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REFLOS
A CODE FOR THE REFINED EVALUATION OF FUEL LOADING SCHEMES

by

W. BÖTTCHER * and E. SCHMIDT *

in co-operation with

W. DE HAAN *, F. HARDT *, J. LIGOU **,
P. TAUCH * and G. VEILHAN **

* Euratom
** GAAA

1969

ORGEL Program

Joint Nuclear Research Center
Ispra Establishment - Italy

ORGEL Project

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The report gives a survey about the methods applied in the individual subroutines of REFLOS, a detailed description of the input parameters and an example for input and output.

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ABSTRACT

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KEYWORDS

R-CODES
FUEL ELEMENTS
LOADING
HEAVY-WATER MODERATOR
REACTOR
REACTIVITY
BURNUP
FUEL CYCLE
COST

CONTENTS

REFLOS, a Code for the Refined Evaluation of Fuel Loading Schemes.*)

1. INTRODUCTION**)

REFLOS is a code for the refined evaluation of fuel loading schemes for heavy water-moderated reactors, or, more generally, for an heteregeneous reactor containing a weakly absorbing moderator. It has been developed for the design calculations for the ORGEL Prototype reactor. The necessity for its development follows from two points :

a) During the design of the ORGEL reactor a certain number of nuclear standard codes has been employed. In order to facilitate their utilization and to reduce the source oferrors arising by different definition of the terms, it has been tried to generate a consistent system of some codes which are needed to simulate the reactor life.

b) Besides this more technical point of view the pretensions concerning the quality of the code may be formulated as follows : if one wants to assess the potentialities of any reactor system, one will normally execute simple fuel cycle calculations applying point models. By means of a typical piece of fuel of the reactor the isotopic and reactivity changes are taken into account. But since nuclear power is becoming progressively more competitive,

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a higher accuracy concerning the economic predictions is needed. One has to take the fuel cycle calculations to the stage where they provide accurate indications of performance attainable in engineering designs. In order to do this, the non-uniform power distribution in an operating reactor as well as the influence of the chosen kind of fuel management must be considered.

REFLOS consists essentially of slightly changed versions of codes developed at ISPRA, as PLUTHARCO (Ref. 1) and RLT-4 (Ref. 2), which have been coupled in ORACLE 1 (Ref. 3) and of the code TRIHET (Ref. 4) (Ref. 5), developed by GAAA under contract with EURATOM. The part of the code which governs the fuel movement in the core has been kept quite generally, hence, a lot of imaginable kinds of radial fuel management schemes can be investigated, namely all combinations of :

- batch re-loading or continuous (element-wise) re-loading;
- movement of the fuel from outside to inside of the core or vice-versa;
- inversion of the re-loading scheme on the edge of two neighboring core zones or no inversion.

After having determined the core states characterizing the equil brium period and having decided the fuel re-loading scheme for the running-in period of the reactor life, the execution of the cost-part of the code is possible. Apart from the fuel cycle cost for a a few given life periods, following in its evaluation the proposals of (Ref. 6), the mass flows of heavy atoms into and from the reactor are

evaluated. Having as input parameters the re-loading plan and the desired power, REFLOS could be taken as a tool for the automatic control for the fissionable materials fed in, and discharged from, a power station. This can be also done for small operation intervals of the reactor, because the mass balances are given for each re-loading event.

The flow-diagram of REFLOS may be described briefly as follows. ORACLE 1 calculates for at maximum ten different kinds of fuel elements heterogeneous constants as function of the burn-up. The initial reactor state is defined by the spatial distribution of the kinds of fuel and the burn-up rate of the individual fuel element pieces in the reactor core. Then, the flux and power distribution, normalized to the desired total power, is calculated by the aid of the three-dimensional heterogeneous reactor code TRIHET. Assuming a constant flux distribution for a specified time interval, a new burn-up state is defined and the cycle of calculations may be re-started. The surplus reactivity may be compensated by iterating for the depth of control rod insertion into the core. Against this, at present, there is no possibility in REFLOS to simulate the reactor control by moderator poisoning or heating, taking into account the influence of these effects on the spectrum and by this on the conversion rate. This could be important lack in the case of high-reactive initial cores.

The scheme for the re-loading of the fuel elements is described by a matrix what has to be specified by the user. The re-loading is automatically released; if one of the following criteria is fulfilled :

- the prescribed life of the reactor is reached;
- the effective multiplication factor falls below a specified level;
- the power form factor falls below a given limit.

The fact, that in REFLOS only from outside imposed fuel loading schemes are applicable, is not taken as a serious restriction. After having got some experience referring to the fuel management in the considered reactor, the user will be able to choose the suitable re-loading plans.

The code is in its application rather variable. Thus, instead to derive the heterogeneous constants by ORACLE 1, one could procure them in any other way and introduce them by punched cards into the code. The program may be used for only one criticality calculation skipping the burn-up part or it may be employed for the investigation of the burn-up behaviour of a reactor without applying any fuel shuffling. Also the economy part may be omitted, if the knowledge of the corresponding data is not of interest. This variety in the execution of the calculation run is obtained by assembling the single parts of REFLOS by means of AIM-cards. Hence the user may deviate easily from the normal flow diagram of the code.

2. THE SUBROUTINE ORACLE 1

2.1. Scope of the program

ORACLE 1 is a lattice cell burn-up code which provides the heterogeneous constants and the composition of the fuel, needed in REFLOS, as function of the mean burn-up of the fuel in the cell.

The nuclear properties of the lattice cell are changed during the burn-up process by two different effects; firstly, by the alternation of the isotope densities of the heavy atoms and of the reactor poisons itself and, secondly, by the influence of the changement of the isotope composition on the thermal neutron spectrum and by this on the effective microscopic cross-sections for thermal and epithermal neutrons. Corresponding to these two problems a lattice cell burn-up code involves the following stages :

A lattice cell code evaluates the cell reactivity, the heterogeneous constants, the effective microscopic cross sections and other cell parameters for the fresh unpoisoned fuel. Then the effective cross sections and the isotope composition of this cell state are introduced into a depletion code. After having irradiated the fuel, for a specified time with a defined flux level, the strongly absorbing poisons are forced into equilibrium, the new isotope composition is evaluated and a new lattice calculation will take place. The sequence of cell lattice and depletion calculations is carried out till a prescribed upper limit for the irradiation time is reached.

2.2. Main physical concepts of ORACLE 1

The lattice cell code

The lattice cell code, incorporated in ORACLE 1, is PLUTHARCO, a plutonium, uranium, thorium assembly reactivity code for heavy water lattice cell calculations. The method is intended for design survey type calculations and for preliminary fuel cycle analysis. It is based on the four-factor-formula, the two group theory and the Westcott cross section formalism.

Subsequently, a survey about the physical features of PLUTHARCO shall be summarized. For more details the reader is refered to (Ref. 1).

The effective cross-sections are defined by :

$$\sigma_{eff} = \sqrt{\frac{\pi T_o}{4 T}}\ \hat{\sigma} = \sqrt{\frac{\pi T_o}{4 T}}\ (g + rs)\ \sigma_{2200}$$

where T, g, r, s mean the neutron temperature and the well--known Westcott-factors. For Pu-239 and Pu-240 the s-value is calculated depending on the corresponding concentrations. In the case of U-238 and Th-232 s is put equal to zero and the resonance absorption is evaluated taking into account correctly the self-shielding.

The thermal multiplication factor, η , is defined as the ratio of generated neutrons in fissionable materials to absorption in the fuel mixture, applying the above defined cross-sections.

For the calculation of T the Canadian formula, correlated to experiments which have been executed with Candu lattices, may be chosen. Other possible choices are the introduction of Termidor parameters or spectrum constants derived by any other technique.

The fast fission factor, ε , is calculated using the method of Fleishman and Soodak; however, the scheme was simplified to a two-groups structure instead of a three-group one. The two groups are separeted by the fission threshold of U-238. The fission source as well as the source of the neutrons next generation is supposed to be flat. In the second group

fission and inelastic scattering is not permitted. Atoms with fissioning capacity beneath the U-238 fission threshold are corrected for the fact that sub-threshold fissioning is not permitted, i.e., the fast fission in the second group is added to the first one.

The calculation run for the resonance escape probability can be divided into three parts. First, the effective surface per gram of fuel for the cluster is evaluated by the method of Hellstrand. After having derived this, the cluster is identified with an effective rod with the same surface per gram and the resonance integral, I, is calculated by :

$$I = A + B \sqrt{\frac{S}{M}}$$

interpolating tables which give A and B as function of the physical temperature and the composition of the fuel. A and B have been derived by fitting of resonance integrals calculated by the aid of the method of Nordheim. Finally, the resonance escape probability, p, is calculated by taking into account the disadvantage-factor of the epithermal flux, what results from the heterogeneous build-up of the lattice cell.

The thermal utilization factor, f, is evaluated by :

$$f = f_{fc} \cdot f_{cc}$$

where f_{fc} represents the fuel to cluster utilization factor and f_{cc} the cluster to cell utilization factor. Both factors

are calculated following the proposals of Amouyal and Benoist. For calculating f_{cc} the lattice cell is approximated by a cylindrical homogeneous fuel zone at the center, being surrounded by five cylindrical regions: outer coolant, pressure tube, insulating gap, calandria tube and moderator.

The diffusion area for the lattice cell, L^2, follows from the diffusion area of the moderator, L_m^2, and from the diffusion area of the central non-moderator region, L_c^2 :

$$L^2 = L_m^2 (1 - f) + fL_c^2$$

The slowing-down area of the moderator τ_m is automatically corrected for the perturbation of the fission spectrum by inelastic scattering in the fuel and for the presence of hydrogen atoms.

In (Ref. 1) an extensive conformation of PLUTHARCO results and experiments (EXPO, Cise, Savannah River, Chalk River) has been described. Generally, the four factors of the four-factor-formula were in good agreement with the measurements. Against this, remarkable discrepancies appeared in L^2 and τ. The differences in the buckling lay normally within 0.3 m^{-2}. For small pitches, however, there is a systematic underestimating of the buckling obtained by PLUTHARCO. It is assumed that these discrepancies arise due to inaccuracies in the technique describing the epithermal flux disadvantage factor and due to the fact that the Westcott formalism is no longer appropriate to hardened thermal neutron spectrums.

The depletion code

As depletion subroutine for ORACLE the slightly changed code RLT4 (Ref. 2) has been employed. Thus, it is possible to consider the Uranium burn-up chain. For specified products of thermal neutron flux and irradiation time, $\phi.t$, the isotope densities for heavy elements and fission products are calculated. The application of the cross-section

$$\sigma_{eff} = \sigma_{2200} (g + rs) \sqrt{\frac{\pi}{4} \cdot \frac{To}{T}}$$

in the burn-up equations means, that ϕ represents the average thermal neutron flux.

The neutron temperature T_n and the epithermal flux fraction r are re-calculated after each irradiation interval $\Delta(\phi\ t)$ by means of PLUTHARCO.

In the case of the fertile elements Th-232 and U-238 the cross-sections $\hat{\sigma}$ are corrected for the resonance absorption defining the effective cross-sections σ ,

$$\sigma = \sigma_{eff} (1 + \omega)$$

ω means the ratio of fast and epithermal to thermal absorptions. It is re-calculated after each irradiation interval $\Delta(\phi\ t)$.

In the depletion code the following heavy atoms are considered :

Th-232, Pa-233, U-233, U-234, U-235, U-236, U-238,

Pu-239, Pu-240, Pu-241.

The decay of Pa-233 into U-233 is taken into account by a half-life of 27.4 days. This is the only decay constant introduced in the burn-up equations. Hence, it is assumed that the (n,γ)-process in Th-232 leads instantaneously to Pa-233. Although the neutron absorption in Pa-233 becomes important only at fluxes above 10^{15} ($\frac{n}{cm^2\ sec}$), this reaction mechanism is taken into account assuming an immediate build-up of U-234 and neglecting thus the build-up and decay of Pa-234.

Referring to the uranium-chain it may be shown by comparing the reaction rates released by neutrons with the spontaneous reactions, that the decays of Pu-239, Pu-240 and especially of Pu-241 play an important role in the depletion calculations anly for fluxes smaller than 10^{12} ($\frac{n}{cm^2\ sec}$). Since this is a flux level which will hardly appear in a power reactor, it is supposed that the neglect of these decay-mechanism does not represent a significant restriction for the application of the code. It may be still mentioned that also the delay in the generation of Pu-239, caused by the build-up and decay of U-239 and Np-239 by absorption in U-238, is not taken into account.

The fission products with high absorption cross-sections are treated explicitly in the depletion code. For Sm-149, Sm-151, Cd-113, Eu-155 and Gd-157 the differential equations are exactly solved while the Xe-135 is always treated to be in equilibrium. The low-cross-section fission products have been collected in three pseudo-fission products following the proposals of the Canadians as Hurst and Walker.

It is foreseen to extend some parts of the depletion code in the next future.

2.3. The heterogeneous constants

ORACLE calculates the heterogeneous constants by two different techniques applying once an analytical approach and the other time the multi-region theory of Amouyal and Benoist. Since in the past only the constants derived by the second method has been used, the following explanations shall remain restricted to this theory.

The heterogeneous constants needed in REFLOS are defined by 4 terms :

- $ALFA = \frac{1}{2\pi D} \times \frac{A}{\phi_a}$

D, A and ϕ_a mean the diffusion coefficient for thermal neutrons in the moderator, the absorption rate in the source region and the asymptotic thermal neutron flux on the edge of the source region.

- $MU = ALFA \times \frac{P}{A}$

P represents the production rate of neutrons.

- GAMA

It means the generated power in MW per cm length of the source region and per unit of ϕ_a.

- BETA

It gives the ratio of mean thermal neutron flux in the fuel to ϕ_a.

In the multi-region Amouyal-Benoist theory the lattice cell is thought to be divided into a number of concentric rings. Let n be the number of rings into which the channel is divided (assuming that the lattice cell consists of moderator and the channel), f_i the absorption fraction within the i^{th} ring zone, and Q the total source of thermal neutrons, then the channel absorption rate is simply defined as

$$A = Q \sum_{i=1}^{n} f_i$$

If D is taken to be known, the only variable still to evaluate is the asymptotic flux, in order to determine ALFA. The direct results of the theory of Amouyal and Benoist are the neutron streams going in and coming out from the region i (J_i^- and J_i^+, respectively). To obtain the asymptotic flux, two considerations have been made :

a) It is assumed that the flux on the edge of the channel can be found by

$$\varphi_n = \phi_a = 2 (J_n^- + J_n^+)$$

which corresponds to an approximation of the diffusion theory, but using streams derived by means of the theory of collision probability.

b) The flux given under a) can be corrected in order to obtain the true diffusion theory value using considerations of (Ref. 7). It has been found that the moderator to fuel absorption ratio $\left(\frac{1}{f} - 1\right)$ of the two theories differs by the term $\Delta\varphi_m$, where the result of the integral theory has to be modified by $\Delta\varphi_m$ in order to find the diffusion theory value. It holds

$$\frac{\Sigma_m \, V_m \, \Delta\varphi_m}{\Sigma_f \, V_f \, \varphi_f} = \frac{V_m \, \Sigma_m}{\pi a} \left(\frac{3}{2}\lambda - 1\right)$$

and thus

$$\Delta\varphi_m \approx \frac{A}{\pi a} \left(\frac{3}{2}\lambda - 1\right)$$

The subscripts f and m refer to fuel and moderator, respectively. The term f means the thermal utilization factor of the cell, and Σ, V, a, λ mean the cross-section, the volume per unit of length, the channel radius and the extrapolation length in terms of mean free path of the moderator on the edge of the channel.

Introducing the correction for φ_a into the formula of ALFA, one obtains

$$\text{ALFA} = \frac{1}{2\pi D} \cdot \frac{A}{2\left(J_n^- + J_n^+\right) + \frac{A}{\pi a}\left(\frac{3}{2}\lambda - 1\right)}$$

It may be noted that the discrepancies between the techniques a) and b) were generally smaller than 1 %.

The source parameter MU can be derived from the ratio of production to absorption of neutrons in the single group concept

$$\frac{MU}{ALFA} = \frac{\varepsilon p \eta f}{A} = \frac{k_\infty}{A}$$

and, consequently,

$$MU = ALFA \times \frac{k_\infty}{A}$$

ε, p, η, f are the factors of the four-factor-formula, k_∞ means the infinite multiplication factor of the lattice cell.

The heterogeneous constant GAMA may be written as

$$GAMA = BETA \times K \times \frac{dM}{dz}$$

BETA will be defined below and $\frac{dM}{dz}$ gives the tons of fuel per cm of source length in axial direction. The specific power per unit of neutron flux within the fuel can easily be written as

$$K = \frac{E \Sigma_f (1 + \Delta)}{\rho_f}$$

where E, Σ_f, Δ and ρ_f mean the energy released per fission, the thermal macroscopic fission cross section of the fuel, the yield to the fission rate by the fast fission process and the density of the fuel.

Finally, it remains to evaluate BETA. Taking again into consideration the n concentrical regions of the channel, the fuel absorption rate A_f and the total channel absorption rate A can be expressed as

$$A_f = \sum_{i=1}^{n} \Sigma_{a,f}^{i} \varphi_i V_i$$

and

$$A = \sum_{i=1}^{n} \Sigma_{a}^{i} \varphi_i V_i .$$

We are looking for the reaction rate in the fuel per unit of neutron flux on the surface of the channel

$$\frac{A_f}{\phi_a} = \frac{A_f}{A} \cdot \frac{A}{\phi_a} = \frac{A_f}{A} \cdot 2\pi D \times ALFA$$

The neutron flux ratio BETA on its turn is related to this term by

$$\frac{A_f}{\phi_a} = BETA \times \sum_{i=1}^{n} \Sigma_{a,f}^{i} V_i = BETA \times \Sigma_{a,f} \cdot V_f$$

and thus

$$BETA = \frac{1}{\sum_{i=1}^{n} \Sigma_{a,f}^{i} V^i} \cdot \frac{A_f}{\phi_a} = \frac{1}{\sum_{i=1}^{n} \Sigma_{a,f}^{i} V^i} \frac{A_f}{A} \pi 2 D \times ALFA$$

The parameter A_f can be found as

$$\sum_{i=1}^{n} \frac{\sum_{a,f}^{i}}{\sum_{a}^{i}} f_i$$

and A is equal to the sum of the f_i for the individual regions within the channel.

Hence the generalized formula for BETA reads :

$$\text{BETA} = \frac{1}{\sum_{i=1}^{n} \sum_{a,f}^{i} V^i} \times \frac{\sum_{i=1}^{n} \frac{\sum_{a,f}^{i}}{\sum_{a}^{i}} f_i}{\sum_{i=1}^{n} f_i} \times 2\pi D \times \text{ALFA}$$

For a single region of the channel this expression may be simplified to

$$\text{BETA} = \frac{2\pi D \times \text{ALFA} \times f_1}{(1 - f_m) V_f \sum_{a,f}}$$

f_1 means the absorption fraction within the fuel.

3. THE REACTOR CODE

The choice of TRIHET (Ref. 4) (Ref. 5) as a subroutine for REFLOS in order to calculate reactivity and neutron flux distribution of the considered reactor was suggested by

- its availability at Ispra and the experience already made with the code ;
- the relatively short running-time, taking into account that TRIHET is a three-dimensional reactor code ;
- the fact that a heterogeneous reactor code facilitates a suitable simulation of fuel shuffling with multi--batch or with element-wise re-loading.

Originally, TRIHET has been established for calculations concerning the test-reactor ESSOR. The basic aspects and the modifications which were made to apply the code in REFLOS are discussed below.

3.1. Principles of the heterogeneous method and assumptions in TRIHET

Essentially, there are two techniques to treat heterogeneous reactors. The first one is respented by the well known unit-cell method of Wigner and Seitz replacing then the heterogeneous assembly by a partly homogeneous one. The other way to evaluate a heterogeneous reactor has been developed by Feinberg and Galanin. They treated the reactor as an assembly consisting of fuel channels and moderator. The fuel channels are taken to be line sources of fast and line sinks of thermal neutrons. The fast source-neutrons are slowed down within the moderator and by means of the Fermi age equation and by superimposing the yields of all existing sources of the assembly, the sources for

thermal neutrons are computed. The thermal neutron flux distribution in the moderator is then calculated by simple diffusion theory. Apart from geometrical data, the influence of the fuel channels on the flux distribution in the moderator is taken into account by the heterogeneous constants, describing the fission and absorption properties of the channel divided by the asymptotic neutron flux on the edge of the channel.

TRIHET represents an extension of the theory of Feinberg and Galanin in so far that the reflector may be considered as finite for thermal neutrons, the slowing-down of the neutrons may be treated by two energy groups, where one of them is governed by age-theory, corrections for the finiteness of the channels have been added and the axial decomposition of the fluxes (expansion of the fluxes in axial direction in Fourier series) has been employed, resulting in a three-dimensional model.

Assumptions representing a certain limitation of the TRIHET code and contained in REFLOS are listed in the following subsection :

- The heterogeneous constants are derived applying the unit-cell model. Consequently, although the thermal flux distribution is calculated later on for the real heterogeneous assembly, the computation is not heterogeneous in the stringent sense of the word.

- The situation is still worse concerning the resonance absorption. The resonance escape probability is introduced in the one-group heterogeneous constant, describing the generation of neutrons. The distribution of the resonance flux is not

calculated in TRIHET. Thus, concerning the resonance absorption, the code does not represent an heterogeneous one.

- The reflector must consist of the same material as the moderator.

- The fluxes in the two fast groups do not fall down to zero at the outside edge of the reflector but in infinity. This approximation means that the results of the reactor code will be in good agreement with the reality, if the tickness of the radial reflector amounts to nearly $4\sqrt{\tau}$ or a greater number. τ is the slowing-down area.

- The fuel channels behave as line sources of fast neutrons. This assumption leads to the requirement that the radii of the channels must not be too great or the channels must not be too closely packed.

- The slowing-down properties of the materials within the channel as, e.g., the organic coolant, are not treated separately but must be included in a suitable way by modifying the slowing-down behaviour of the moderator.

3.2. Modifications of TRIHET making it applicable to REFLOS

The necessary informations, which must be provided by the subroutine TRIHET, are :

- the k_{eff} for the given reactor state or the position of a specified control rod bank to reach the desired k_{eff};

- the specific power for each fuel element channel at j points along the channel in units of $(\frac{MW}{cm})$

- the average specific power for each axial piece of the fuel elements, defined by the j points in units of $(\frac{MW}{cm})$

- the mean thermal neutron flux in the fuel $(\frac{n}{cm^2\ sec})$ for each fuel channel at j points within the channel

- the power form factor giving the maximum $(\frac{MW}{cm})$ divided by the mean $(\frac{MW}{cm})$ of the reactor.

The formulas for the specific power, together with other items referring to the modification of TRIHET, are described in (Ref. 8).

In occasion of the work for REFLOS, some parts of TRIHET have been simplified, reducing so the possibilities of the subroutine to a measure which corresponds to the necessity to evaluate real power reactor. Hence, the version of TRIHET used in REFLOS can investigate only reactors with axial reflectors and with channels, which are occupied by fuel elements of the same length. The search of criticality by varying the absorption rate within the fuel elements has been left out.

The heterogeneous constants, defining points within the reactor, are taken to depend linearly on the length of the axial fuel pieces. Moreover, two important features has been added: first, TRIHET has been formally splitted in Prevol and Trevol, whereat Prevol creates a matrix depending only on

geometrical data and moderator properties. The terms within the matrix remain constant during all the reactor life and are to evaluate consequently only once. The matrix is fed into Trevol, what takes in consideration the composition of the fuel and, thus, the time-dependent component in a reactor. This feature leads to an appreciable saving of computation time in the case of fuel shuffling investigations.

Secondly, a new symmetry has been introduced, resulting also in a reduction of calculation time, but, and this is of higher importance, also in an increase of the assembly calculable by the code. In contrast with the old rotation symmetry, the new one represents a specular symmetry, whereat the mirror line is the angle bisector of the sector of the assembly defined by the input. Note that a combination of both symmetries is allowed.

4. THE ECONOMY PART

The scope of this subroutine of Reflos consists of the evaluation of the fuel cycle cost and the consumption of nuclear fuels for the reactor in consideration. In order to contribute to a certain standardization in the field of cost calculations, the applied technique has been based on the procedure established by a group of European firms in co-operation and under contract with EURATOM, which is explained in (Ref. 6). In the sense of the terminology of this reference, the quantities calculated here are necessarily "a priori costs".

Since credits and expenditures caused by the fuel cycle occur at different points of time, one has to actualize them to the same point of time before striking the balance. So, the losses and gains of interest will be taken into account. Commonly, this method is named present-worth method.

It may be noted that the equilibrium fuel cycle cost of a reactor may be determined with a certain approximation by balancing simply the real credits and expenditures. In the case of the transient period, however, the present-worth method represents the only reasonable technique because there is no proportionality between energy generation (corresponding to credits) and expenditures and, moreover, because the expenditures occur strongly discontinuously.

4.1. Surveyabout the calculation technique

The course of the calculations is most easily explainable, if one considers the life-time scale of the reactor which is defined by the start-up of the reactor and by charging and discharging events of fuel elements. Mass and composition of the charged and discharged fuel are determined by the applied loading scheme, the kind of the used fuel and the burn-up rate of the fuel. All these terms are known after having executed the nuclear subroutines and the fuel management subroutine of Reflos.

Because expenditures and credits for the irradiated fuel do not occur directly at the time-point of the loading event, but are rather distributed around it, one has still to investigate the life-time scale of the fuel elements, in order to be able to derive the worth of one kilogram of fuel actualized to the time of the charging or discharging event, respectively. This is done by taking into account the following time intervals of the "history" of the fuel elements:

- Transport time for the fresh raw material*.
- Fabrication time of the fuel elements.
- Waiting time for fresh fuel elements before insertion into the reactor.
- In-core time of the fuel elements.

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* It is assumed that the integral payment of the raw material is effected at the beginning of the transport time.

- Cooling time for fuel elements, which have been discharged from the reactor.
- Waiting time for the discharged fuel, in order to accumulate sufficiently great batches for the reprocessing.
- Transport time for the irradiated fuel from the reactor to the reprocessing plant.
- Time needed for the reprocessing.

Partly, in the above-cited time intervals, many working processes will be summarized. Thus, e.g., during the fabrication time, an eventually necessary conversion of the fuel into the needed form, the pellet sintering and the fuel element fabrication will be done and, during the reprocessing time, the remaining fuel will be reconverted into a valuable form.

The mass losses of the fuel materials during the individual working processes are taken into account by suitable factors and influence consequently the costs. The costs for the first core may be weighed by the excess elements on reserve.

It is possible to introduce a tax-rate on the worth of the capital bound in the fuel cycle. This tax-rate is paid for the half of the fuel element life on the worth of the fresh element and for the other half of the life on the worth of the discharged fuel.

After having derived such values for one kilogram of fresh and irradiated fuel, the total expenditures and credits per reloading event are derived multiplying the specific values by the charged and discharged masses. Then, the total values per reloading event are summed up for intervals prescribed by input. Normally, these intervals will correspond to running-in, equilibrium and running-out period of the reactor. The running-out may be simply

defined as a fraction of the equilibrium period, since this yield will be normally of negligible influence on the total fuel cycle costs extended on the reactor life time.

4.2. Formula *)

Waiting times (in months) :

If ITWA = 1 and I > 1 :

$$TWA_I^{TN} = \frac{\ln \left[\frac{\sum_{N=1}^{I+IK-1} DF_N^{TN} \; (1+0.01\,PM) - \frac{LIFE\;(N)}{30.4}}{\sum_{N=I}^{I+IK-1} DF_N^{TN} \; (1+0.01\,PM) - \frac{LIFE\;(I+IK-1)}{30.4}} \right]}{\ln\;(1 + 0.01\,PM)}$$

If I+IK-1 > Maximum (LIMIT 1), the calculation of a new TWA is omitted and the last computed value is employed. TN and I refer to the table number and to the step of the discharging event.

If ITWE = 1 and I > 1 :

$$TWE_I^{TN} = \frac{\ln \left[\frac{\sum_{N=1}^{I+IM-1} CF_N^{NT} \; (1+0.01\,PM) - \frac{LIFE\;(I)}{30.4}}{\sum_{N=1}^{I+IM-1} CF_N^{TN} \; (1+0.01\,PM) - \frac{LIFE\;(N)}{30.4}} \right]}{\ln\;(1 + 0.01\,PM)}$$

*) The symbols used here, are explained in subsection 5.4.

If I+IM-1 > Maximum (LIMIT 1), the calculation of a new TWE is skipped and the last computed value is used.

Specific cost for enriched or depleted Uranium(in $ per kg metal) :

$$KCR_1 = (2.6 \times KYC + KC) \cdot \frac{y-R}{0.711-R} + \frac{CT}{100} \left[(2y-100) \ln \frac{y}{100-y} - \right.$$

$$- \frac{y-R}{0.711-R} (2 \times 0.711 - 100) \ln \frac{0.711}{100-0.711} +$$

$$\left. + \frac{y-0.711}{0.711-R} (2R - 100) \ln \frac{R}{100-R} \right]$$

If $KCR_2 < KR$, the code puts automatically :

$$KCR_2 = KR$$

The so-calculated value is always used, if BCA is determined. It is employed for the calculation of BCE only, if the value, specified in the input, is equal to zero.

Calculation of BCA, BCE (in $ per Kg metal charged or discharged) :

If IRP = 0

$$BCA_I^{TN} = KL \times (1 + 0.01\ PM) - (TK + TTA + TWA_I^{TN})$$

If IRP = 1

$$BCA_I^{*TN} = (XINU_1 \times WPC_1^{I,TN} + XINU_2 \times WPC_2^{I,TN}) \cdot KCR_2 + \sum_{K=3}^{IS\emptyset} XINU_K \times WPC_K^{I,TN} \times KCR_K$$

$$BCA_I^{TN} = \left[BCA_I^{*TN} - (WPC_1^{I,TN} + WPC_2^{I,TN}) \; KRC_2 - \sum_{K=3}^{IS\emptyset} WPC_K^{I,TN} \; KRC_K - KRP^{TN} - KTR^{TN} \right] \times \left[1 - \frac{ST}{12} \; 0.01 \; (TK+TTA+TWA^{TN}+TRP^{TN}+0.5ICT_I^{TN}) \right] \times (1.0 + 0.01 \; PM)^{-(TK + TTA + TWA^{TN} + TRP)}$$

The expression within the second bracket of BCA_I^{TN} is put automatically zero, if BCA_I^{TN} results in a value with negative sign.

For I = LC (last core)

$$BCA_{LC}^{TN} = \left[BCA_{LC}^{*TN} - (WPC_1^{LC,TN} + WPC_2^{LC,TN})\, KRC_2 - \sum_{K=3}^{ISØ} WPC_K^{LC,TN} \times KRC_K - \right.$$

$$\left. - KRP^{TN} - KTR^{TN} \right] \times \left[1 - \frac{ST}{12} 0.01\ (TK + TTA + TRP + 0.5\ ICT_{LC}^{TN}) \right] \times$$

$$\times (1.0 + 0.01\ PM)^{-(TK + TTA + TRP)} +$$

$$+ RHØ \left[BCA_{LC}^{*TN} - (WPC_1^{LC,TN} + WPC_2^{LC,TN})\, KRC_2 - \sum_{K=3}^{ISØ} (WPC_K^{LC,TN} \times \right.$$

$$\left. \times KRC_K) - KRP^{TN} - KTR^{TN} \right] \times \left[1 - \frac{ST}{12} \cdot 0.01\ (TK + TTA + TRP + \right.$$

$$\left. + 0.5 \times 12 \times VIE) \right] \times (1.0 + 0.01\ PM)^{-(TK + TTA + TRP)}$$

$$BCE^{*TN} = (XIM_1 \times WPC_1^{1,TN} + XIM_2 \times WPC_2^{1,TN})\, KCR_2 +$$

$$+ \sum_{K=3}^{ISØ} XIM_K \times WPC_K^{1,TN} \cdot KCR_K$$

If I = 1 (initial core) :

$$BCE_I^{TN} = BCE^{xTN} \left[1 + \frac{ST}{12} \cdot 0.01 \left(TTO + TFO^{TN} + TWEO^{TN} + 0.5\ ICT_I \right) \right] x$$

$$x\ (1 + 0.01\ PM)^{TTO + TFO^{TN} + TWEO^{TN}} +$$

$$+ \sum_{j=1}^{NNO} \frac{KF^{TN}}{NNO} \left[1 + \frac{ST}{12} \cdot 0.01 \left(TFO^{TN} \frac{NNO-j}{NNO-1} + TWEO^{TN} + 0.5\ ICT_I^{TN} \right) \right] x$$

$$x\ (1 + 0.01\ PM)^{\frac{NNO-j}{NNO-1}\ TFO^{TN} + TWEO^{TN}} +$$

$$+ RH\emptyset \left\{ BCE^{*TN} \left[1 + \frac{ST}{12} \cdot 0.01 \left(TTO + TFO^{TN} + TWEO^{TN} + 0.5 \times 12 \times VIE \right) \right] \right.$$

$$x\ (1 + 0.01\ PM)^{TTO + TFO^{TN} + TWEO^{TN}} +$$

$$+ \sum_{j=1}^{NNO} \frac{KF^{TN}}{NNO} \left[1 + \frac{ST}{12}\ 0.01 \left(TFO^{TN} \times \frac{NNO-j}{NNO-1} + TWEO^{TN} + 0.5 \times 12 \times VIE \right) \right]$$

$$\left. x\ (1 + 0.01\ PM)^{\frac{NNO-j}{NNO-1}\ TFO^{TN} + TWEO^{TN}} \right\}$$

If $I > 1$:

$$BCE_I^{IN} = BCE^{*TN} \left[1 + \frac{ST}{12} \cdot 0.01 \left(TT + TF^{TN} + TWE^{TN} + 0.5\ ICT_I^{TN} \right) \right] x$$

$$x\ (1 + 0.1\ PM)^{TT + TF^{TN} + TWE^{TN}} +$$

$$+ \sum_{j=1}^{NN} \frac{KF^{TN}}{NN} \left[1 + \frac{ST}{12}\ 0.01 \left(TF^{TN} \frac{NN-j}{NN-1} + TWE^{TN} + 0.5\ ICT^{TN} \right) \right] x$$

$$x\ (1 + 0.01\ PM)^{\frac{NN-j}{NN-1} TF^{TN} + TWE^{TN}}$$

If the expression NN-1 becomes zero, it is treated to be 1 during the evaluation of BCE_I^{TN} .

Calculation of KF^{TN} :

If the input value KF^{TN} is equal to zero, the code evaluates the following formulas :

If $y = \frac{WPC_1}{WPC_1 + WPC_2} \cdot 100 < 1.0$:

$$KF^{TN}\ (\$/KgU) = 67.0 + 0.047\ KCR_2$$

If $y \geq 1.0$:

$$KF^{TN} \ (\$/kgU) = 76.5 + 0.047 \ KCR_2$$

Calculation of BKA and BKE :

$$BKA_I^{TN} \ (\$) = DF_I^{TN} \times FHA^{TN} \times BCA_I^{TN}$$

$$BKE_I^{TN} \ (\$) = CF_I^{TN} \times FHA^{TN} \times BCE_I^{TN}$$

$$BKA_I \ (\$) = \sum_{I=1}^{TN} BKA_I^{TN}$$

$$BKE_I \ (\$) = \sum_{I=1}^{TN} BKE_I^{TN}$$

Discharged and charged materials :

$$DF_{I,K}^{TN} \ (to) = \sum_{\substack{\text{reloaded} \\ \text{axial} \\ \text{pieces}}} WPC_K^{I,TN} \times DF^{TN} \times FHA^{TN}$$

$$CF_{I,K}^{TN} \ (to) = \sum_{\substack{\text{charged} \\ \text{axial} \\ \text{pieces}}} WPC_K^{O,TN} \times CF^{TN} \times FHA^{TN}$$

$$DMHA_I^{TN}\ (to) = DF_I^{TN} \cdot FHA^{TN}$$

$$CMHA_I^{TN}\ (to) = CF_I^{TN} \cdot FHA^{TN}$$

$$DF_K^M\ (to) = \sum_{TN} \sum_{I=n_1}^{n_2} DF_{I,K}^{TN}$$

$$CF_K^M\ (to) = \sum_{TN} \sum_{I=n_1}^{n_2} CF_{I,K}^{TN}$$

M varies from 1 to LIM 2.

If M = 1 : n_1 = 1

If M > 1 : n_1 = LIMIT 2 (M-1) + 1

n_2 = LIMIT 2 (M).

Effective expenditures for M intervals of the reactor life

$$BK^M\ (\$) = \sum_{I=m1}^{m2} (BKE_I - BKA_I)\ (1 + 0.01\ PM)^{-\frac{LIFE(I)}{30.4}}$$

The index M varies from 1 to LIM 1.

If M = 1 : m1 = 1

If M > 1 : m1 = LIMIT 1 (M-1) + 1

m2 = LIMIT 1 (M).

Cost for the first core

$$BKO\ (\$) = BK^{M} \text{ with } M = 1 \rightarrow m1 = 1$$

$$m2 = LIMIT\ 1\ (1) = 1$$

Cost for the transient period of the reactor

$$BK\ TRANS\ (\$) = \sum_{M} BK^{M} - BKO - SR^{*}$$

Cost for one equilibrium period of the reactor

$$SR^{*} = BK^{M} \qquad M = LIM\ 1 \rightarrow$$

$$m1 = LIMIT\ 1\ (LIM\ 1 - 1) + 1$$

$$m2 = LIMIT\ 1\ (LIM\ 1)$$

Duration of one equilibrium period of the reactor

$$TFEC\ (days) = LIFE\ (IE2) - LIFE\ (IE1)$$

$$LIFE\ (IE1) = LIFE\ LIMIT\ 1\ (LIM\ 1)$$

$$LIFE\ (IE2) = LIFE\ LIMIT\ 1\ (LIM\ 1 - 1)$$

Number of equilibrium periods during the whole reactor life

$$NEC = \frac{VIE \times 365 - LIFE\ (IE1)}{TFEC}$$

If this value is not equal to an integer, NEC is decreased to the next integer.

Total cost for all equilibrium periods of the reactor

$$BKG\ (\$) = SR^{*}\ \frac{1 - (1 + 0.01\ PM)^{-\frac{NEC \times TFEC}{30.4}}}{1 - (1 + 0.01\ PM)^{-\frac{TFEC}{30.4}}}$$

$$= \sum_{j=1}^{NEC} SR^{*}\ (1 + 0.01\ PM)^{\frac{LIFE\ (IE1)}{30.4}}\ x$$

$$x\ (1 + 0.01\ PM)^{-\frac{(j - 1)\ TFEC + LIFE\ (IE2)}{30.4}}$$

Begin of the running-out period

$$TXF\ (days) = LIFE\ (IE1) + NEC \times TFEC$$

Cost for the running-out period

$$BKR\ (\$) = \sum_{K=IE2+1}^{IMAX-1} (BKE - BKA)_K\ (1 + 0.01\ PM)^{-\frac{LIFE(K) + TXF}{30.4}}$$

$$- BKA_{LC}\ (1 + 0.01\ PM)^{-12 \times VIE}$$

Total fuel cycle cost

$$BCF\ (\$) = BK(1) + BK\ (LIM\ 1 - 1) + BKG + BKR$$

Variable and fixed cost for the extrapolated fuel cycle

BCF2 ($) =

$$SR^{*} (1+0.01\ PM)^{\frac{LIFE\ (IE1)}{30.4}} \times \frac{1 - (1+0.01\ PM)^{-\frac{VIE \times 365}{30.4} - TWE^{0}}}{1 - (1+0.01\ PM)^{-\frac{TFEC}{30.4}}}$$

BCF1 = BCF - BCF2

Energy produced in the whole reactor life and discounted to LIFE = 0

$$BE\ (kWh) = \sum_{J=1}^{12 \times VIE} (1 + 0.01\ PM)^{-j} \times W\emptyset RK$$

Energy produced in the transient period and discounted to LIFE = 0

$$BEA\ (kWh) = \sum_{j=1}^{Ny1} W\emptyset RK \times (1 + 0.01\ PM)^{-j} + W\emptyset RK\ (y_1 - Ny1) \times$$

$$\times (1 + 0.01\ PM)^{-y_1}$$

$$y_1 = \frac{LIFE\ (IE1)}{30.4}$$

Ny1 = largest integer of y_1.

Energy produced in one equilibrium period and discounted to the beginning of the equilibrium period

$$BEG\ (kWh) = \sum_{j=1}^{Ny2} (1 + 0.01\ PM)^{-j}\ W\emptyset RK + W\emptyset RK\ (y_2 - Ny2)\ (1 + 0.01\ PM)^{-y_1}$$

$$y_2 = \frac{TFEC}{30.4}$$

Ny2 = Largest integer of y_2.

Fixed specific fuel cycle cost :

$$BCF1^*\ \left(\frac{mills}{kWh}\right) = \frac{BCF1}{BE} \cdot 10^3$$

Total specific fuel cycle cost :

$$BCF1^*\ \left(\frac{mills}{kWh}\right) = BCF1^* + BCF2^*$$

Specific fuel cost for transition period

$$BCFE\ \left(\frac{mills}{kWh}\right) = \frac{BK\ TRANS + BKO}{BEA} \cdot 10^3$$

$$BCFE^*\ \left(\frac{mills}{kWh}\right) = \frac{BK\ TRANS}{BEA} \cdot 10^3$$

Specific fuel cost for one equilibrium period

$$BCFG\ \left(\frac{mills}{kWh}\right) = \frac{SR^{*}\ (1 + 0.01\ PM)}{BEG} + \frac{LIFE\ (IE1)}{30.4} \cdot 10^{3}$$

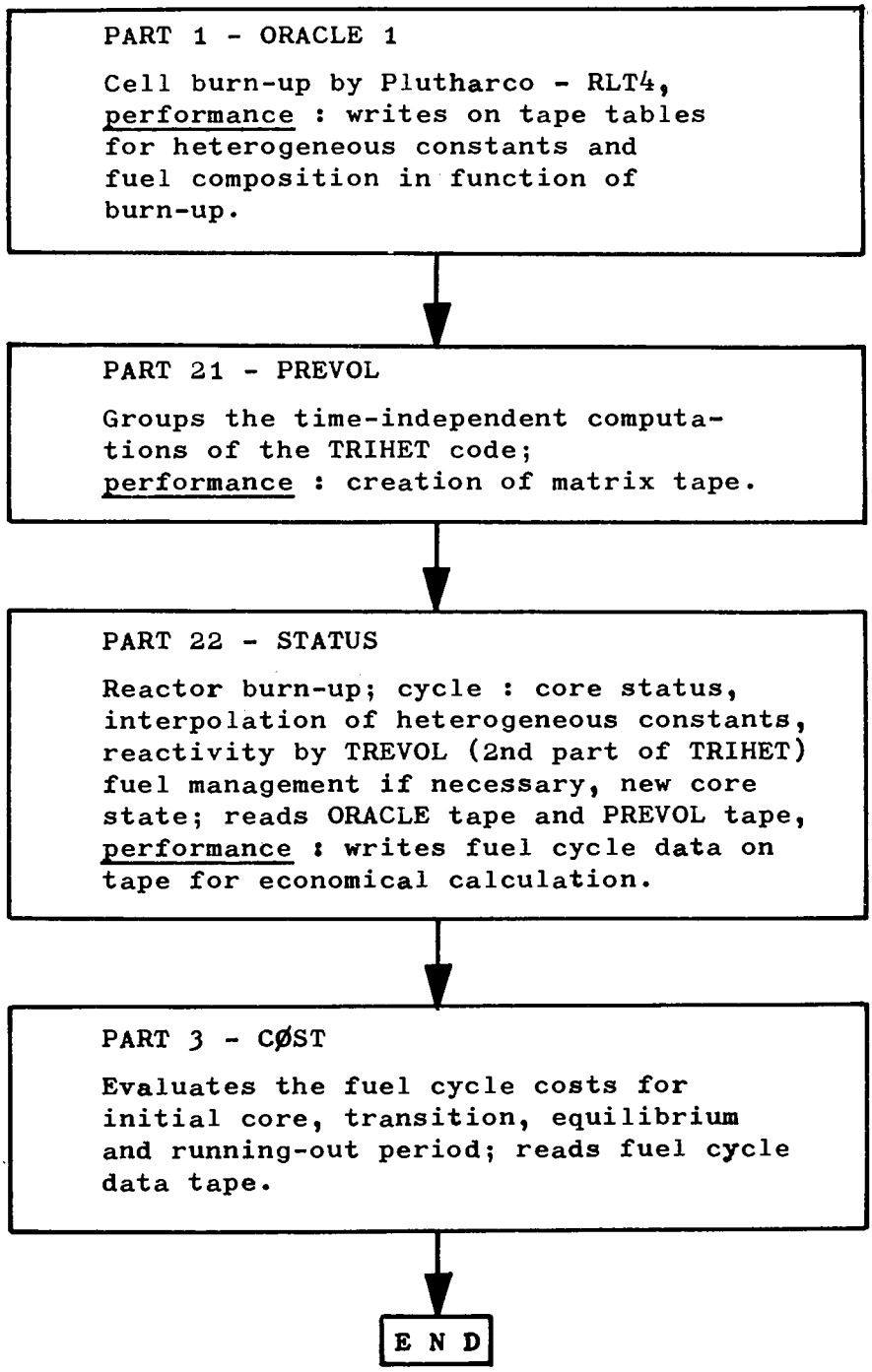
5. TECHNICAL INFORMATION CONCERNING REFLOS

5.1. Identification

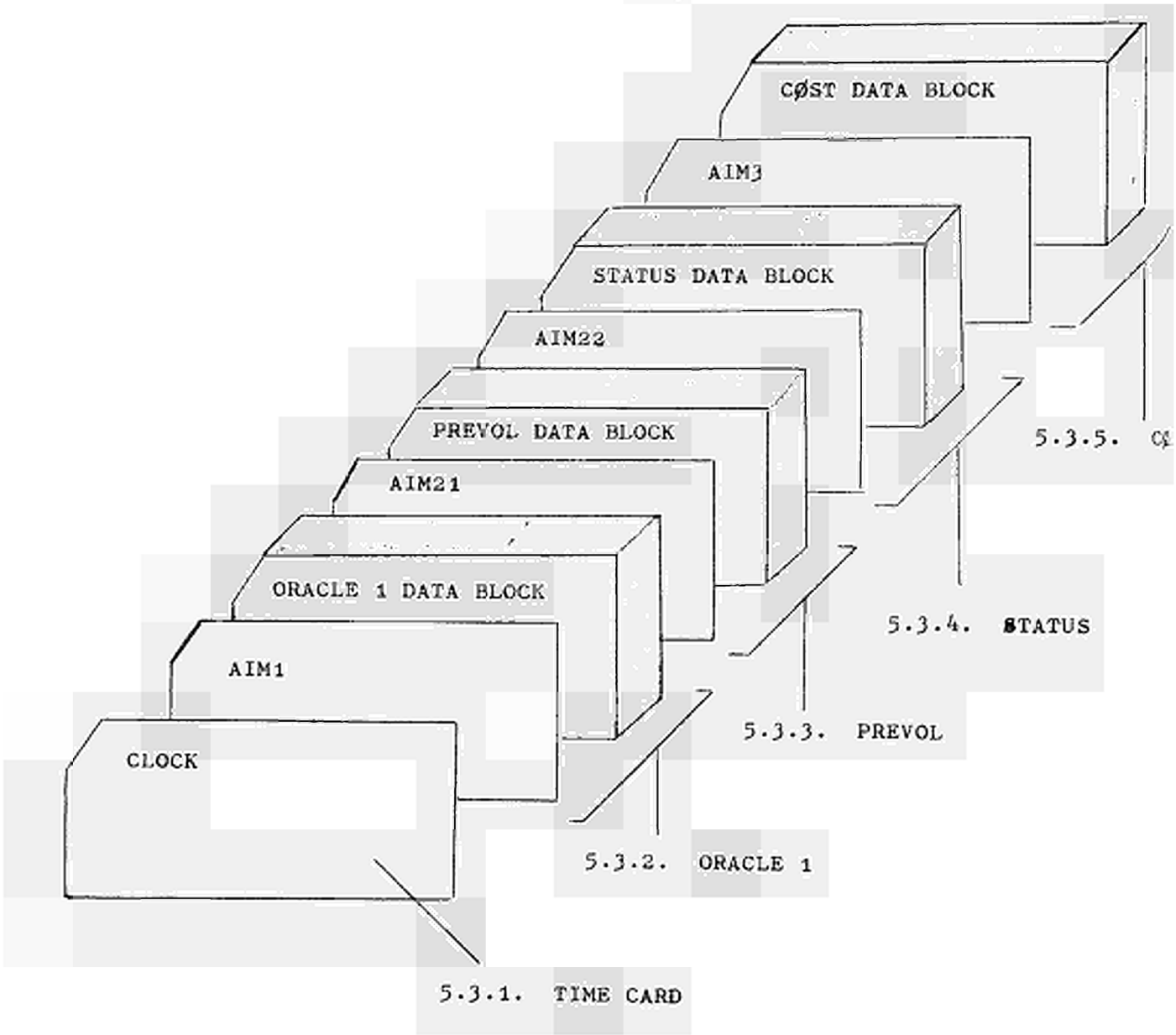
Name	REFLOS (Refined Evaluation of Fuel Loading Schemes)
ID-Number	68.8125
Codification	FØRTRAN IV
System	IBM 360/65 (300 K) 2 library tapes 2 scratch tapes (disc) 1 calcomp tape
Origin	ORGEL Project, CCR Ispra, December 10, 19

5.2. Survey about the construction of the code

The following flow-chart shows the subdivision of REFLOS.



5.3. Sequence of input cards



Time card

- 1 card FØRMAT

  CLØCK I3

  Total execution time at disposition of the program

ORACLE 1

- 1 card

  AIM1 I3

  = 0 ORACLE 1 is/was not used; ORACLE 1 data block is omitted,

  = 1 execute ORACLE 1; the appropriate data block follows,

  = 2 don't execute ORACLE 1, ORACLE 1 data block is omitted; previously calculated tables at disposition on tape.

The ORACLE 1 data block is composed of two sets of cards for each calculation (i.e., for each table).

- 1. A set of two identity cards, in which any message may be punched in col. 1-72. This will be printed out on listing before starting the calculation.

- 2. Data cards.
  The data cards contain the desired input data which are only marked by an index number (input-list location). The data will remain unchanged during the execution of ORACLE 1 as long as a new input overwrites them. We thus need only to replace the entries which have to be changed after a calculation, instead of giving all the data again.

The set-up is as follows (FØRMAT : A1, 2I3, 6F 10.5) :

Col. 1 Any figure (numeric or alfabetical card count, f.i.) may be entered here. An asterisk(*) however must be used only in the last card of the set, which forms part of one calculation.

Col. 2-4 The input-list location which will be modified by the first of the six data fields on the card.

Col. 5-7 The input-list location which will be modified by the last (between 1 and 6) data field of the card.

Col. 8-17, 18-27, 28-37, 38-47, 48-57, 58-67 Data fields. The decimal point may be placed on the places 10 n + 12 (n = 0,5). If no decimal points are entered, the point is supposed to be between col. 10 n + 12 and 10 n + 13 (n = 0,5).

The last card of the last calculation is immediately followed by a card, which contains in columns 1 to 3 the letters END.

PREVOL	FØRMAT
- 1 card	
AIM21	I3
- card	
ABC1	20A4
- 1 card	
FLDEUX, TAU2, H, R2	4E12.6
- 1 card	
NR, NE, KPLEC, IP, KR2, IZNUL, NSYR, NSYE, NTE, IMAT, NANA, NANA1, NANA2, NANA3, ITRI.	15I3
- (NR - NSYR) + (NE - NSYE) + NSYR + NSYE cards	
AAI, BI, AI, TI, NI	4E12.8, I3
- Only if (NSYR + NSYE) not equal 0, punch	
(NR - NSYR) + (NE - NSYE) values, 24 per card	
NGS	24I3
- only if NR not equal 0, punch NR-NSYR values, 6 per card	
HIR	6E12.8
ARIR	6E12.8
ARSR	6E12.8
- always present	
NTE values, 6 per card	
XE	6E12.8

- NE-NSYE values, 6 per card

ARIE	6E12.8
ARSE	6E12.8

STATUS	FØRMAT

- 1 card

AIM22	I3

- 1 card

TAB, UNIT1, NR, PRINT1, RUN, UNIT2, PRINT2, PRINT3, PRINT4, PRINT5, PRINT6, CYCLE, PUNCH, PERFO	14I3

- only if CYCLE > 1

- 3 cards (j = 1 .... 6)

NUM, TEST1, TEST2, (j=1) NUM, TEST1, TEST2 (j=2)	2(I6, 2E12.7

- only if CYCLE > 1

- 1 card

DT	E12.7

- only if CYCLE = 3

- 9 cards

LØAD	20I3

- always present

- 1 card
  NRL, NEL, NTL, IBANAL, IMAT, NCØD, NRM, NAN1,
  NAN2, NAN3, NAN4 — 11I3

- 1 card
  C, FKSIØ, RKSI, DKSI, WTR, ERREUR — 6E12.7

- only if NRL > 0

- NRL values, 6 per card
  ZIR — 6E12.7

- only if NCØD = 2

- NRM values, 20 per card
  NGR — 20I3

- only if TAB = 2

- 1 card
  K, J, DENS — 2I6, E12.7
- J cards
  BU, ALFA, MU, GAMA, BETA — 5E12.7

} NR times

- only if TAB = 3

- NZ = NEL x (NTL - 1) cards
  M, ALFA, MU, GAMA, BETA — I6, 6X, 4E12.7

- only if RUN = 1

- 1 card
  LIFE, FKSIØ — 2E12.7
- 1 card
  IMØVE, IP — 2I6
- 1 to NEL (NTL - 1) cards
  NM, NG, K1, K2, CT, BU, BUM — 4I6, 3E12.7

CØST	FØRMAT
- 1 card AIM3	I3
- 1 card NCALC, TN, ISØ, LIM1, LIM2, ITWE, ITWA, NN, IRP, NNO	10I3
- 1 card LIMIT 1	10I3
- 1 card LIMIT 2	10I3
- ISØ cards XINU, KCR, KRC, XIM	4E12.7
- TN cards IK, KRP, KTR, TRP, TWA, FHA	I12, 5E12.7
- TN cards IM, KF, TF, TWE, TFO	I12, 4E12.7
- 1 card TK, TTA, TT, TTO, TWEO	5E12.7
- 1 card ST, PM, RHØ, KL	4E12.7
- 1 card VIE, WØRK	2E12.7

- 1 card
  KYC, KC, R, CS, KR — 4E12.7

- only if TN < 0

- 1 card
  K, J, — 2I3

- 1 card
  BU, MPL, WPCU235, WPCU, WPCPUFI — 5E12.7

- 1 card
  WPC PUFE, WPC TH, WPC U233 — 3E12.7

J times; TN times

5.4. Explanation of the meaning of the used symbols for the input

ORACLE 1

1. Compound index for fuel
   1. Metal
   2. Oxide
   3. Monocarbide
   4. Dicarbide
   7. Other fuel (cross-sections to be entered in NRS 72-89)

2. Diluent spectr. const. (°K)

3. ----

4. Canning spectr. const. (°K)

5. Coolant index

   0. Void
   1. Gilotherm (Santowax)
   2. Diphenyl
   3. Heavy water
   6. Other organic coolant (data to be entered in NRS 90, 91, 104 and 105)
   7. Other coolant (cross-sections to be entered in NRS 137-149 AND 167-179)

6. Coolant and inner filler spectr. const. (°K)

7. ----

8. Outer coolant and outer spectr. const. (°K)

10. Pressure tube spectr. const. (°K)

11. Insulation index

   0. Void
   1. Gilotherm (Santowax)
   2. Diphenyl
   3. Heavy water
   4. Al_2O_3
   5. $Si\ O_2$
   6. Other organics
   7. Other material (cross-sections to be entered in NRS.152-164)

12. Insulation spectr. const. (°K)

13. Occupied (KHET)

14. Calandria spectr. const. (°K)

15. Moderator spectr. const. (°K)

16. Physical temperature fuel (°K)

17. Physical temperature coolant (°K)

18. Physical temperature insulation (°K)

19. Physical temperature moderator (°K)

20. -1. Correlated spectr. const.
    0. Other spectr. const.
    1. Termidor spectr. const. (enter data in NRS. 195-200)

21. Poisoning coefficient, only for irradiated fuel.
    Absorption in poisoned fuel devided by absorption in
    unpoisoned fuel.

22. SGR Filler density (Graphite) relative to reference
    density (1.65 GR/CM3)

23. ALFA, Weight percentage of AL2 O3 in SAP (value between 0 and 1)

24. RHO-SAP SAP density (in GR/CM3)

25. HBR Percentage of high boiling residues in Santowax (in percents)

26. SAL Effective absorption section (averaged over a maxwellian
    flux at fuel temperature t(n) due to alloys contained
    in the fuel.

27. PU Purity of heavy water (value between 0 and 1)

28. CHW Additional heavy water absorption section due to impurities other than light water (value at 2200 m/sec).

29. EXSAP Extra absorption in SAP due to impurities (value at 2200 m/sec times 1.0E 5).

30. S

Cylindrical geometry	Outer radius of first (outer) tube
All other geometries	Fuel rod radius

All geometrical data in CM

31. S1

7-Rod Hexagonal	Clad rod radius
6-Rod Hexagonal	Clad rod radius
18-Rod Hexagonal	Clad rod radius
19-Rod Hexagonal	Clad rod radius
19-Rod Circular	Clad rod radius
22-Rod	Radius of central rod
4-Rod	Clad rod radius
Single rod	Cladding inner radius
Cylindrical	Inner radius of first (outer) tube

32. S2

22-Rod	Radius of second-ring rods
Single rod	Cladding outer radius
Cylindrical	Outer radius of second tube
6-Rod (DUMM2)	External radius of central tube
18-Rod (DUMM3)	External radius of central tube

33. S3

22-Rod	Radius of thrid-ring rods
Cylindrical	Inner radius of second tube
6-Rod (DUMM2)	Internal radius of central tube
18-Rod (DUMM3)	Internal radius of central tube

34. A All geometries — Internal radius of pressure tube

35.	A1	All geometries	External radius of pressure tube
36.	A2	All geometries	Internal radius of calandria tube
37.	A3	All geometries	External radius of calandria tube
38.	R	4-Rod	External radius of central filling
		Cylindrical	Outer radius of third tube
		6-Rod	External radius of filler tube
39.	OR	4-Rod	Thickness of central filling tube (Same composition as cladding)
		Cylindrical	Inner radius of third tube
		6-Rod (DUMM2)	Thickness of filler tube

40. Geometry index for the fuel cluster

-- Comment -- With negative values for these clusters the introduction of the Dancoff correction factor (see Head 126) is supposed.

1. 7-Rod Hexagonal
2. 19-Rod Hexagonal
3. 19-Rod Circular
4. 22-Rod
5. 4-Rod
6. Single Rod
7. 3-Rod geometry
8. Cylindrical

-9. Special geometry (data to be entered in NRS. 107-126)

10. 6-Rod geometry
11. 18-Rod geometry

41.	D	7-Rod Hexagonal	Axial distance from rods in hexagonal geometry
		19-Rod Hexagonal	Axial distance from rods in hexagonal geometry

		19-Rod Circular	Axial distance from rods in hexagonal geometry
		22-Rod	Distance from center of external ring of rods to center of element
		4-Rod	Distance from center of element to outer rods
		Cylindrical	Outer radius of fourth (Inner) tube
42.	D1	22-Rod	Cladding thickness of central rod
		Cylindrical	Inner radius of fourth (Inner) tube
43.	D2	22-Rod	Cladding thickness of rods in first ring
44.	D3	22-Rod	Cladding thickness of rods in second ring
		Cylindrical	Cladding thickness of cylindrical tubes
45.	VR	Cylindrical	Total volume of filling at center of fuel element in cm^3/cm
		All other geometries	Total volume of filling
		For four rod	Except central filling tube
46.	VRIT	Cylindrical	Volume of filling at center of fuel element for calculation of thermal utilisation factor
		All other geometries	Volume of filling inside homogenized central rod for calculation of thermal Utilisation factor
47.	VRIF	Cylindrical	Volume of filling at center of fuel element for calculation of fast fission factor
		All other geometries	Volume of filling inside homogenized center rod for calculation of fast fission factor.

48. Occupied

49. ----

50. Printing index

    0. Output with intermediate results
    1. Output without intermediate results

51. Second flight correction — Correction factor to make allowance for non-uniformity of neutron density after first collision.

52. Atomic fraction TH-232

53. Atomic fraction U-233

54. Atomic fraction U-235

55. Atomic fraction U-236

56. Atomic fraction U-238

57. Atomic fraction Pu-239

58. Atomic fraction Pu-240

59. Atomic fraction Pu-241

60. Mixed fuel density in G/cm^3

61. Mixed fuel molecular number

62. Spectr. const. (°K) TH-232

63. Spectr. const. (°K) U-233

64. Spectr. const. (°K) U-235

65. Spectr. const. (°K) U-236

66. Spectr. const. (°K) U-238

67. Spectr. const. (°K) Pu-239

68. Spectr. const. (°K) Pu-240

69. Spectr. const. (°K) Pu-241

70. Lattice cell index

    1. VM/VF
    2. Square pitch
    3. Hexagonal pitch

71. Value of VM/VF (dimensionless) or pitch (cm)

Cross-sections for special fuel (see 1; Compound index) /1/cm/

72. Absorption (Thermal) (SACT)

73. Fission (Thermal) (SFCT)

74. Scattering (Thermal) (SSCT)

75. Transport (Thermal) (STRCT)

76. Scattering (Epithermal) (SSCE)

77. Transport (Epithermal) (STRCE)

78. Slowing down (Epithermal) (SXSCE)

79. Total (Fast) (STCF)
80. Elastic (Fast) (SECF)
81. Inelastic (Fast) (SICF)
82. Fission (Fast) (SFCF)
83. Capture (Fast) (SCCF)
84. Nu times fission (Fast) (SNUCF

Above the fission threshold of U-238

85. Total 2 (Fast) (STCF2)
86. Scattering 2 (Fast) (SSCF2)
87. Capture 2 (Fast) (SCCF2)

Needed for the evaluation of the fast fission effect for the group below the fission threshold of U-238

88. A- Res. Int. (U1) If $RI=A+B\sqrt{S/M}$

89. B- Res. Int. (U2)

$U1=N \cdot A \cdot F$

$U2=N \cdot B \cdot F / \sqrt{\rho F}$

F = Atomic fraction

ρ = density

N = Atoms/cm^3

90. Organic density at 0 centigrade G/cm^3 (see 5. Coolant index)

91. (Density temp. coeff.)times 1.E4 (see 5. Coolant index)

92. Nu times fission (Thermal) (SNUFCT)

94.
95. } Not occupied

96. Table-number in that the results are to be stored; (≤ 10). If this value is negative, it is set positive and the tables are also punched on unit 7.

97.
⋮ Internal occupied
102.

103. Not occupied

104. Number of C-Atoms/organic molecule (see 5. Coolant index)

105. Number of H-Atoms/organic molecule (see 5. Coolant index)

106. Geometrical data for special geometry (see 40. Geometry index)

107. VC (cm^3/cm) Volume of combustible in the cell

108. VG (cm^3/cm) Volume of canning in the cell

109. VO (cm^3/cm) Volume of coolant in the cell

110. VT1 (cm^3/cm) Volume of pressure tube in the cell

111. VT2 (cm^3/cm) Volume of insulation gap in the cell

112. VT3 (cm^3/cm) Volume of calandria tube in the cell

113. VM (cm^3/cm) Volume of moderator in the cell

114. ----

115. ----

116. VBT Volume (cm^3/cm) included in a rubberband strung around the canned cluster

117. ABT = $\sqrt{VBT/\pi}$

118. VOIT = VBT - VC - VG

119. VOET = VO - VOIT

120. VBF Volume (cm^3/cm) included in a rubberband strung around the uncanned cluster

121. ABF = $\sqrt{VBF/\pi}$

122. VGIF Volume (cm^3/cm) of can inside of VBF

123. VOIF = VBF - VC - VGIF

124. SU Surface (cm^2/cm) of fuel in the cluster

125. SF Surface (cm^2/cm) of the rubberband as defined for VBF

126. Dancoff correction factor

127. Organic fraction of filler tube holes in 6-Rod clusters

128. Periferical filler rod center distance to cluster center

129. 6-Rod cluster: Metal identification of central pin

130. Max. integrated flux for burn-up calculation /Neutrons/kilobarn/

131. Step in integrated flux for burn-up calculation /Neutrons/kilobarn/
(maximum : 50 burn-up steps)

132. Actuel integrated flux for burn-up calculation /Neutrons/kilobarn/

133. Occupied

134. Effective (energy averaged !) thermal neutron flux existing in fuel element (for TH-U233 chain and Xe-equilibrium ; in units of 10^{13} n/cm^2 sec).

135. ----

136. ----

Cross-section for special coolant (see 5. Coolant index) /1/cm/

137.	Absorption	(AT 2200 m/sec)	(SANT)	
138.	Scattering	(Thermal)	(SSNT)	
139.	Transport	(Thermal)	(STRNT)	
140.	Scattering	(Epithermal)	(SSNE)	
141.	Transport	(Epithermal)	(STRNE)	
142.	Slowing down	(Epithermal)	(SXSNE)	
143.	Total	(Fast)	(STN)	Above fission threshold of U - 238
144.	Elastic	(Fast)	(SEN)	
145.	Inelastic	(Fast)	(SJN)	
146.	Capture	(Fast)	(SCN)	

147.	Total 2	(Fast)	(STN2)	Below fission thereshold of U - 238
148.	Scattering 2	(Fast)	(SEN2)	
149.	Capture 2	(Fast)	(SCN2)	
150.	----			
151.	Occupied			

Cross-sections for special insulation (see 11. Insulation index) /1/cm/

152.	Absorption	(AT 2200 m/sec)	(SANT)
153.	Scattering	(Thermal)	(SSNT)
154.	Transport	(Thermal)	(STRNT)
155.	Scattering	(Epithermal)	(SSNE)
156.	Transport	(Epithermal)	(STRNE)
157.	Slowing down	(Epithermal)	(SXSNE)

158.	Total	(Fast)	(STN)	Above the fission threshold of U - 238
159.	Elastic	(Fast)	(SEN)	
160.	Inelastic	(Fast)	(SJN)	
161.	Capture	(Fast)	(SCN)	

162.	Total 2	(Fast)	(STN2)	Below the fission thereshold of U - 238
163.	Scattering 2	(Fast)	(SEN2)	
164.	Capture 2	(Fast)	(SCN2)	

165. - 166. ----

Cross-sections for special outer coolant (see 5. Coolant index)

/ 1/cm /

167.	Absorption	(AT 2200 m/sec)	(SANT)	
168.	Scattering	(Thermal)	(SSTN)	
169.	Transport	(Thermal)	(STRNT)	
170.	Scattering	(Thermal)	(SSNE)	
171.	Transport	(Thermal)	(STRNE)	
172.	Slowing down	(Epithermal)	(SXSNE)	
173.	Total	(Fast)	(STN)	Above fission thereshold of U - 238
174.	Elastic	(Fast)	(SEN)	
175.	Inelastic	(Fast)	(SJN)	
176.	Capture	(Fast)	(SCN)	
177.	Total 2	(Fast)	(STN2)	Below fission thereshold of U - 238
178.	Scattering 2	(Fast)	(SEN2)	
179.	Capture 2	(Fast)	(SCN2)	

180. - 194. ----

Termidor cross-sections (see 20. Spectral constant index)

195. Spectrum mean microscopic U-235 absorption cross-section

196. Spectrum mean microscopic U-235 fission cross-section

197. Spectrum mean microscopic PU-239 absorption cross-section

198. Spectrum mean microscopic PU-239 fission cross-section

199. Spectrum mean microscopic 1/V absorption cross-section/barn (2200m/sec) in fuel

200. Spectrum mean microscopic 1/V absorption cross-section/barn (2200m/sec) in moderator

Volume fractions of structural material for canning

201. Air

202. Berylium

203. Graphite

205. Lead

206. SAP

207. Stainless steel

208. Zircaloy-2

209. - 210. ----

Volume fractions of structural material for pressure tube

211. Air

212. Berylium

213. Graphite

214. Magnesium

215. Lead

216. SAP

217. Stainless steel

218. Zircaloy-2

219. - 220. Occupied

Volume fraction of structural material for calandria tube

221. Air

222. Berylium

223. Graphite

224. Magnesium

225. Lead

226. SAP

227. Stainless steel

228. Zircaloy-2

229. Occupied

230.

Volume fractions of structural material for inner filler

231. Air

232. Berylium

233. Graphite

234. Magnesium

235. Lead

236. SAP

237. Stainless steel

238. Zircaloy-2

239. - 240. Occupied

Volume fractions of structural material for outer filler

241. Air

242. Berylium

243. Graphite

244. Magnesium

245. Lead

246. SAP

247. Stainless steel

248. Zircaloy-2

240. - 250. Occupied

350. If 0, no intermediate results at the individual burn-up steps are printed out; output consists only of input and tables.

If 1, intermediate results are printed.

PREVOL

AIM21 = 1 execute PREVOL, creation of a new matrix tape IMAT.

= 2 skip PREVOL, matrix tape at disposition.

ABC1 Any alpha - numerical information referring to the case being studied (TITLE card).

FLDEUX Diffusion area of thermal neutrons in the moderator (cm^2)

TAU2 Slowing-down area (cm^2).

It holds TAU2 + TI = Fermi-age of thermal neutrons = τ_{th}. The meaning of TI has been explained further below. TAU2 defines the energy range of fast or epithermal neutrons which is treated by diffusion theory. Putting zero this term means application of Fermi-age theory for the whole fast group and existence of only one fast group.

Comparisons with experiments and homogeneous theory suggest, to use the τ_{th} for the cell instead of the one of the moderator if inside of the channel a remarkable moderation exists.

H Extrapolated height of the reactor (cm), including physical height of core and reflectors as well as an average extrapolation lenght for neutrons. This value is used for all energy groups. It is impossible to evaluate a reactor without axial reflectors.

R2 Extrapolated radius of the reactor (cm). The definition corresponds to that given for H.

Leave blank if there is an infinite radial reflector.

NR — Number of groups of channels occupied by control rods in the reactor.

NE — Number of groups of channels occupied by fuel elements in the reactor.

Limitation : NR + NE - NSYR - NSYE $\leq$ 60

NSYR + NSYE $\leq$ 60

See below for the meaning of NSYR and NSYE.

By means of NR and NE a rotation symmetry is represented. The application of this method is justified, if there is a repetition of the design of a certain sector of the reactor considering the radial section.

Channels may be gathered to a group if the following conditions are fulfilled :

Their extension (radius AI) is the same.

Their distance from the center of the reactor is the same.

Their nuclear parameters are the same.

They have the same fluxes on the their edge.

The angle between two channels of the considered group must be equal to $2\pi/NI$.

KPLEC — Desired approach for the series of Bessel functions used for the calculation of the flux distribution in radial direction.

Limitation : KPLEC $\leq$ 12

It is proposed to use KPLEC = 12.

IP — Desired approach for the calculation of the neutron flux in axial direction (number of harmonics).

It is proposed to use a number of 12 or 19. Only for special investigations as flux peaking in junctions a higher number of harmonics is needed.

Limitation : (NR - NE) x IP $\leq$ 760

IP $\leq$ 19

KR2

= 0 if the considered reactor has a finite radial reflector.

= 1 if the radial extension of the reflector is infinite.

IZNUL

= 0 if the axial central plane of the reactor is a symmetry plane e.g., $\phi\left(\frac{H}{2} - z\right) = \phi\left(\frac{H}{2} + z\right)$.

= 1 if there is no axial symmetry.

NSYR

Number of symmetries for channels occupied by control rods.
NSYR = NR minus (number of control rod channels situated on the symmetry line), divided by two.

Leave blank if this symmetry shall not be used or does not exist.

NSYE

Number of symmetry for channels occupied by fuel elements.
NSYE = NE minus (number of fuel element channels situated on the symmetry line), divided by two.

Leave blank if this symmetry shall not be used or does not exist.

In contrast to the rotation symmetry expressed by gathering of individual channels in groups of channels, NSYR and NSYE mean a specular symmetry without inversion. For instance, a configuration of the kind of figure 1 may be calculated by NE = 4 and NSYE = 0.

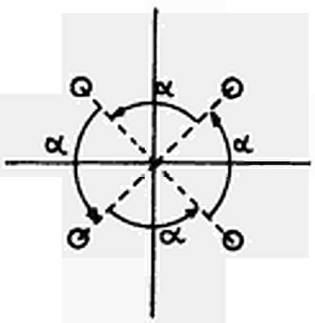


Fig. 1

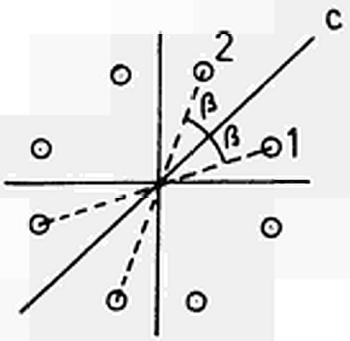


Fig. 2

(The points in the figures mean channels). One has to introduce in this case only the necessary data for one of the channels. After a specified angle α the configuration of the reactor is repeated. In the case of Fig. 1 we would treat really a quarter of the reactor. In the case of Fig. 2, one could again apply NE = 4 and NSYE = 0. Using the fact that the line C is a symmetry line, one could also calculate this configuration by NE = 4 and NSYE = 1. Note that also here all data for the two channels in a quarter of the reactor must be introduced and that the code reduces automatically the assembly to be calculated. The advantage of this possibility is

- a smaller calculation time for the same number of (NR + NE).
- that a greater assembly is calculable (see limitation of (NR + NE).

Note that, using NSYR and/or NSYE $\neq$ 0, one has to introduce the AAI, BI, a.s.o., first, for the control rod channels of the first bisector, secondly, for the fuel element channels of the first bisector (in both sequences the channels on the symmetry line are included), thirdly, for the control rod channels in the second bisector and at the end for the fuel element channels in the second bisector.

NTE — Number of axial pieces of the fuel element channels included the reflector. Consequently the fuel element consists of (NTE - 2) axial pieces, while the other are the bottom and the top reflectors.
Limitation : $3 \leq NTE \leq 20$

This subdivision is valid for all fuel channels.
It may be noted that, apart from the reflector, if there are two neighboring axial pieces with strongly different

nuclear properties, one has to foreseen an artificial axial piece of small thickness between these ones, in order to avoid errors which would arise by the fact, that the heterogeneous constants for any point are calculated by interpolation of the values of the two neighbouring axial pieces.

IMAT — Symbolic tape unit on which the matrix is written. Put 11.

NANA
NANA 1
NANA 2
NANA 3

Technical information referring to the code PREVOL.

= 0, if this information shall not be printed

= 1, if this information shall be printed.

ITRI — = 0, if the sequence of channels given in the input is definitive.

= 1 means, that the given sequence of fuel element channels is tested by the code and rearranged in a sequence of ascending radii and angles with the x-axis.
If NSYR + NSYE $\neq$ 0, one has to use ITRI = 0.

AAI — Locating the origin of coordinates in the center of the radial section of the reactor, AAI means the x-coordinate of the I^{th} channel in the reactor, measured in cms.
AAI may be also a value with negative sign.

$$1 \leqslant I \leqslant NR + NE$$

BI — The y-coordinate of the I^{th} channel in cms. Values with negative signs are allowed.

AI — The radius of the I^{th} channel (cm). Its definition must correspond with that one of the heterogeneous constants. Often it is defined so, that outside of this radius there is only moderator.

TI — Fermi-age of thermal neutrons (cm^2) for the I^{th} channel. TI defines the energy range of fast neutrons which is treated by Fermi-age theory.
TI = 0 means, that the calculations are carried out with one fast and one thermal energy group and application of diffusion theory for the fast group. For more details see the definition of TAU2 given above. Note, that TAU2 + TI = Fermi-age of thermal neutrons.
Put 0, if this channel is a control rod channel, or more general, a channel which does not represent a source of neutrons but only a sink (ALFA $\neq$ 0, MU = 0). For the definition of ALFA, MU see below.

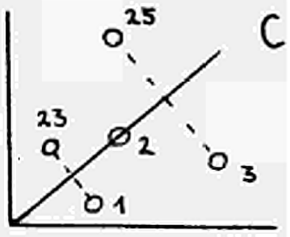
NI — Quantity of channels which may be gathered to the group whose member the I^{th} channel is (see definition of group, given under item NE).
NI may be different for each group !

If (NSYR + NSYE) = 0, the sequence of AAI, BI, AI, TI, NI, must be given in the order, that first all control rod channels appear.
If (NSYR + NSYE) = 0, give this sequence as prescribed under item NSYE.
Prepare a quantity of (NR + NE) cards of this kind.
Together with the applied symmetry conditions all channels of the reactor must be covered.

NGS — This cards appear only, if (NSYR + NSYE) $\neq$ 0. Give (NR + NSYR) + (NE - NSYE) values.

In the case of (NSYR + NSYE) $\neq$ 0, there is a symmetry line in the sector of the reactor. This sector is characterized by the channels $1 \leq i \leq$ (NR + NE). The symmetry line is the angle bisector. Specify the numbers i of the channels which are reflected with respect to the

angle bisector in the order of increasing i, situated in the first bisector. If a channel is located on the symmetry line, one has to introduce a nought. The subsequent figure gives an example. The symmetry line may be the angle bisector of a quarter of the reactor. The specified numbers are the numbers i of the channels.



Consequently, the values NGS to be introduced would be : 23; 0; 25.

HIR — Appears only if NR ≠ 0. Introduce (NR - NSYR) values. The first value characterizes the first control rod channel, a.s.o. HIR means the length (cm) of the central piece of the control rod channel, considering the control rod channel in axial direction as a channel which consists of a bottom reflector piece, a central piece and a top reflector piece.

ARIR — Appears only if NR ≠ 0. Introduce (NR - NSYR) values. The sequence of the input data is as for HIR. ARIR means the ALFA of the control rod channel for the bottom reflector piece as well as for the top reflector piece. For the definition of ALFA see below.

ARSR — Appears only if NR ≠ 0. Introduce (NR - NSYR) values. ARSR means the ALFA for the central piece of the control rod channel.

XE — The distances of the end points (cm) of the NTE axial pieces of a fuel element channel, counted from the bottom end of the reactor. Thus, the first value represents the distance between the bottom end of the reactor and the beginning of the fuel element, while the last value represents H and the last but one value is the distance between the top end of the fuel element and the bottom end of the reactor.
Introduce NTE values.

ARIE — ALFA's for the axial bottom pieces of the fuel element channels. If NE values are introduced, than each channel is evaluated by means of its own ALFA. The sequence of these values must correspond to that one of AAI, BI a.s.o. for fuel element channels. It exists the possibility, to introduce only one value being valid for all bottom pieces of the fuel element channels.

ARSE — ALFA's for the axial top pieces of the fuel element channels. The prescription given for ARIE are also valid for ARSE.

STATUS

AIM22 — Put 1, if the status part shall be executed.
Put 2, if this execution is not desired.

TAB — Put 1, if the heterogeneous constants characterizing the fuel element channels as function of the burn-up have been calculated by ORACLE1.

Put 2, if the heterogeneous constants are given as tables on punched cards and entered on symbolic tape unit UNIT1.
Put 3, if the heterogeneous constants are given point-wise for the whole reactor in form of punched cards (for the reactor state in investigation). In this case only one calculation for the existing state of the reactor is possible.

UNIT1 Leave blank, if TAB = 1 or 3.
Put symbolic tape unit on which the tables are charged, if TAB = 2.
Put 5, if tables are entered by cards.

NR Quantity of introduced tables of heterogeneous constants, NR ≤ 10.
By this, up to 10 different kinds of fuel may be incorporated in the reactor.

PRINT1 Put 1, if the subsequent data shall be printed in the output.
Put 0, if no print is desired.
The tables of heterogeneous constants may be printed.

RUN XEQ - index.
Put 1, if the initial run of the STATUS calculation will be carried out.
Put 2, if the STATUS calculation is a continuation of a previous one.

UNIT2 Symbolic tape unit which contains the reactor core specification.
Put 12.

PRINT2 Print index as under PRINT1.
The reactor core specification may be printed in the output before each burn-up step and before and after each reloading event. The core specification consists of a table which gives for each point in the core (at each point (XE - 1) of each fuel channel group)

- the table number K1 of fuel located there;
- the charge number K2 describing occasional which charging event the fuel has been inserted in the reactor ;
- the incore-time (days), CT, of this fuel under irradiation ;
- the burn-up ($\frac{MWd}{to}$), BU, of the fuel at this point ;
- the burn-up ($\frac{MWd}{to}$), BUM of the (NTE - 2) axial pieces of each fuel channel group.

PRINT3 Print index as under PRINT1.
At the same points of time and space as under PRINT2 the mean thermal neutron flux ($n/cm^2 sec$) may be printed in the output.

PRINT4 Print index as under PRINT1.
At the same points of time and space as under PRINT2, the specific power (MW_{th}/cm) may be printed in the output.

PRINT5 Print index as under PRINT1.
At the same points of time as under PRINT2 the mean specific power (MW_{th} /cm) for the (NTE - 2) axial pieces of each fuel channel group may be printed in the output.

PRINT6 Print index as under PRINT1.
At the same points of time as under PRINT2 the interpolated heterogeneous constants used for the evaluation of the reactor may be printed in the output.

CYCLE Put 1, if the reactivity and the power distribution of only one reactor state shall be evaluated.
Put 2, if the history of a reactor under irradiation shall be investigated without to execute any fuel movement.
Put 3, if radial fuel movement shall happen, prescribed in the input-vector LØAD (see below).

PUNCH Put 1, if the execution of the CØST part is foreseen. In this case the necessary output data of STATUS are written on a tape.
Put 0, if no execution of CØST is foreseen.

PERFØ Put 1, if the specific power distribution as described under NAN3 shall be punched (by means of standard unit 7) before and after each fuel movement.

NUM Appears only if CYCLE > 1.
Kind of management decision which shall initiate the reloading process. All the tests specified by the input are executed in the given sequence. The reloading process is released by the <u>first</u> positive test in the given sequence.

<u>Put 1</u>, if the life time LIFE of the reactor serves for the descision process. The following decision will be made :

LIFE $\geq$ TEST2 (days) $\longrightarrow$ calculation is stopped ;
at the time TEST2 the core is discharged.

LIFE = n. TEST1 (days) $\longrightarrow$ reloading is executed
as prescribed by LØAD (see below).

LIFE $\neq$ n . TEST1 (days) $\longrightarrow$ no reloading is executed,
the calculation run is continued.

n means any integer 1, 2 .....

Put 2, if the effective multiplication factor keff of the reactor serves for the decision process. The following decisions will be made :

keff $\geq$ TEST1 (desired keff) $\longrightarrow$ no reloading, the calculation run is continued.

TEST1 > keff $\geq$ TEST2 (desired keff) $\longrightarrow$ reloading is executed as prescribed by LØAD.

TEST2 > keff $\longrightarrow$ the code itself searches for the life of the reactor, at which the desired keff is reached and carries out the fuel movement prescribed by LØAD at this point of time.

Put 3, if the power form factor $\left(\frac{MW}{cm}\right)$ mean / $\left(\frac{MW}{cm}\right)$ max , FFPW, serves for the decision process. The following decisions will be made :

FFPW $\geq$ TEST1 $\longrightarrow$ no reloading, the calculations run is continued.

TEST1 > FFPW $\geq$ TEST2 $\longrightarrow$ reloading is executed as prescribed by LØAD.

TEST2 > FFPW $\longrightarrow$ the code itself searches for the life of the reactor, at which the desired FFPW is reached and carries out the reloading as prescribed by LØAD.

Put 4, if the calculation run shall be interrupted after having executed a certain number of reloadings REL.
The following decisions will be made :

REL < TEST1 → calculation run is continued

REL = TEST1 → calculation run is stopped. The core is not discharged.

TEST2 is not used.

TEST1 The upper limit for the management decision. Depending on the kind of the applied management decision, this term has different meanings (see under item NUM !).

TEST2 As TEST1, but the lower limit for the decision process.

DT The time intervall (days) of reactor operation without taking into account an alteration of the reactor state by the burn-up process, if no fuel movement happens. Consequently, nuclear composition and power distribution remain constant during DT.
Note, that independent on DT at each reloading process a new core state is defined. Counting from the time point of the reloading process the next definition of the core state occurs after DT days, if in the meantime there did not happen a reloading process.

LØAD Vector to govern the radial fuel movement.
All groups of channels have a number I, $1 \leq I \leq 60$. The position of these groups in the reactor is known (see AAI, BI). Let us take a sequence of groups of channel numbers L1, L2, L3, L4, L5...., a sequence of table names (kind of fuels !) K1, K2, K3, and an index Z.
By this one can prepare a vector.
L1, L2, L3, K_1, Z, L4, L5, K_2, Z, a.s.o.

Let us moreover name L1, L2, L3, K_1, Z the first sub-vector a.s.o., defining as a sub-vector a sequence of numbers of groups of channels terminated by a table name and by Z.
Thus, the information of the above cited vector means : If fuel movement has to be carried out, the fuel of the groups of channels named by L1 is discharged from the reactor. The fuel of the group L2 is reloaded to the group L1, the fuel of the group L3 is reloaded to L2 and in the group L3 is introduced fresh fuel of the table K_1. The same will happen for the second sub-vector : the fuel of L4 is discharged, the fuel of L5 is reloaded to L4 and in L5 is charged fresh fuel of the kind defined in table K2.

The axial positions of the fuel after the reloading process remain unchanged.
Pay attention that each group, included in the same sub-vector, must contain the same quantity of channels !

If all the information included in the vector are read and the calculation run is not terminated, the code returns automatically to the beginning of the vector.

If the calculation run is interrupted because, for instance, the required calculation time was to small, the code will storage the correct position of the vector and starts to read the commands of the vector at this position in a continuation run. The index Z, finally, provides the information, how many sub-vectors shall be considered during one reloading event.
Put Z = 71, if reloading specified in the following sub-vector shall happen at the same point of time as the preceding one.
Put Z = 72, if the reloading specified in the following sub-vector shall happen on occasion of the next reloading event.

NRL — Put (NR - NSYR) (see above).

NEL — Put (NE - NSYE) (see above).

NTL — Has the same meaning as NTE (see above).

IBANAL — Symbolic tape unit for scratch tape used by TREVOL. Put a 2.

NCØD — Put 1, if the keff of the existing reactor configuration with the specified positions of the groups of control rods shall be searched; iteration for keff. Put 2, if the control rod position is searched in order to reach the required keff of the reactor RKS1 (see below). Iteration for ZIR (see below).

NRM — Put 0, if NCØD = 1.
Put the quantity of groups of control rod channels which shall participate in the iteration process, if NCØD = 2. This quantity will be consequently used to control the reactor, while the rest, (NRL - NRM) of control rods, remains at its position, given by the input.

NAN1, NAN2 — Put 1, if intermediate results of TREVOL shall be printed. If no print is wished, put 0.

NAN3 — Put 0, if the print of the axial power distribution is not wished.
Put a quantity < 100. Then, the specific power ($\frac{MW}{cm}$) along all fuel element channels is printed in the output at the given quantity of equidistant points in axial direction. The first point lies at the beginning of

the fuel element. If PERFO = 1, the specific power distribution is also punched on cards.

NAN4 — Put 0, if no print is wished.
Put a number ≠ 0, in order to obtain in the output the individual harmonics and the unnormalized thermal neutron fluxes on the edge of each channel at 40 equidistant points in axial direction, distributed about core and reflectors.

C — Convergence coefficient, depending on the reactor geometry. It is calculated by the code automatically if a nought is introduced here.

FKSIØ — Initial value (guess) of the iterated quantity.
If NCØD = 1, put an estimate for the existing keff.
If NCØD = 2, put the estimated ZIR (see below for the definition) for the NRM control rod groups in cms. In order to save calculation time, it is better to overestimate the value of ZIR, than to underestimate it.

RKSI — If NCØD = 1, put FKSIØ.
If NCØD = 2, put the desired keff, for which the control rod positions shall be searched by the iteration process.

DKSI — Put 0, of NCØD = 1.
Put a guess of the total efficiency of the completely inserted NRM control rod groups (in units of keff), if NCØD = 2.

WTR — Total fission power to be generated in the reactor (MW).

ERREUR — Desired precision for the iterated quantity in units of keff. (= in units of 10^5 pcm).

ZIR — Omit this cards, if NRL = 0. Introduce NRL values, if NRL ≠ 0. ZIR gives the distances between the middleof the value HIR and H/2 in cms in the same sequence as HIR, if the control rods are inserted in the reactor. This value may be also of negative sign. In the case of NCØD = 2, the ZIR - values for the NRM control rods are all equal and as specified under FKSIØ, while the ZIR-values of the (NRL - NRM) control rods can be arbitrary.

NGR — The numbers of the NRM groups of control rod channels, specified by the sequence of the corresponding AAI, BI, a.s.o.

K — Table number which represents the name of the table, $1 \leq K \leq 10$.

J — Quantity of burn-up steps in the corresponding table. Limitation : $1 \leq J \leq 50$.

DENS — Mass of fuel (UO_2, for instance) in metric tons per unit of the channel (to/cm).

BU — Burn-up state (MWd/to). Extracted energy from one metric ton of fresh fuel (consequently, e.g., of uranium oxide).

ALFA — Heterogeneous constant characterizing the absorption of neutrons by the considered fuel element channel.

$$\text{ALFA} = \frac{1}{2\pi D} \times \frac{\text{Absorption of thermal neutrons}}{\text{Asymptotic thermal neutron flux on the surface of the channel}}$$

D means the thermal diffusion coefficient of the moderator.

MU — Heterogeneous constant characterizing the production of neutrons in the considered fuel element channel.

$$MU = ALFA \times \frac{\text{Production of neutrons by fission}}{\text{Absorption of thermal neutrons}}$$

GAMA — Heterogeneous constant characterizing the generation of fission energy in the considered fuel element channel.

$$\left(\frac{MW}{cm \times \phi_a} \right).$$

ϕ_a = asymptotic thermal neutron flux $\left(\frac{\text{neutrons}}{cm^2 \ sec} \right)$ on the edge of the channel.

BETA — Mean thermal neutron flux in the fuel divided by the asymptotic thermal neutron flux on the edge of the channel.

M — Current index, $1 \leq M \leq NZ$ (NZ = NEL x (NTL - 1)) for the individual points in the reactor. The order to count the points in the reactor, is the following : Point 1 is situated at the bottom end of fuel channel 1, the point (NTL - 1) is situated at the top end of fuel channel 1, the point NTL is situated at the bottom end of fuel channel 2, a.s.o.

LIFE — Initial value (days) for the reactor life.

FKSIØ — See definition on page 77.

IMØVE — Starting the calculation run with an intermediate reactor state and using the fuel management decision process NUM = 1, it may happen that the code is not able to decide whether or not the necessary reloading process is already executed.
Put 2, if NUM = 1 and the required fuel movement for the time step LIFE has been already executed.
Put 1, if NUM $\neq$ 1 or if NUM = 1 and the required fuel movement for the time step LIFE has not yet been executed.

IP Starting the calculation run with an intermediate reactor state and using PERFØ = 1, the code is not able to decide, whether the specific power distribution must be punched or not.
Put 1, if the specific power distribution of this initial intermediate reactor state shall be punched.
Put 2, if the specific power distribution shall be punched beginning with the first reloading event which occurs in this calculation run.

NM Lower delimiting point for a region in the reactor with the same state $1 \leq NM \leq NEL \times (NTL - 1)$.

NG Upper delimiting point for a region in the reactor with the same reactor state.
The way to count the points in the correct manner is explained under item M.

K1 Table number of heterogeneous constants of fuel located in the reactor region delimited by NM; NG.

K2 Charge number of fuel located in the reactor region delimitated by NM; NG.
This number gives the charging event occasional which the fuel has been inserted in the reactor, starting with a number 1 for the initial core.

CT Incore-time (days) of the fuel located in the reactor region delimited by NM; NG. The incore-time takes into account only the irradiation time.

BU Burn-up (MWd/to) of the fuel at all the points delimited by NM and NG (the burn-up means generated energy per metric ton of fresh fuel; consequently, e.g., of Uranium oxide).

BUM — Burn-up (MWd/to) of the axial fuel pieces situated in the region delimited by NM and NG. For definition, see under BU.

CØST

AIM3 — Put 1, if the execution of the CØST sub-routine shall be made.
Put 2, if this execution is not desired.

Block A

NCALC — Current number of the calculation run, starting with 1. It is possible to evaluate the same fuel cycle data with different economical input data, changing a few input data and repeating the whole block A.
If $TN < 0$, put NCALC everytime equal to 1, when the input data of block B will be changed.

TN — The quantity of used tables which characterizes the possibly different fuel channels in the reactor as function of the burn-up $|TN| \leq 10$.
Put TN with a positive sign, if the tables are calculated by ORACLE 1 in the first run of REFLOS.
Put TN with a negative sign, if the tables are calculated in any other way and given in the subsequent Block B.

ISØ — Maximum identification number of isotope (or mixture of isotopes) of heavy atoms which appears in the tables. ISØ ≤ 6. The identification numbers are related to the isotopes in the following way :

K = 1	U-235	
K = 2	U-234, U-236, U-238	(fertile uranium)
K = 3	PU-239, PU-241	(fissile plutonium)
K = 4	PU-240	(fertile plutonium)
K = 5	Th-232	
K = 6	U-233	

LIM1 Quantity of intervals of the reactor life for which economical data of the fuel cycle shall be accumulated and printed.
$1 \leq LIM1 \leq 10$

LIM2 Quantity of intervals of the reactor life, for which the mass balances of certain heavy atoms are printed.
$1 \leq LIM2 \leq 10$.

ITWE Index indicating whether TWE has to be calculated (see below for the meaning of TWE).
Put 0, if TWE shall be taken as specified in the input.
Put 1, if TWE shall be calculated by the code itself.

ITWA Index indicating whether TWA has to be calculated (see below for the meaning of TWA).
Put 0, if TWA shall be taken as specified in the input.
Put 1, if TWA shall be calculated by the code itself.

NN Quantity of instalments for the fabrication costs of the fuel elements.

IRP Index indicating whether reprocessing of the burnt-up fuel is wished.
Put 0, if the burnt-up fuel shall not be reprocessed.
Put 1, if the burnt-up fuel shall be reprocessed.

NNO As NN, but for the initial core.

LIMIT1 Put LIM1 numbers which specify the individual reloading events delimiting the intervals for which the in these intervals accumulated economical data are calculated.
An interval extends from 1 or the proceeding reloading event plus 1 up to and including the specified reloading event.

LIMIT2 As LIMIT1, but the here defined intervals are valid for the mass balances of certain heavy atoms.

XINU Reprocessing-loss factor (1), giving the fraction of mass of each specified isotope coming out from the reprocessing plant, if the feeding mass amounts to one.

KCR Specific expenditures or credits ($ per kg heavy atoms) for the isotopes or mixtures of isotopes mentioned under ISØ. If for U-235 and U-fertile a zero is inserted, the corresponding values are calculated by means of a formula which follows from the theory of the ideal cascade. It is valid for both, enriched and depleted uranium (Ref. 9).

KRC Reconversion costs ($/kg) for the isotopes or mixtures of isotopes mentioned under ISØ. Hence, this value contains the expenditures to convert the regained heavy atoms in a form usual in trade. Take the sequence given under ISØ.

XIM Fabrication-loss factor (1), giving the mass of heavy atoms which must be feeded to the fabrication plant in order to obtain a mass equal to unity as fabricated fuel element. Take the sequence given under ISØ.

IK Quantity of discharged fuel batches, dependent on the table number, which shall be accumulated before the irradiated fuel is given to the reprocessing plant.
Put 0, if ITWA = 0.
The sequence of input preparation is the one of increasing table numbers.

KRP — Expenditures for reprocessing, dependent on table number ($/kg).

KTR — Expenditures for transport and insurance of the irradiated fuel, dependent on table number ($/kg).

TRP — Time needed for the reprocessing (months); dependent on the table number.

TWA — Average time (months) during which the discharged fuel will be accumulated, before it is transferred to the reprocessing plant, in order to get sufficiently great batch sizes for feeding the reprocessing plant, dependent on the table number.
Put 0, if ITWA = 1.

FHA — Weight-fraction of heavy atoms (metal) in the fuel compound.

IM — Quantity of fuel batches which shall be accumulated for a greater batch size for the fabrication process, depending on the table number.
Put 0, if ITWE = 0.

KF — Fabrication costs ($/kg) for the fuel elements, containing 1 kilogram of heavy atoms. Dependent on table number.

TF — Fabrication time (months), dependent on the fuel type.

TWE — Average time (months) for the storage of fresh fuel in order to obtain sufficiently great batch sizes for the fabrication process. Dependent on table number.
Put 0, if ITWE = 0.

TFO — As TF, but for the initial core of the reactor. Dependent on the table number.

TK — Cooling time of the discharged irradiated fuel (months).

TTA — Time needed for the transport of the irradiated fuel to the reprocessing plant (months).

TT — Time needed in order to transfer the fresh fuel to the fabrication plant (months).

TTO — As TT, but referring to the initial core.

TWEO — As TWE, but referring to the initial core.

ST — Tax rate for the invested capital (per cent/year).

PM — Monthly interest rate (per cent/month) (= present worth rate).

RHØ — Contribution to the fuel cycle cost by excess fuel elements on reserve. It is assumed that the expenditures of the initial core are multiplied by the factor (1 + RHØ). Put 0, if no excess fuel elements on reserve shall be taken into account.

KL — Expenditures for storaging of the irradiated fuel ($/kg), if no reprocessing is wished.
Put 0, if IRP = 1.

VIE — Total life of the reactor in operation (years).

WØRK — Produced electrical energy per month (kWhe/month).
= Nominal power x η_1 x η_2 x k x 729.6
= Fission power x η_1 x η_2 x 729.6.

η_1 means the fraction of the energy released by fissions, which is transferred to the coolant.

η_2 means the plant efficiency, giving the fraction of thermal energy in the coolant which is converted in electrical energy.

k means the load factor of the plant.

KYC — Cost of yellow cake (U_3O_8) ($/lb).
Actual USAEC-value : 8 $/lb.

KC — Conversion cost for the process $U_3O_8 \longrightarrow UF_6$ ($/kg).
Actual value : 2.66 $/kg.

R — Tail assay (weight-procent). Actual value 0.2%.

CS — Cost of the separation work unit ($/kg).
Actual value : 26 $/kg.

KR — Minimum value of depleted uranium.
Actual value : 3 $/kg.

The actual values are taken from (Ref. 9).

Block B

This block appears only, if TN < 0 and NCALC = 1.

K — Number of the table, $1 \leq K \leq 10$.

J — Number of burn-up steps included in this table.

BU — Burn-up in MWd/to (burn-up means generated energy per metric ton of fresh fuel, consequently, e.g., of uranium oxide).

MPL — Mass of fuel per length unit of the fuel element channel (to/cm).

WPC U 235
WPC U
WPC PUFI
WPC PUFE
WPC TH
WPC U 233

Weight fractions of U-235, fertile Uranium, fissile plutonium, fertile plutonium, thorium and U-233 in the mass of heavy atoms (for each burn-up step normalized to one).

5.5. Output description

All executed program parts print out the corresponding input data, using the same symbols as described in the input description.

ORACLE 1

Amongst a lot of other cell data, ORACLE 1 provides the heterogeneous constants as function of the burn-up

ALFA, MU, GAMA, BETA,
the mass and the composition of the fuel as functinn of the burn-up,
MPL, WPC for the individual isotopes or mixtures of isotopes and τ_{th}, FLDEUX.

These data are also automatically written on magnetic tape and may be optionally punched on cards.

PREVOL

The calculated matrix, representing the coupling between the sources, sinks and peripheral thermal fluxes, defined in the theory of Feinberg and Galanin without to employ the fuel properties, is not printed but automatically storaged on a tape and will be kept unchanged during the whole reactor life. In order to facilitate the control of the specified co-ordinates of the channels, the reactor configuration is plotted by CALCOMP.

STATUS

After each DT and before and after each reloading process for each fuel channel group CH and for each point (NTE-1) in this channel are printed :

- the core state, defined by K_1, K_2, CT, BU, BUM (optionally for the DT steps!),
- the specific powers (MW/cm) and powers per channel (MW) (optionally),
- the mean specific powers for each axial fuel piece (NTE-2 values per channel!) (MW/cm) (optionally),
- the reactor life under irradiation LIFE (days)
- the iterated value IT VALUE
- the form factor for the specific power FFPW (corresponds to mean MW/cm divided my maximum MW/cm),

- the fission power of the reactor /MW/ — POWER
- the k_{eff}-value of the reactor — K EFF
- the maximum specific power in the reactor /$\frac{MW}{cm}$/ — PSLMAX
- the channel number and the point in this channel counted from the bottom end of the core, where the maximum of the specific power is situated — CH and PT
- the kind of used fuel movement — CYCLE

If wished, the specific power distribution in axial direction is printed and punched on cards for all channels.

CØST

For each loading event and each table are given :

- the reactor life LIFE /days/, when the loading event happened
- the mass of the total discharged fuel /to/ — DF
- the mass of the discharged heavy atoms (metal) /to/ — DM HA
- the mean burn-up of the discharged fuel /$\frac{MWd}{to}$/ — MEAN-BU
- the in-core time of the discharged fuel /days/ — ICT DF
- TWA /months/ (see input)
- the value of the heavy isotopes which are contained in the discharged fuel /$/kg/ — BCA*
- the credits for the fuel after reprocessing and reconversion to a form usual in trade, discounted to the time point of discharging of the fuel /$/kg/ — BCA

  A negative value means, that this value must be spent, in order to regain the irradiated fuel.
- the credits for the discharged fuel, discounted to the time point of discharging the fuel /$/ — BKA

  Again, a negative value means that the reprocessing is connected with net expenditures.

- the discharged masses of

Uranium-335	DM U FI
fertile Uranium	DM U FE
Fissile Plutonium	DM PU FI
fertile Plutonium	DM PU FE
Thorium	DM TH 03
Uranium-233	DM U 23

- the mass of the charged heavy atoms (metal) — CM HA
- the fabrication costs /$/kg/ — KF
- the in-core time of charged fuel /months/ — ICT CF
- TWE /months/ (see input)
- the value of the heavy isotopes which are contained in the charged fuel /$/kg/ — BCE*
- the expenditures for the charged fuel, including fabrication costs, discounted to the time point of charging of the fuel /$/kg/ — BCE

For the initial core the so defined value is automatically increased for the value of the fuel elements on reserve.

- the expenditures for the charged fuel, discounted to the time point of charging the fuel /$/. For the initial core (step nr. 1) the so defined value is automatically increased for the yield of RHØ. — BKE
- the charged masses of

Uranium-235	CM U FI
fertile Uranium	CM U FE
Fissile Plutonium	CM PU FI
Fertile Plutonium	CM PU FE
Thorium	CM TH 03
Uranium-233	CM U 23

- For each time interval, defined by LIMIT 2, the total discharged and charged masses for all isotopes, mentioned above, are printed. — DISCHARGED MATERIALS / CHARGED MATERIALS

- For each time interval, defined by LIMIT 1, the effective expenditures /-$_7 for the fuel cycle, discounted to the time point of beginning of power production (corresponds to LIFE = 0) are given under — BK

- In the subsequent line these effective expenditures /-$_7 are summed up to LIMIT 1 for the whole preceding reactor life, excepted the expenditures concerning the initial core.

Finally, the following cost data for the fuel cycle are summarized :

- the expenditures for the initial core /-$_7 including the fuel elements on reserve, and discounted to LIFE = 0 . — BKO

- The effective expenditures during the transition period of the reactor /-$_7, discounted to LIFE = 0, apart from the initial core. — BK TRANS

  Included in the transition period are all loading events which occur up to the reactor life, and including this time, defined by the number (LIM1-1) of LIMIT 1.

- The effective expenditures during the sum of the individual equilibrium periods of the reactor /-$_7, discounted to LIFE = 0. — BKG

  The equilibrium period is represented by the reactor life limited by the loading events (LIM1-1) and LIM1 of LIMIT 1, at which the loading

event (LIM1-1) is not added to the equilibrium period wheras LIM1 is added to it. The addition happens for all n integer equilibrium periods, of which the reactor life (VIE - transition period) consists.

- The effective expenditures during the running-out period of the reactor [$], discounted to LIFE = 0. Here, the reloading events of the part of the reactor life (VIE - transition period - n x equilibrium period) and the discharging of the last core are taken into account. BKR

- The total net expenditures for the fuel cycle during the whole reactor life, included the expenditures for the initial core, discounted to LIFE = 0, [$]. BCF

- The present-worth value (discounted to LIFE = 0) for the "variable cost" part of the extrapolated fuel cycle, [$]. This cost part is proportional to the produced energy. BCF2

- The present worth value of the "fixed cost" part of the complete fuel cycle period [$]. This cost part does not directly depend on the amount of produced energy. BCF1

- The present-worth value (discounted monthly to LIFE = 0) of the total electrical energy produced [kWhe] . BE

- The "fixed cost" part of the specific fuel cycle cost $\left[\frac{\text{mill}}{\text{kWhe}}\right]$. BCF1*

- The "variable cost" part of the specific fuel cycle cost $\left[\frac{\text{mill}}{\text{kWhe}}\right]$. BCF2*

- The total specific fuel cycle cost $\left[\frac{\text{mill}}{\text{kWhe}}\right]$. BCF*

- The pesent-worth value of the electrical energy produced in the transition period [kWhe] . BEA
- The present-worth value of the electrical energy produced during the first equilibrium period [kWhe]. BEG
- The specific fuel cost for the transition period [$\frac{\text{mill}}{\text{kWhe}}$], included the cost for the initial core BCFE
- The specific fuel cycle cost for the transition period [$\frac{\text{mill}}{\text{kWhe}}$], excepted the costs for the initial core. BCFE*
- The specific fuel cycle cost for the first equilibrium period [$\frac{\text{mill}}{\text{kWhe}}$]. BCFG

5.6. Coding Information

Deck-composition

FORTRAN-deck numbered REF 0001 to REF 7032

Tape formats

The program uses 2 library tapes, 2 scratch tapes and 1 calcomp tape, which contain the following information :

Number of data sets	DESCRIPTION
4	data set 1: Library ORACLE (E O F) — symb. UNIT 9 data set 2: Tables from ORACLE (E O F) — 10 data set 3: MATRIX - tape (E O F) — symb. UNIT 11 data set 4: CØST tape (E O F) — 13
1	ACTUAL CØRE COMPOSITION (E O F) — symb. UNIT 12
1	scratch tape placed on disc: PARTS OF MATRIX-TAPE (E O F) — symb. UNIT 2
1	scratch tape placed on disc: INTERMEDIATE RESULTS FOR CØST CALC. (E O F) — symb. UNIT 4
1	PREVOL output for CALCOMP: design of channel distr. (E O F) — symb. UNIT CAL

Timing

PART 1 ORACLE 1

about 2 min. for 1 case (about 15 burn-up steps)

PART 21 PREVOL

about 3 min. (60 channels)

PART 22 STATUS

about 0,45 min. per cycle (60 fuel channels)

interpolation : $\frac{\text{time}}{\text{cycle}} = 0{,}45 \left(\frac{\text{fuel channels}}{60} \right)^2$

PART 3 CØST

about 3 min. for total cost evaluation.

Printed lines

PART 1 ORACLE 1

about 50001ines/case (about 15 burn-up steps)

reduced out-put : (50 + 6 x burn-up steps) lines/case.

PART 21 PREVOL

about 150 lines

PART 22 STATUS

depends on desired output quantity

$$1000 \frac{\text{lines}}{\text{case}} +$$

$$+ 300 \text{ (PRINT2 + PRINT3 + PRINT4 + PRINT5)} \frac{\text{lines}}{\text{cycle}} \text{ x n° cycles}$$

PART 3 CØST

about 1000 lines.

6. SAMPLE FOR INPUT AND OUTPUT

6.1. Problem description

In order to give an example, an arbitrary reactor concept has been chosen. It may be emphasized that the numbers given in this example do not correspond to any special design. Similarly, the cost data shall give only a formal impression, they must not mean realistic numbers.

Coolant	:Organic liquid
Fuel	:Natural and slightly enriched uranium carbide
Fuel element	:19-rod-bundle
Reflector	:Heavy water
Number of fuel channels	168
Number of control rods	8
Electrical power	250 MW
Fission power	707 MW

The design of the core allows to utilize during the reactor calculation a rotation symmetry 4. Thus, only a quarter of the core must be treated. Moreover, there is a specular symmetry, too, in the $\frac{\pi}{4}$-sector of the core, so that the number of channels in the reactor, which must be explicitly considered, amounts to 24 fuel channels and one control rod channel. Since also the axial symmetry condition is fulfilled, the needed calculation time will be reduced by applying this symmetry condition in the present computation.

Concerning the fuel management, it is to say that the initial core consists of a central zone loaded with natural uranium (56 fuel channels) and an outer zone loaded with enriched uranium (112 fuel channels).

The management is executed if k_{eff} falls below the specified limit. Then, the central zone is always discharged, the fuel elements of the outer zones are transferred to the middle of the core and new enriched fuel is introduced to the empty channels (radial out-in fuel movement with three zones).

The flux-distribution calculations are carried out by applying one fast and one thermal energy group. The control rods are not used to compensate the exess reactivity of the reactor.

It may be mentioned that the input sample was prepared, following the sequence given in section 5.3.

6.2. Print of input and output data

```
col:  1          12,13          24,25          36,37          48,49          60,61          72
  15
   1
 SAMPLE PROBLEM REFLOS FUEL NR.1 (G19 UC-SAP, Y=1.00 PC REL)
 ************************************************************
    1  6       3          540            0          540            1          540
    7 12       0          500            0          450            0          400
   13 18       0          370          350          933          591            0
   19 24     338           -1            0            0           07           27
   25 29      15            0          998            0            0
   30 31            7336          8678
   36 37           52516         53716
   40 41               3         18496
   60 61      13321     250
   64 66     540        0          540
   70 71               2          243
 130134                3            1                                      415
 206206                1
 216216                1
 228228                1
   34 35           46317         48537
   54 56           00714             0          99286
*  96 96               1
 SAMPLE PROBLEM REFLOS FUEL NR.2 (G19 UC-SAP, Y=1.15 PC REL)
 ************************************************************
   54 56           00821             0          99179
*  96 96               2
END
   1
 SAMPLE PROBLEM REFLOS FUEL 1/2  2 GROUPS
 132214   +05  111939   +03  430      +03  221      +03
   2 42 12 13    0  0  1 18  12 11   0  0   0  0   0
 15795    +03  6075     +02  53716    +01                    4
 1215     +02  1215     +02  53716    +01                    4
 3645     +02  3645     +02  53716    +01                    4
 3645     +02  1215     +02  53716    +01                    4
 6075     +02  1215     +02  53716    +01                    4
 6075     +02  3645     +02  53716    +01                    4
 8505     +02  1215     +02  53716    +01                    4
 85050    +02  3640     +02  53716    +01                    4
 10935    +03  1215     +02  53716    +01                    4
 6075     +02  6075     +02  53716    +01                    4
 85050    +02  8505     +02  53716    +01                    4
 85050    +02  6075     +02  53716    +01                    4
 10935    +03  3640     +02  53716    +01                    4
 10935    +03  6075     +02  53716    +01                    4
 13365    +03  1215     +02  53716    +01                    4
 13365    +03  3640     +02  53716    +01                    4
 10935    +03  8505     +02  53716    +01                    4
 10935    +03  10935    +03  53716    +01                    4
 13365    +03  13365    +03  53716    +01                    4
 13365    +03  6075     +02  53716    +01                    4
 15795    +03  1215     +02  53716    +01                    4
 13365    +03  8505     +02  53716    +01                    4
 15795    +03  3640     +02  53716    +01                    4
 13365    +03  10935    +03  53716    +01                    4
 15795    +03  8505     +02  53716    +01                    4
 6075     +02  15795    +03  53716    +01                    4
 12150    +02  3645     +02  53716    +01                    4
 12150    +02  6075     +02  53716    +01                    4
 3645     +02  6075     +02  53716    +01                    4
 12150    +02  8505     +02  53716    +01                    4
 3645     +02  8505     +02  53716    +01                    4
 1215     +02  10935    +03  53716    +01                    4
 6075     +02  8505     +02  53716    +01                    4
col:  1          12,13          24,25          36,37          48,49          60,61          72
```

PREVOL (CONT.)

```
3645      +02 10935     +03 53716     +01                    4
6075      +02 10935     +03 53716     +01                    4
1215      +02 13365     +03 53716     +01                    4
3645      +02 13365     +03 53716     +01                    4
8505      +02 10935     +03 53716     +01                    4
6075      +02 13365     +03 53716     +01                    4
1215      +02 15795     +03 53716     +01                    4
8505      +02 13365     +03 53716     +01                    4
3645      +02 15795     +03 53716     +01                    4
10935     +03 13365     +03 53716     +01                    4
8505      +02 15795     +03 53716     +01                    4
26  0  0 27 28 29 30 31 32  0  0 33 34 35 36 37 38  0  0 39 40 41 42 43
44
360       +03
1         +00
1         +00
35        +02 71        +02 107       +03 143       +03 179       +03 215       +03
251       +03 287       +03 323       +03 359       +03 395       +03 430       +03
1         +00
1         +00
```

STATUS

```
 1
 1  0  2  1  1 12  0  0  0  0  0  3  0  1
    2 100100   +00 1        +00       1 0          +00 360       +02
----- blank
----- blank
25        +01
 1  9 17 62 71  2 10 18 62 71  3 11 19 62 71  4 12 20 62 71
 5 13 21 62 71  6 14 22 62 71  7 15 23 62 71  8 16 24 62 72
-----
-----
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----- blank
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-----
-----
 1 24 12  2 11  1  0  0  0  0  0
           1030      +00 1030      +00                    707       +02 1         -04
0         +00
           1030      &00
     1         2
     1        88       1        1 0          +00 0          +00 0          +00
    89       264       2        1 0          +00 0          +00 0          +00
```

COST

```
 1
 1  2  4  3  3  0  0  3  1  3
 1  4  7
 1  4  7
 99        +00                                    101       +01
 1         +01                    56        +01   101       +01
 98        +00 10000     +05 1500      +04   101       +01
 98        +00 0         +00 1500      +04   101       +01
              1 25        +02 10        +02   1         +01 0         +00 952       +00
              1 25        +02 10        +02   1         +01 0         +00 952       +00
              1 0         +00 5         +01   0         +00 5         +01
              1 0         +00 5         +01   0         +00 5         +01
 3         +01 3         +01 1         +01   1         +01 0         +00
 27        +01 575       +00 5         -01   0         +00
 3         +01 1824      +09
 8         +01 27        +01 2         +00   30        +02 0         +00
/*
```

PART1 - ORAKEL 1 (CELL BURNUP CODE)

*** ORAKEL 1 ***

(CELL BURN-UP CODE, SPECIAL VERSION FOR USE IN REFLOS)

YOUR INPUT CARD ARRANGEMENT WAS AS FOLLOWS

SAMPLE PROBLEM REFLOS FUEL NR.1 (G19 UC-SAP, Y=1.00 PC REL)

****

1	6	0.30000D 01	0.54000D 03	0.0	0.54000D 03	0.10000D 01	0.54000D 03
7	12	0.0	0.50000D 03	0.0	0.45000D 03	0.0	0.40000D 03
13	18	0.0	0.37000D 03	0.35000D 03	0.93300D 03	0.59100D 03	0.0
19	24	0.33800D 03	-0.10000D 01	0.0	0.0	0.70000D-01	0.27000D 01
25	29	0.15000D 02	0.0	0.99800D 00	0.0	0.0	
30	31	0.73360D 00	0.86780D 00				
36	37	0.52516D 01	0.53716D 01				
40	41	0.30000D 01	0.18496D 01				
60	61	0.13321D 02	0.25000D 03				
64	66	0.54000D 03	0.0	0.54000D 03			
70	71	0.20000D 01	0.24300D 02				
130	134	0.30000D 01	0.10000D 00	0.0	0.0	0.41500D 01	
206	206	0.10000D 01					
216	216	0.10000D 01					
228	228	0.10000D 01					
34	35	0.46317D 01	0.48532D 01				
54	56	0.71400D-02	0.0	0.99286D 00			
* 96	96	0.10000D 01					

TABLEA 1

K	J	DENS
1	34	4.279162D-04

BURN-UP	ALFA	MU	GAMA	BETA
0.0	6.429950E-01	6.944656E-01	5.297489D-17	6.256987E-01
1.090257E 02	6.617597E-01	6.943322E-01	5.264800D-17	6.140705E-01
2.194271E 02	6.676831E-01	7.028950E-01	5.300186D-17	6.104023E-01
3.311255E 02	6.731853E-01	7.107421E-01	5.331718D-17	6.069924E-01
4.440161E 02	6.783661E-01	7.173823E-01	5.359349D-17	6.037801E-01
5.579998E 02	6.832503E-01	7.243711E-01	5.383389D-17	6.007496E-01
7.906414E 02	6.921430E-01	7.354756E-01	5.421082D-17	5.952270E-01
1.026277E 03	7.000750E-01	7.445897E-01	5.447969D-17	5.902956E-01
1.264367E 03	7.071596E-01	7.520034E-01	5.465709D-17	5.858866E-01
1.504431E 03	7.134944E-01	7.579562E-01	5.475668D-17	5.819407E-01
1.746046E 03	7.191654E-01	7.626436E-01	5.478992D-17	5.784052E-01
1.988338E 03	7.242439E-01	7.662504E-01	5.476648D-17	5.752336E-01
2.232479E 03	7.288121E-01	7.689074E-01	5.469457D-17	5.723847E-01
2.476676E 03	7.329144E-01	7.707455E-01	5.458139D-17	5.698218E-01
2.721177E 03	7.366083E-01	7.718741E-01	5.443313D-17	5.675126E-01
2.965758E 03	7.399400E-01	7.723891E-01	5.425520D-17	5.654287E-01
3.210227E 03	7.429508E-01	7.723741E-01	5.405231D-17	5.635446E-01
3.454416E 03	7.456759E-01	7.719027E-01	5.382863D-17	5.618377E-01
3.693182E 03	7.481507E-01	7.710397E-01	5.358781D-17	5.602882E-01
3.941401E 03	7.504008E-01	7.698420E-01	5.333301D-17	5.588781E-01
4.183969E 03	7.524527E-01	7.683598E-01	5.306706D-17	5.575917E-01
4.425797E 03	7.543290E-01	7.666376E-01	5.279242D-17	5.564150E-01
4.666312E 03	7.560501E-01	7.647143E-01	5.251128D-17	5.553352E-01
4.906961E 03	7.576339E-01	7.626246E-01	5.222552D-17	5.543413E-01
5.146191E 03	7.590963E-01	7.603990E-01	5.193678D-17	5.534232E-01
5.384465E 03	7.604517E-01	7.580643E-01	5.164659D-17	5.525721E-01
5.621754E 03	7.617127E-01	7.556443E-01	5.135615D-17	5.517799E-01
5.858039E 03	7.628959E-01	7.531598E-01	5.106658D-17	5.510397E-01
6.093312E 03	7.639962E-01	7.506291E-01	5.077884D-17	5.503451E-01
6.327562E 03	7.650377E-01	7.480684E-01	5.049375D-17	5.496905E-01
6.560789E 03	7.660233E-01	7.454918E-01	5.021206D-17	5.490710E-01
6.792996E 03	7.669603E-01	7.429115E-01	4.993435D-17	5.484819E-01
7.024195E 03	7.678548E-01	7.403383E-01	4.966110D-17	5.479193E-01
7.254398E 03	7.687126E-01	7.377815E-01	4.939281D-17	5.473799E-01

TABLE3 1

K J
1 34

BURN-UP	MASS/L	U FISS.	U FERT.	PU FISS.	PU FERT.	TH 232	U 233		
0.0	4.279152D-04	7.050634D-03	9.929494D-01	0.0	0.0	0.0	0.0	0.0	0.0
1.090257E 02	4.278612D-04	6.903388D-03	9.929682D-01	1.272975D-04	1.116057D-06	0.0	0.0	0.0	0.0
2.194271E 02	4.278055D-04	6.759376D-03	9.929875D-01	2.488083D-04	4.351564D-06	0.0	0.0	0.0	0.0
3.311255E 02	4.277492D-04	6.618473D-03	9.930072D-01	3.647762D-04	9.541764D-06	0.0	0.0	0.0	0.0
4.440161E 02	4.276922D-04	6.480610D-03	9.930274D-01	4.755001D-04	1.653396D-05	0.0	0.0	0.0	0.0
5.579998E 02	4.276347D-04	6.345705D-03	9.930478D-01	5.812597D-04	2.518824D-05	0.0	0.0	0.0	0.0
7.906414E 02	4.275181D-04	6.084373D-03	9.930906D-01	7.781212D-04	4.692259D-05	0.0	0.0	0.0	0.0
1.026277E 03	4.273997D-04	5.834098D-03	9.931338D-01	9.582044D-04	7.385553D-05	0.0	0.0	0.0	0.0
1.264367E 03	4.272799D-04	5.594366D-03	9.931773D-01	1.123104D-03	1.052418D-04	0.0	0.0	0.0	0.0
1.504431E 03	4.271588D-04	5.364700D-03	9.932206D-01	1.274227D-03	1.404434D-04	0.0	0.0	0.0	0.0
1.746046E 03	4.270367D-04	5.144645D-03	9.932636D-01	1.412831D-03	1.789037D-04	0.0	0.0	0.0	0.0
1.988338E 03	4.269138D-04	4.933773D-03	9.933060D-01	1.540048D-03	2.201315D-04	0.0	0.0	0.0	0.0
2.232479E 03	4.267903D-04	4.731681D-03	9.933477D-01	1.656898D-03	2.636902D-04	0.0	0.0	0.0	0.0
2.476676E 03	4.266663D-04	4.537981D-03	9.933885D-01	1.764308D-03	3.091913D-04	0.0	0.0	0.0	0.0
2.721177E 03	4.265418D-04	4.352306D-03	9.934283D-01	1.863116D-03	3.562872D-04	0.0	0.0	0.0	0.0
2.965758E 03	4.264172D-04	4.174316D-03	9.934669D-01	1.954083D-03	4.046684D-04	0.0	0.0	0.0	0.0
3.210227E 03	4.262923D-04	4.003674D-03	9.935044D-01	2.037901D-03	4.540582D-04	0.0	0.0	0.0	0.0
3.454416E 03	4.261674D-04	3.840072D-03	9.935405D-01	2.115199D-03	5.042112D-04	0.0	0.0	0.0	0.0
3.698182E 03	4.260425D-04	3.683206D-03	9.935753D-01	2.186546D-03	5.549081D-04	0.0	0.0	0.0	0.0
3.941401E 03	4.259179D-04	3.532793D-03	9.936088D-01	2.252464D-03	6.059555D-04	0.0	0.0	0.0	0.0
4.183969E 03	4.257929D-04	3.388561D-03	9.936408D-01	2.313421D-03	6.571808D-04	0.0	0.0	0.0	0.0
4.425797E 03	4.256683D-04	3.250251D-03	9.936715D-01	2.369849D-03	7.084327D-04	0.0	0.0	0.0	0.0
4.666812E 03	4.255439D-04	3.117614D-03	9.937007D-01	2.422138D-03	7.595774D-04	0.0	0.0	0.0	0.0
4.906961E 03	4.254198D-04	2.990415D-03	9.937284D-01	2.470642D-03	8.104972D-04	0.0	0.0	0.0	0.0
5.146191E 03	4.252959D-04	2.868426D-03	9.937548D-01	2.515684D-03	8.610893D-04	0.0	0.0	0.0	0.0
5.384465E 03	4.251723D-04	2.751431D-03	9.937797D-01	2.557559D-03	9.112645D-04	0.0	0.0	0.0	0.0
5.621754E 03	4.250490D-04	2.639224D-03	9.938033D-01	2.596534D-03	9.609449D-04	0.0	0.0	0.0	0.0
5.858039E 03	4.249260D-04	2.531606D-03	9.938255D-01	2.632853D-03	1.010063D-03	0.0	0.0	0.0	0.0
6.093312E 03	4.248033D-04	2.428389D-03	9.938463D-01	2.666739D-03	1.058562D-03	0.0	0.0	0.0	0.0
6.327562E 03	4.246810D-04	2.329390D-03	9.938658D-01	2.698394D-03	1.106392D-03	0.0	0.0	0.0	0.0
6.560789E 03	4.245590D-04	2.234436D-03	9.938840D-01	2.728002D-03	1.153513D-03	0.0	0.0	0.0	0.0
6.792996E 03	4.244374D-04	2.143362D-03	9.939010D-01	2.755732D-03	1.199890D-03	0.0	0.0	0.0	0.0
7.024195E 03	4.243160D-04	2.056006D-03	9.939168D-01	2.781737D-03	1.245493D-03	0.0	0.0	0.0	0.0
7.254398E 03	4.241950D-04	1.972217D-03	9.939313D-01	2.806158D-03	1.290302D-03	0.0	0.0	0.0	0.0

*** ORAKEL 1 ***

(CELL BURN-UP CODE, SPECIAL VERSION FOR USE IN REFLOS)

YOUR INPUT CARD ARRANGEMENT WAS AS FOLLOWS

SAMPLE PROBLEM REFLOS FUEL NR.2 (G19 UC-SAP, Y=1.15 PC REL)

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    54    56       0.82100D-02       0.0               0.99179D 00
*   96    96       0.20000D 01
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TABLEA 2

K	J	DENS
2	34	4.279162D-04

BURN-UP	ALFA	MU	GAMA	BETA
0.0	6.747302E-01	7.699879E-01	5.373462D-17	6.060688E-01
1.245233E 02	6.938124E-01	7.661849E-01	5.312337D-17	5.941972E-01
2.502466E 02	6.992294E-01	7.732974E-01	5.336255D-17	5.908299E-01
3.770967E 02	7.042328E-01	7.797428E-01	5.356725D-17	5.877178E-01
5.049648E 02	7.089242E-01	7.855184E-01	5.373602D-17	5.847978E-01
6.337493E 02	7.133302E-01	7.906792E-01	5.387187D-17	5.820539E-01
8.951594E 02	7.213048E-01	7.992551E-01	5.404983D-17	5.770833E-01
1.153832E 03	7.283568E-01	8.059760E-01	5.413061D-17	5.726832E-01
1.424223E 03	7.345977E-01	8.111221E-01	5.412997D-17	5.687855E-01
1.690852E 03	7.401232E-01	8.149227E-01	5.406073D-17	5.653318E-01
1.958300E 03	7.450176E-01	8.175685E-01	5.393351D-17	5.622701E-01
2.226198E 03	7.493552E-01	8.192201E-01	5.375728D-17	5.595549E-01
2.494223E 03	7.532012E-01	8.200150E-01	5.353958D-17	5.571457E-01
2.762097E 03	7.566134E-01	8.200719E-01	5.328709D-17	5.550071E-01
3.029573E 03	7.596422E-01	8.194941E-01	5.300540D-17	5.531077E-01
3.296443E 03	7.623326E-01	8.183713E-01	5.769953D-17	5.514196E-01
3.562525E 03	7.647241E-01	8.167825E-01	5.737384D-17	5.499184E-01
3.827666E 03	7.668518E-01	8.147967E-01	5.703205D-17	5.485820E-01
4.091735E 03	7.687467E-01	8.124748E-01	5.667758D-17	5.473914E-01
4.354621E 03	7.704365E-01	8.098703E-01	5.631330D-17	5.463291E-01
4.616242E 03	7.719457E-01	8.070303E-01	5.594178D-17	5.453801E-01
4.876520E 03	7.732961E-01	8.039964E-01	5.556533D-17	5.445305E-01
5.135395E 03	7.745070E-01	8.008053E-01	5.518584D-17	5.437683E-01
5.392824E 03	7.755959E-01	7.974895E-01	5.480507D-17	5.430828E-01
5.648777E 03	7.765779E-01	7.940772E-01	5.442455D-17	5.424643E-01
5.903234E 03	7.774669E-01	7.905938E-01	5.404554D-17	5.419042E-01
6.156176E 03	7.782750E-01	7.870613E-01	5.366922D-17	5.413949E-01
6.407598E 03	7.790131E-01	7.834991E-01	5.329656D-17	5.409296E-01
6.657508E 03	7.796908E-01	7.799242E-01	5.292841D-17	5.405021E-01
6.905910E 03	7.803167E-01	7.763515E-01	5.256553D-17	5.401073E-01
7.152820E 03	7.808985E-01	7.727940E-01	5.220850D-17	5.397403E-01
7.398250E 03	7.814429E-01	7.692630E-01	5.185785D-17	5.393968E-01
7.642230E 03	7.819558E-01	7.657681E-01	5.151399D-17	5.390730E-01
7.884785E 03	7.824428E-01	7.623178E-01	5.117736D-17	5.387657E-01

TABLE3 2

K J
2 34

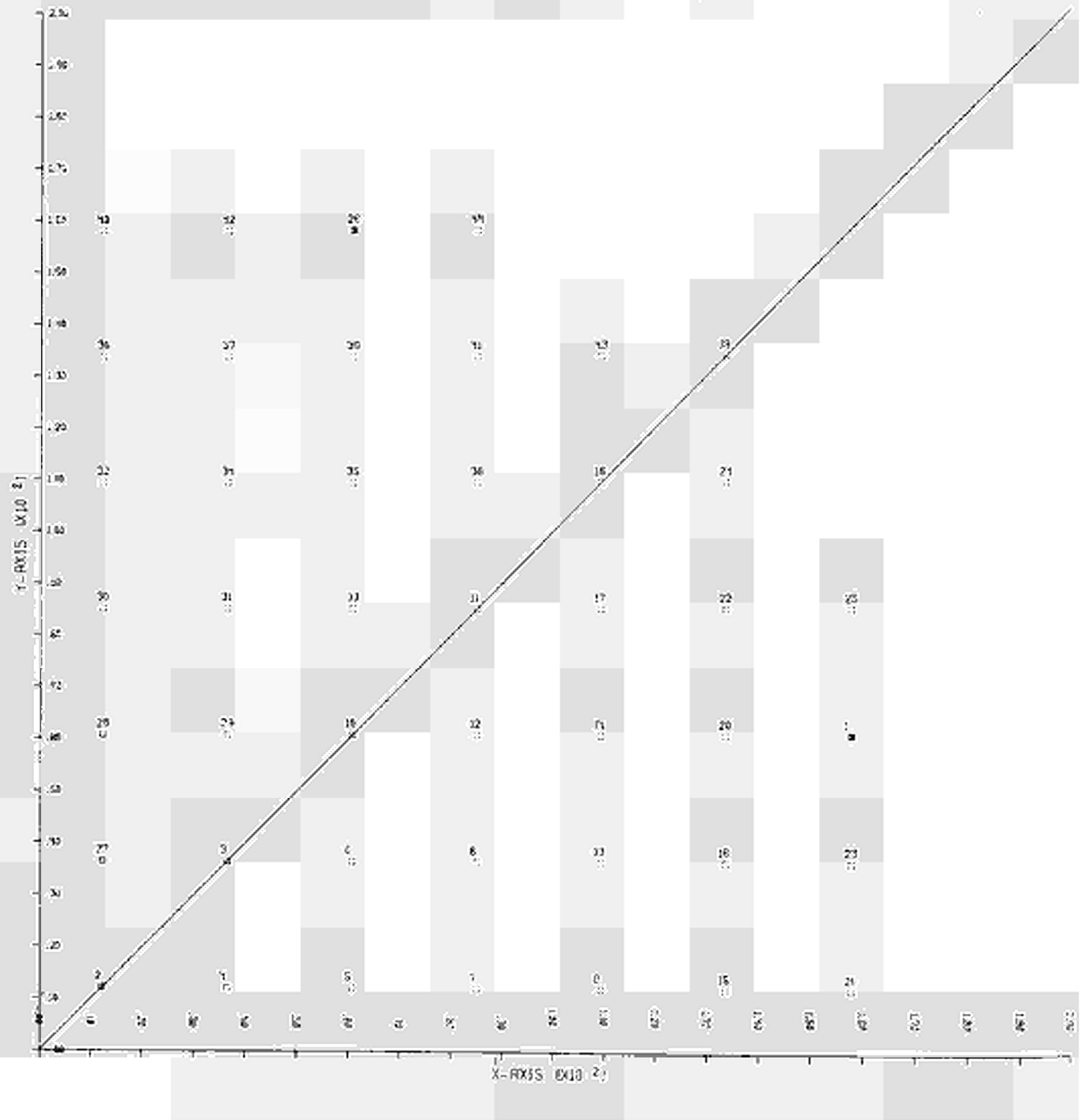
BURN-UP	MASS/L	U FISS.	U FERT.	PU FISS.	PU FERT.	TH 232	U 233		
0.0	4.279162D-04	8.197351D-03	9.918926D-01	0.0	0.0	0.0	0.0	0.0	0.0
1.245233E 02	4.278534D-04	7.938862D-03	9.919284D-01	1.315723D-04	1.169816D-06	0.0	0.0	0.0	0.0
2.502466E 02	4.277900D-04	7.774055D-03	9.919643D-01	2.570575D-04	4.555317D-06	0.0	0.0	0.0	0.0
3.770967E 02	4.277259D-04	7.612735D-03	9.920005D-01	3.767121D-04	9.975864D-06	0.0	0.0	0.0	0.0
5.049648E 02	4.276614D-04	7.454966D-03	9.920369D-01	4.908600D-04	1.726539D-05	0.0	0.0	0.0	0.0
6.337493E 02	4.275964D-04	7.300515D-03	9.920734D-01	5.998024D-04	2.627295D-05	0.0	0.0	0.0	0.0
8.951594E 02	4.274650D-04	7.001254D-03	9.921474D-01	8.024529D-04	4.884362D-05	0.0	0.0	0.0	0.0
1.158832E 03	4.273323D-04	6.714591D-03	9.922211D-01	9.875549D-04	7.674492D-05	0.0	0.0	0.0	0.0
1.424223E 03	4.271984D-04	6.439917D-03	9.922941D-01	1.156799D-03	1.091936D-04	0.0	0.0	0.0	0.0
1.690852E 03	4.270637D-04	6.176998D-03	9.923661D-01	1.311672D-03	1.455233D-04	0.0	0.0	0.0	0.0
1.958300E 03	4.269283D-04	5.924426D-03	9.924369D-01	1.453499D-03	1.851549D-04	0.0	0.0	0.0	0.0
2.226198E 03	4.267925D-04	5.682515D-03	9.925063D-01	1.583470D-03	2.275783D-04	0.0	0.0	0.0	0.0
2.494223E 03	4.266554D-04	5.450804D-03	9.925742D-01	1.702659D-03	2.723434D-04	0.0	0.0	0.0	0.0
2.762097E 03	4.265201D-04	5.228560D-03	9.926404D-01	1.812037D-03	3.190473D-04	0.0	0.0	0.0	0.0
3.029573E 03	4.263837D-04	5.015479D-03	9.927047D-01	1.912483D-03	3.673327D-04	0.0	0.0	0.0	0.0
3.296443E 03	4.262475D-04	4.811145D-03	9.927672D-01	2.004794D-03	4.169809D-04	0.0	0.0	0.0	0.0
3.562525E 03	4.261114D-04	4.615205D-03	9.928277D-01	2.089696D-03	4.674090D-04	0.0	0.0	0.0	0.0
3.827966E 03	4.259756D-04	4.427300D-03	9.928862D-01	2.167843D-03	5.186650D-04	0.0	0.0	0.0	0.0
4.091735E 03	4.258401D-04	4.247083D-03	9.929427D-01	2.239834D-03	5.704261D-04	0.0	0.0	0.0	0.0
4.354621E 03	4.257049D-04	4.074251D-03	9.929970D-01	2.306208D-03	6.224940D-04	0.0	0.0	0.0	0.0
4.616242E 03	4.255702D-04	3.908473D-03	9.930494D-01	2.367466D-03	6.746948D-04	0.0	0.0	0.0	0.0
4.876320E 03	4.254359D-04	3.749470D-03	9.930996D-01	2.424034D-03	7.268745D-04	0.0	0.0	0.0	0.0
5.135395E 03	4.253021D-04	3.596952D-03	9.931478D-01	2.476340D-03	7.788982D-04	0.0	0.0	0.0	0.0
5.392824E 03	4.251689D-04	3.450654D-03	9.931940D-01	2.524745D-03	8.306474D-04	0.0	0.0	0.0	0.0
5.648777E 03	4.250362D-04	3.310319D-03	9.932381D-01	2.569587D-03	8.820193D-04	0.0	0.0	0.0	0.0
5.903234E 03	4.249040D-04	3.175702D-03	9.932802D-01	2.611171D-03	9.329243D-04	0.0	0.0	0.0	0.0
6.156176E 03	4.247724D-04	3.046566D-03	9.933204D-01	2.649775D-03	9.832854D-04	0.0	0.0	0.0	0.0
6.407598E 03	4.246414D-04	2.922683D-03	9.933586D-01	2.685654D-03	1.033036D-03	0.0	0.0	0.0	0.0
6.657508E 03	4.245109D-04	2.803852D-03	9.933950D-01	2.719037D-03	1.082119D-03	0.0	0.0	0.0	0.0
6.905910E 03	4.243811D-04	2.689851D-03	9.934295D-01	2.750135D-03	1.130437D-03	0.0	0.0	0.0	0.0
7.152320E 03	4.242518D-04	2.580488D-03	9.934623D-01	2.779140D-03	1.178100D-03	0.0	0.0	0.0	0.0
7.398250E 03	4.241230D-04	2.475573D-03	9.934933D-01	2.806225D-03	1.224924D-03	0.0	0.0	0.0	0.0
7.642230E 03	4.239949D-04	2.374926D-03	9.935226D-01	2.831551D-03	1.270933D-03	0.0	0.0	0.0	0.0
7.884785E 03	4.238672D-04	2.278372D-03	9.935503D-01	2.855262D-03	1.316106D-03	0.0	0.0	0.0	0.0

PART2- MATRIX CALCULATION
SAMPLE PROBLEM REFLOS FUEL 1/2 2 GROUPS

FLDEUX	TAU2	H	R2	
0.1322140E 05	0.1119390E 03	0.4300000E 03	0.2210000E 03	
NR	NE	KPLEC	IP	KR2
2	42	12	13	0
IZNUL	NSYR	NSYE	NTE	IMAT
0	1	18	12	11
NANA	NANA1	NANA2	NANA3	ITRI
0	0	0	0	0

ARRANGEMENT OF FUEL CHANNELS(○) AND CONTROL RODS(●)

SAMPLE PROBLEM REFLOS FUEL 1/2 2 GROUPS



I	NI	X	Y	RI	PHI	AI	TI
1	4	0.1579500E 03	0.6075000E 02	0.1692299E 03	0.3671739E 00	0.5371599E 01	0.0
2	4	0.1215000E 02	0.1215000E 02	0.1718268E 02	0.7853981E 00	0.5371599E 01	0.0
3	4	0.3645000E 02	0.3645000E 02	0.5154807E 02	0.7853981E 00	0.5371599E 01	0.0
4	4	0.3645000E 02	0.1215000E 02	0.3842166E 02	0.3217505E 00	0.5371599E 01	0.0
5	4	0.6075000E 02	0.1215000E 02	0.6195308E 02	0.1973955E 00	0.5371599E 01	0.0
6	4	0.6075000E 02	0.3645000E 02	0.7084605E 02	0.5404194E 00	0.5371599E 01	0.0
7	4	0.8504999E 02	0.1215000E 02	0.8591345E 02	0.1418970E 00	0.5371599E 01	0.0
8	4	0.8504999E 02	0.3639999E 02	0.9251193E 02	0.4043950E 00	0.5371599E 01	0.0
9	4	0.1093500E 03	0.1215000E 02	0.1100229E 03	0.1106572E 00	0.5371599E 01	0.0
10	4	0.6075000E 02	0.6075000E 02	0.8591347E 02	0.7853981E 00	0.5371599E 01	0.0
11	4	0.8504999E 02	0.8504999E 02	0.1202788E 03	0.7853981E 00	0.5371599E 01	0.0
12	4	0.8504999E 02	0.6075000E 02	0.1045182E 03	0.6202496E 00	0.5371599E 01	0.0
13	4	0.1093500E 03	0.3639999E 02	0.1152492E 03	0.3213389E 00	0.5371599E 01	0.0
14	4	0.1093500E 03	0.6075000E 02	0.1250919E 03	0.5070985E 00	0.5371599E 01	0.0
15	4	0.1336500E 03	0.1215000E 02	0.1342011E 03	0.9065986E-01	0.5371599E 01	0.0
16	4	0.1336500E 03	0.3639999E 02	0.1385181E 03	0.2659037E 00	0.5371599E 01	0.0
17	4	0.1093500E 03	0.8504999E 02	0.1385313E 03	0.6610431E 00	0.5371599E 01	0.0
18	4	0.1093500E 03	0.1093500E 03	0.1546442E 03	0.7853981E 00	0.5371599E 01	0.0
19	4	0.1336500E 03	0.1336500E 03	0.1890096E 03	0.7853981E 00	0.5371599E 01	0.0
20	4	0.1336500E 03	0.6075000E 02	0.1468090E 03	0.4266275E 00	0.5371599E 01	0.0
21	4	0.1579500E 03	0.1215000E 02	0.1584166E 03	0.7677186E-01	0.5371599E 01	0.0
22	4	0.1336500E 03	0.8504999E 02	0.1584166E 03	0.5667292E 00	0.5371599E 01	0.0
23	4	0.1579500E 03	0.3639999E 02	0.1620900E 03	0.2264982E 00	0.5371599E 01	0.0
24	4	0.1336500E 03	0.1093500E 03	0.1726839E 03	0.6857295E 00	0.5371599E 01	0.0
25	4	0.1579500E 03	0.8504999E 02	0.1793926E 03	0.4939412E 00	0.5371599E 01	0.0
26	4	0.6075000E 02	0.1579500E 03	0.1692299E 03	0.1203622E 01	0.5371599E 01	0.0
27	4	0.1215000E 02	0.3645000E 02	0.3842166E 02	0.1249045E 01	0.5371599E 01	0.0
28	4	0.1215000E 02	0.6075000E 02	0.6195308E 02	0.1373400E 01	0.5371599E 01	0.0
29	4	0.3645000E 02	0.6075000E 02	0.7084605E 02	0.1030376E 01	0.5371599E 01	0.0
30	4	0.1215000E 02	0.8504999E 02	0.8591345E 02	0.1428899E 01	0.5371599E 01	0.0
31	4	0.3645000E 02	0.8504999E 02	0.9253162E 02	0.1165904E 01	0.5371599E 01	0.0
32	4	0.1215000E 02	0.1093500E 03	0.1100229E 03	0.1460138E 01	0.5371599E 01	0.0
33	4	0.6075000E 02	0.8504999E 02	0.1045182E 03	0.9505466E 00	0.5371599E 01	0.0
34	4	0.3645000E 02	0.1093500E 03	0.1152650E 03	0.1249045E 01	0.5371599E 01	0.0
35	4	0.6075000E 02	0.1093500E 03	0.1250919E 03	0.1063697E 01	0.5371599E 01	0.0
36	4	0.1215000E 02	0.1336500E 03	0.1342011E 03	0.1480136E 01	0.5371599E 01	0.0
37	4	0.3645000E 02	0.1336500E 03	0.1385313E 03	0.1304543E 01	0.5371599E 01	0.0
38	4	0.8504999E 02	0.1093500E 03	0.1385313E 03	0.9097529E 00	0.5371599E 01	0.0
39	4	0.6075000E 02	0.1336500E 03	0.1468090E 03	0.1144168E 01	0.5371599E 01	0.0
40	4	0.1215000E 02	0.1579500E 03	0.1584166E 03	0.1494023E 01	0.5371599E 01	0.0
41	4	0.8504999E 02	0.1336500E 03	0.1584166E 03	0.1004066E 01	0.5371599E 01	0.0
42	4	0.3645000E 02	0.1579500E 03	0.1621012E 03	0.1343997E 01	0.5371599E 01	0.0
43	4	0.1093500E 03	0.1336500E 03	0.1726839E 03	0.8850663E 00	0.5371599E 01	0.0
44	4	0.8504999E 02	0.1579500E 03	0.1793926E 03	0.1076855E 01	0.5371599E 01	0.0

ABAISSEMENT DU RAIS PAR SYMETRIE/BISSECTRICE
****

GROUPE DE REFERENCE	GROUPE SYMETRIQUE
1	26
4	27
5	28
6	29
7	30
8	31
9	32
12	33
13	34
14	35
15	36
16	37
17	38
20	39
21	40
22	41
23	42
24	43
25	44

CANAUX-BARRES DE CONTROLE (3 TRONCONS)
****

I	HI	ALFA(REFLE),	ALFA(BARRE)
1	0.3600000E 03	0.9999996E-01	0.9999996E-01

CANAUX-ELEMENTS DE COMBUSTIBLE
****

MEME DECOUPAGE EN 12 TRONCONS

0.3500000E 02 0.7100000E 02 0.1070000E 03 0.1430000E 03 0.1790000E 03 0.2150000E 03 0.2510000E 03
0.2870000E 03 0.3230000E 03 0.3590000E 03 0.3950000E 03 0.4300000E 03

I	ALFA/REFLEC.INF	ALFA/REFLEC.SUP
	0.9999996E-01	0.9999996E-01

CHARGEMENT DE LA BANDE PREVOL TERMINE

**PART21 TERMINATED

XEQ TIME= 3.05

```
**PART22 - REACTOR CALCULATION AND FUEL MANAGEMENT
SAMPLE PROBLEM REFLOS FUEL 1/2  2 GROUPS

**INPUT DATA**

          AIM                XEQ TIME              TAB               UNIT1                NR
            1                      15                1                   0                 2

       PRINT1                  RUN                UNIT2             PRINT2             PRINT3
            1                    1                  12                  0                  0

       PRINT4                PRINT5               PRINT6             CYCLE              PUNCH
            0                    0                  0                   3                  1

        PERFO
            0

MANAGEMENT DECISIONS,(TYPE OF TEST, LIMIT1, LIMIT2)
2  0.1000999E 01  0.1000000E 01                                    1  0.0          0.3600000E 03

     DT
0.2500000E 02

CHANNEL CORRESPONDENCES FOR RADIAL MOVEMENTS
  1  9 17 62 71  2 10 18 62 71  3 11 19 62 71  4 12 20 62 71  5 13 21 62 71  6 14 22 62 71
  7 15 23 62 71  8 16 24 62 72

      NRL                NEL                NTL               NSC               IBANAL
        1                 24                 12                 0                   2

     IMAT               NCOD                NRM               NAN1               NAN2
       11                  1                  0                  0                  0

     NAN3               NAN4
        0                  0

      C                 EKSIO              RKSI              DKSI               WTR
0.0                0.1030000E 01      0.1030000E 01      0.0              0.7070000E 03

   ERREUR
0.9999999E-04

ZIR VALUES (POSITION OF CONTROL RODS)
0.0
```

HARMONIQUES 13
****

IT1	IT2	KSI	PC	DEL
1	1	0.1030000E 01	0.1232911E 01	-0.1970005E 00
1	2	0.1036935E 01	0.1117915E 01	-0.7809544E-01
1	3	0.1039702E 01	0.1040392E 01	-0.6628036E-03
1	4	0.1039725E 01	0.1034060E 01	0.5449355E-02
1	5	0.1039531E 01	0.1036199E 01	0.3205478E-02
1	6	0.1039416E 01	0.1037854E 01	0.1502931E-02
1	7	0.1039362E 01	0.1038749E 01	0.5900264E-03
1	8	0.1039340E 01	0.1039140E 01	0.1927018E-03
1	9	0.1039332E 01	0.1039289E 01	0.4225969E-04

XEQ TIME= 0.11

LIFE	IT VALUE	FFPW	POWER	K EFF
0.0	0.1039332E 01	0.5268804E 00	0.7069983E 03	0.1039332E 01

PSLMAX	CH.	PT.	C
0.2218685E-01	9	6	0.0

HARMONIQUES 13
****

IT1	IT2	KSI	PC	DEL
1	1	0.9872183E 00	0.1411900E 01	-0.4301796E 00
1	2	0.1000057E 01	0.1018033E 01	-0.1797390E-01
1	3	0.1000000E 01	0.1000740E 01	-0.1392365E-03
1	4	0.1000303E 01	0.1000196E 01	0.4060268E-03
1	5	0.1000589E 01	0.1000218E 01	0.3708005E-03
1	6	0.1000577E 01	0.1000355E 01	0.2220869E-03
1	7	0.1000569E 01	0.1000447E 01	0.1220107E-03
1	8	0.1000565E 01	0.1000507E 01	0.5722046E-04

XEQ TIME= 0.05

LIFE	IT VALUE	EFFW	POWER	K EFF
0.7649377E 02	0.1000565E 01	0.6052768E 00	0.7060985E 03	0.1000565E 01

PSLMAX	CH.	PT.	C
0.1931318E-01	1	6	0.0

ZONE-SPECIFICATIONS FORMAT*TABLE-INDEX,CHARGE NUMBER,INCORE-TIME,BURNUP,MEAN-BURNUP*

CH 1	1			966.5		CH 2	1			939.1		CH 3	1			950.7		CH 4	1			914.8	
	1	1	76.	1800.0	1352.0		1	1	76.	1751.3	1314.8		1	1	76.	1771.3	1330.2		1	1	76.	1706.0	1280.7
	1	1	76.	2704.9	2280.4		1	1	76.	2633.2	2219.4		1	1	76.	2662.8	2244.5		1	1	76.	2566.6	2162.7
	1	1	76.	3358.7	3041.4		1	1	76.	3271.0	2961.5		1	1	76.	3307.4	2994.6		1	1	76.	3189.9	2887.4
	1	1	76.	3744.9	3580.5		1	1	76.	3648.1	3487.4		1	1	76.	3688.4	3526.1		1	1	76.	3558.9	3401.6
	1	1	76.	3895.2	3839.9		1	1	76.	3794.8	3740.9		1	1	76.	3836.6	3782.1		1	1	76.	3702.5	3649.7
	1	1	76.	3744.9	3839.9		1	1	76.	3648.0	3740.9		1	1	76.	3688.4	3782.1		1	1	76.	3558.9	3649.7
	1	1	76.	3358.7	3580.5		1	1	76.	3271.0	3487.4		1	1	76.	3307.4	3526.1		1	1	76.	3189.9	3401.6
	1	1	76.	2704.9	3041.4		1	1	76.	2633.2	2961.5		1	1	76.	2662.8	2994.6		1	1	76.	2566.6	2887.3
	1	1	76.	1800.0	2280.4		1	1	76.	1751.3	2219.4		1	1	76.	1771.3	2244.5		1	1	76.	1706.0	2162.7
	1	1	76.	966.5	1352.0		1	1	76.	939.1	1314.8		1	1	76.	950.7	1330.2		1	1	76.	914.8	1280.7
CH 5	1			909.3		CH 6	1			852.7		CH 7	1			848.7		CH 8	1			759.7	
	1	1	76.	1698.9	1274.6		1	1	76.	1593.1	1195.1		1	1	76.	1589.9	1191.8		1	1	76.	1424.0	1067.1
	1	1	76.	2555.5	2153.6		1	1	76.	2399.4	2020.8		1	1	76.	2393.8	2016.5		1	1	76.	2147.0	1807.3
	1	1	76.	3175.5	2874.7		1	1	76.	2985.0	2700.7		1	1	76.	2976.9	2693.9		1	1	76.	2674.4	2418.3
	1	1	76.	3542.5	3386.1		1	1	76.	3332.9	3184.5		1	1	76.	3323.2	3175.4		1	1	76.	2988.9	2854.5
	1	1	76.	3685.3	3632.8		1	1	76.	3468.2	3418.5		1	1	76.	3457.8	3408.3		1	1	76.	3111.4	3066.3
	1	1	76.	3542.5	3632.9		1	1	76.	3332.9	3418.5		1	1	76.	3323.2	3408.3		1	1	76.	2988.9	3066.3
	1	1	76.	3175.5	3386.1		1	1	76.	2985.0	3184.5		1	1	76.	2976.9	3175.4		1	1	76.	2674.4	2854.5
	1	1	76.	2555.5	2874.7		1	1	76.	2399.4	2700.7		1	1	76.	2393.8	2693.9		1	1	76.	2147.0	2418.3
	1	1	76.	1698.9	2153.6		1	1	76.	1593.1	2020.8		1	1	76.	1589.9	2016.5		1	1	76.	1424.0	1807.3
	1	1	76.	909.2	1274.6		1	1	76.	852.7	1195.1		1	1	76.	848.7	1191.8		1	1	76.	759.7	1067.1
CH 9	2			970.7		CH10	2			829.3		CH11	2			903.1		CH12	2			820.5	
	2	1	76.	1805.5	1356.6		2	1	76.	1551.5	1163.5		2	1	76.	1684.9	1264.6		2	1	76.	1529.6	1148.2
	2	1	76.	2707.5	2285.5		2	1	76.	2330.9	1966.0		2	1	76.	2529.0	2133.9		2	1	76.	2299.2	1938.6
	2	1	76.	3357.1	3042.0		2	1	76.	2894.8	2621.2		2	1	76.	3138.1	2842.5		2	1	76.	2857.4	2586.4
	2	1	76.	3740.8	3577.8		2	1	76.	3229.5	3087.0		2	1	76.	3499.0	3345.4		2	1	76.	3189.2	3047.9
	2	1	76.	3890.3	3835.5		2	1	76.	3360.2	3312.2		2	1	76.	3639.5	3588.0		2	1	76.	3318.9	3271.3
	2	1	76.	3740.8	3835.5		2	1	76.	3229.5	3312.2		2	1	76.	3499.0	3588.0		2	1	76.	3189.2	3271.3
	2	1	76.	3357.1	3577.8		2	1	76.	2894.8	3087.0		2	1	76.	3138.1	3345.4		2	1	76.	2857.4	3047.9
	2	1	76.	2707.5	3041.9		2	1	76.	2330.9	2621.2		2	1	76.	2529.0	2842.5		2	1	76.	2299.2	2586.4
	2	1	76.	1805.5	2285.5		2	1	76.	1551.5	1966.0		2	1	76.	1684.9	2133.9		2	1	76.	1529.6	1938.6
	2	1	76.	970.7	1356.6		2	1	76.	829.3	1163.5		2	1	76.	903.1	1264.6		2	1	76.	820.5	1148.2
CH13	2			781.3		CH14	2			687.8		CH15	2			661.5		CH16	2			701.2	
	2	1	76.	1460.7	1095.5		2	1	76.	1282.3	962.5		2	1	76.	1234.2	926.2		2	1	76.	1313.1	984.2
	2	1	76.	2195.9	1851.5		2	1	76.	1930.2	1626.4		2	1	76.	1857.7	1565.3		2	1	76.	1976.1	1665.3
	2	1	76.	2729.3	2470.4		2	1	76.	2403.1	2173.3		2	1	76.	2312.8	2091.7		2	1	76.	2458.3	2224.1
	2	1	76.	3046.6	2911.4		2	1	76.	2686.0	2565.2		2	1	76.	2585.2	2468.9		2	1	76.	2746.1	2623.3
	2	1	76.	3170.4	3124.9		2	1	76.	2796.5	2755.9		2	1	76.	2691.6	2652.5		2	1	76.	2858.3	2817.1
	2	1	76.	3046.6	3125.0		2	1	76.	2686.0	2755.9		2	1	76.	2585.2	2652.5		2	1	76.	2746.1	2817.1
	2	1	76.	2729.3	2911.4		2	1	76.	2403.1	2565.2		2	1	76.	2312.8	2469.9		2	1	76.	2458.3	2623.3
	2	1	76.	2195.9	2470.4		2	1	76.	1930.2	2173.3		2	1	76.	1857.7	2091.7		2	1	76.	1976.1	2224.1
	2	1	76.	1460.7	1851.5		2	1	76.	1282.3	1626.4		2	1	76.	1234.2	1565.3		2	1	76.	1313.1	1665.3
	2	1	76.	781.3	1095.5		2	1	76.	687.8	962.5		2	1	76.	661.5	926.2		2	1	76.	701.2	984.2
CH17	2			577.5		CH18	2			284.4		CH19	2			608.8		CH20	2			511.0	
	2	1	76.	1081.5	810.5		2	1	76.	528.9	397.4		2	1	76.	1138.1	853.7		2	1	76.	948.6	713.3
	2	1	76.	1629.9	1372.7		2	1	76.	798.0	671.5		2	1	76.	1713.5	1443.5		2	1	76.	1427.8	1202.7
	2	1	76.	2031.0	1836.2		2	1	76.	997.3	900.3		2	1	76.	2134.3	1929.9		2	1	76.	1780.8	1609.1
	2	1	76.	2271.3	2168.6		2	1	76.	1117.8	1066.1		2	1	76.	2386.3	2278.6		2	1	76.	1993.2	1902.4
	2	1	76.	2365.2	2330.7		2	1	76.	1165.0	1147.7		2	1	76.	2484.8	2448.6		2	1	76.	2076.4	2045.8
	2	1	76.	2271.3	2330.7		2	1	76.	1117.8	1147.7		2	1	76.	2386.3	2448.6		2	1	76.	1993.2	2045.8
	2	1	76.	2031.0	2168.6		2	1	76.	997.3	1066.1		2	1	76.	2134.3	2278.6		2	1	76.	1780.8	1902.4
	2	1	76.	1629.9	1836.2		2	1	76.	798.0	900.3		2	1	76.	1713.5	1929.9		2	1	76.	1427.8	1609.1
	2	1	76.	1081.5	1372.7		2	1	76.	528.9	671.5		2	1	76.	1138.1	1443.5		2	1	76.	948.6	1202.7
	2	1	76.	577.5	810.5		2	1	76.	284.4	397.4		2	1	76.	608.8	853.7		2	1	76.	511.0	713.3

ZONE-SPECIFICATIONS FORMAT*TABLE-INDEX,CHARGE NUMBER,INCORE-TIME,BURNUP,MEAN-BURNUP*

CH21	2			529.1		CH22	2			476.5		CH23	2			423.2		CH24	2			346.2	
	2	1	76.	988.0	741.2		2	1	76.	885.1	665.6		2	1	76.	790.5	593.0		2	1	76.	643.2	483.7
	2	1	76.	1489.0	1253.9		2	1	76.	1332.1	1122.0		2	1	76.	1192.3	1003.6		2	1	76.	968.7	815.6
	2	1	76.	1856.4	1677.8		2	1	76.	1661.8	1501.5		2	1	76.	1488.4	1344.4		2	1	76.	1209.9	1092.6
	2	1	76.	2076.8	1932.6		2	1	76.	1860.6	1775.5		2	1	76.	1666.7	1590.4		2	1	76.	1355.8	1293.2
	2	1	76.	2163.1	2131.4		2	1	76.	1938.3	1909.7		2	1	76.	1736.6	1710.9		2	1	76.	1412.8	1391.9
	2	1	76.	2076.8	2131.4		2	1	76.	1860.6	1909.7		2	1	76.	1666.7	1710.9		2	1	76.	1355.8	1391.9
	2	1	76.	1856.4	1982.6		2	1	76.	1661.8	1775.5		2	1	76.	1488.4	1590.4		2	1	76.	1209.9	1293.2
	2	1	76.	1489.0	1677.8		2	1	76.	1332.1	1501.5		2	1	76.	1192.3	1344.4		2	1	76.	968.7	1092.6
	2	1	76.	988.0	1253.9		2	1	76.	885.1	1122.0		2	1	76.	790.5	1003.6		2	1	76.	643.2	815.6
	2	1	76.	529.1	741.2		2	1	76.	476.5	665.6		2	1	76.	423.2	593.0		2	1	76.	346.2	483.7

CYCLE= 3

RADIAL MOVEMENT WITH FIXED LOADING SCHEME, LOAD 8 CHANNEL(S)

ZONE-SPECIFICATIONS FORMAT*TABLE-INDEX,CHARGE NUMBER,INCORE-TIME,BURNUP,MEAN-BURNUP*

CH 1	2		970.7		CH 2	2		829.3		CH 3	2		903.1		CH 4	2		820.5	
	2 1	76.	1805.5	1356.6		2 1	76.	1551.5	1163.5		2 1	76.	1684.9	1264.6		2 1	76.	1529.6	1148.2
	2 1	76.	2707.5	2285.5		2 1	76.	2330.9	1966.0		2 1	76.	2529.0	2133.9		2 1	76.	2299.2	1938.6
	2 1	76.	3357.1	3042.0		2 1	76.	2894.8	2621.2		2 1	76.	3138.1	2842.5		2 1	76.	2857.4	2586.4
	2 1	76.	3740.8	3577.8		2 1	76.	3229.5	3087.0		2 1	76.	3499.0	3345.4		2 1	76.	3189.2	3047.9
	2 1	76.	3890.3	3835.5		2 1	76.	3360.2	3312.2		2 1	76.	3639.5	3588.0		2 1	76.	3318.9	3271.3
	2 1	76.	3740.8	3835.5		2 1	76.	3229.5	3312.2		2 1	76.	3499.0	3588.0		2 1	76.	3189.2	3271.3
	2 1	76.	3357.1	3577.8		2 1	76.	2894.8	3087.0		2 1	76.	3138.1	3345.4		2 1	76.	2857.4	3047.9
	2 1	76.	2707.5	3041.9		2 1	76.	2330.9	2621.2		2 1	76.	2529.0	2842.5		2 1	76.	2299.2	2586.4
	2 1	76.	1805.5	2285.5		2 1	76.	1551.5	1966.0		2 1	76.	1684.9	2133.9		2 1	76.	1529.6	1938.6
	2 1	76.	970.7	1356.6		2 1	76.	829.3	1163.5		2 1	76.	903.1	1264.6		2 1	76.	820.5	1148.2

CH 5	2		781.3		CH 6	2		687.8		CH 7	2		661.5		CH 8	2		701.2	
	2 1	76.	1460.7	1095.5		2 1	76.	1282.3	962.5		2 1	76.	1234.2	926.2		2 1	76.	1313.1	984.2
	2 1	76.	2195.9	1851.5		2 1	76.	1930.2	1626.4		2 1	76.	1857.7	1565.3		2 1	76.	1976.1	1665.3
	2 1	76.	2729.3	2470.4		2 1	76.	2403.1	2173.3		2 1	76.	2312.8	2091.7		2 1	76.	2458.3	2224.1
	2 1	76.	3046.6	2911.4		2 1	76.	2686.0	2565.2		2 1	76.	2585.2	2468.9		2 1	76.	2746.1	2623.3
	2 1	76.	3170.4	3124.9		2 1	76.	2796.5	2755.9		2 1	76.	2691.6	2652.5		2 1	76.	2858.3	2817.1
	2 1	76.	3046.6	3125.0		2 1	76.	2686.0	2755.9		2 1	76.	2585.2	2652.5		2 1	76.	2746.1	2817.1
	2 1	76.	2729.3	2911.4		2 1	76.	2403.1	2565.2		2 1	76.	2312.8	2468.9		2 1	76.	2458.3	2623.3
	2 1	76.	2195.9	2470.4		2 1	76.	1930.2	2173.3		2 1	76.	1857.7	2091.7		2 1	76.	1976.1	2224.1
	2 1	76.	1460.7	1851.5		2 1	76.	1282.3	1626.4		2 1	76.	1234.2	1565.3		2 1	76.	1313.1	1665.3
	2 1	76.	781.3	1095.5		2 1	76.	687.8	962.5		2 1	76.	661.5	926.2		2 1	76.	701.2	984.2

CH 9	2		577.5		CH10	2		284.4		CH11	2		608.8		CH12	2		511.0	
	2 1	76.	1081.5	810.5		2 1	76.	528.9	397.4		2 1	76.	1138.1	853.7		2 1	76.	948.6	713.3
	2 1	76.	1629.9	1372.7		2 1	76.	798.0	671.5		2 1	76.	1713.5	1443.5		2 1	76.	1427.8	1202.7
	2 1	76.	2031.0	1836.2		2 1	76.	997.3	900.3		2 1	76.	2134.3	1929.9		2 1	76.	1780.8	1609.1
	2 1	76.	2271.3	2168.6		2 1	76.	1117.8	1066.1		2 1	76.	2386.3	2278.6		2 1	76.	1993.2	1902.4
	2 1	76.	2365.2	2330.7		2 1	76.	1165.0	1147.7		2 1	76.	2484.8	2449.6		2 1	76.	2076.4	2045.8
	2 1	76.	2271.3	2330.7		2 1	76.	1117.8	1147.7		2 1	76.	2386.3	2448.6		2 1	76.	1993.2	2045.8
	2 1	76.	2031.0	2168.6		2 1	76.	997.3	1066.1		2 1	76.	2134.3	2278.6		2 1	76.	1780.8	1902.4
	2 1	76.	1629.9	1836.2		2 1	76.	798.0	900.3		2 1	76.	1713.5	1929.9		2 1	76.	1427.8	1609.1
	2 1	76.	1081.5	1372.7		2 1	76.	528.9	671.5		2 1	76.	1138.1	1443.5		2 1	76.	948.6	1202.7
	2 1	76.	577.5	810.5		2 1	76.	284.4	397.4		2 1	76.	608.9	853.7		2 1	76.	511.0	713.3

CH13	2		529.1		CH14	2		476.5		CH15	2		423.2		CH16	2		346.2	
	2 1	76.	988.0	741.2		2 1	76.	885.1	665.6		2 1	76.	790.5	593.0		2 1	76.	643.2	483.7
	2 1	76.	1489.0	1253.9		2 1	76.	1332.1	1122.0		2 1	76.	1192.3	1003.6		2 1	76.	968.7	815.6
	2 1	76.	1856.4	1677.8		2 1	76.	1661.8	1501.5		2 1	76.	1488.4	1344.4		2 1	76.	1209.9	1092.6
	2 1	76.	2076.8	1982.6		2 1	76.	1860.6	1775.5		2 1	76.	1666.7	1590.4		2 1	76.	1355.8	1293.2
	2 1	76.	2163.1	2131.4		2 1	76.	1938.3	1909.7		2 1	76.	1736.6	1710.9		2 1	76.	1412.8	1391.9
	2 1	76.	2076.8	2131.4		2 1	76.	1860.6	1909.7		2 1	76.	1666.7	1710.9		2 1	76.	1355.8	1391.9
	2 1	76.	1856.4	1982.6		2 1	76.	1661.8	1775.5		2 1	76.	1488.4	1590.4		2 1	76.	1209.9	1293.2
	2 1	76.	1489.0	1677.8		2 1	76.	1332.1	1501.5		2 1	76.	1192.3	1344.4		2 1	76.	968.7	1092.6
	2 1	76.	988.0	1253.9		2 1	76.	885.1	1122.0		2 1	76.	790.5	1003.6		2 1	76.	643.2	815.6
	2 1	76.	529.1	741.2		2 1	76.	476.5	665.6		2 1	76.	423.2	593.0		2 1	76.	346.2	483.7

CH17	2		0.0		CH18	2		0.0		CH19	2		0.0		CH20	2		0.0	
	2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0
	2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0
	2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0
	2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0
	2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0
	2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0
	2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0
	2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0
	2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0
	2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0		2 2	0.	0.0	0.0

ZONE-SPECIFICATIONS FORMAT*TABLE-INDEX,CHARGE NUMBER,INCORE-TIME,BURNUP,MEAN-BURNUP*

CH21

CH22

CH23

CH24

HARMONIQUES 13
****

IT1	IT2	KSI	PC	DEL
1	1	0.1000565E 01	0.1976722E 01	-0.9756060E 00
1	2	0.1030161E 01	0.1079265E 01	-0.4766560E-01
1	3	0.1031649E 01	0.1031910E 01	-0.2527237E-03
1	4	0.1031655E 01	0.1030438E 01	0.1179576E-02
1	5	0.1031617E 01	0.1030753E 01	0.8375645E-03
1	6	0.1031590E 01	0.1031066E 01	0.5084872E-03
1	7	0.1031573E 01	0.1031297E 01	0.2681017E-03
1	8	0.1031564E 01	0.1031431E 01	0.1285076E-03
1	9	0.1031559E 01	0.1031487E 01	0.7027388E-04

XEQ TIME= 0.06

LIFE	IT VALUE	FFPW	POWER	K EFF
0.7649377E 02	0.1031559E 01	0.5432985E 00	0.7069985E 03	0.1031559E 01

PSLMAX	CH.	PT.	C
0.2151638E-01	1	6	0.0

HARMONIQUES 13
****

IT1	IT2	KSI	PC	DEL
1	1	0.1016171E 01	0.5252916E 00	0.4830680E 00
1	2	0.1001676E 01	0.1002986E 01	-0.1307487E-02
1	3	0.1001713E 01	0.1001082E 01	0.6293058E-03
1	4	0.1001694E 01	0.1002091E 01	-0.3967285E-03
1	5	0.1001704E 01	0.1002244E 01	-0.5388260E-03
1	6	0.1001719E 01	0.1002122E 01	-0.4014969E-03
1	7	0.1001731E 01	0.1001982E 01	-0.2498627E-03
1	8	0.1001738E 01	0.1001903E 01	-0.1640320E-03
1	9	0.1001741E 01	0.1001848E 01	-0.1058579E-03
1	10	0.1001743E 01	0.1001824E 01	-0.8010864E-04

XEQ TIME= 0.06

LIFE	IT VALUE	FFPW	POWER	K EFF
0.3788762E 03	0.1001743E 01	0.6427906E 00	0.7069980E 03	0.1001743E 01

PSLMAX	CH.	PT.	C
0.1818604E-01	9	6	0.0

PART22 TERMINATED

**PART3 - FUEL CYCLE COSTS **

INPUT DATA

N CALC	TN	ISO	STEPS	LIM1	LIM2
1	2	4	**	3	3

ITWE	ITWA	NN	IRP	IE1	IE2
0	0	3	1	4	7

NNO
3

INTERVALS FOR SEPARATE COST-EVALUATIONS

1	4	7

INTERVALS FOR SEPARATE MATERIAL-ACCUMULATIONS

1	4	7

DATA DEPENDING FROM ISOTOPES

ISO	XINU	KCR	KRC	XTM
1	9.899999E-01	0.0	0.0	1.0099999E 00
2	1.0000000E 00	0.0	5.599999E 00	1.0099999E 00
3	9.8000000E-01	1.0000000E 04	1.5000000E 03	1.0099999E 00
4	9.8000000E-01	0.0	1.5000000E 03	1.0099999E 00

DATA DEPENDING FROM FUEL TYPE, CONCERNING DISCHARGE

TN	IK	KRP	KTR	TRP	THA	FHA
1	1	2.5000000E 01	1.0000000E 01	1.0000000E 00	0.0	9.5200000E-01
2	1	2.5000000E 01	1.0000000E 01	1.0000000E 00	0.0	9.5200000E-01

DATA DEPENDING FROM FUEL TYPE, CONCERNING CHARGE

TN	IM	KF	TF	TWE	TFO
1	1	0.0	5.0000000E 00	0.0	5.0000000E 00
2	1	0.0	5.0000000E 00	0.0	5.0000000E 00

TK	TTA	TT	TTO	THEO
3.0000000E 00	3.0000000E 00	1.0000000E 00	1.0000000E 00	0.0

ST	PM	RHO	KL	VIE	WORK
2.7000000E 00	5.7500000E-01	5.0000000E-02	0.0	3.0000000E 01	1.8240000E 08

KYC	KC	R	CT	KP
8.0000000E 00	2.7000000E 00	2.0000000E-01	3.0000000E 01	0.0

STEP NR. 1 (LIFE=0.0)

DF (T)	DM HA	MEAN-BU	ICT DF	THA	BCA*	BCA	BKA
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0		0.0	0.0	0.0

DM U FI	DM U FE	DM PUFI	DM PUFE	DM THO3	DM U23
0.0	0.0	0.0	0.0		
0.0	0.0	0.0	0.0		

CF (T)	CM HA	KF($/KG)	ICT CF	TWE	BCE*	BCE	BKE
8.626768E 00	8.212683E 00	6.858263E 01	7.649352E 01	0.0	2.326500E 01	1.934456E 02	1.588707E 06
1.725343E 01	1.642526E 01	6.898564E 01	1.477972E 02	0.0	3.192574E 01	2.044454E 02	3.358070E 06

CM U FI	CM U FE	CM PUFI	CM PUFE	CM THO3	CM U23
6.082418E-02	8.565943E 00	0.0	0.0		
1.398796E-01	1.711354E 01	0.0	0.0		

STEP NR. 2 (LIFE=7.649377E 01)

DF (T)	DM HA	MEAN-BU	ICT DF	TWA	BCA*	BCA	BKA
8.600313E 00	8.187497E 00	2.593909E 03	7.649356E 01	0.0	-2.142421E 01	-2.058142E 01	-1.685103E 05
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DM U FI	DM U FE	DM PUFI	DM PUFE	DM THO3	DM U23
3.684796E-02	8.133466E 00	1.438306E-02	2.797006E-03		
0.0	0.0	0.0	0.0		

CF (T)	CM HA	KF($/KG)	ICT CF	TWE	BCE*	BCE	BKE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.626780E 00	8.212693E 00	6.898564E 01	1.505794E 02	0.0	3.192574E 01	1.039819E 02	8.539712E 05

CM U FI	CM U FE	CM PUFI	CM PUFE	CM THO3	CM U23
0.0	0.0	0.0	0.0		
6.994027E-02	8.556839E 00	0.0	0.0		

STEP NR. 3 (LIFE=1.244231E 02)

DF (T)	DM HA	MEAN-BU	ICT DF	TWA	BCA*	BCA	BKA
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.585583E 00	8.173474E 00	4.018373E 03	1.244228E 02	0.0	-1.922469E 01	-1.846841E 01	-1.509511E 05

DM U FI	DM U FE	DM PUFI	DM PUFE	DM THO3	DM U23
0.0	0.0	0.0	0.0		
3.575545E-02	8.115492E 00	1.760569E-02	4.612114E-03		

CF (T)	CM HA	KF($/KG)	ICT CF	TWE	BCE*	BCE	BKE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.626780E 00	8.212693E 00	6.898564E 01	1.526498E 02	0.0	3.192574E 01	1.039898E 02	8.540359E 05

CM U FI	CM U FE	CM PUFI	CM PUFE	CM THO3	CM U23
0.0	0.0	0.0	0.0		
6.994027E-02	8.556839E 00	0.0	0.0		

STEP NR. 4 (LIFE=1.711718E 02)

DF (T)	DM HA	MEAN-BU	ICT DF	TWA	BCA*	BCA	BKA
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.582006E 00	8.170069E 00	4.363180E 03	1.711714E 02	0.0	-1.969116E 01	-1.891655E 01	-1.545494E 05

DM U FI	DM U FE	DM PUFI	DM PUFE	DM TH03	DM U23
0.0	0.0	0.0	0.0		
3.391579E-02	8.112675E 00	1.831564E-02	5.154163E-03		

CF (T)	CM HA	KF($/KG)	ICT CF	TWE	BCE*	BCE	BKE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.626780E 00	8.212693E 00	6.898564E 01	1.577033E 02	0.0	3.192574E 01	1.040090E 02	8.541938E 05

CM U FI	CM U FE	CM PUFI	CM PUFE	CM TH03	CM U23
0.0	0.0	0.0	0.0		
6.994027E-02	8.556839E 00	0.0	0.0		

STEP NR. 5 (LIFE=2.270736E 02)

DF (T)	DM HA	MEAN-BU	ICT DF	TWA	BCA*	BCA	BKA
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.583649E 00	8.171624E 00	4.206059E 03	1.505795E 02	0.0	-1.947729E 01	-1.871109E 01	-1.528999E 05

DM U FI	DM U FE	DM PUFI	DM PUFE	DM TH03	DM U23
0.0	0.0	0.0	0.0		
3.469858E-02	8.113983E 00	1.803624E-02	4.903153E-03		

CF (T)	CM HA	KF($/KG)	ICT CF	TWE	BCE*	BCE	BKE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.626780E 00	8.212693E 00	6.898564E 01	1.505794E 02	0.0	3.192574E 01	1.039819E 02	9.539712E 05

CM U FI	CM U FE	CM PUFI	CM PUFE	CM TH03	CM U23
0.0	0.0	0.0	0.0		
6.994027E-02	8.556839E 00	0.0	0.0		

STEP NR. 6 (LIFE=2.770735E 02)

DF (T)	DM HA	MEAN-BU	ICT DF	TWA	BCA*	BCA	BKA
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.583396E 00	8.171392E 00	4.229402E 03	1.526503E 02	0.0	-1.951112E 01	-1.874359E 01	-1.531612E 05

DM U FI	DM U FE	DM PUFI	DM PUFE	DM TH03	DM U23
0.0	0.0	0.0	0.0		
3.458843E-02	8.113791E 00	1.807291E-02	4.940875E-03		

CF (T)	CM HA	KF($/KG)	ICT CF	TWE	BCE*	BCE	BKE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.626780E 00	8.212693E 00	6.898564E 01	1.526498E 02	0.0	3.192574E 01	1.039898E 02	9.540359E 05

CM U FI	CM U FE	CM PUFI	CM PUFE	CM TH03	CM U23
0.0	0.0	0.0	0.0		
6.994027E-02	8.556839E 00	0.0	0.0		

STEP NR. 7 (LIFE=3.288762E 02)

DF (T)	DM HA	MEAN-BU	ICT DF	TWA	BCA*	BCA	BKA
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.583120E 00	8.171130E 00	4.256195E 03	1.577043E 02	0.0	-1.954723E 01	-1.877827E 01	-1.534397E 05

DM U FI	DM U FE	DM PUFI	DM PUFE	DM TH03	DM U23
0.0	0.0	0.0	0.0		
3.444812E-02	8.113566E 00	1.812572E-02	4.983321E-03		

CF (T)	CM HA	KF($/KG)	ICT CF	TWE	BCE*	BCE	BKE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.626780E 00	8.212693E 00	6.898564E 01	1.577033E 02	0.0	3.192574E 01	1.040090E 02	8.541938E 05

CM U FI	CM U FE	CM PUFI	CM PUFE	CM TH03	CM U23
0.0	0.0	0.0	0.0		
6.994027E-02	8.556839E 00	0.0	0.0		

STEP NR. 8 (LIFE=3.788762E 02)

DF (T)	DM HA	MEAN-BU	ICT DF	TWA	BCA*	BCA	BKA
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.580376E 01	2.456517E 01	2.472141E 03	1.011373E 02	0.0	-1.659680E 01	-1.640569E 01	-4.030082E 05

DM U FI	DM U FE	DM PUFI	DM PUFE	DM TH03	DM U23
0.0	0.0	0.0	0.0		
1.384100E-01	2.438191E 01	3.746362E-02	7.408582E-03		

CF (T)	CM HA	KF($/KG)	ICT CF	TWE	BCE*	BCE	BKE
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	1.595794E 02	0.0	0.0	0.0	0.0

CM U FI	CM U FE	CM PUFI	CM PUFE	CM TH03	CM U23
0.0	0.0	0.0	0.0		
0.0	0.0	0.0	0.0		

DISCHARGED MATERIALS

U FI 1- 1	U FI 2- 4	U FI 5- 7
0.0	1.065192E-01	1.037351E-01

U FE 1- 1	U FE 2- 4	U FE 5- 7
0.0	2.436162E 01	2.434132E 01

PUFI 1- 1	PUFI 2- 4	PUFI 5- 7
0.0	5.030433E-02	5.423487E-02

PUFE 1- 1	PUFE 2- 4	PUFE 5- 7
0.0	1.256323E-02	1.482735E-02

CHARGED MATERIALS

U FI 1- 1	U FI 2- 4	U FI 5- 7
2.007037E-01	2.098208E-01	2.098208E-01

U FE 1- 1	U FE 2- 4	U FE 5- 7
2.567947E 01	2.567052E 01	2.567052E 01

PUFI 1- 1	PUFI 2- 4	PUFI 5- 7
0.0	0.0	0.0

PUFE 1- 1	PUFE 2- 4	PUFE 5- 7
0.0	0.0	0.0

*ACC. COSTS FOR DEFINED INTERVALS

BK 1- 1	*BK* 2- 4	*BK* 5- 7
4.946777E 06	2.966214E 06	2.867614E 06

BK 1- 1	*BK* 2- 4	*BK* 2- 7
4.946777E 06	2.966214E 06	5.833823E 06

BKO	BK TRANS	BKG	BKR	BCF	BCF2
4.946777E 06	2.966214E 06	8.490784E 07	1.023133E 05	9.292312E 07	8.823728E 07

BCF1	BE	BCF1*	BCF2*	BCF*	BEA
4.685840E 06	2.769596E 10	1.691885E-01	3.185925E 00	3.355114E 00	1.007765E 09

BEG	BCFE	BCFE*	BCFG
9.296123E 08	7.852017E 00	2.943358E 00	3.185946E 00

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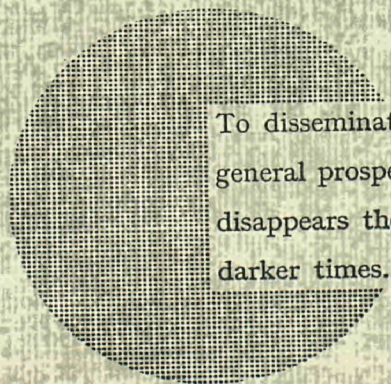

To disseminate knowledge is to disseminate prosperity — I mean general prosperity and not individual riches — and with prosperity disappears the greater part of the evil which is our heritage from darker times.

Alfred Nobel

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