.392	0.492
0.100E+06	0.100E+14	0.233E-05	0.149E-07	0.137E-08	0.863E-08	0.280E-05	0.361	0.473
0.150E+06	0.100E+14	0.135E-05	0.998E-08	0.696E-09	0.558E-08	0.175E-05	0.321	0.452
0.200E+06	0.100E+14	0.933E-06	0.768E-08	0.389E-09	0.409E-08	0.125E-05	0.298	0.450
0.400E+06	0.100E+14	0.424E-06	0.390E-08	0.595E-10	0.167E-08	0.573E-06	0.262	0.476
0.600E+06	0.100E+14	0.279E-06	0.232E-08	0.146E-10	0.916E-09	0.369E-06	0.257	0.500
0.800E+06	0.100E+14	0.206E-06	0.144E-08	0.626E-11	0.571E-09	0.267E-06	0.259	0.513
0.100E+07	0.100E+14	0.161E-06	0.919E-09	0.424E-11	0.383E-09	0.206E-06	0.262	0.517

PU-239T ROPEY DECAY HEAT WITH UNCERTAINTY ACTIVITIES AND AVERAGE ENERGIES EVALUATION H1

DECAY TIME(SEC)	IRRADIATION TIME(SEC)	VALUE MEV/FISSI	TOTAL UNCERTAINTY	COR.ENERGY UNCERTAINTY	UNC.ENERGY UNCERTAINTY	ACTIVITY	AVE.BETA (MEV)	AVE.GAMMA (MEV)
0.100E+01	0.100E+14	0.934E+01	0.675E+00	0.644E+00	0.177E+00	0.531E+01	0.938	0.822
0.150E+01	0.100E+14	0.914E+01	0.642E+00	0.611E+00	0.173E+00	0.525E+01	0.925	0.816
0.200E+01	0.100E+14	0.896E+01	0.615E+00	0.584E+00	0.169E+00	0.519E+01	0.914	0.812
0.400E+01	0.100E+14	0.846E+01	0.537E+00	0.507E+00	0.160E+00	0.503E+01	0.881	0.799
0.600E+01	0.100E+14	0.811E+01	0.487E+00	0.457E+00	0.152E+00	0.492E+01	0.858	0.792
0.800E+01	0.100E+14	0.785E+01	0.450E+00	0.421E+00	0.146E+00	0.483E+01	0.840	0.787
0.100E+02	0.100E+14	0.764E+01	0.421E+00	0.392E+00	0.141E+00	0.475E+01	0.824	0.783
0.150E+02	0.100E+14	0.724E+01	0.368E+00	0.340E+00	0.132E+00	0.461E+01	0.796	0.776
0.200E+02	0.100E+14	0.696E+01	0.330E+00	0.302E+00	0.125E+00	0.450E+01	0.774	0.771
0.400E+02	0.100E+14	0.627E+01	0.239E+00	0.210E+00	0.108E+00	0.423E+01	0.724	0.758
0.600E+02	0.100E+14	0.587E+01	0.190E+00	0.161E+00	0.965E-01	0.406E+01	0.695	0.749
0.800E+02	0.100E+14	0.558E+01	0.159E+00	0.129E+00	0.880E-01	0.394E+01	0.675	0.742
0.100E+03	0.100E+14	0.537E+01	0.137E+00	0.107E+00	0.814E-01	0.384E+01	0.660	0.736
0.150E+03	0.100E+14	0.498E+01	0.106E+00	0.762E-01	0.700E-01	0.367E+01	0.633	0.725
0.200E+03	0.100E+14	0.473E+01	0.897E-01	0.601E-01	0.628E-01	0.355E+01	0.615	0.718
0.400E+03	0.100E+14	0.415E+01	0.636E-01	0.368E-01	0.479E-01	0.326E+01	0.572	0.702
0.600E+03	0.100E+14	0.382E+01	0.515E-01	0.281E-01	0.388E-01	0.309E+01	0.546	0.690
0.800E+03	0.100E+14	0.358E+01	0.430E-01	0.224E-01	0.319E-01	0.296E+01	0.527	0.679
0.100E+04	0.100E+14	0.338E+01	0.366E-01	0.182E-01	0.266E-01	0.287E+01	0.511	0.669
0.150E+04	0.100E+14	0.303E+01	0.266E-01	0.111E-01	0.178E-01	0.268E+01	0.482	0.647
0.200E+04	0.100E+14	0.278E+01	0.213E-01	0.712E-02	0.130E-01	0.255E+01	0.462	0.628
0.400E+04	0.100E+14	0.224E+01	0.141E-01	0.191E-02	0.712E-02	0.228E+01	0.415	0.568
0.600E+04	0.100E+14	0.197E+01	0.111E-01	0.104E-02	0.571E-02	0.214E+01	0.393	0.528
0.800E+04	0.100E+14	0.181E+01	0.900E-02	0.842E-03	0.488E-02	0.206E+01	0.380	0.500
0.100E+05	0.100E+14	0.170E+01	0.760E-02	0.767E-03	0.429E-02	0.200E+01	0.370	0.480
0.150E+05	0.100E+14	0.151E+01	0.598E-02	0.670E-03	0.344E-02	0.189E+01	0.354	0.448
0.200E+05	0.100E+14	0.140E+01	0.549E-02	0.601E-03	0.303E-02	0.181E+01	0.343	0.431
0.400E+05	0.100E+14	0.117E+01	0.491E-02	0.438E-03	0.245E-02	0.162E+01	0.319	0.405
0.600E+05	0.100E+14	0.105E+01	0.452E-02	0.359E-03	0.219E-02	0.150E+01	0.307	0.394
0.800E+05	0.100E+14	0.973E+00	0.421E-02	0.312E-03	0.201E-02	0.142E+01	0.300	0.387
0.100E+06	0.100E+14	0.919E+00	0.395E-02	0.280E-03	0.188E-02	0.135E+01	0.297	0.383
0.150E+06	0.100E+14	0.831E+00	0.345E-02	0.231E-03	0.164E-02	0.124E+01	0.293	0.376
0.200E+06	0.100E+14	0.775E+00	0.308E-02	0.205E-03	0.148E-02	0.117E+01	0.292	0.371
0.400E+06	0.100E+14	0.653E+00	0.217E-02	0.171E-03	0.116E-02	0.100E+01	0.294	0.356
0.600E+06	0.100E+14	0.585E+00	0.171E-02	0.165E-03	0.102E-02	0.912E+00	0.298	0.343
0.800E+06	0.100E+14	0.537E+00	0.146E-02	0.163E-03	0.940E-03	0.850E+00	0.301	0.331
0.100E+07	0.100E+14	0.500E+00	0.132E-02	0.162E-03	0.888E-03	0.803E+00	0.303	0.320

PU-239T ROPEY DECAY HEAT WITH UNCERTAINTY ACTIVITIES AND AVERAGE ENERGIES EVALUATION H2

DECAY TIME(SEC)	IRRADIATION TIME(SEC)	VALUE MEV-SEC/F	TOTAL UNCERTAINTY	COR.ENERGY UNCERTAINTY	UNC.ENERGY UNCERTAINTY	ACTIVITY	AVE.BETA (MEV)	AVE.GAMMA (MEV)
0.100E+01	0.100E+14	0.938E+01	0.718E+00	0.686E+00	0.181E+00	0.498E+01	0.999	0.883
0.150E+01	0.100E+14	0.142E+02	0.105E+01	0.100E+01	0.268E+00	0.784E+01	0.973	0.839
0.200E+01	0.100E+14	0.186E+02	0.136E+01	0.130E+01	0.354E+00	0.103E+02	0.969	0.844
0.400E+01	0.100E+14	0.357E+02	0.250E+01	0.238E+01	0.680E+00	0.201E+02	0.942	0.836
0.600E+01	0.100E+14	0.522E+02	0.352E+01	0.334E+01	0.989E+00	0.297E+02	0.927	0.831
0.800E+01	0.100E+14	0.680E+02	0.446E+01	0.422E+01	0.128E+01	0.391E+02	0.914	0.825
0.100E+02	0.100E+14	0.834E+02	0.532E+01	0.503E+01	0.157E+01	0.484E+02	0.904	0.821
0.150E+02	0.100E+14	0.120E+03	0.728E+01	0.685E+01	0.224E+01	0.706E+02	0.882	0.818
0.200E+02	0.100E+14	0.155E+03	0.901E+01	0.845E+01	0.286E+01	0.925E+02	0.864	0.812
0.400E+02	0.100E+14	0.285E+03	0.145E+02	0.135E+02	0.512E+01	0.176E+03	0.818	0.800
0.600E+02	0.100E+14	0.411E+03	0.187E+02	0.171E+02	0.709E+01	0.269E+03	0.763	0.764
0.800E+02	0.100E+14	0.524E+03	0.221E+02	0.200E+02	0.886E+01	0.346E+03	0.750	0.765
0.100E+03	0.100E+14	0.632E+03	0.249E+02	0.223E+02	0.105E+02	0.420E+03	0.739	0.766
0.150E+03	0.100E+14	0.892E+03	0.307E+02	0.269E+02	0.140E+02	0.614E+03	0.704	0.748
0.200E+03	0.100E+14	0.113E+04	0.352E+02	0.302E+02	0.171E+02	0.786E+03	0.691	0.748
0.400E+03	0.100E+14	0.201E+04	0.487E+02	0.394E+02	0.270E+02	0.147E+04	0.643	0.727
0.600E+03	0.100E+14	0.281E+04	0.591E+02	0.458E+02	0.349E+02	0.210E+04	0.619	0.720
0.800E+03	0.100E+14	0.355E+04	0.677E+02	0.508E+02	0.415E+02	0.271E+04	0.599	0.711
0.100E+04	0.100E+14	0.424E+04	0.749E+02	0.549E+02	0.469E+02	0.329E+04	0.586	0.704
0.150E+04	0.100E+14	0.584E+04	0.889E+02	0.620E+02	0.570E+02	0.467E+04	0.559	0.691
0.200E+04	0.100E+14	0.729E+04	0.989E+02	0.665E+02	0.638E+02	0.598E+04	0.540	0.679
0.400E+04	0.100E+14	0.122E+05	0.124E+03	0.740E+02	0.773E+02	0.108E+05	0.493	0.642
0.600E+04	0.100E+14	0.164E+05	0.142E+03	0.767E+02	0.847E+02	0.152E+05	0.467	0.615
0.800E+04	0.100E+14	0.202E+05	0.156E+03	0.786E+02	0.910E+02	0.194E+05	0.450	0.593
0.100E+05	0.100E+14	0.237E+05	0.169E+03	0.802E+02	0.966E+02	0.234E+05	0.437	0.575
0.150E+05	0.100E+14	0.317E+05	0.193E+03	0.838E+02	0.109E+03	0.331E+05	0.415	0.542
0.200E+05	0.100E+14	0.390E+05	0.213E+03	0.869E+02	0.120E+03	0.423E+05	0.400	0.520
0.400E+05	0.100E+14	0.643E+05	0.287E+03	0.970E+02	0.158E+03	0.764E+05	0.369	0.473
0.600E+05	0.100E+14	0.864E+05	0.364E+03	0.105E+03	0.194E+03	0.107E+06	0.352	0.452
0.800E+05	0.100E+14	0.107E+06	0.439E+03	0.111E+03	0.228E+03	0.137E+06	0.342	0.439
0.100E+06	0.100E+14	0.125E+06	0.512E+03	0.117E+03	0.262E+03	0.164E+06	0.335	0.430
0.150E+06	0.100E+14	0.169E+06	0.682E+03	0.130E+03	0.340E+03	0.229E+06	0.323	0.415
0.200E+06	0.100E+14	0.209E+06	0.836E+03	0.141E+03	0.410E+03	0.289E+06	0.317	0.407
0.400E+06	0.100E+14	0.350E+06	0.133E+04	0.177E+03	0.644E+03	0.504E+06	0.306	0.388
0.600E+06	0.100E+14	0.474E+06	0.169E+04	0.210E+03	0.837E+03	0.695E+06	0.304	0.378
0.800E+06	0.100E+14	0.585E+06	0.198E+04	0.243E+03	0.101E+04	0.871E+06	0.303	0.369
0.100E+07	0.100E+14	0.689E+06	0.222E+04	0.276E+03	0.117E+04	0.104E+07	0.303	0.362

X. APPENDIX B

A. Input Data Description for GOODY Program

The purpose of this part is to describe the use of the GOODY program which is written in standard FORTRAN-IV language for use on the IBM general system. The GOODY code is based on the ROPEY1 code which is used to evaluate shutdown decay powers and its uncertainties for a fissioning nuclide. A detailed description of input data preparation and file structure are explained in this part.

Input data preparation is a very simple and easy job. Only one basic card is needed for running the GOODY program. Thus, the user can easily run the program without spending much time to understand a long input data file. The only thing to do is to put an appropriate number in one line:

Table 41. GOODY Input Data Format

Card	Col	Input Name	Format	Description
1	1-4	NOFA	i4	Number of fission products. (any integer > 790)
	7-9	NTIME	i3	Number of time steps.
	12-13	NO	i2	Number of files containing acivities of fission products.
	16-18	NOI	i2	Number of files containing activities of fission products. (ex, 9)

Since GOODY calculates H0 and H1 functions simultaneously, it needs 6 sets of data; two sets of activity data from two fissioning nuclides, two H0 functions and their uncertainties, two H1 functions and their uncertainties. All these data are generated from ROPEY1 program and are stored on disk automatically; so we just use the data stored on the disk. The data file structure used in the GOODY program is shown in Figure 36.

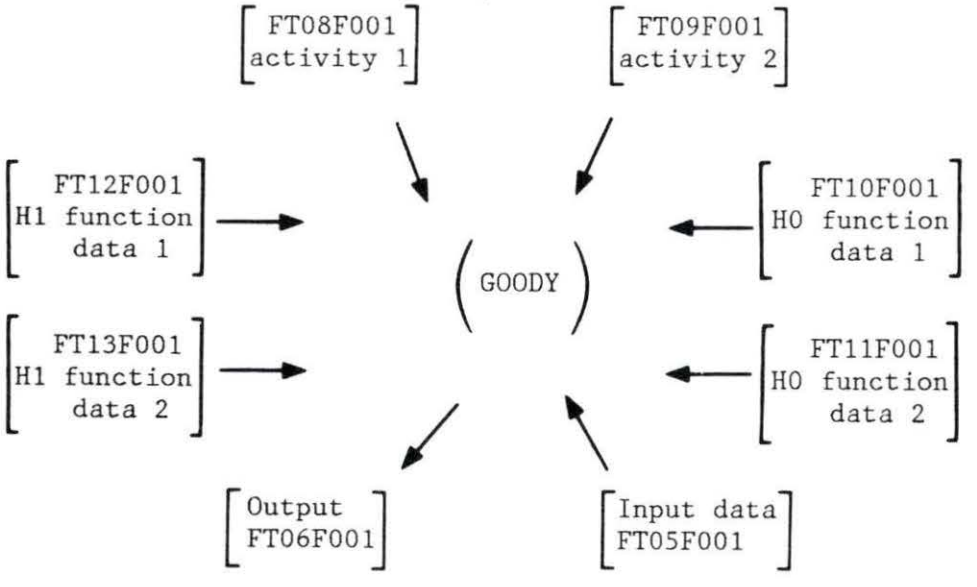

Figure 36. Data Structure in Program GOODY

B. GOODY Source Program

```
C THIS IS THE  RATIO PROGRAM DEVELOPED BY B.I.SPINRAD AND S.K.CHUNG
C AT IOWA STATE UNIVERSITY,MAY.1984.
C THE RATIO EVALUATES THE H,H1 DECAY POWER FROM RATIO TECHNIQUE
C FOR IRRADIATION AND DECAY TIME OF ANS STANDARD 5.1.
C THE UNCERTAINTY IN EACH FUNCTION CAN ALSO BE EVALUATED AND COMPARED
C  WITH THAT OF DIRECT  CLACULATION FROM ROPEY1.
C
      COMMON/ACT/SSACH0(800,50),SSACH1(800,50),NAME(800)
      COMMON/AACT/SACH0(800,50),SACH1(800,50)
      COMMON/DENER/EB(800),EG(800)
      COMMON/UDENER/EBU(800),EGU(800),EBC(800),EGC(800)
      COMMON/CO/COVEH0(50),COVEH1(50)
      DIMENSION AVCH0(50),AVCH1(50),AAVCH0(50),AAVCH1(50),AVUH0(50),
     +AVUH1(50)
C
C READING THE INPUT DATA
      READ(5,100)NOFA,NTIME,NO,NOI
 100  FORMAT(I4,2X,I3,2X,I2,2X,I2)
C NO NO1 NUMBER INDICATING NUCLIDE
C
      DO 1 I=1,NOFA
      READ(NO,END=109)NAME(I),((SSACH0(I,J),SSACH1(I,J)),J=1,NTIME),
     +EBU(I),EGU(I),EBC(I),EGC(I)
      READ(NOI,END=109)NAME(I),((SACH0(I,J),SACH1(I,J)),J=1,NTIME)
   1  CONTINUE
C
C NAME  NAME OF NUCLIDE
C SSACH0 ,SSACH1  INDIVIDUAL NUCLIDE ACTIVITY OF H0 AND H1
C EB,EG  DECAY ENERGY OF BETA AND GAMMA
C EBU.EGU  UNCORRELATED UNCERTAINTY OF DECAY ENERGY FOR BOTH BETA

C AND GAMMA
C EBC,EGC  CORRELATED UNCERTAINTY OF DECAY ENERGY FOR BOTH BETA
C AND GAMMA
C
C CALLING THE NUCLIDE
 109  CONTINUE
C CALLING THE NUCLIDE
      CALL FIRST(NOFA,NTIME,AVCH0,AVCH1)
C CALLING THE ANOTHER NUCLIDE
      CALL SECOND(NOFA,NTIME,AAVCH0,AAVCH1)
C CALLING THE UNCORRELATED UNCERTAINTY FOR NUCLIDE
```

```
      CALL THIRD(NOFA,NTIME,AVUH0,AVUH1)
C CALCULATING THE COVARIANCE
      DO 6 I=1,NTIME
      COVEH0(I)=AVCH0(I)*AAVCH0(I)+AVUH0(I)
      COVEH1(I)=AVCH1(I)*AAVCH1(I)+AVUH1(I)
   6  CONTINUE
C
C CALLING THE REED TO OBTAIN THE FINAL VALUE
      CALL REED(NTIME)
      STOP
      END
C
```

```
C
      SUBROUTINE FIRST(NOFA,NTIME,AAVCH0,AAVCH1)
      COMMON/ACT/SSACH0(800,50),SSACH1(800,50),NAME(800)
      COMMON/UDENER/EBU(800),EGU(800),EBC(800),EGC(800)
      DIMENSION AAVCH0(NTIME),AAVCH1(NTIME)
C
      DO 3 I=1,NTIME
       AVC1=0.0
       AVC2=0.0
      DO 4 J=1,NOFA
      TEVC=EBC(J)**2+EGC(J)**2
C TEVC  TOTAL CORRELATED VARIANCE OF DECAY ENERGY
      AVC1=SSACH0(J,I)*SQRT(TEVC)+AVC1
      AVC2=SSACH1(J,I)*SQRT(TEVC)+AVC2
  4   CONTINUE
       AAVCH0(I)=AVC1
       AAVCH1(I)=AVC2
  3   CONTINUE
      RETURN
      END
C
```

```
C
      SUBROUTINE SECOND(NOFA,NTIME,AVCH0,AVCH1)
      COMMON/AACT/SACH0(800,50),SACH1(800,50)
      COMMON/UDENER/EBU(800),EGU(800),EBC(800),EGC(800)
      DIMENSION AVCH0(NTIME),AVCH1(NTIME)
C
      DO 3 I=1,NTIME
      AVC1=0.0
      AVC2=0.0
      DO 4 J=1,NOFA
      TEVC=EBC(J)**2+EGC(J)**2
C TEVC  TOTAL CORRELATED VARIANCE OF DECAY ENERGY
      AVC1=SACH0(J,I)*SQRT(TEVC)+AVC1
      AVC2=SACH1(J,I)*SQRT(TEVC)+AVC2
  4   CONTINUE
      AVCH0(I)=AVC1
      AVCH1(I)=AVC2
  3   CONTINUE
      RETURN
      END
C
```

```
C
      SUBROUTINE THIRD(NOFA,NTIME,AVUH0,AVUH1)
      COMMON/ACT/SSACH0(800,50),SSACH1(800,50),NAME(800)
      COMMON/AACT/SACH0(800,50),SACH1(800,50)
      COMMON/UDENER/EBU(800),EGU(800),EBC(800),EGC(800)
      DIMENSION AVUH0(NTIME),AVUH1(NTIME)
C
      DO 5 I=1,NTIME
       AVU1=0.0
       AVU2=0.0
      DO 6 J=1,NOFA
      TEVU=EBU(J)**2.+EGU(J)**2.
C TEVU  TOTAL UNCORRELATED VARIANCE OF DECAY ENERGY
      AVU1=(SACH0(J,I)*SSACH0(J,I)*TEVU)+AVU1
      AVU2=(SACH1(J,I)*SSACH1(J,I)*TEVU)+AVU2
  6   CONTINUE
      AVUH0(I)=AVU1
      AVUH1(I)=AVU2
  5   CONTINUE
      RETURN
      END
C
```

```
C
      SUBROUTINE REED(NTIME)
      COMMON/CO/COVEH0(50),COVEH1(50)
      COMMON/VARI0/DEH0(50),VDEH0(50),DDEH0(50),VVDEH0(50)
      COMMON/VARI1/DEH1(50),VDEH1(50),DDEH1(50),VVDEH1(50)
      COMMON/CORR/COF1(50),COF2(50)
      COMMON/ANS/ANEH0(37),UANEH0(37),ANEH1(37),UANEH1(37)
      DIMENSION RVARH0(50),RVARH1(50),
     +A1(50),RATIO1(50),RATIO2(50),VARIA0(50),VARIA1(50),
     +RAVAL1(50),RAVAL2(50)
C READING THE INPUT DATA
      DO 1 I=1,NTIME
      READ(10,999)A1(I),DEH0(I),VDEH0(I),COEH0,UNEH0
      READ(11,998)DDEH0(I),VVDEH0(I),CCOEH0,UUNEH0
      READ(12,998)DEH1(I),VDEH1(I),COEH1,UNEH1
      READ(13,998)DDEH1(I),VVDEH1(I),CCOEH1,UUNEH1
C TOTAL VARIANCE FOR DECAY ENERGY
      COEH0=COEH0**2+UNEH0**2
      CCOEH0=CCOEH0**2+UUNEH0**2
      COEH1=COEH1**2+UNEH1**2
      CCOEH1=CCOEH1**2+UUNEH1**2
      COF1(I)=COVEH0(I)/SQRT(COEH0*CCOEH0)
      COF2(I)=COVEH1(I)/SQRT(COEH1*CCOEH1)
      RATIO1(I)=DDEH0(I)/DEH0(I)
      RATIO2(I)=DDEH1(I)/DEH1(I)
C RAVAL DECAY HEAT OF SOME NUCLEAR FROM RATIO TECH
      RAVAL1(I)=RATIO1(I)*ANEH0(I)
      RAVAL2(I)=RATIO2(I)*ANEH1(I)
  1   CONTINUE
C CALLING STANH0 TO GET THE VARIANCE FOR RATIO
      CALL STANH0(NTIME,RVARH0)
      CALL STANH1(NTIME,RVARH1)
C FINDING THE FINAL UNCERTAINTY FOR RATIO TECH
      CALL FINAL(NTIME,ANEH0,UANEH0,RATIO1,RVARH0,VARIA0)
      CALL FINAL(NTIME,ANEH1,UANEH1,RATIO2,RVARH1,VARIA1)
C WRITING THE OUTPUT
      WRITE(6,1000)
      WRITE(6,200)
      DO 5 I=1,NTIME
      RU1=(VVDEH0(I)/DDEH0(I))*100.
      RU2=(VARIA0(I)/RAVAL1(I))*100.
      WRITE(6,1005)A1(I),DDEH0(I),RU1,RAVAL1(I),RU2
```

```
  5    CONTINUE
C
 1005 FORMAT(10X,F10.1,7X,E10.3,4X,F10.2,7X,E10.3,4X,F10.2)
C
      WRITE(6,1000)
      WRITE(6,201)
      DO 6 I=1,NTIME
      RRU1=(VVDEH1(I)/DDEH1(I))*100.
      RRU2=(VARIA1(I)/RAVAL2(I))*100.
      WRITE(6,1005)A1(I),DDEH1(I),RRU1,RAVAL2(I),RRU2
  6    CONTINUE
      WRITE(6,1000)
      WRITE(6,1010)
C
 1010 FORMAT(/////////,28X,'DECAY',13X,'DECAY',6X,'UNCERTAINTY',/29X,
     +'Time',13X,'Power',/27X,'(Seconds)',7X,'(Mev/fis-sec)' //)
C
      DO 2 I=1,NTIME
      WRITE(6,1001)A1(I),RAVAL1(I),VARIA0(I)
  2    CONTINUE
C
      WRITE(6,1000)
      WRITE(6,1009)
C
 1009 FORMAT(/////////,28X,'DECAY',13X,'DECAY',6X,'UNCERTAINTY',/29X,
     +'Time',13X,'Power',/27X,'(Seconds)',7X,'(Mev/fission)' //)
C
      DO 3 I=1,NTIME
      WRITE(6,1001)A1(I),RAVAL2(I),VARIA1(I)
  3    CONTINUE
C
      WRITE(6,1000)
      WRITE(6,1008)
C
 1008 FORMAT(/////////,30X,'DECAY',6X,'CORRELATION',5X,'COEFFICIENT',/
     +31X,'Time',24X,'Infinite',/28X,'(Seconds)',7X,'Burst',10X,
     +'Irradiation' //)
C
      DO 4 I=1,NTIME
      WRITE(6,1003)A1(I),COF1(I),COF2(I)
  4    CONTINUE
C COEH0 CORRELATED VARIANCE,UNEH0 UNCORRELATED VARIANCE FOR H0
```

```
C COEH1       "          "          "                    "          FOR H1
C CCOEH0,UUNEH0
 1003 FORMAT(26X,E10.2,4X,F10.3,7X,F10.3)
  999 FORMAT(E10.4,4(2X,E10.3))
 200  FORMAT(//////////,13X,'SHUTDOWN',9X,'DIRECT CALCULATION',15X,
     +'RATIO METHOD',/15X,'Time',8X,'Decay Power',5X,'Relative',7X,
     +'Decay Power',5X,'Relative',/13X,'Seconds',7X,'Mev/fis-sec',
     +3X,'Uncertainty',1X,'%',4X,'Mev/fis-sec',3X,'Uncertainty',1X,
     +'%' //)
 201  FORMAT(//////////,13X,'SHUTDOWN',9X,'DIRECT CALCULATION',15X,
     +'RATIO METHOD',/15X,'Time',8X,'Decay Power',5X,'Relative',7X,
     +'Decay Power',5X,'Relative',/13X,'Seconds',7X,'Mev/fission',
     +3X,'Uncertainty',1X,'%',4X,'Mev/fission',3X,'Uncertainty',1X,
     +'%' //)
 998  FORMAT(12X,E10.3,3(2X,E10.3))
1000  FORMAT(1H1)
 1001 FORMAT(26X,E10.2,7X,E10.3,4X,E10.3)
      RETURN
      END
C
```

```
C
      SUBROUTINE STANH0(NTIME,RVARH0)
      COMMON/VARI0/DEH0(50),VDEH0(50),DDEH0(50),VVDEH0(50)
      COMMON/CORR/COF1(50),COF2(50)
      DIMENSION RVARH0(NTIME)
C
      DO 1 I=1,NTIME
      TEMP1=(VDEH0(I)**2)/(DEH0(I)**2)
      TEMP1=TEMP1+1.
      TEMP2=(VVDEH0(I)**2)/(DDEH0(I)**2)
      TEMP2=TEMP2+1.
      STAN1=ALOG(TEMP1)
      STAN2=ALOG(TEMP2)
      SQSTA1=SQRT(STAN1)
      SQSTA2=SQRT(STAN2)
      RVARH0(I)=(STAN1+STAN2)-(2.*COF1(I)*SQSTA1*SQSTA2)
C STAN1,STAN2  VARIANCE FOR EACH NUCLIDE
C SQSTA1,SQSTA2 STANDARD DEVIATION FOR EACH NUCLIDE
C RVARH0 VARIANCE OF RATIO VALUE FOR H0 FUNCTION.
   1  CONTINUE
      RETURN
      END
C
C
```

```
C
      SUBROUTINE STANH1(NTIME,RVARH1)
      COMMON/VARI1/DEH1(50),VDEH1(50),DDEH1(50),VVDEH1(50)
      COMMON/CORR/COF1(50),COF2(50)
      DIMENSION RVARH1(NTIME)
C
      DO 1 I=1,NTIME
      TEMP1=(VDEH1(I)**2)/(DEH1(I)**2)
      TEMP1=TEMP1+1.
      TEMP2=(VVDEH1(I)**2)/(DDEH1(I)**2)
      TEMP2=TEMP2+1.
      STAN1=ALOG(TEMP1)
      STAN2=ALOG(TEMP2)
      SQSTA1=SQRT(STAN1)
      SQSTA2=SQRT(STAN2)
      RVARH1(I)=(STAN1+STAN2)-(2.*COF2(I)*SQSTA1*SQSTA2)
C STAN1,STAN2  VARIANCE FOR EACH NUCLIDE
C SQSTA1,SQSTA2 STANDARD DEVIATION FOR EACH NUCLIDE
C RVARH1 VARIANCE OF RATIO VALUE FOR H0 FUNCTION.
   1  CONTINUE
      RETURN
      END
C
```

```
C
      SUBROUTINE FINAL(NTIME,ANE,UANE,RATIO,RVAR,VAR)
      DIMENSION ANE(NTIME),UANE(NTIME),RATIO(NTIME),RVAR(NTIME),
     +VAR(NTIME)
C
      DO 1 I=1,NTIME
      VAR1=(RATIO(I)**2)*(UANE(I)**2)
      VAR2=(ANE(I)**2)*RVAR(I)
      VAR3=(UANE(I)**2)*RVAR(I)
      VART=VAR1+VAR2+VAR3
      VAR(I)=SQRT(VART)
C VAR UNCERTAINTY OF DECAY HEAT FROM RATIO TECH
  1   CONTINUE
      RETURN
      END
C
```

```
C
      BLOCK DATA
      COMMON/ANS/ANEH0(37),UANEH0(37),ANEH1(37),UANEH1(37)
      DATA ANEH0/7.123E-01,6.167E-01,5.390E-01,3.431E-01,2.443E-01,
     +1.876E-01,1.512E-01,9.981E-02,7.366E-02,3.546E-02,2.321E-02,
     +1.684E-02,1.295E-02,7.867E-03,5.479E-03,2.383E-03,1.581E-03,
     +1.195E-03,9.588E-04,6.345E-04,4.648E-04,1.977E-04,1.152E-04,
     +7.891E-05,5.897E-05,3.419E-05,2.302E-05,9.328E-06,5.372E-06,
     +3.558E-06,2.579E-06,1.434E-06,9.465E-07,3.981E-07,2.663E-07,
     +2.015E-07,1.606E-07/
      DATA UANEH0/2.818E-01,1.097E-01,0.445E-01,0.146E-01,0.087E-01,
     +0.059E-01,0.048E-01,0.255E-02,0.179E-02,0.072E-02,0.045E-02,
     +0.033E-02,0.023E-02,0.149E-03,0.105E-03,0.044E-03,0.029E-03,
     +0.023E-03,0.175E-04,0.116E-04,0.082E-04,0.037E-04,0.021E-04,
     +0.139E-05,0.104E-05,0.054E-05,0.033E-05,0.134E-06,0.074E-06,
     +0.048E-06,0.035E-06,0.029E-06,0.189E-07,0.080E-07,0.053E-07,
     +0.040E-07,0.032E-07/
      DATA ANEH1/1.231E+01,1.198E+01,1.169E+01,1.083E+01,1.026E+01,
     +9.830E+00,9.494E+00,8.882E+00,8.455E+00,7.459E+00,6.888E+00,
     +6.493E+00,6.198E+00,5.696E+00,5.369E+00,4.667E+00,4.282E+00,
     +4.009E+00,3.796E+00,3.408E+00,3.137E+00,2.534E+00,2.234E+00,
     +2.044E+00,1.908E+00,1.685E+00,1.545E+00,1.258E+00,1.117E+00,
     +1.030E+00,9.691E-01,8.734E-01,8.154E-01,6.975E-01,6.331E-01,
     +5.868E-01,5.509E-01/
      DATA UANEH1/0.040E+01,0.032E+01,0.028E+01,0.023E+01,0.021E+01,
     +0.198E+00,0.187E+00,0.170E+00,0.159E+00,0.137E+00,0.125E+00,
     +0.118E+00,0.112E+00,0.103E+00,0.097E+00,0.083E+00,0.076E+00,
     +0.071E+00,0.067E+00,0.060E+00,0.055E+00,0.045E+00,0.039E+00,
     +0.036E+00,0.033E+00,0.030E+00,0.027E+00,0.023E+00,0.021E+00,
     +0.020E+00,0.194E-01,0.175E-01,0.163E-01,0.140E-01,0.127E-01,
     +0.117E-01,0.110E-01/
      END
```

C. Sample Outputs

U-238F DECAY HEAT

SHUTDOWN Time Seconds	DIRECT CALCULATION Decay Power Mev/fis-sec	Relative Uncertainty %	RATIO METHOD Decay Power Mev/fis-sec	Relative Uncertainty %
1.0	0.132E+01	22.42	0.143E+01	39.65
1.5	0.101E+01	21.98	0.119E+01	18.03
2.0	0.822E+00	21.41	0.100E+01	8.75
4.0	0.452E+00	19.69	0.560E+00	5.31
6.0	0.308E+00	18.25	0.367E+00	4.74
8.0	0.235E+00	17.19	0.269E+00	4.37
10.0	0.191E+00	16.49	0.211E+00	4.19
15.0	0.129E+00	15.89	0.133E+00	3.59
20.0	0.965E-01	15.65	0.966E-01	3.67
40.0	0.447E-01	15.01	0.449E-01	3.78
60.0	0.279E-01	13.58	0.288E-01	3.77
80.0	0.198E-01	12.07	0.207E-01	3.82
100.0	0.150E-01	10.80	0.157E-01	3.62
150.0	0.880E-02	8.43	0.932E-02	3.43
200.0	0.595E-02	6.86	0.635E-02	3.20
400.0	0.239E-02	4.08	0.259E-02	2.64
600.0	0.152E-02	3.83	0.166E-02	2.62
800.0	0.114E-02	3.88	0.124E-02	2.67
1000.0	0.920E-03	3.83	0.989E-03	2.54
1500.0	0.619E-03	3.46	0.648E-03	2.37
2000.0	0.455E-03	3.01	0.468E-03	2.14
4000.0	0.192E-03	2.08	0.190E-03	2.01
6000.0	0.110E-03	2.04	0.106E-03	1.96
8000.0	0.734E-04	2.15	0.709E-04	1.93
10000.0	0.538E-04	2.21	0.522E-04	1.93
15000.0	0.305E-04	2.17	0.299E-04	1.76
20000.0	0.204E-04	2.24	0.201E-04	1.65
40000.0	0.835E-05	2.75	0.831E-05	1.71
60000.0	0.495E-05	2.73	0.491E-05	1.59
80000.0	0.335E-05	2.62	0.332E-05	1.52
100000.0	0.246E-05	2.58	0.244E-05	1.51
150000.0	0.140E-05	2.61	0.140E-05	2.11
200000.0	0.945E-06	2.65	0.952E-06	2.09
400000.0	0.412E-06	2.91	0.416E-06	2.13
600000.0	0.271E-06	3.18	0.274E-06	2.13
800000.0	0.201E-06	3.37	0.205E-06	2.15
1000000.0	0.157E-06	3.55	0.160E-06	2.17

SHUTDOWN Time Seconds	DIRECT CALCULATION Decay Power Mev/fission	Relative Uncertainty %	RATIO METHOD Decay Power Mev/fission	Relative Uncertainty %
1.0	0.142E+02	10.70	0.151E+02	4.63
1.5	0.136E+02	10.29	0.144E+02	4.13
2.0	0.132E+02	9.85	0.139E+02	3.89
4.0	0.120E+02	8.83	0.125E+02	3.48
6.0	0.112E+02	8.25	0.116E+02	3.33
8.0	0.107E+02	7.78	0.110E+02	3.21
10.0	0.103E+02	7.41	0.106E+02	3.11
15.0	0.947E+01	6.78	0.970E+01	3.00
20.0	0.892E+01	6.26	0.914E+01	2.91
40.0	0.762E+01	4.80	0.785E+01	2.66
60.0	0.692E+01	3.93	0.714E+01	2.47
80.0	0.645E+01	3.36	0.665E+01	2.36
100.0	0.610E+01	3.00	0.628E+01	2.27
150.0	0.553E+01	2.48	0.569E+01	2.15
200.0	0.517E+01	2.24	0.531E+01	2.09
400.0	0.444E+01	1.97	0.452E+01	1.98
600.0	0.406E+01	1.87	0.411E+01	1.94
800.0	0.380E+01	1.79	0.383E+01	1.91
1000.0	0.360E+01	1.73	0.362E+01	1.89
1500.0	0.322E+01	1.65	0.322E+01	1.87
2000.0	0.295E+01	1.63	0.294E+01	1.86
4000.0	0.237E+01	1.67	0.236E+01	1.88
6000.0	0.208E+01	1.73	0.207E+01	1.86
8000.0	0.190E+01	1.76	0.189E+01	1.88
10000.0	0.177E+01	1.80	0.177E+01	1.85
15000.0	0.157E+01	1.86	0.157E+01	1.91
20000.0	0.145E+01	1.90	0.145E+01	1.88
40000.0	0.119E+01	1.99	0.120E+01	1.98
60000.0	0.107E+01	2.05	0.108E+01	2.05
80000.0	0.985E+00	2.11	0.995E+00	2.10
100000.0	0.928E+00	2.16	0.940E+00	2.18
150000.0	0.836E+00	2.25	0.848E+00	2.20
200000.0	0.778E+00	2.31	0.789E+00	2.21
400000.0	0.658E+00	2.42	0.668E+00	2.26
600000.0	0.592E+00	2.43	0.602E+00	2.30
800000.0	0.545E+00	2.44	0.553E+00	2.32
1000000.0	0.510E+00	2.41	0.518E+00	2.35

DECAY Time (Seconds)	DECAY Power (Mev/fis-sec)	UNCERTAINTY
0.10E+01	0.143E+01	0.567E+00
0.15E+01	0.119E+01	0.214E+00
0.20E+01	0.100E+01	0.877E-01
0.40E+01	0.560E+00	0.297E-01
0.60E+01	0.367E+00	0.174E-01
0.80E+01	0.269E+00	0.117E-01
0.10E+02	0.211E+00	0.884E-02
0.15E+02	0.133E+00	0.478E-02
0.20E+02	0.966E-01	0.355E-02
0.40E+02	0.449E-01	0.170E-02
0.60E+02	0.288E-01	0.109E-02
0.80E+02	0.207E-01	0.791E-03
0.10E+03	0.157E-01	0.567E-03
0.15E+03	0.932E-02	0.320E-03
0.20E+03	0.635E-02	0.203E-03
0.40E+03	0.259E-02	0.683E-04
0.60E+03	0.166E-02	0.434E-04
0.80E+03	0.124E-02	0.331E-04
0.10E+04	0.989E-03	0.251E-04
0.15E+04	0.648E-03	0.153E-04
0.20E+04	0.468E-03	0.100E-04
0.40E+04	0.190E-03	0.382E-05
0.60E+04	0.106E-03	0.209E-05
0.80E+04	0.709E-04	0.136E-05
0.10E+05	0.522E-04	0.101E-05
0.15E+05	0.299E-04	0.526E-06
0.20E+05	0.201E-04	0.330E-06
0.40E+05	0.831E-05	0.142E-06
0.60E+05	0.491E-05	0.779E-07
0.80E+05	0.332E-05	0.504E-07
0.10E+06	0.244E-05	0.368E-07
0.15E+06	0.140E-05	0.296E-07
0.20E+06	0.952E-06	0.199E-07
0.40E+06	0.416E-06	0.887E-08
0.60E+06	0.274E-06	0.585E-08
0.80E+06	0.205E-06	0.440E-08
0.10E+07	0.160E-06	0.347E-08

DECAY Time (Seconds)	DECAY Power (Mev/fission)	UNCERTAINTY
0.10E+01	0.151E+02	0.697E+00
0.15E+01	0.144E+02	0.596E+00
0.20E+01	0.139E+02	0.541E+00
0.40E+01	0.125E+02	0.435E+00
0.60E+01	0.116E+02	0.386E+00
0.80E+01	0.110E+02	0.353E+00
0.10E+02	0.106E+02	0.329E+00
0.15E+02	0.970E+01	0.291E+00
0.20E+02	0.914E+01	0.266E+00
0.40E+02	0.785E+01	0.208E+00
0.60E+02	0.714E+01	0.176E+00
0.80E+02	0.665E+01	0.157E+00
0.10E+03	0.628E+01	0.143E+00
0.15E+03	0.569E+01	0.122E+00
0.20E+03	0.531E+01	0.111E+00
0.40E+03	0.452E+01	0.896E-01
0.60E+03	0.411E+01	0.799E-01
0.80E+03	0.383E+01	0.733E-01
0.10E+04	0.362E+01	0.684E-01
0.15E+04	0.322E+01	0.601E-01
0.20E+04	0.294E+01	0.545E-01
0.40E+04	0.236E+01	0.442E-01
0.60E+04	0.207E+01	0.384E-01
0.80E+04	0.189E+01	0.356E-01
0.10E+05	0.177E+01	0.328E-01
0.15E+05	0.157E+01	0.301E-01
0.20E+05	0.145E+01	0.273E-01
0.40E+05	0.120E+01	0.237E-01
0.60E+05	0.108E+01	0.220E-01
0.80E+05	0.995E+00	0.209E-01
0.10E+06	0.940E+00	0.205E-01
0.15E+06	0.848E+00	0.186E-01
0.20E+06	0.789E+00	0.174E-01
0.40E+06	0.668E+00	0.151E-01
0.60E+06	0.602E+00	0.139E-01
0.80E+06	0.553E+00	0.129E-01
0.10E+07	0.518E+00	0.122E-01

DECAY Time (Seconds)	CORRELATION COEFFICIENT Burst	Infinite Irradiation
0.10E+01	0.990	0.972
0.15E+01	0.983	0.974
0.20E+01	0.986	0.970
0.40E+01	0.984	0.969
0.60E+01	0.982	0.967
0.80E+01	0.979	0.965
0.10E+02	0.981	0.964
0.15E+02	0.984	0.962
0.20E+02	0.978	0.957
0.40E+02	0.971	0.944
0.60E+02	0.967	0.932
0.80E+02	0.957	0.920
0.10E+03	0.957	0.911
0.15E+03	0.947	0.897
0.20E+03	0.939	0.895
0.40E+03	0.872	0.908
0.60E+03	0.860	0.918
0.80E+03	0.868	0.926
0.10E+04	0.880	0.932
0.15E+04	0.898	0.941
0.20E+04	0.917	0.945
0.40E+04	0.941	0.947
0.60E+04	0.951	0.945
0.80E+04	0.952	0.942
0.10E+05	0.955	0.943
0.15E+05	0.951	0.940
0.20E+05	0.949	0.942
0.40E+05	0.955	0.936
0.60E+05	0.965	0.926
0.80E+05	0.969	0.930
0.10E+06	0.971	0.921
0.15E+06	0.975	0.922
0.20E+06	0.973	0.920
0.40E+06	0.970	0.913
0.60E+06	0.969	0.897
0.80E+06	0.968	0.888
0.10E+07	0.970	0.875

XI. APPENDIX C

A. Data Library Format for ENDF/B-V and ROPEY1

Tables 43 and 44 show the format of the ROPEY1 data file and the ENDF/B-V data file respectively. The data structures are quite different. In addition, the ENDF/B-V data file is divided into two parts ; one is for decay energies, half lives and branching ratios, the other is for yields. Therefore, it is necessary to sort the ENDF data before we can put them into the ROPEY1 data file. To sort the ENDF data, two programs (ROENDF and DATSORT) were used; then ROPEY1 decay energy, half life, and branching ratio data were changed by substituting ENDF/B-V data, as a result of running program INFINAL. We obtained output BNMASTER which has ENDF/B-V decay energy, half life, and branching ratio data but has ROPEY1 (ENDF/B-IV) yield data. This procedure is shown in Figure 37, where the ENDFCPY is a system program moving the ENDF/B-V data on a tape to the computer disk. The next step is to change yield data. This step also uses three programs; ENDFCPY, YDATCOM, and YIESORT. Figure 38 shows this step. Finally, using YIFINAL program, the two outputs (one from the Figure 37 procedure and another from Figure 38) are merged to make a ROPEY1 decay data file which come from ENDF/B-V decay data.

Table 42. ROPEY1 Data File Format

Record Number	Data Block	Columns in Card Image	Format	Contents
1	1.1	1-5	I5	Library identification number
	1.2	6-10	I5	Number of fissionable nuclides in library
	1.3	11-80	7A10	Library title
2	2.1	1-10	A10	Names of fissionable nuclides in library
	2.2	11-20	E10.4	Average energy per fission
	2.3	21-30	E10.4	Uncertainty in the average energy per fission
3	3.1	1-10	I10	Fission product identification (A*1000 + Z*10 + S)
	3.2	11-20	E10.4	Decay constant (sec^{-1})
	3.3	21-30	E10.4	Beta decay energy (MeV)
	3.4	31-40	E10.4	Uncorrelated uncertainty in beta decay energy (MeV)
	3.5	41-50	E10.4	Correlated uncertainty in beta decay energy (MeV)
	3.6	51-60	E10.4	Gamma decay energy (MeV)

Table 42. (Continued)

Record Number	Data Block	Columns in Card Image	Format	Contents
	3.7	61-70	E10.4	Uncorrelated uncertainty in gamma decay energy (MeV)
	3.8	71-80	E10.4	Correlated uncertainty in gamma decay energy (MeV)
4	4.1	1-10	I10	Number of decay branches
	(4.2,4.3) et seq.	11-30 et seq.	N(I10,E10.4)	Daughter identification and branching ratio
5	(5.1,5.2)	1-20 et seq.	N(8E10.4)	Percent independent yield and its uncertainty from each fissionable nuclide in record 2, in order of record 2 listing
Records 3, 4 and 5 are repeated until a-1 occurs in the fission product identification section of record 3.				
6	6.1	1-10	I10	Number of nuclides in mass rope
	6.2	11-20	I10	Number of nuclides with rope mass
	6.3	21-30	I10	Rope mass number
7	(7.1,7.2) et seq.	1-20 et seq.	N(8E10.4)	Chain yield for mass number and its uncertainty for each fissionable nuclide in record 2, in order of record 2 listing

Table 42. (Continued)

Record Number	Data Block	Columns in Card Image	Format	Contents
8	8.1 et seq.	1-10 et seq.	8I10	Nuclide identifiers in mass rope, in rope order
Records 6, 7 and 8 are repeated until an end of file occurs				

Table 43. ENDF/B-V Data File Format

Decay Energy Format

[MAT, 8,457/	ZA	AWR	LIS	LISO	b	NSP	]	HEAD
[MAT, 8,457/	$T_{1/2}$	$\Delta T_{1/2}$	b	b	6	b	/	
	$\bar{E}_{"\beta"}$	$\Delta\bar{E}_{"\beta"}$	$\bar{E}_{"\gamma"}$	$\Delta\bar{E}_{"\gamma"}$	$\bar{E}_{"\alpha"}$	$\Delta\bar{E}_{"\alpha"}$	]	LIST
[MAT,8,457/	SPI	PAR	b	b	6*NDK	NDK	/	
	$RTYP_1$	RFS_1	Q_1	ΔQ_1	BR_1	ΔBR_1		
	.							
	.							
	.							
	$RTYP_{NDK}$	RFS_{NDK}	Q_{NDK}	ΔQ_{NDK}	BR_{NDK}	ΔBR_{NDK}	]	LIST
								Repeat NSP times
[MAT,8,457/	b	STYP	LCON	b	6	NER	/	(omit if NSP=0)
	FD	ΔFD	$\overline{ER}$	$\Delta\overline{ER}$	FC	ΔFC	]	LIST
[MAT,8,457/	ER_1	ΔER_1	b	b	NT	b	/	(omit if LCON=1)
	$RTYP_1$	$TYPE_1$	RI_1	ΔRI_1	RIS_1	ΔRIS_1		
	$RICC_1$	$\Delta RICC_1$	$RICK_1$	$\Delta RICK_1$	$RICL_1$	$\Delta RICL_1$	]	LIST
	ER_{NER}	ΔER_{NER}	b	b	NT	b	/	
	$RTYP_{NER}$	$TYPE_{NER}$	RI_{NER}	ΔRI_{NER}	----		]	LIST
[MAT,8,457/	RTYP	0.0	b	b	NR	NP	/	(omit if LCON=0)
	X_{int}	/	ER_k	RP_k]			TAB1	
[MAT,8,0/	b	b	b	b	b	b	]	SEND.

Yield Format

(MAT, 8,454/ ZA			)HEAD	
(MT,8,454/ZAFP	FPS	Yi	DYi	/
		,		
		,		
		,		
		,		
		,		

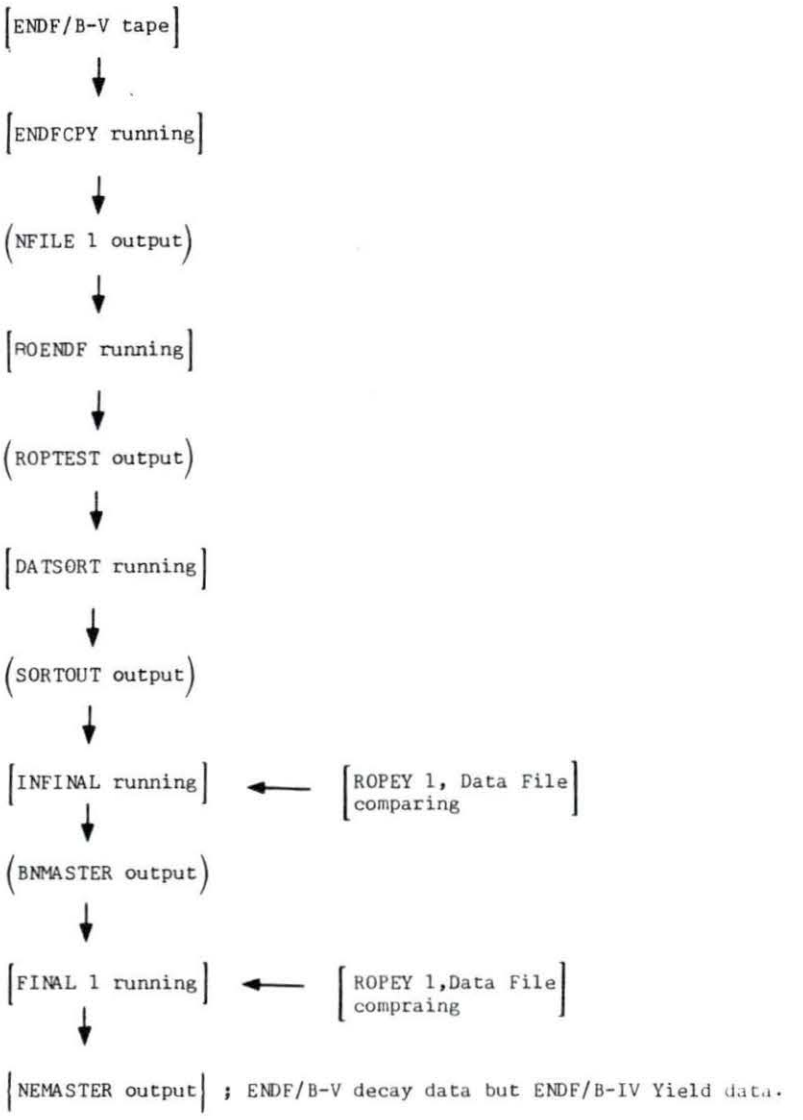

Figure 37. Procedure to Sort ENDF/B-V Decay Energy Data

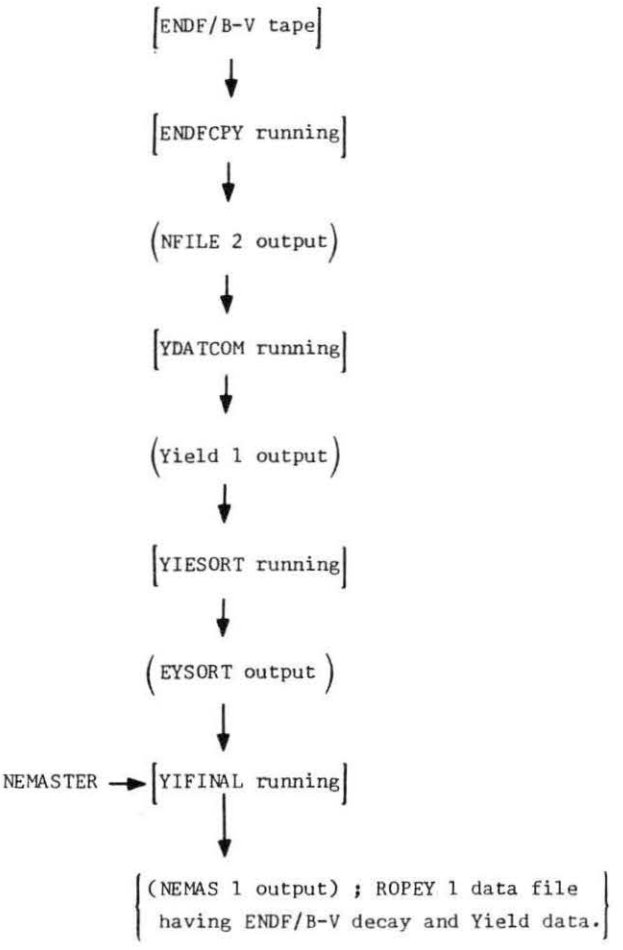

Figure 38. Procedure to Sort ENDF/B-V Yield Data

B. Source Programs Used in These Procedures

```
//ROENDFV  JOB  U3805,CHUNG,MSGLEVEL=(1,1)
/*JOBPARM  BIN=400
/*JOBPARM  BLOCK=(NIGHT,NIGHT)
//S1 EXEC FORTVCLG
//FORT.SYSIN DD *
C THIS PROGRAM IS TO ARRANGE THE DECAY DATA OF ENDF/V
C AND REWRITE ON FILE 9 BEFORE MAKING THE ROPEY FILE
      DIMENSION FORMT(3),NYTR(10),EBR(10),NNN(10)
      CHARACTER*11 A,A1,T12,DT12,EB,DEB,EG,DEG,EA,DEA,SPI,PAR,
     +RTYP,RFS,Q,DQ,BR,DBR
      CHARACTER*18 FORMT,TTT
      DATA MNDK,DIVI/10,1000000./
      DATA FORMT/'(I10,1(I10,E10.4))','(I10,2(I10,E10.4))',
     +'(I10,3(I10,E10.4))'/
      REWIND 8
C
C READING ENDF/V DECAY DATA AND WRITING NUMBER OF NUCLEI
    1 READ(5,100,END=400)A,MT
  100 FORMAT(A11,61X,I3)
      READ(5,100,END=400)A1,MT1
      WRITE(8,210)A(5:5),MT1
  210 FORMAT(A1,I3)
      WRITE(8,205)A(5:7),A(2:2),A(4:4)
  205 FORMAT(A3,A1,A1,'0')
      IF(MT1.EQ.0)GO TO 1
C
C READING ENDF/V HALF LIFE,ENERGY,AMD SPIN....
      READ(5,110,END=400)T12,DT12
      READ(5,120,END=400)EB,DEB,EG,DEG,EA,DEA
      READ(5,130,END=400)SPI,PAR,NDK
      IF(NDK.GT.MNDK)STOP
C
C WRITING THE DECAY DATA ON FILE 8
      WRITE(8,201)T12(1:8),T12(9:11),EB(1:8),EB(9:11),DEB(1:8),
     +DEB(9:11),EG(1:8),EG(9:11),DEG(1:8),DEG(9:11),NDK
      DO 88 I=1,NDK
      READ(5,140,END=400)RTYP,RFS,Q,DQ,BR,DBR
      WRITE(8,200)RTYP(1:2),BR(1:8),BR(9:11)
   88 CONTINUE
      MTT=457
      DO 2 I=1,50000
       READ(5,150,END=400)MT2
       MTT=MT2
      IF(MTT.EQ.0)GOTO 1
    2 CONTINUE
  400 ENDFILE 8
      REWIND 8
      REWIND 9
C
    3 READ(8,520,END=800)JJ,MT1
  520 FORMAT(I1,I3)
      IF(JJ.EQ.0)GOTO 55
      READ(8,499,END=800)N1
      GOTO 65
  499 FORMAT(I6)
   55 READ(8,500,END=800)N1
  500 FORMAT(I6)
   65 IF(MT1.EQ.0)GOTO 3
      READ(8,505,END=800)HF,BE,DBE,GE,DGE,KDN
      DEC=0.693/HF
```

```
      BE=BE/DIVI
      DBE=DBE/DIVI
      GE=GE/DIVI
      DGE=DGE/DIVI
      WRITE(9,700)N1,DEC,BE,DBE,GE,DGE,KDN
 700  FORMAT(I10,3(E10.4),10X,2(E10.4),2X,I1)
 505  FORMAT(5E12.5,1X,I1)
C
C BRANCHING RATIO AND ITS NUCLIDE
      DO 600 I=1,KDN
      READ(8,510,END=800)NYTR(I),EBR(I)
  510 FORMAT(I2,E12.5)
      NNN(I)=N1
      IF(NYTR(I).EQ.1)NNN(I)=N1+10
 600  CONTINUE
      IF(KDN.EQ.1)TTT=FORMT(1)
      IF(KDN.EQ.2)TTT=FORMT(2)
      IF(KDN.EQ.3)TTT=FORMT(3)
      WRITE(9,TTT)KDN,(NNN(I),EBR(I),I=1,KDN)
      GOTO 3
 800  ENDFILE 9
C
  201 FORMAT(5(A8,'E',A3),1X,I1)
 110  FORMAT(2A11)
 120  FORMAT(6A11)
 130  FORMAT(2A11,42X,I2)
 140  FORMAT(6A11)
 150  FORMAT(72X,I3)
 300  FORMAT(//)
 200  FORMAT(A2,A8,'E',A3)
      STOP
      END
//GO.FT05F001  DD  *
//GO.FT08F001  DD  UNIT=SCRTCH,SPACE=(TRK,(10,5),RLSE),
//    DSN=&WORKLIB,
//    DISP=(NEW,PASS),DCB=(RECFM=FB,LRECL=80,BLKSIZE=1600,BUFNO=1)
//GO.FT09F001 DD DSN=S.U3805.ROPTEST,DISP=(NEW,CATLG),
//    UNIT=DISK,SPACE=(TRK,(3,1),RLSE),
//    DCB=(RECFM=FB,LRECL=80,BLKSIZE=1600)
//GO.FT6F001 DD SYSOUT=A
//
```

```
//DATSORT  JOB  U3805,CHUNG,MSGLEVEL=(1,1)
/*JOBPARM  BIN=400
/*JOBPARM  BLOCK=(EVENING,EVENING)
//S1 EXEC FORTVCLG
//FORT.SYSIN DD *
C THIS PROGRAM IS TO SORT THE DATA IN ORDER OF NUCLIDE NUMBER
C FOR ROPEY.MASTER LIBRARY.
      DIMENSION N1(600),DEC(600),BE(600),DBE(600),GE(600),
     +NNN(600,5),EBR(600,5),NDK(600),FORMT(3),DGE(600),KDN(600)
      CHARACTER*18 FORMT,TTT
      DATA FORMT/'(I10,1(I10,E10.4))','(I10,2(I10,E10.4))',
     +'(I10,3(I10,E10.4))'/
      READ(5,20)M
   20 FORMAT(I4)
      DO 1 I=1,M

      READ(5,10,END=400)N1(I),DEC(I),BE(I),DBE(I),GE(I),DGE(I),KDN(I)
  10  FORMAT(I10,3(E10.4),10X,2(E10.4),2X,I1)
      IF(KDN(I).EQ.1)TTT=FORMT(1)
      IF(KDN(I).EQ.2)TTT=FORMT(2)
      IF(KDN(I).EQ.3)TTT=FORMT(3)
      READ(5,TTT,END=400)NDK(I),(NNN(I,J),EBR(I,J),J=1,KDN(I))
  1   CONTINUE
C SORTING START
400   MM=M-1
      DO 100 J=1,MM
C FINDING LOCATION L OF SMALLEST
      L=J
      JJ=J+1
      DO 200 I=JJ,M
       IF(N1(L).LE.N1(I))GOTO 200
       L=I
  200 CONTINUE
      WRITE(8,300)N1(L),DEC(L),BE(L),DBE(L),GE(L),DGE(L)
 300  FORMAT(I10,3(E10.4),10X,2(E10.4),2X)
      IF(KDN(L).EQ.1)TTT=FORMT(1)
      IF(KDN(L).EQ.2)TTT=FORMT(2)
      IF(KDN(L).EQ.3)TTT=FORMT(3)
      WRITE(8,TTT)NDK(L),(NNN(L,LL),EBR(L,LL),LL=1,KDN(L))
      DO 15 LL=1,KDN(L)
      KAL=NNN(L,LL)
      B=EBR(L,LL)
      NNN(L,LL)=NNN(J,LL)
      EBR(L,LL)=EBR(J,LL)
      NNN(J,LL)=KAL
      EBR(J,LL)=B
  15  CONTINUE
      L1=N1(L)
      T2=DEC(L)
      T3=BE(L)
      T4=DBE(L)
      NDK(L)=NDK(J)
      KDN(L)=KDN(J)
      N1(J)=L1
      DEC(J)=T2
```

```
      BE(J)=T3
      DBE(J)=T4
      GE(J)=T5
      DGE(J)=T6
      NDK(J)=L7
      KDN(J)=L8
  100 CONTINUE
      STOP
      END
//GO.FT05F001  DD  *
//GO.GT06F001  DD  SYSOUT=A
//GO.FT08F001  DD DSN=S.U3805.SORTOUT,DISP=(NEW,CATLG),
//     UNIT=DISK,SPACE=(TRK,(10,5),RLSE),
//     DCB=(RECFM=FB,LRECL=80,BLKSIZE=1600)
//
```

```
//INFINAL  JOB  U3805,CHUNG,MSGLEVEL=(1,1)
/*JOBPARM  BIN=400
/*JOBPARM  BLOCK=(EVENING,EVENING)
//S1 EXEC FORTVCLG,REGION=1024K
//FORT.SYSIN DD *
C THIS PROGRAM IS TO MAKE NEW ROPEY MASTER LIBRARY HAVING
C ENDF/V NEW DECAY DATA  WHICH EXIST ONLY ON THE ROPEY.
C THE OUTPUT OF THIS PROGRAM HAS ONLY DECAY DATA FOR ROPEY.
C OF COURSE,THESE DATA COME FROM ENDF/V VERSION.
C
      DIMENSION N1(1600),DEC(1600),BE(1600),DBE(1600),GE(1600),
     +NDK(1600),NNN(1600,3),EBR(1600,3),ID(900),DGE(1600)
     +,MM(900,2),BR(900,2),B(8),C(4),A(900,6),NO(900),D(900)
      CHARACTER*10 NDK,NNN,EBR,MM,BR
C
      READ(5,88)N,M
  88  FORMAT(2I4)
C READING THE ENDF/V DECAY DATA
      DO 1 I=1,N
      READ(3,200,END=400)N1(I),DEC(I),BE(I),DBE(I),GE(I),DGE(I)
 200  FORMAT(I10,3(E10.4),10X,2(E10.4))
      READ(3,210,END=400)NDK(I),(NNN(I,L),EBR(I,L),L=1,3)
 210  FORMAT(A10,3(2A10))
  1   CONTINUE
C
C READING ROPEY MASTER LIBRARY
 400  K=1
 1000 READ(4,100,END=500)ID(K),D(K),(A(K,I),I=1,6)
      READ(4,110,END=500)NO(K),(MM(K,I),BR(K,I),I=1,2)
      READ(4,120,END=500)(B(I),I=1,8)
      READ(4,130,END=500)(C(I),I=1,4)
      K=K+1
      GOTO 1000
C
  500 CONTINUE
      DO 10 I=1,M
      DO 20 J=1,N
      IF(ID(I).EQ.N1(J))GOTO 600
 20   CONTINUE
      WRITE(9,100)ID(I),D(I),(A(I,KK),KK=1,6)
      WRITE(9,110)NO(I),(MM(I,KK),BR(I,KK),KK=1,2)
      GOTO 10
 600  WRITE(9,200)N1(J),DEC(J),BE(J),DBE(J),GE(J),DGE(J)
      WRITE(9,210)NDK(J),(NNN(J,L),EBR(J,L),L=1,3)
  10  CONTINUE
100    FORMAT(I10,E10.4,6E10.4)
110    FORMAT(I10,2(A10,A10))
 120   FORMAT(8E10.4)
 130   FORMAT(4E10.4)
      STOP
      END
//GO.FT05F001  DD  *
 749 739
//GO.FT06F001  DD  SYSOUT=A
//GO.FT03F001  DD  DSN=S.U3805.SORTOUT,DISP=SHR
//GO.FT04F001  DD  DSN=S.U3805.ROPEY.OLD,DISP=SHR
//GO.FT09F001  DD  DSN=S.U3805.BNMASTER,DISP=(NEW,CATLG),
//    UNIT=DISK,SPACE=(TRK,(2,1),RLSE),
//    DCB=(RECFM=FB,LRECL=80,BLKSIZE=1600)
//
```

```
//FINAL1  JOB  U3805,CHUNG,MSGLEVEL=(1,1)
/*JOBPARM  BIN=400
/*JOBPARM  BLOCK=(EVENING,EVENING)
//S1 EXEC FORTVCLG,REGION=1024K
//FORT.SYSIN DD *
C THIS PROGRAM IS TO MAKE THE FINAL NEW ROPEY MASTER LIBRARY
C MAKING USE OF THE ENDF/V DECAY DATA.
C
      DIMENSION A(800,6),B(800,8),C(800,4),
     +N1(800),DEC(800),BE(800),DBE(800),GE(800),DGE(800),
     +NDK(800)
      CHARACTER*10 ID,M(1,2),BR(1,2),NNN(800,2),EBR(800,2)
C
      READ(5,99)KK
  99  FORMAT(I4)
C READING THE ROPEY MASTER LIBRARY
      DO 1 I=1,900
      READ(9,100,END=400)ID,D,(A(I,J),J=1,6)
100   FORMAT(A10,E10.4,6E10.4)
      READ(9,110,END=400)NO,(M(I,J),BR(I,J),J=1,2)
  110 FORMAT(I10,2(2A10))
      READ(9,120,END=400)(B(I,J),J=1,8)
      READ(9,130,END=400)(C(I,J),J=1,4)
  120 FORMAT(8E10.4)
  130 FORMAT(4E10.4)
    1 CONTINUE
C
C READING THE ENDF/V DECAY DATA
 400  CONTINUE
      DO 2 I=1,900
      READ(10,140,END=500)N1(I),DEC(I),BE(I),DBE(I),GE(I),DGE(I)
 140  FORMAT(I10,3(E10.4),10X,2(E10.4))
      READ(10,150,END=500)NDK(I),(NNN(I,J),EBR(I,J),J=1,2)
 150  FORMAT(I10,2(2A10))
   2  CONTINUE
C
 500  CONTINUE
C
C WRITING THE NEW MASTER LIBRARY FROM BNMASTER WHICH IS MADE
C BY BOTH SORTOUT AND ROPEY.OLD.
      DO 3 I=1,KK
      WRITE(8,160)N1(I),DEC(I),BE(I),DBE(I),A(I,3),GE(I),DGE(I),A(I,6)
 160  FORMAT(I10,7(E10.4))
      WRITE(8,150)NDK(I),(NNN(I,J)(1:10),EBR(I,J)(1:10),J=1,2)
      WRITE(8,120)(B(I,J),J=1,8)
      WRITE(8,130)(C(I,J),J=1,4)
   3  CONTINUE
      STOP
      END
//GO.FT05F001  DD  *
  34
//GO.FT06F001  DD  SYSOUT=A
//GO.FT09F001  DD  DSN=S.U3805.ROPEY.OLD,DISP=SHR
//GO.FT10F001  DD  DSN=S.U3805.BNMASTER,DISP=SHR
//GO.FT08F001 DD  DSN=S.U3805.NMASTER,DISP=(NEW,CATLG),
//     UNIT=DISK,SPACE=(TRK,(4,1),RLSE),
//     DCB=(RECFM=FB,LRECL=80,BLKSIZE=1600)
//
```

```
//YDATCOM  JOB  U3805,CHUNG,MSGLEVEL=(1,1)
/*JOBPARM  BIN=400
/*JOBPARM  BLOCK=(NIGHT,NIGHT)
//S1  EXEC  FORTVCLG
//FORT.SYSIN DD *
C THIS PROGRAM IS TO CLASSIFY THE YIELD DATA OF ENDF/V
C
      CHARACTER*11 A(12)
      CHARACTER*12 FP
C
      REWIND 8
C READING THE ENDF/V YIELD DATA AND PRINTING IT ON FILE 8
10    READ(5,50,END=200)(A(I),I=1,6)
      READ(5,50,END=100)(A(I),I=7,12)
      WRITE(8,60)((A(I)(1:8),A(I)(9:11)),I=1,4)
      WRITE(8,60)((A(I)(1:8),A(I)(9:11)),I=5,8)
      WRITE(8,60)((A(I)(1:8),A(I)(9:11)),I=9,12)
       GOTO 10
  100 WRITE(8,60)((A(I)(1:8),A(I)(9:11)),I=1,4)
      WRITE(8,60)((A(I)(1:8),A(I)(9:11)),I=5,8)
   50 FORMAT(6A11)
   60 FORMAT(4(A8,'E',A3,1X))
  200 ENDFILE 8
      REWIND 8
      REWIND 9
C READING DATA ON FILE 8
C
   20 READ(8,400,END=800)FP,DMETA,YI,UYI
  400 FORMAT(A12,3(1X,E12.5))
      YI=YI*100.
      UYI=UYI*100.
      IF(DMETA.EQ.1.0)GOTO 111
      WRITE(9,500)FP(5:7),FP(2:2),FP(4:4),YI,UYI
      GOTO 211
111   WRITE(9,502)FP(5:7),FP(2:2),FP(4:4),YI,UYI
   502 FORMAT(A3,A1,A1,'1',2(E10.4))
  500  FORMAT(A3,A1,A1,'0',2(E10.4))
  211  GOTO 20
  800  ENDFILE 9
       STOP
       END
//GO.FT05F001  DD  *
//GO.FT06F001  DD  SYSOUT=A
//GO.FT08F001  DD  UNIT=SCRTCH,SPACE=(TRK,(10,5),RLSE),
//     DSN=&WORKLIB,
//     DISP=(NEW,PASS),DCB=(RECFM=FB,LRECL=80,BLKSIZE=6160,BUFNO=1)
//GO.FT09F001  DD  DSN=S.U3805.YIELD1,DISP=(NEW,CATLG),
//     UNIT=DISK,SPACE=(TRK,(10,1),RLSE),
//     DCB=(RECFM=FB,LRECL=80,BLKSIZE=6160)
//
```

```
//YIESORT  JOB  U3805,CHUNG,MSGLEVEL=(1,1)
/*JOBPARM  BIN=400
/*JOBPARM  BLOCK=(NIGHT,NIGHT)
//S1 EXEC  FORTVCLG
//FORT.SYSIN  DD  *
C
C THIS PROGRAM IS TO SORT THE YIELD DATA IN TERMS OF THE ORDER
C OF THR ROPEY MASTER LIB
C
      DIMENSION N1(1200),YI(1200),UYI(1200)
C READING THE NUMBER OF DATA
      READ(5,55)M
  55  FORMAT(I4)
C READING THE INPUT DATA
C
      DO 20 I=1,M
      READ(9,100,END=400)N1(I),YI(I),UYI(I)
 100  FORMAT(I6,2E10.4)
   20 CONTINUE
C
C SORT THE DATA
400   MM=M-1
      DO 105 J=1,MM
C FINDING THE LOCATION L OF THE SMALLEST
      L=J
      JJ=J+1
      DO 200 I=JJ,M
      IF(N1(L).LE.N1(I))GOTO 200
      L=I
 200  CONTINUE
      WRITE(8,700)N1(L),YI(L),UYI(L)
      L1=N1(L)
      T1=YI(L)
      T2=UYI(L)
      N1(L)=N1(J)
      YI(L)=YI(J)
      UYI(L)=UYI(J)
      N1(J)=L1
      YI(J)=T1
      UYI(J)=T2
  105 CONTINUE
 700  FORMAT(I10,2E10.4)
      STOP
      END
//GO.FT05F001  DD  *
1153
//GO.FT09F001  DD  DSN=S.U3805.YIELD1,DISP=SHR
//GO.FT08F001  DD  DSN=S.U3805.EYSORT,DISP=(NEW,CATLG),
//     UNIT=DISK,SPACE=(TRK,(3,1),RLSE),
//     DCB=(RECFM=FB,LRECL=80,BLKSIZE=6160)
//
```

```
//YIFINAL  JOB  U3805,CHUNG,MSGLEVEL=(1,1)
/*JOBPARM  BIN=400
/*JOBPARM  BLOCK=(NIGHT,NIGHT)
//S1 EXEC  FORTVCLG,REGION=1024K
//FORT.SYSIN  DD  *
C
C THIS PROGRAM IS TO MAKE THE NEW ROPEY MASTER LIB WHICH CONTAINS
C BOTH ENDF/V DECAY DATA AND YIELD DATA.
C
      DIMENSION N1(1500),YI(1500),UYI(1500),ID(800),D(800),A(800,6),
     +NO(800),MM(800,2),BR(800,2),B(800,8),C(800,4)
      CHARACTER*10 MM,BR
C
      REWIND 9
C READING THE NO OF YIELD DATA IN ENDF/V AND NO OF NEMASTER CARD
      READ(5,88)N,M
  88  FORMAT(2I4)
C READING THE ENDF/V YIELD DATA  FROM FILE3 EYSORT
      DO 1,I=1,N
      READ(3,200,END=400)N1(I),YI(I),UYI(I)
  1   CONTINUE
 200  FORMAT(I10,2E10.4)
C
C READING ROPEY NEMASTER LIB  FROM FILE4 ROPEY.OLD11 WHICH HAS

C DECAY DATA
 400  K=1
1000  READ(4,100,END=500)ID(K),D(K),(A(K,I),I=1,6)
      READ(4,110,END=500)NO(K),(MM(K,I),BR(K,I),I=1,2)
      READ(4,120,END=500)(B(K,I),I=1,8)
      READ(4,130,END=500)(C(K,I),I=1,4)
      K=K+1
      GOTO 1000
C
 500  CONTINUE
      DO 10 I=1,M
       DO 20 J=1,N
      IF(ID(I).EQ.N1(J))GOTO 600
  20  CONTINUE
      WRITE(9,100)ID(I),D(I),(A(I,II),II=1,6)
      WRITE(9,110)NO(I),(MM(I,II),BR(I,II),II=1,2)
      WRITE(9,120)(B(I,II),II=1,8)
      WRITE(9,130)(C(I,II),II=1,4)
      GOTO 10
 600  WRITE(9,100)ID(I),D(I),(A(I,II),II=1,6)
      WRITE(9,110)NO(I),(MM(I,II),BR(I,II),II=1,2)
      WRITE(9,120)YI(J),UYI(J),(B(I,II),II=3,8)
      WRITE(9,130)(C(I,II),II=1,4)
  10  CONTINUE
 100  FORMAT(I10,E10.4,6E10.4)
 110  FORMAT(I10,2(A10,A10))
 120  FORMAT(8E10.4)
 130  FORMAT(4E10.4)
      ENDFILE 9
      STOP
      END
//GO.FT05F001  DD  *
1153 739
//GO.FT03F001  DD  DSN=S.U3805.EYSORT,DISP=SHR
//GO.FT04F001  DD  DSN=S.U3805.ROPEY.OLD11,DISP=SHR
//GO.FT09F001  DD  DSN=S.U3805.NEMAS1,DISP=(NEW,CATLG),
//     UNIT=DISK,SPACE=(TRK,(10,1),RLSE),
//     DCB=(RECFM=FB,LRECL=80,BLKSIZE=1600)
//
```

```
//YCUMY  JOB  U3805,CHUNG,MSGLEVEL=(1,1)
/*JOBPARM  BIN=393
/*JOBPARM  BLOCK=(NIGHT,NIGHT)
//S1 EXEC FORTVCLG
//FORT.SYSIN DD *
C THIS PROGRAM IS TO CHANGE THE CUMULATIVE YIELD DATA FROM
C THE NEMAS1
C
      DIMENSION  ID(2),A(1000),CY(8),CCY(4),
     +AN(20,8),BN(1,8),PU(1000)
      CHARACTER*10 AN,BN
C
      K=1
      KK=1
      BB=0.0
      CC=0.0
      REWIND 8
C
C READING THE DECAY AND INDEPENDENT YIELD DATA FROM NMAS1
 1000 READ(9,100,END=400)ID(K)
      READ(9,110,END=400)NO
      READ(9,120,END=400)B
      READ(9,130,END=400)C
      IF(ID(K).NE.ID(KK))GOTO 2000
C BB IS CUMULATIVE YIELD,CC IS ALSO CUMULATIVE YIELD FOR PU-239F
      BB=BB+B
      CC=CC+C
      KK=K
      K=K+1
      GOTO 1000
C
 2000 WRITE(8,200)BB,CC
      BB=B
      CC=C
      KK=K
      K=K+1
      GOTO 1000
  200 FORMAT(2E10.4)
  400 ENDFILE 8
C
C BEGIN FILE 8
      REWIND 8
      REWIND 10
      J=1
 3000 READ(8,200,END=550)A(J),PU(J)
C A IS CUMULATIVE YIELD IN FILE 8 ,FOR U-235T AND PU PU-239F
      J=J+1
      GOTO 3000
550   CONTINUE
      DO 500 I=1,2000
      READ(5,210,END=600)NN,MM,LL
 210  FORMAT(3I10)
      WRITE(10,210)NN,MM,LL
      READ(5,220,END=600)(CY(K),K=1,8)
      WRITE(10,220)A(I),(CY(K),K=2,8)
      READ(5,230,END=600)(CCY(K),K=1,4)
      WRITE(10,230)(CCY(K),K=1,2),PU(I),CCY(4)
      IF(NN-8)3,3,5
C
  5   DO 15 II=1,20
      READ(5,240,END=500)(AN(II,K),K=1,8)
      WRITE(10,240)(AN(II,K),K=1,8)
      III=II*8
```

```
      IF(III.GE.NN)GOTO 500
   15 CONTINUE
C
    3 READ(5,240,END=500)(BN(1,K),K=1,NN)
      WRITE(10,240)(BN(1,K),K=1,NN)
  500 CONTINUE
  600 ENDFILE 10
  220 FORMAT(8E10.4)
  230 FORMAT(4E10.4)
  240 FORMAT(8A10)
  100 FORMAT(I7)
  110 FORMAT(I10)
  120 FORMAT(E10.4)
  130 FORMAT(20X,E10.4)
      STOP
      END
//GO.FT05F001  DD  *
//GO.FT06F001 DD SYSOUT=A
//GO.FT08F001  DD  UNIT=SCRTCH,SPACE=(TRK,(10,10),RLSE),
//     DSN=&TEMP,
//     DISP=(NEW,PASS),DCB=(RECFM=FB,LRECL=80,BLKSIZE=6160,BUFNO=1)
//GO.FT09F001  DD  DSN=S.U3805.NEMAS2,DISP=SHR
//GO.FT10F001  DD  DSN=S.U3805.YCUM,DISP=(NEW,CATLG),
//     UNIT=DISK,SPACE=(TRK,(3,1),RLSE),
//     DCB=(RECFM=FB,LRECL=80,BLKSIZE=6160)
//
```