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MEDUSA-PIJ : A CODE FOR ONE-DIMENSIONAL LASER FUSION ANALYSIS TAKING ACCOUNT OF NEUTRON HEATING EFFECT

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MEDUSA-PIJ : A Code for One-Dimensional Laser Fusion Analysis Taking Account of Neutron Heating Effect

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In the one-dimensional Lagrangian hydro-burn code MEDUSA, the neutrons emitted by D-T and D-D reactions are assumed to escape freely from the system without further interaction. The assumption is not practicable, however, in plasmas highly compressed by laser irradiation.

In the modified code MEDUSA-PIJ, the energy deposition due to the emitted neutrons is calculated by collision probability method. The total energy deposition is considered in the energy balance equation of the system at each time step, and a hydrodynamic equation is solved. Neutron spectra escaping from fuel sphere are calculated by a neutron slowing-down equation derived under the two-collision model.

The MEDUSA-PIJ code is designed for FACOM-230/75 computer with a FORTRAN IV H-level compiler.

Keywords : Laser Fusion, Neutron Heating, Collision Probability, MEDUSA Code, Neutron Slowing Down, Energy Deposition

中性子加熱を考慮した１次元レーザー核融合解析コード（ＭＥＤＵＳＡ－ＰＩＪ）

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１次元のラグランジアン熱核融合燃焼コードＭＥＤＵＳＡにおいては，Ｄ－ＴとＤ－Ｄ反応によって生れた中性子は，衝突なしに系から逃れると仮定されている。この仮定はレーザー照射によって高密度に圧縮されたプラズマ状態では実際的ではない。

新しく改良したＭＥＤＵＳＡ－ＰＩＪ　コードでは，この放出中性子によるエネルギーデポジションを衝突確率法を用いて計算することができる。このエネルギーデポジションは各タイムステップ毎に系のエネルギーバランス方程式に考慮され，流体方程式が解かれる。燃料球から逃れる中性子のスペクラムが２回衝突モデルから導出した中性子の減速方程式を用いて計算される。

ＭＥＤＵＳＡ－ＰＩＪコードはＦＡＣＯＭ→３０／７５のＦＯＲＴＲＡＮ－ＩＶ－Ｈコンパイラーを使用するようになっている。

Contents

目　　次

1. Introduction

Theoretical studies for inertially confined fusion reactor indicate that symmetric illumination of a hydrogen fuel pellet will lead to high-pellet-compression ratios of $\sim 10^4$ times liquid density with an associated implosion heating process. A description based on the classical theory can be given for this process as follows: Under laser irradiation, electrons near the critical surface of the pellet are heated by inverse bremsstrahlung, resonance absorption and various anomalous mechanisms.(1) This heat is transported inward by classical thermal conductivity, and transferred to the ions by classical electron-ion collisions. The pellet surface is ablated by the electrons heated and the recoil force due to the expansion of ablating ions compresses the fuel sphere to high dense plasma. The thermal wavefront with the ablation surface acts the role like a piston. Once ignition of the central region of the imploded pellet occurs, a thermonuclear burn front propagates radially outward and ignites additional fuel. The MEDUSA code(2) can calculate one-dimensional hydrodynamic and thermodynamic behaviour such as the implosion and burnning process of plasma described above.

In the MEDUSA code, the 4 thermonuclear reactions are considered as follows:

$$D + T \rightarrow {}^4He\ (3.6\ MeV) + n\ (14.1\ MeV)$$
$$D + D \rightarrow T\ (1.0\ MeV) + H\ (3.0\ MeV)$$
$$D + D \rightarrow {}^3He\ (0.8\ MeV) + n\ (2.45\ MeV)$$
$$D + {}^3He \rightarrow {}^4He\ (3.6\ MeV) + H\ (14.7\ MeV)$$

Here, the charged reaction products H, T, ^3He and ^4He are assumed to deposit their energy locally to the ions and electrons. The neutrons are assumed to escape freely from the system without further interaction. The assumption made for the neutron escape is not reliable in the state of high dense plasma compressed. This can be easily understood from the following simple reasoning : The neutron escape probability, which one 14.1 MeV neutron emitted uniformaly at the center of a sphere with uniform density escapes without collision, is $e^{-\Sigma x}$, where Σ is the macroscopic cross section of the sphere. In the initial state of D-T fuel, the distance x is ~10^{-1} cm and the density ρ_0 is ~0.1 g/cm^3, and in a over-dense plasma, x is ~10^{-3} cm and ρ is ~1000 g/cm^3 ; Thus, the neutron escape probabilities are 96 % for the initial state and 67 % for the over-dense state, respectively. In the over-dense state, therefore, 30 % of the neutron energy is deposited before the neutron escapes, and the energy deposited becomes larger than that of α-particle. Hence, the effect of neutron heating by neutron-ion interaction should not be neglected in laser fusion analysis.

The MEDUSA-PIJ code can calculate the effect of the neutron heating and the spectrum of neutron escaping from the fuel sphere to blanket region by using the collision probability method.(3) In the Chapter 2, the calculational methods for the neutron spectrum and energy deposition are described. The MEDUSA-PIJ usage is described in the Chapter 3.

2. Calculational Method of Neutron Heating Effect and Neutron Spectrum

In the newly modified MEDUSA-PIJ code, the energy deposition by neutrons is calculated with the use of the collision probability method.(3) The D-T fuel sphere is devided into M shells which are expressed at the points of a moving Lagrangian mesh as shown in Fig.1. All physical quantities are calculated at the Lagrangian mesh points at each time step. Then, the collision probability P_{IJ} is defined as the probability that a neutron emitted isotropically in a shell I has its next collision in a shell J. The probability P_{IJ} is given by

$$P_{IJ} = \frac{1}{4\pi V_I} \int_{V_I} dx_I \int_{4\pi} d\Omega \int dR \; \Sigma_J \; e^{-\widetilde{\Sigma R}}$$

where

V_I = volume of sphere I

$R = |x_I - x_J|$ = distance between point x_I and x_J in the shell I and J, respectively

$\Omega = (x_I - x_J)/R$

$\widetilde{\Sigma R} = \int_0^R \Sigma \, (x_I - \Omega R')dR'$ = optical distance between x_I and x_J.

The neutron slowing down and energy deposition equations for the first collision are given by

$$Q_I^{(1)}(n) = \sum_J N_J P_{JI}(1) \sum_A \frac{\Sigma_{A,I}^{(1)}}{\Sigma_I^{(1)}} T_A\,(1,n) \tag{2}$$

and

$$< DE(n) >_I^{(1)} = \sum_J N_J P_{JI}(1) \sum_A \frac{\Sigma_{A,I}^{(1)}}{\Sigma_I^{(1)}} T_A\,(1,n) E_A(1,n) \quad , \tag{3}$$

where N_J is the neutrons emitted isotropically at the J-th shell region,

$P_{JI}(1)$ the collision probability that a neutron of the energy group 1 emitted at the region J will have the next collision at the region I, $\Sigma_{A,I}(1)$ the macroscopic neutron elastic scattering cross section of material A for the energy group 1, $\Sigma_I(1)$ the total cross section summed over material A, $T_A(1,n)$ and $E_A(1,n)$ mean the energy transfer and energy loss matrices from group 1 to n, respectively. $Q_I^{(1)}(n)$ expresses the number of neutrons slowing down to group n by the first collision and $\langle DE(n)\rangle_I^{(1)}$ the energy deposition by the slowing down of neutrons in the region I. The energy group 1 is 14.1 MeV and the other group boundaries are determined by dividing the energy space with equal lethargy width Δu=0.22. The energy group structure and elastic scattering cross sections of D, T, H, ^{3}He and ^{4}He are shown in Table 1.

In Eq.(2), the energy transfer matrix, $T_A(m,n)$ is defined as follows:

① m=1

$$T_A(1,n) = \begin{cases} 0.0 & \ldots\ldots\ n=1 \\ \Delta E_n/(1-\alpha_A)E_0 & \ldots\ldots\ n\neq 1, L_A \\ (E_{L_A-1} - \alpha_A E_0)/(1-\alpha_A)E_0 & \ldots\ldots\ n=L_A \\ 0.0 & \ldots\ldots\ n > L_A \end{cases} \quad (4)$$

② m≠1, n=m

$$T_A(m,n) = \int_{E_m}^{E_{m-1}} \int_{E_m}^{E'} \frac{1}{(1-\alpha_A)E'}\, dE dE' \Big/ \int_{E_m}^{E_{m-1}} dE'$$

$$= (\Delta E_m - E_u \Delta u) \ / \ (1-\alpha_A)\Delta E_m \quad (5)$$

③ m≠1, m < n < m+L_A-1

$$T_A(m,n) = \int_{E_m}^{E_{m-1}} \int_{E_n}^{E_{n-1}} \frac{1}{(1-\alpha_A)E'}\, dE dE' \Big/ \int_{E_m}^{E_{m-1}} dE'$$

$$= \Delta E_n \Delta u \ / \ (1-\alpha_A)\Delta E_m \quad (6)$$

④ $m \neq 1,\ n = m + L_A - 1$

$$T_A(m,n) = \left\{ \int_{E_n/\alpha_A}^{E_{m-1}} \int_{\alpha_A E'}^{E_{n-1}} \frac{1}{(1-\alpha_A)E'}\, dEdE' + \int_{E_m}^{E_n/\alpha_A} \int_{E_m}^{E_{n-1}} \frac{1}{(1-\alpha_A)E'}\, dEdE' \right\} \Bigg/ \int_{E_m}^{E_{m-1}} dE'$$

$$= \frac{1}{(1-\alpha_A)\Delta E_m} \{\Delta E_n \Delta u - (\alpha_A E_{m-1} - E_n) + E_n (L_A \Delta u - \xi_A)\} \qquad (7)$$

⑤ $m \neq 1,\ n = m + L_A$

$$T_A(m,n) = \int_{E_m}^{E_{n-1}/\alpha_A} \int_{\alpha_A E'}^{E_{n-1}} \frac{1}{(1-\ \ _A)E'}\, dEdE' \Bigg/ \int_{E_m}^{E_{m-1}} dE'$$

$$= \frac{1}{(1-\alpha_A)\Delta E_m} [E_{n-1}(\xi_A - (L_A - 1)\Delta u) - (E_{n-1} - \alpha_A E_m)] \qquad (8)$$

where L_A is the maximum group number of slowing down and $\alpha_A = (M-1)^2/(M+1)^2$ is a well-known parameter concerning the atomic mass M of material A.

In Eq.(3), the energy loss matrix $E_A(m,n)$ is difined as follows:

① $m=1$

$$E_A(1,n) = \begin{cases} 0 & \ldots\ldots\ n=1 \\ E_0 - \bar{E}_n & \ldots\ldots\ n \neq 1, L_A \\ E_0 - \frac{1}{2}(E_{L_A - 1} + \alpha_A E_0) & \ldots\ldots\ n = L_A \\ 0 & \ldots\ldots\ n > L_A \end{cases} \qquad (9)$$

② $m \neq 1,\ n = m$

$$E_A(m,n) = \int_{E_m}^{E_{m-1}} \int_{E_n}^{E'} \frac{E' - E}{(1-\alpha_A)E'}\, dEdE' \Bigg/ \int_{E_m}^{E_{m-1}} \int_{E_n}^{E'} \frac{1}{(1-\alpha_A)E'}\, dEdE'$$

$$= \frac{1}{2} \{\Delta E_m (E_n - 2E_n) + E_n^{\ 2} \Delta u\} \ /\ T_A(m,n)(1-\alpha_A)\Delta E_m \qquad (10)$$

③ $m \neq 1,\ m < n < m+L_A-1$

$$E_A(m,n) = \int_{E_m}^{E_{m-1}} \int_{E_n}^{E_{n-1}} \frac{E'-E}{(1-\alpha_A)E'}\, dEdE' \Big/ \int_{E_m}^{E_{m-1}} \int_{E_n}^{E_{n-1}} \frac{1}{(1-\alpha_A)E'}\, dEdE'$$

$$= \Delta E_m(\Delta E_m - \bar{E}_n \Delta u)\ /\ T_A(m,n)\Delta E_m(1-\alpha_A) \qquad (11)$$

④ $m \neq 1,\ n=m+L_A-1$

$$E_A(m,n) = \left\{ \int_{E_n/\alpha_A}^{E_{m-1}} \int_{\alpha_A E'}^{E_{n-1}} \frac{E'-E}{(1-\alpha_A)E'}\, dEdE' + \int_{E_m}^{E_n/\alpha_A} \int_{E_n}^{E_{n-1}} \frac{E'-E}{(1-\alpha_A)E'}\, dEdE' \right\} \Big/$$

$$\left\{ \int_{E_n/\alpha_A}^{E_{m-1}} \int_{\alpha_A E'}^{E_{n-1}} \frac{1}{(1-\alpha_A)E'}\, dEdE' + \int_{E_m}^{E_n/\alpha_A} \int_{E_n}^{E_{n-1}} \frac{1}{(1-\alpha_A)E'}\, dEdE' \right\}$$

$$= \{\frac{1}{2}\ [(E_{m-1}-E_n/\alpha_A)(2E_{n-1}-\alpha_A(1-\frac{\alpha_A}{2})(E_{m-1}+E_n/\alpha_A))$$

$$- E_{n-1}^2(L_A\Delta u-\xi_A)] + \Delta E_n[(E_n/\alpha_A-E_m)-\bar{E}_n(\xi_A-(L_A-1)\Delta u)]\} \ /$$

$$T_A(m,n)(1-\alpha_A)\Delta E_m \qquad (12)$$

⑤ $m \neq 1,\ n=m+L_A$

$$E_A(m,n) = \int_{E_m}^{E_{n-1}/\alpha_A} \int_{\alpha_A E'}^{E_{n-1}} \frac{E'-E}{(1-\alpha_A)E'}\, dEdE' \Big/ \int_{E_m}^{E_{n-1}/\alpha_A} \int_{\alpha_A E'}^{E_{n-1}} \frac{1}{(1-\alpha_A)E'}\, dEdE'$$

$$= \frac{1}{2}\ [(E_{n-1}/\alpha_A-E_m)(2E_{n-1}-\alpha_A(1-\frac{\alpha_A}{2})(E_{n-1}/\alpha_A+E_n))$$

$$- E_{n-1}^2(\xi_A-(L_A-1)\Delta u)]\ /\ T_A(m,n)(1-\alpha_A)\Delta E_m \qquad (13)$$

By considering the second collision of neutrons, the slowing down and energy deposition equations are respectively expressed by

$$Q_I^{(2)}(n) = \sum_J \sum_m Q_J^{(1)}(m) P_{JI}(m) \sum_A \frac{\Sigma_{A,I}(m)}{\Sigma_I(m)} T_A(m,n)\ , \qquad (14)$$

and

$$< DE(n) >_I^{(2)} = \sum_J \sum_m Q_J^{(1)}(m) P_{JI}(m) \sum_A \frac{\Sigma_{A,I}(m)}{\Sigma_I(m)} T_A(m,n) E_A(m,n) \quad . \qquad (15)$$

Thus the total energy deposition by the neutrons with considering two collisions is given by, $<DE>_I = \sum_n [<DE(n)>_I^{(1)} + <DE(n)>_I^{(2)}]$. The spectrum of neutrons escaping from the spherical shell to blanket region is given by

$$S(n) = \begin{cases} \sum_J N_J P_J(n) \ , & n = 1 \qquad (16) \\ \sum_J (Q_J^{(1)}(n) + Q_J^{(2)}(n)) P(n) \ , & 1 < n \qquad (17) \end{cases}$$

where $P_J(n) = 1 - \sum_I P_{JI}(n)$ is the collision escape probability.

In the MEDUSA-PIJ code, the total energy deposition of the emitted neutrons is considered in the energy balance equation of the system at each time step, and a hydrodynamic equation is solved. The internal energy per unit mass, U, is assumed to be separable into electric and ionic components, U_e and U_i, which are directly coupled only through electron-ion collisional energy exchange. The electron and ion pressures are assumed only to do PdV work on the electrons and ions, respectively. The internal energy balance equations for electrons and ions are written as

$$\frac{dU_e}{dt} = - P_e \frac{dv}{dt} + He + K + Ye + J + X \qquad (18)$$

$$\frac{dU_i}{dt} = - P_i \frac{dv}{dt} + Hi - K + Yi + Q \quad , \qquad (19)$$

where H is the flow heat due to thermal conduction, K the rate of energy exchange between electrons and ions, Y the rate of thermonuclear energy release, J the rate of bremsstrahlung emission, X the absorption rate of laser light and Q the rate of viscous shock heating. The energy deposition by the neutron is added to the thermonuclear energy rate Yi in the MEDUSA-PIJ code.

3. Input Data Description

In the MEDUSA-PIJ code, the input of data are mainly made with "namelist" function. The input variables are defined by "default" values. Therefore, only the variables to be changed in the calculation need to be read with the use of "namelist" function.

3.1 Input Data

1 (12A4) Tittle is described by four cards

LABEL 1(12), LABEL 2(12), LABEL 3(12), LABEL 4(12)

2 Namelist NEWRUN

Variable	Descriptions	Default value
AK 0	a_0, Control variable of time centering in Eq.(A-39)	5.0
AK 1	a_1, Control variable of time step Δt by sound speed in Eq.(A-35)	0.25
AK 2	a_2, Control variable of time step Δt by density variation in Eq.(A-36)	0.25
AK 3	a_3, Control variable of time step Δt by ion temperature variation in Eq.(A-37)	0.25
AK 4	a_4, Control variable of time step Δt by electron temperature variation in Eq.(A-38)	0.25
BNEUM	b, Factor for the rate of shock heating in Eq.(A-33)	1.0
DELTAT	Time step interval Δt_0, $\Delta t \leq \Delta t_0$ (sec)	1×10^{-12}
DTEMAX	δTe, Convergence condition for electron temperature in Eq.(A-42)	0.1
DTIMAX	δTi, Convergence condition for ion temperature in Eq.(A-41)	0.1
DUMAX	δu, Convergence condition for plasma velocity in Eq.(A-40)	0.1
DEUTER	f_D, Initial fraction of D	0.5

TRITIU	f_T, Initial fraction of T	0.5
HELIU 3	$f_{^3He}$, Initial fraction of ^3He	0.0
NETRAL	f_N, Initial fraction of neutrals	0.0
HELIU 4	$f_{^4He}$, Initial fraction of ^4He	0.0
XTRA	f_X, Initial fraction of arbitrary ion X	0.0
HYDROG	f_H, Initial fraction of H	0.0
GAMMAE	γ_e	$\frac{5}{3}$
GAMMAI	γ_i	$\frac{5}{3}$
LAMDA 1	λ, Wavelength of laser light (m)	1×10^{-5}
NTRLMS	M_N, Atomic mass number of neutrals (kg)	0.0
RHOINI	ρ_o, Initial density of fuel (kg/m^3)	124.0
RINI	R_o, Initial size of system (m)	4.8×10^{-4}
TEINI	Te, Initial electron temperature (°K)	500
TIINI	Ti, Initial ion temperature (°K)	500
TINUCL	Ignition temperature for nuclear fusion reaction (°K)	1×10^{7}
TSTOP	Maximum calculational time (sec)	1×10^{-6}
XMASS	M_X, Atomic mass number of arbitrary ion X (kg)	0.0
XZ	Z_X, Charge number of X	0.0
SCP	Scaling factor of pressure for output format	1.0
SCR	Scaling factor of coordinate r for output format	1.0
SCRHO	Scaling factor of density ρ for output format	1.0
SCTE	Scaling factor of electron temperature Te	1.0
SCTI	Scaling factor of ion temperature Ti	1.0
SCTIME	Scaling factor of time	1.0
MESH	Number of Lagrangian mesh cells ($\leq$ 150)	40
NCASE	Boundary condition =1 $P(R_o) = 0$, zero thermal flux =2 $u(R_o) = 0$, $Ti(R_o) = Ti(t)$, $Te(R_o) = Te(t)$	

	=3 $P(R_o) = P(t)$, zero thermal flux =4 $u(R_o) = u(t)$, zero thermal flux	
GEOM	Geometory =1 Slab =2 Cylinder =3 Sphere	
NITMAX	Maximum number of iteration for convergence criterion	5
NP1	Physical quantities Ti, Te, ρ etc are printed from NP1 mesh point to NP2 points	1
NP2	Last mesh number for printing the physical quantities	MESH
NP3	The physical quantities are printed for mesh interval of NP3 increment	$\frac{MESH}{20}$
NPRNT	Print at each NPRNT time step	100
NLPRNT	Print option	T
NPRINT	Logical unit number of print	6
NIN	Logical unit number of read	5
NPUNCH	Logical unit number of punch	7
NRUN	Maximum number of time steps	0
NLABS	Absorption by inverse-bremsstrahlung	T
NLBRMS	Bremsstrahlung	T
NLBURN	Burnup of fuel	T
NLCRI1	Dump laser power at critical density ρ_c	T
NLDEPO	Deposition of thermonuclear energies	T
NLECON	Electron thermal conduction	T
NLICON	Ion thermal conduction	T
NLFUSE	Thermonuclear reactions	T
NLITE	Solve equations by iterations	T
NLMOVE	Hydrodynamic motion	T
NLPFE	Perfect electron gas laws	T
NLPFI	Perfect ion gas laws	T

NLX	Ion-electron energy change	T
LASER 1(1)	Starting time for laser irradiation (sec)	0.0
LASER 1(2)	Initial laser power P_o(w)	0.0
LASER 1(3)	Laser pulse duration τ (sec)	0.0
LASER 1(4)	Laser pulse shape factor q	0.0
LASER 1(5)	Time to switch off the laser (sec)	0.0
LASER 1(6)	Maximum permissible power level (w)	0.0
LASER 1(7)	Total maximum energy by laser irradiation (joule)	0.0
PIQ (10)	Modify free streaming limit coefficient, a in Eq.(A-6), a' = a × PIG(10)	0.0
PIQ (11)	=1, initial mesh width is devided by equal volume	0.0
PIQ (12)	=1, change initial density distribution, data of density are read in "namelist" INRHO	0.0
PIQ (13)	=1, change initial composition of pellet, composition data are read in "namelist" INFRAC	0.0
PIQ (20)	Modify coulomb logarithm coefficient Λ in Eq.(A-4), $\Lambda' = \Lambda \times$ PIQ(20)	0.0
PIQ (21)	Modify absorption coefficient α in Eq.(A-16), $\alpha' = \alpha \times$ PIQ(21)	0.0
PIQ (24)	Modify bremsstrahlung coefficient, J in Eq.(A-11), J' = J × PIQ(24)	0.0
PIQ (25)	Modify rate of energy exchange, K in Eq.(A-9), K' = K × PIQ(25)	0.0
PIQ (26)	Modify ion conduction coefficient, Ki in Eq.(A-3), Ki' = Ki × PIQ(26)	0.0
PIQ (27)	Modify electron conduction coefficient, Ke in Eq.(A-2), Ke' = Ke × PIQ(27)	0.0
PIQ (28)	$P^n_{DT} = Te^n/[Te^n + 3.71 \times 10^8(1+PIQ(28))]$ in Eq.(A-27)	0.0
PIQ (29)	$P^n_{DD} = Te^n/[Te^n + 1.2 \times 10^9(1+PIQ(29))]$ in Eq.(A-28)	0.0
PIQ (30)	$P_{D^3He} = T_e{}^n/[Te^n + 1.2 \times 10^9(1+PIQ(39))]$ in Eq.(A-29)	0.0

PIQ (31)	Print option for coordinate	if PIQ < 0.0, none print; = 0.0, only array; > 0.0, array and scale factor	0.0
PIQ (32)	Print option for velocity		0.0
PIQ (33)	Print option for density		0.0
PIQ (34)	Print option for pressure		0.0
PIQ (35)	Print option for Ti		0.0
PIQ (36)	Print option for Te		0.0
PIQ (38)	Modify reaction rate in Eq.(A-24) $(\overline{\sigma v})'_{DD} = (\overline{\sigma v})_{DD}$ (1 + PIQ(38))		0.0
PIQ (39)	$(\overline{\sigma v})'_{DT} = (\overline{\sigma v})_{DT}$ (1 + PIQ(39)) in Eq.(A-22)		0.0
PIQ (40)	$(\overline{\sigma v})'_{DT} = 7.5 \times 10^{-22}$ (7 + PIQ(40)) in Eq.(A-23)		0.0
PIQ (41)	$(\overline{\sigma v})'_{D^3He} = (\overline{\sigma v})_{D^3He}$ (1 + PIQ(41)) in Eq.(A-26)		0.0
NLPLOT	Switch option of plotter or COM production		F
NPLOT	Frequency of dumping physical variables for plotting production. The variables are written on disk or tape of unit 20. The graphical representations of the physical variables can be performed with the MEDU-PLOT(4) code.		10

\# 3 Namelist INRAD if PIQ(11) $\neq$ 0.0

(BUF 1(J), J = 1, MESH + 1) : coordinates r

if PIQ(11) > 0.0

$$R(J) = R_o \times (J-1)^{1/3} / (MESH)^{1/3}$$

if PIQ(11) < 0.0

$$R(J) = BUF\ 1(J)$$

$$R_o = BUF\ 1(MESH + 1)$$

\# 4 Namelist INRHO if PIQ(12) $\neq$ 0.0

(BUF 3(J), J = 1, MESH + 1) : densities ρ

if PIQ(12) > 0.0

$$\rho_J = \rho_o \times BUF3(J)$$

if PIQ(12) < 0.0

$$\rho_J = BUF3(J)$$

5 Namelist INFRAC if PIQ(13) ≠ 0.0

(BUF 1(J), J = 1, MESH + 1) : $f_{D,J} = f_D \times$ BUF 1(J)

(BUF 2(J), J = 1, MESH + 1) : $f_{H,J} = f_H \times$ BUF 2(J)

(BUF 4(J), J = 1, MESH + 1) : $f_{N,J} = f_N \times$ BUF 4(J)

(BUF 5(J), J = 1, MESH + 1) : $f_{T,J} = f_T \times$ BUF 5(J)

(BUF 6(J), J = 1, MESH + 1) : $f_{X,J} = f_X \times$ BUF 6(J)

6 Namelist INTEM if PIQ(14) < 0.0

(BUF 5(J), J = 1, MESH + 1) : $T_{i,J}$ = BUF 5(J)

(BUF 6(J), J = 1, MESH + 1) : $T_{e,J}$ = BUF 6(J)

7 Namelist PIJRUN

Variable	Descriptions	Default value
NGR	Order of division of Gauss integration for radial direction	8
NGA	Order of division of Gauss integration for angular direction	2
NDA	Order of division for angular integration	1
NDR	Number of coarse mesh regions for collision probability calculation, ≤ 10	10
NNR	Lagrangian mesh number corresponding to coarse mesh number	
SIGD	Neutron elastic scattering cross sections of D	Valves in Table 1
SIGH	Neutron elastic scattering cross sections of H	Valves in Table 1
SIGHE 3	" of ^{3}He	"
SIGHE 4	" of ^{4}He	"
SIGT	" of T	"
MUD	$\mu = \overline{\cos\theta}$ for D, θ is the scattering angle in the center of mass system	-1
MUT	$\mu = \overline{\cos\theta}$ for T, θ is the same described above.	-1

YIELDS	When the yield calculated become larger than YIELDS, calculations of neutron heating are performed	1×10^{-3}
NLPIJ	Switch option for neutron heating calculation	F

3.2 Usage of MEDUSA-PIJ in the computer of FACOM 230/75

The jobcontrol cards of MEDUSA-PIJ in FACOM-230/75 are arranged as follows:

```
1       ¥ NO RMEDU,0350 ,     T.5C.4W.4P.0 ,     LRGC35
2       ¥ USER     J2031 ,
3  VM   ¥ GJOB        3102031,HI,TAKANO,431,12,MEDUSA.P,SMF=CLS
4       ¥
5       ¥             IF COM PRODUCTION REQUIRED COMLIB=CALL
6       ¥             IF PLOT PRODUCTION REQUIRED PLTLIB=CALL
7  VM   ¥ HLIED       RFNAME=J2031,MDS1HRB,GRFD=ON,COMLIB=CALL,
                      SIMPL=OVLY,A=NOLIST,B=NOMAP,SYSOUS=CLS
8  VM   ¥ HRUN        SYSOUT=CLS,SIZE=20
9       ¥             LOGICAL UNIT NUMBER F12 IS SCRATCH UNIT FOR PIJ
                      CALCULATION
10 VM   ¥ TPDISK      F12,PIJWRK,RSIZE=216,BSIZE=12960
11      ¥             LOGICAL UNIT NUMBER F20 IS SCRATCH UNIT FOR
                      COM AND PLOT
12 VM   ¥ TPDISK      F20,PLTWRK,RSIZE=910,BSIZE=6370
13      ¥             IF PLOT PRODUCTION REQUIRED REPLACE NEXT CARD TO
                      ¥ PLOT
14      ¥             IF NOT  ¥ DISK   F77
15 VM   ¥ DISK        F77
16      ¥             IF COM PRODUCTION REQUIRED REPLACE NEXT CARD TO
                      ¥ GCOM35
17      ¥             IF NOT  ¥ DISK   F78
```

```
18 VM  ¥ GCOM35

19 VM  ¥ PRTFD        F51,SYSOUT=CLS

20 VM  ¥ DATA

       Title cards (4)

       $ NEWRUN
           Input variable = x ,

                 "        = z

       $ PIJRUN
           Input variable = y

       $ END

21     ¥ JEND
```

3.3 Output Data

1 The list of the input data

All the input data in Section 3.2 are printed.

2 At each time step, the following quantities are printed: time t(sec), Δt; R_o, u, P, Ti, Te and C_s at outer boundary ; E_{th}(=PV/r-1); $E_k(=\frac{1}{2}mv^2)$, E_f(=Yi +Ye); $\Delta E(=E_k + E_{th} - E_f - E_{in} + E_b)$, where E_{in} is the input laser power and E_b the radiation loss ; $\langle\rho R\rangle = \int_o^{R_o} \rho R\, dr \,/ \int_o^{R_o} dr$; Energy gain = $(E_f + E_n)/E_{in}$; Produced neutrons ; $E_n(=R_{DT}E_{DT} + \frac{1}{2} R_{DD}E_{DD})$; Laser power P_t(J)

3 Lagrangian radial coordinates from center to outer boundary (m)

4 Hydrodynamic velocities (m/sec)

5 Densities ρ(kg/m) : (=log ρ)

6 Hydrodynamic pressures $P(J/m^3)$: (log P)

7 Ion temperatures Ti(°K) : log Ti

8 Electron temperatures Te(°K) : log Te

9 Thermonuclear energy

#10 Neutrons released by D-D reactions

#11 Neutrons released by D-T reactions

#12 Neutron energy produced by D-D reactions

#13 Neutron energy produced by D-T reactions

#14 Neutrons with the first collision at the cell j

#15 Neutrons with the second collision at the cell j

#16 Energy deposited by the first collision

#17 Energy deposited by the second collision

#18 Energy loss of neutrons by the first collision

#19 Energy loss of neutrons by second collision

#20 Escape neutron spectrum

#21 Escape neutron probabilities P_{gj}, which the neutron produced at the region j and energy group g escape from the system without the next collision

Acknowledgements

The authors are indebited to Mr. K. Tsuchihashi for his offering to use collision probability calculation code. They also wish to thank Mr. K. Nakano of CRC for programming MEDUSA-PIJ code.

References

1) BRUECKNER, K.A., JORNA, S. : Rev. Mod. Phys., 46, No.2, 325 (1974)

2) ROBERTS, K.V. : Comp. Phys. Comm., 7, 237 (1974)

3) TSUCHIHASHI, K., GOTOH, Y. : Nucl. Sci. Eng., 58, 213 (1975)

4) TAKANO, H., SUWA, to be published

5) SPITZER, L. : "Physics of fully ionized gases", 2nd Ed., Interscience, New York (1961)

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9) CHRISTIANSEN, J.P., et al. : CLM-RBO (1973)

10) RICHTMEYER, R.D., MORTON, K.W. : "Difference methods for initial value problems", 2nd Ed. Inter. Publishers (1967)

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1) BRUECKNER, K.A., JORNA, S. : Rev. Mod. Phys., 46, No.2, 325 (1974)
2) ROBERTS, K.V. : Comp. Phys. Comm., 7, 237 (1974)
3) TSUCHIHASHI, K., GOTOH, Y. : Nucl. Sci. Eng., 58, 213 (1975)
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10) RICHTMEYER, R.D., MORTON, K.W. : "Difference methods for initial value problems", 2nd Ed. Inter. Publishers (1967)

Table 1. Neutron elastic scattering cross sections (barns)

Group No.	Eg(MeV)	D	T	α	$_2He^3$	H
1	14.1 ~11.31	0.7	1.1	1.25	1.1	0.75
2	11.31~9.07	0.9	1.4	1.45	1.3	0.90
3	9.07 ~7.27	1.1	1.6	1.60	1.5	1.1
4	7.27 ~5.83	1.3	1.9	1.80	1.7	1.25
5	5.83 ~4.68	1.55	2.2	2.15	1.9	1.45
6	4.68 ~3.75	1.80	2.4	2.35	2.0	1.75
7	3.75 ~3.01	2.0	2.5	2.60	2.1	2.10
8	3.01 ~2.41	2.2	2.4	3.00	2.15	2.40
9	2.41 ~1.94	2.4	2.2	3.65	2.15	2.75
10	1.94 ~1.56	2.6	2.0	4.90	2.1	3.2
11	1.56 ~1.25	2.7	1.9	6.40	2.1	3.6
12	1.25 ~1.00	2.8	1.8	7.30	2.0	4.0
13	1.00 ~0.803	2.9	1.75	5.70	1.9	4.4
14	0.803~0.644	3.0	1.70	3.30	1.9	4.9
15	0.644~0.517	3.1	1.6	2.0	1.9	5.3
16	0.517~0.414	3.1	1.5	1.4	1.9	5.8
17	0.414~0.332	3.15	1.45	1.1	1.9	6.2
18	0.332~0.267	3.15	1.42	0.91	1.9	6.7
19	0.267~0.214	3.15	1.40	0.83	1.9	8.5
20	0.214~0.172	3.20	1.35	0.80	1.9	10.0
21	0.172~0.138	3.20	1.35	0.78	1.8	11.5
22	0.138~0.110	3.20	1.35	0.77	1.7	13.0
23	0.110~0.886	3.20	1.35	0.76	1.6	14.0

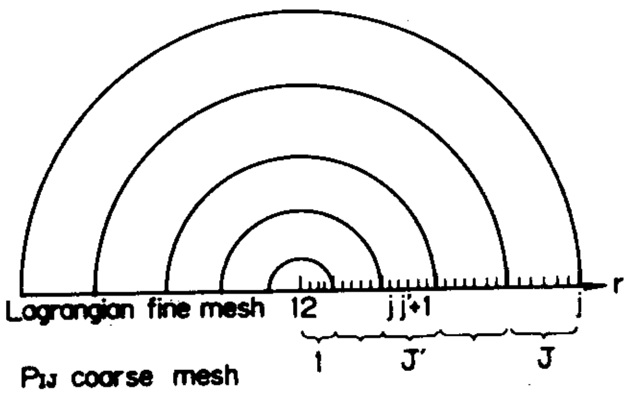

Fig. 1 Lagrangian mesh and coarse mesh for calculation of collision probability

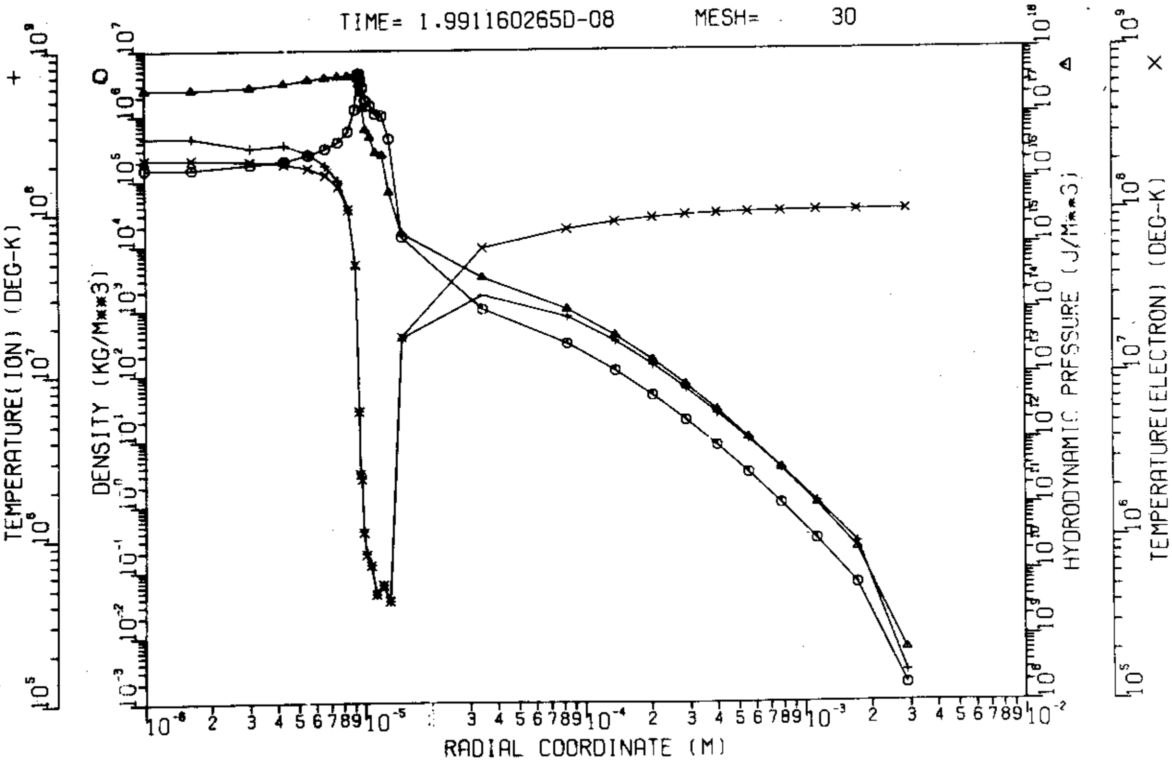

Fig. 2　Density, hydrodynamic pressure, electron and ion temperatures versus radius during the implosion of D－T pellet

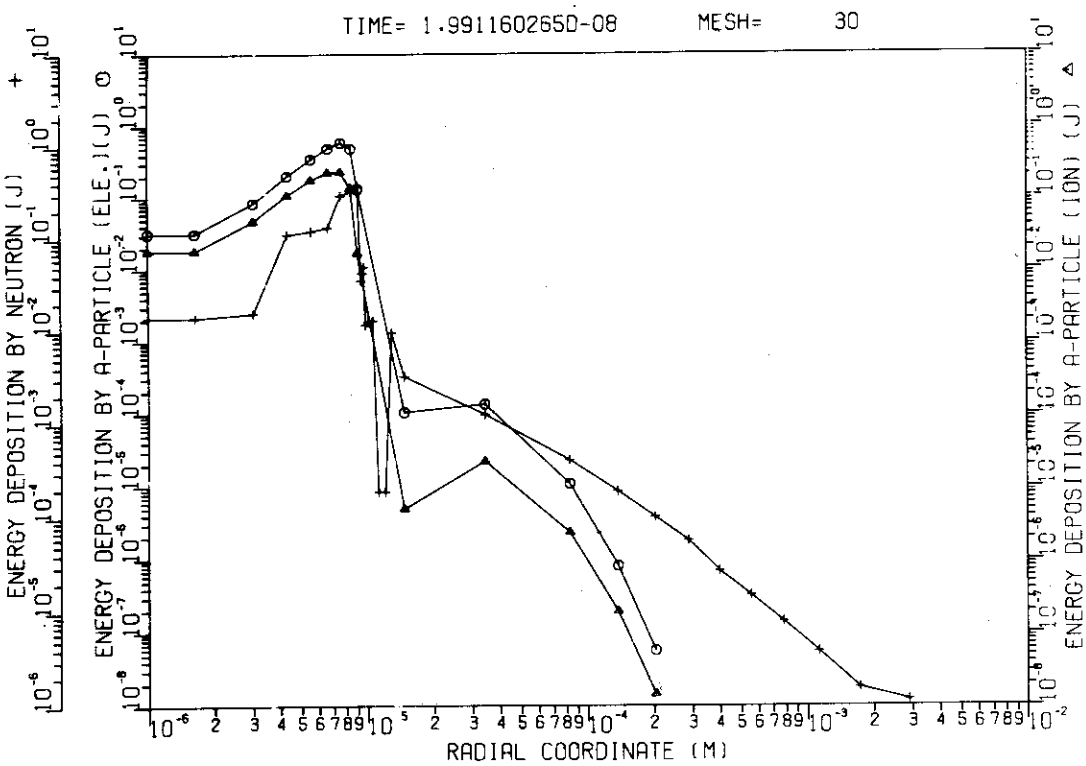

Fig. 3　Comparison of energy deposition by neutrons and alpha－particles

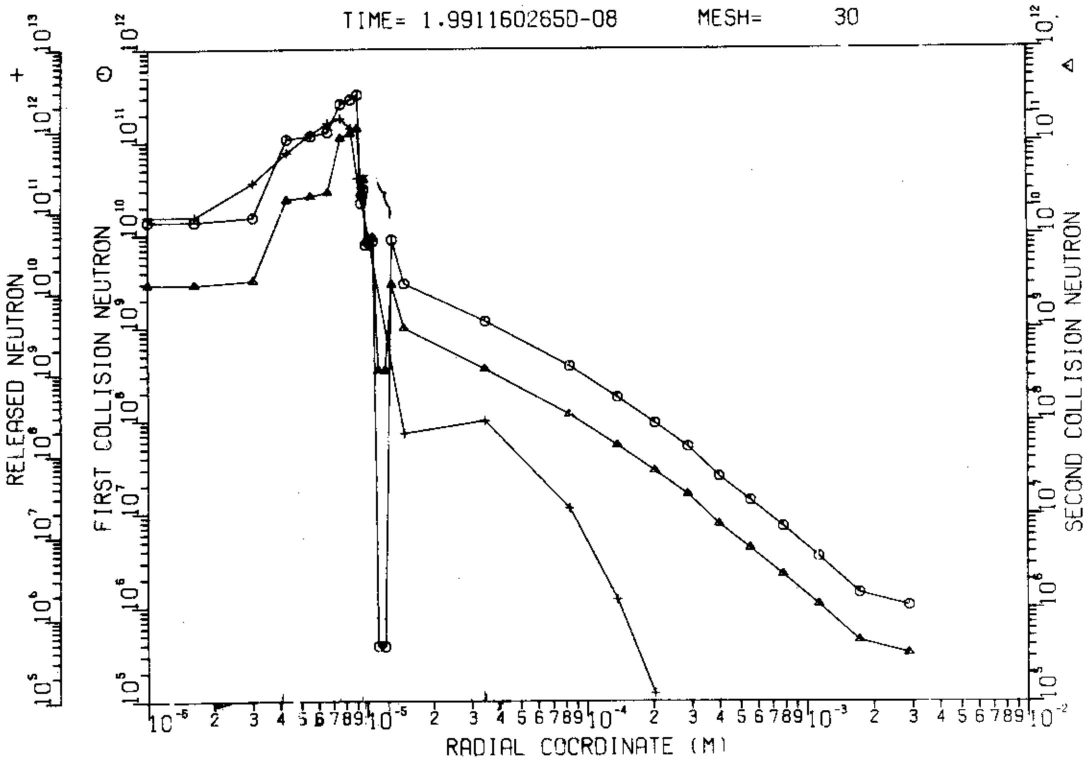

Fig. 4 Fusion neutrons and the first and second colision neutrons

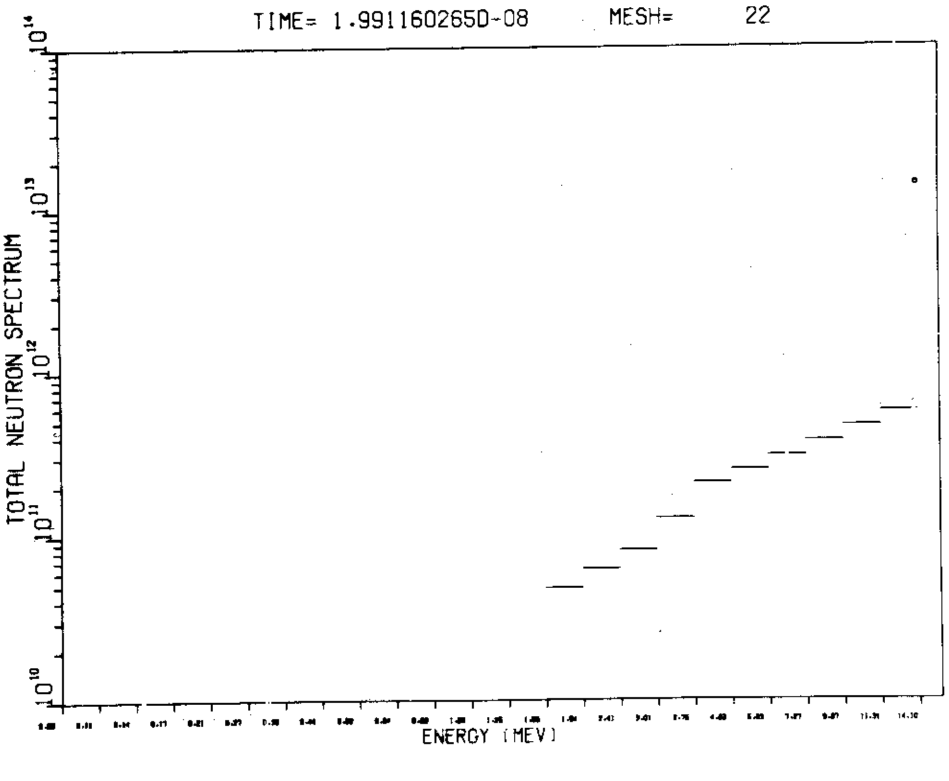

Fig. 5 Neutron energy spectrum degraded by elastic scattering

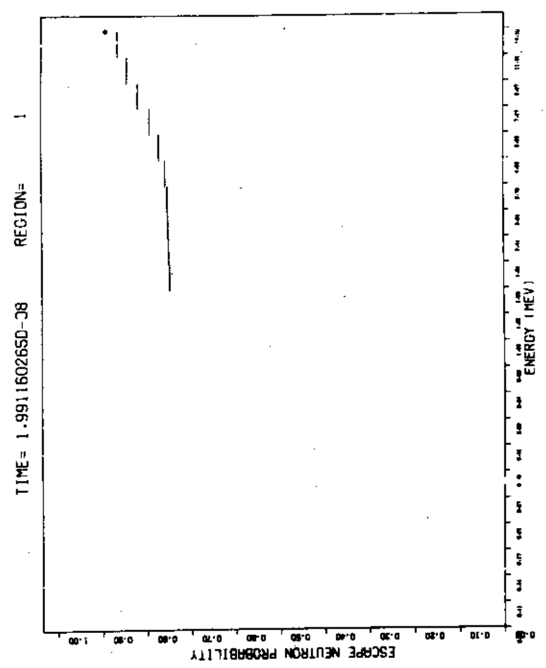

Fig. 6 Escape neutron probability depending on each energy group

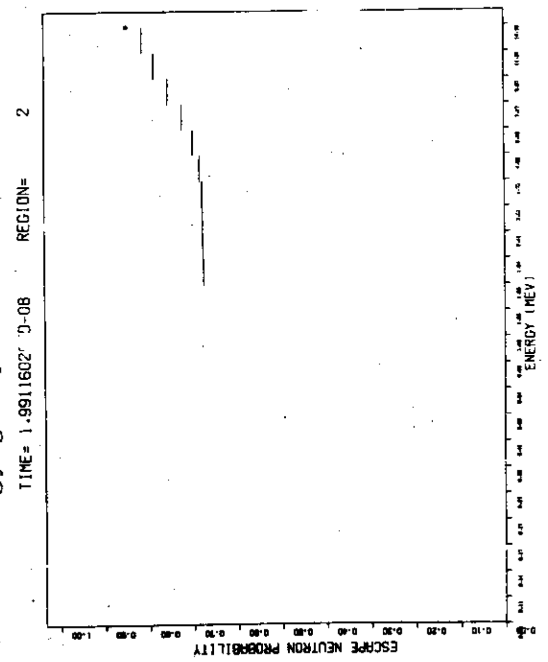

Fig. 7 Escape neutron probability depending on each energy group

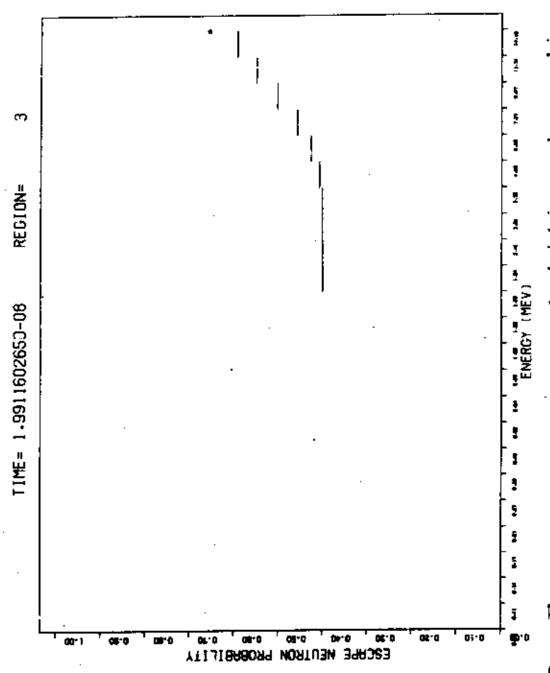

Fig. 8 Escape neutron probability depending on each energy group

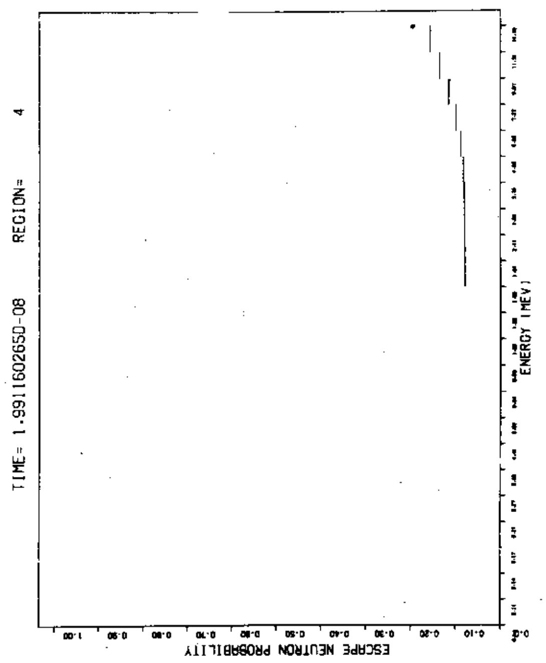

Fig. 9 Escape neutron probability depending on each energy group

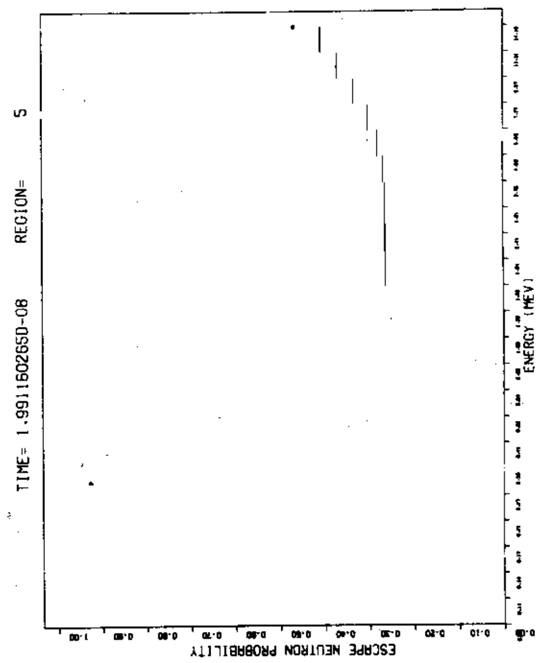

Fig. 10 Escape neutron probability depending on each energy group

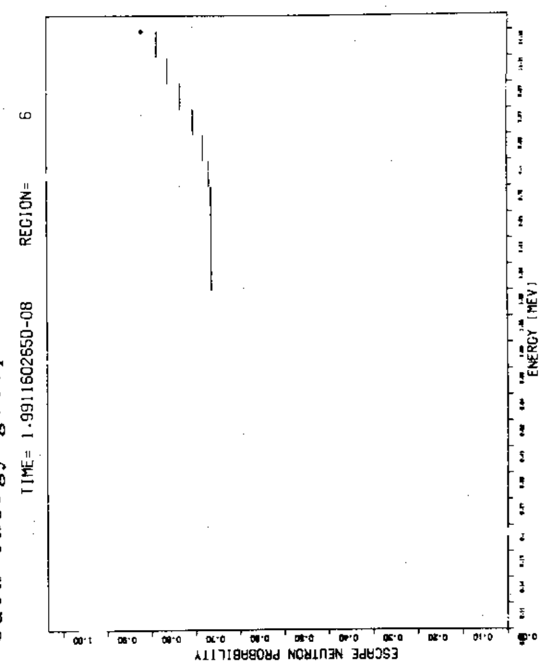

Fig. 11 Escape neutron probability depending on each energy group

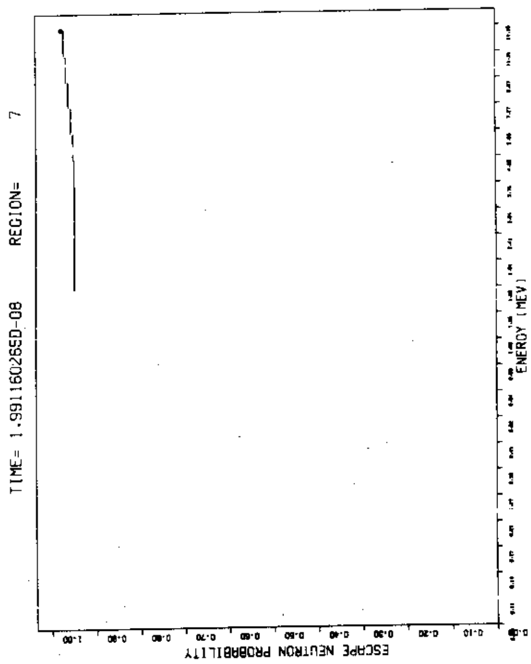

Fig. 12 Escape neutron probability depending on each energy group

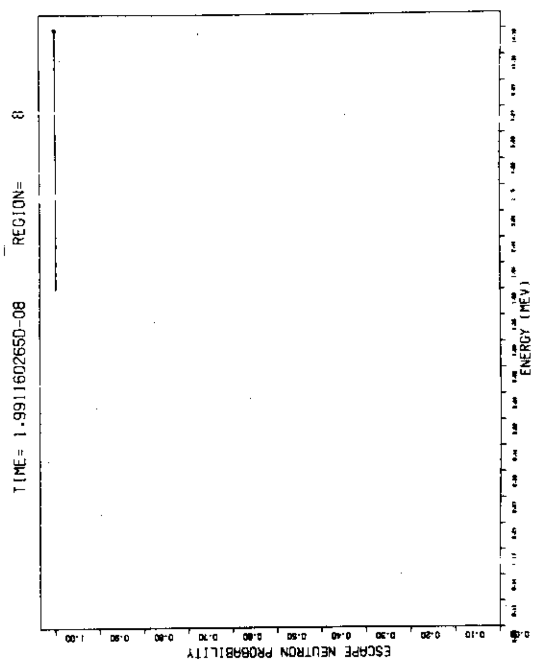

Fig. 13 Escape neutron probability depending on each energy group

Appendix A. Expressions for Various Terms in Energy Balance Equations

a) Thermal conductivity (H)

$$H = \frac{1}{\rho} \nabla \cdot k \nabla T \qquad \text{(A-1)}$$

where ρ is the density of plasma, T the temperature of plasma and k the thermal conductivity. The expressions for k by Spitzer[(5)] are given by

$$k_e = 1.83 \times 10^{-10}\ Te^{5/2}\ /\ (Z \log\Lambda) \qquad \text{(A-2)}$$

$$k_i = 4.30 \times 10^{-12}\ T_i^{5/2}\ /\ (M^{1/2} Z^4 \log\Lambda) \qquad \text{(A-3)}$$

$$\Lambda = 1.24 \times 10^7\ Te^{3/2}\ n_e^{-1/2}\ /\ Z \qquad \text{(A-4)}$$

where the subscripts e and i stand for the electron and ion, respectively, M the atomic mass number, Z the charge number and log Λ the Coulomb logarithm.

The electron thermal flux $Fe = k_e \nabla Te$ is limited by the so-called streaming limit.[(2)]

$$\frac{1}{Fe'} = \frac{1}{Fe} + \frac{1}{Fe,max} \qquad \text{(A-5)}$$

$$F_{e,max} = \frac{a}{4} n_e \overline{v_e}\ k\ T_e \qquad \text{(A-6)}$$

$$k_e' = k_e \left(1 + a \frac{\lambda_e}{T_e} \frac{dTe}{dx}\right)^{-1} \qquad \text{(A-7)}$$

$$\lambda_e = 7.92 \times 10^9\ T_e^2 / n_i Z^2 \log\Lambda \quad \text{(m)} \qquad \text{(A-8)}$$

where a is an adjustable constant for (Fe)max and λ_e the electron mean free path.

b) Electron-ion collisional exchange[(6)] (K)

$$K = \frac{\omega}{\rho} n_e(Ti-Te) = 0.59\times10^{-8} n_e(Ti-Te) Te^{3/2}\ \overline{M^{-1} Z^{-2}}\ \log\Lambda\ kM^{-1} m_H^{-1} \quad \text{(W/kg)} \qquad \text{(A-9)}$$

$$\omega = \frac{M^{-1}Z^{-2}\ e^4 n_i\ \log\Lambda\ m_e^{1/2}}{32\sqrt{2\pi}\ \varepsilon_o^2\ m_H}\ (k\ T_e)^{-3/2} \qquad \text{(A-10)}$$

c) Radiation loss[6] (J)

$$J = -\frac{Z^2 e^6\ n_e\ \overline{v_e}}{24\pi\xi_o^3 c^3 m_e m_H Mh} \qquad \text{(A-11)}$$

$$= -\ 8.5 \times 10^{-14}\ n_e(\delta T)^{1/2}\ \overline{Z^2 M^{-1}} \qquad \text{(A-12)}$$

where

$$\delta T = T_e - (n_e/n_e^o)^{\gamma_e - 1}\ T_e^o \qquad \text{(A-13)}$$

d) Laser absorption[7] (X)

$$X(r,t) = \frac{1}{dM}\,P_L(r,t)(1 - e^{-\alpha(R_o - r)}) \quad (W/kg) \qquad \text{(A-14)}$$

$$P_L(r,t) = P_L(R_o,t)\ e^{-\alpha(R_o - r)} \qquad \text{(A-15)}$$

$$\alpha = 13.5\ \lambda^{-2}\beta^2(1-\beta)^{-1/2}\ T_e^{-3/2}[5.05 + \log(\lambda T_e)]\bar{Z} \quad (m^{-1}) \qquad \text{(A-16)}$$

where $P_L(R_o,t)$ is the laser power incident on the plasma boundary at $r = R_o$, α the absorption coefficient,[7] λ the wavelength of laser light and $\beta = \rho/\rho_c < 1$. At the critical surface ($r=r_c$, $\rho=\rho_c$, $\omega_p=\omega_c$), the remaining laser power is all assumed to be absorbed.

e) Thermonuclear processes

$$-\frac{dN_D}{dt} = -\frac{dN_T}{dt} = \frac{dN_{^4He}}{dt} = \frac{dN_n}{dt} = N_D\ N_T\,\overline{(\sigma v)}_{DT} \qquad \text{(A-17)}$$

$$\frac{dN_D}{dt} = -\ N_D^{\,2}\,\overline{(\sigma v)}_{DD} - N_D N_T\,\overline{(\sigma v)}_{DT} - N_D N_{^3He}\,\overline{(\sigma v)}_{D^3He} \qquad \text{(A-18)}$$

$$\frac{dN_T}{dt} = - N_D N_T \overline{(\sigma v)}_{DT} + \frac{1}{4} N_D{}^2 \overline{(\sigma v)}_{DD} \tag{A-19}$$

$$\frac{dN_n}{dt} = \frac{1}{4} N_D{}^2 \overline{(\sigma v)}_{DD} \tag{A-20}$$

$$\frac{dN_{^3He}}{dt} = \frac{1}{4} N_D{}^2 \overline{(\sigma v)}_{DD} \tag{A-21}$$

where the reaction rates are given as the function of ion temperature as follows:

$$\overline{(\sigma v)}_{DT} = \begin{cases} 3.68 \times 10^{-18} \; T_i^{-3/2} \exp(-19.94 \times T_i^{-3/2}) \quad (m^3/sec) & \text{(A-22)} \\ 7.5 \times 10^{-22} \;, \qquad T_i > 35 \text{ keV} & \text{(A-23)} \end{cases}$$

$$\overline{(\sigma v)}_{DD} = 2.23 \times 10^{-20} \; T_i^{-2/3} \exp(-19.42 \; T_i^{-1/3}) \tag{A-24}$$

$$\overline{(\sigma v)}_{D^3He} = \begin{cases} 0 & \text{(A-25)} \\ 10^{-23} \;, \qquad T_i > 50 \text{ keV} & \text{(A-26)} \end{cases}$$

The charged reaction products H, T, ^3He and ^4He are assumed to deposit their energy locally to the ions and electrons in ratios as a function of T_e[8]:

$$P_{DT} = \frac{T_e}{T_e + 3.71 \times 10^8} \tag{A-27}$$

$$P_{DD} = \frac{T_e}{T_e + 1.2 \times 10^9} \tag{A-28}$$

$$P_{D^3He} = \frac{T_e}{T_e + 1.2 \times 10^9} \tag{A-29}$$

Then, the thermonuclear energy release is

$$Y_i = P_{DD}E_{DD}R_{DD} + P_{DT}E_{DT}R_{DT} + P_{D^3He}E_{D^3He}R_{D^3He} + \langle DE \rangle \tag{A-30}$$

$$Y_e = (1-P_{DD})E_{DD}R_{DD} + (1-P_{DT})E_{DT}R_{DT} + (1-P_{D^3He})E_{D^3He}R_{D^3He} \quad \text{(A-31)}$$

where E_{xx} is the energy of the charged reaction product, R_{xx} the total reaction rate and <DE> the energy deposition of the emitted neutrons.

f) Shock heating[9] (Q)

$$Q = - q \frac{dV}{dt} \quad \text{(A-32)}$$

where q is the viscous pressure expressed as

$$q = b^2 \frac{1}{2} \rho \, u \, \eta \quad \text{(A-33)}$$

$$\eta = (\partial r \nabla u)/(\partial r \nabla \cdot u) = r^{g-1} \partial u / \partial r^{g-1} u \quad \text{(A-34)}$$

g) Boundary condition

The MEDUSA code does not specifically allow for hollow shells, and the inner boundary conditions are $u(r=0) \equiv 0$ and zero thermal flux. At the outer boundary point $r = R_o$, the following four cases can be choosen:

(1) $\underline{P}(R_o) = 0$; zero thermal flux

(2) $u(R_o) = 0$; $T_i(R_o) = T_i(t)$; $T_e(R_o) = T_e(t)$

(3) $\underline{P}(R_o) = P(t)$; zero thermal flux

(4) $u(R_o) = u(t)$; zero thermal flux

h) Control of convergence by iteration for solving difference equations

The difference equations used in the calculation of MEDUSA are in the Lagrange formulation, i.e. in a reference frame moving with the plasma. For solving the difference equations, the arrangement of the space and time meshs are deviced for various basic quantities. Several iterations are performed on one time-step, because a non-linear dependence of the physical terms H, K, Y, J and X in Eqs.(18) and (19) on the temperature T_i and T_e. The difference equations are numerically solved with the explict and implict methods[10] as described in Ref.(2). The time-interval Δt for time step n are automatically determined by the following conditions:

$$\Delta t^{n+\frac{1}{2}} < a_1 \, M_{in} \left(\frac{R^n_{j+1} - R^n_j}{C^n_\ell} \right) \tag{A-35}$$

$$\Delta t^{n+\frac{1}{2}} \leq a_2 \, M_{in} \left(\frac{V^{n+1} - V^n}{V^{n+1} + V^n} \right)_\ell \Delta t^{n-1/2} \tag{A-36}$$

$$\Delta t^{n+\frac{1}{2}} \leq a_3 \, M_{in} \left(\frac{T_i^{n+1} - T_i^n}{T_i^{n+1} + T_i^n} \right)_\ell \tag{A-37}$$

$$\Delta t^{n+\frac{1}{2}} \leq a_4 \, M_{in} \left(\frac{T_e^{n+1} - T_e^n}{T_e^{n+1} + T_e^n} \right)_\ell \tag{A-38}$$

$$\Delta t^{n+\frac{1}{2}} \leq a_0 \, \Delta t^{n-\frac{1}{2}} \tag{A-39}$$

where a_1, a_2, a_3 and a_4 are respectively constants less than 1, a_0 the time-centering constant and C^n_ℓ the sound speed in cell ℓ. The smallest Δt satisfying these conditions is found and the iterations on T_i, T_e and u are performed by checking the following convergence conditions:

$$M_{ax} \left(\frac{|u^m - u^{m-1}|}{|u^m + u^{m-1}|} \right)_j^{n+1/2} \leq \delta u \tag{A-40}$$

$$M_{ax} \left(\frac{T_i^m - T_i^{m-1}}{T_i^m + T_i^{m-1}} \right)_j^{n+1/2} \leq \delta T_i \tag{A-41}$$

$$M_{ax} \left(\frac{T_e^m - T_e^{m-1}}{T_e^m + T_e^{m-1}} \right)_j^{n+1/2} \leq \delta T_e \tag{A-42}$$

where m indicates the iteration numbers.

Appendix B. Example of Input Date

```
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8

T E S T   1   2 0 / 9 / 1 9 7 8
S T E P  2   T E S T   1
C O 2   L A S E R L I G H T   O N   A   6 0
M G R M   5 0 - 5 0   D T   P E L L E T
*NEWRUN
       DELTAT=1,0E-13,
       LAMDA1=1,0E-5,
       LASER1(2)=1,5E9,
       LASER1(3)=2,0E-8,
       LASER1(4)=-2,0,
       LASER1(5)=2,0E-8,
       LASER1(6)=1,0E16,
       LASER1(7)=4,0E3,
        MESH=30,
        NLDUMP=F,
       NLFILM=F,
       NLHCPY=F,
       NLPFE=F,
        NRUN=1300,
        NPRNT=100,
       TEINI=1,0E3,
       TIINI=1,0E3,
       PIQ(31)=1,
       PIQ(32)=1,
       PIQ(33)=1,
       PIQ(34)=1,
       PIQ(35)=1,
       PIQ(36)=1,
        PIQ(42)=1,0,
        PIQ(43)=1,0,
        PIQ(44)=1,0,
        TSTOP=2,0-8,
        TIMEE(1)=6*2,0E-8,
        TIMES(1)=6*1,1E-8,
        NPLOT=10,
       NTYPE(1,1)=6*1,
       NTYPE(1,2)=6*2,
       NTYPE(1,3)=6*3,
       NTYPE(1,4)=6*4,
       NTYPE(1,5)=6*5,
       NTYPE(1,6)=6*6,
        OPT1=0,
        NLPLOT=T
*END
*PIJRUN
        NGR=8,
        NDR=10,
        NNR=1,4,7,10,13,16,18,20,25,30,
        YIELDS=1,0-3,
        NLPIJ=T
*END
```

Output data

```
&NEWRUN
AK0=  5.00000000000000000    ,AK1= 0.250000000000000000    ,AK2= 0.250000000000000000    ,AK3= 0.250000000000000000    ,AK4=
 0.250000000000000000    ,AK5= 0.0                      ,BNEUM=  1.00000000000000000    ,DELTAT= 0.100000000000000000D-12,DEUTER=
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  1.66666666666666667    ,GAMMAI=  1.66666666666666667    ,HELIU3= 0.0                     ,HELIU4= 0.0                    ,HYDROG=
 0.0                     ,LAMDA1= 0.100000000000000000D-04,NETRAL= 0.0                     ,NTRLMS= 0.0                    ,RHOINI=
  124.000000000000000    ,RINI= 0.480000000000000000D-03,SCP=  1.00000000000000000    ,SCR=  1.00000000000000000    ,SCRHO=
  1.00000000000000000    ,SCTE=  1.00000000000000000    ,SCTI=  1.00000000000000000    ,SCTIME=  1.00000000000000000    ,TEINI=
  1000.00000000000000    ,TIINI=  1000.00000000000000    ,TINUCL=  10000000.0000000000    ,TRITIU= 0.500000000000000000    ,TSTOP=
 0.200000000000000000D-07,XMASS=  1.00000000000000000    ,XTRA= 0.0                       ,XZ=  1.00000000000000000    ,MESH=          30,
NCASE=          1,NDUMP=          10,NFILM=          1,NGEOM=          3,NHDCPY=          100,NITMAX=          5,NP1=          1,
NP2=          40,NP3=          2,NPRNT=          100,NREP=          0,NLABS=T,NLBRMS=T,NLBURN=T,NLCRI1=T,NLDEPO=T,NLDUMP=F,NLECON=T,
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  4000.00000000000000    , 0.0                      , 0.0                      , 0.0                      , 0.0                   ,
 0.0                     , 0.0                      , 0.0                      , 0.0                      ,PI0= 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                      , 0.0                   ,
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 0.0                     , 0.0                      , 0.0                      , 0.0                      ,  1.00000000000000000  ,
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 0.0                     , 0.0                      , 0.0                      , 0.0                      , 0.0                   ,
  1.00000000000000000    ,  1.00000000000000000    ,  1.00000000000000000    , 0.0                      , 0.0                   ,
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NLEDGE=          30,NONLIN=          1,NOUT=          6,NPRINT=          6,NIN=          5,NPUNCH=          7,NRUN=          1300,
MXDUMP=          10,NADUMP=          0,          0,          0,          0,          0,          0,          0,          0,
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          0,          0,NPDUMP=          0,          0,          0,          0,          0,          0,          0,          0
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          0,          0,NVDUMP=          0,          0,          0,          0,          0,          0,          0,          0
          0,          0,          0,          0,          0,          0,          0,          0,          0,          0,
          0,          0,NLCHED=F,NLHEAD=F,F,F,F,F,F,F,F,NLOMT1=F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F
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NLOMT3=F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,F,NLREPT=F,TIMEE=
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 0.0                     , 0.0                      , 0.0                      , 0.0                      , 0.0                   ,
 0.0                     , 0.0                      , 0.0                      , 0.0                      , 0.0                   ,TIMES=
 0.110000000000000000D-07, 0.110000000000000000D-07, 0.110000000000000000D-07, 0.110000000000000000D-07, 0.110000000000000000D-07,
 0.110000000000000000D-07, 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                   ,MTIME=
        300,        600,        800,        900,       1000,       1100,        300,        600,        800,        900,
       1000,       1100,        300,        600,        800,        900,       1000,       1100,        300,        600,
        900,        300,        600,        900,          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,          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,          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,MTYPE=
          2,          2,          2,          2,          2,          2,          3,          3,          3,          3,
          3,          3,          4,          4,          4,          4,          4,          4,          5,          5,
          5,          6,          6,          6,          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,          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,          0,          0,          0,          0,          0,          0,
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        0.,          0.,          0.,          0.,          0.,          0.,          0.,          0.,          0.,          0.,
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       24.,         30.,          6.,         10.,         14.,         20.,         24.,         30.,          6.,         10.,
       14.,         20.,         24.,         30.,          6.,         10.,         14.,         20.,         24.,         30.,
        6.,         10.,         14.,         20.,         24.,         30.,          0.,          0.,          0.,          0.,
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        0.,          0.,          0.,          0.,          0.,          0.,          0.,          0.,          0.,          0.,
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       10.,NTYPE=          1.,          1.,          1.,          1.,          1.,          1.,          2.,          2.,          2.,
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        0.,          0.,          0.,          0.,          0.,          0.,          0.,          0.,          0.,          0.,
        0.,          0.,          0.,          0.,          0.,          0.,          0.,          0.,          0.,          0.,
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&END
&PIJRUN
NGR=          8.,NGA=          1.,NDR=          10.,NDA=          1.,NNR=          1.,          4.,          7.,          10.,          13
       16.,         18.,         20.,         25.,         30.,          0.,          0.,          0.,          0.,          0.,
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        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.,
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0.11000000000000000D-27, 0.13000000000000000D-27, 0.15500000000000000D-27, 0.18000000000000000D-27, 0.20000000000000000D-27,
0.22000000000000000D-27, 0.24000000000000000D-27, 0.26000000000000000D-27, 0.27000000000000000D-27, 0.28000000000000000D-27,
0.29000000000000000D-27, 0.30000000000000000D-27, 0.31000000000000000D-27, 0.31000000000000000D-27, 0.31500000000000000D-27,
0.31500000000000000D-27, 0.31500000000000000D-27, 0.32000000000000000D-27, 0.32000000000000000D-27, 0.32000000000000000D-27,SIGH=
0.75000000000000000D-28, 0.90000000000000000D-28, 0.11000000000000000D-27, 0.12500000000000000D-27, 0.14500000000000000D-27,
0.17500000000000000D-27, 0.21000000000000000D-27, 0.24000000000000000D-27, 0.27500000000000000D-27, 0.32000000000000000D-27,
0.36000000000000000D-27, 0.40000000000000000D-27, 0.44000000000000000D-27, 0.49000000000000000D-27, 0.53000000000000000D-27,
0.58000000000000000D-27, 0.62000000000000000D-27, 0.67000000000000000D-27, 0.85000000000000000D-27, 0.10000000000000000D-26,
0.11500000000000000D-26, 0.11500000000000000D-26,SIGHE3= 0.11000000000000000D-27, 0.13000000000000000D-27, 0.15000000000000000D-27
0.17000000000000000D-27, 0.19000000000000000D-27, 0.20000000000000000D-27, 0.21000000000000000D-27, 0.21500000000000000D-27,
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0.19000000000000000D-27, 0.19000000000000000D-27, 0.18000000000000000D-27, 0.18000000000000000D-27,SIGHE4= 0.12500000000000000D-27
0.14500000000000000D-27, 0.16000000000000000D-27, 0.18000000000000000D-27, 0.21500000000000000D-27, 0.23500000000000000D-27,
0.26000000000000000D-27, 0.30000000000000000D-27, 0.36500000000000000D-27, 0.49000000000000000D-27, 0.64000000000000000D-27,
0.73000000000000000D-27, 0.57000000000000000D-27, 0.33000000000000000D-27, 0.20000000000000000D-27, 0.14000000000000000D-27,
0.11000000000000000D-27, 0.91000000000000000D-28, 0.83000000000000000D-28, 0.80000000000000000D-28, 0.78000000000000000D-28,
0.78000000000000000D-28,SIGT= 0.11000000000000000D-27, 0.14000000000000000D-27, 0.16000000000000000D-27, 0.19000000000000000D-27,
0.22000000000000000D-27, 0.24000000000000000D-27, 0.25000000000000000D-27, 0.24000000000000000D-27, 0.22000000000000000D-27,
0.20000000000000000D-27, 0.19000000000000000D-27, 0.18000000000000000D-27, 0.17500000000000000D-27, 0.17000000000000000D-27,
0.16000000000000000D-27, 0.15000000000000000D-27, 0.14500000000000000D-27, 0.14200000000000000D-27, 0.14000000000000000D-27,
0.13500000000000000D-27, 0.13500000000000000D-27, 0.13500000000000000D-27,YIELDS= 0.10000000000000000D-02,NLPIJ=T,
&END
```

```
TIMESTEP NUMBER   900                 TIME =  1.9914406D-08                      DELTA T =  1.6902254D-14
                                 DELTA T DETERMINED BY CONDITION   3  AT MESHPOINT  18

BOUNDARY :  R = 9.0748D-03  U =  0.0          P = 1.0000D-16  TI = 0.0          TE = 0.0          SOUND SPEED = 7.4845D+05

ENERGIES :  THERMAL  1.00993D+04   KINETIC  3.39742D+03   NUCLEAR  2.12745D+04   ERROR -3.25947D+02   RHO R  3.35082D+00

FUSION   :  YIELD  5.29587D+00   NEUTRONS  7.48119D+15   RATE  1.33724D+28   ENERGY  1.11257D+04

DEPOSIT  :  ENERGY  5.78365D+03

RADIATION LOSS -3.32678D+02

    COORDINATES (M) *  1.000000D+00
 0.0         1.1792D-06  2.3106D-06  3.4211D-06  4.4927D-06  5.5108D-06  6.7085D-06  7.4408D-06  8.0909D-06  8.5598D-06
 8.9463D-06  9.3135D-06  9.7917D-06  1.0303D-05  1.0833D-05  1.1375D-05  1.1739D-05  1.2268D-05  1.3851D-05  3.4801D-05
 8.5642D-05  1.4066D-04  2.0688D-04  2.9093D-04  4.0255D-04  5.5695D-04  7.8188D-04  1.1327D-03  1.7299D-03  2.8933D-03

    HYDRODYNAMIC VELOCITIES (M/SEC) *  1.000000D+00
 0.0        -2.0197D+05 -2.6989D+05 -4.0784D+05 -5.8886D+05 -7.0163D+05 -8.4630D+05 -1.5088D+06 -2.4272D+06 -2.6133D+06
-3.1231D+06 -2.0433D+06 -8.2883D+05  2.6062D+05  1.1896D+06  2.3169D+06  2.3647D+06  1.2240D+06 -1.6986D+05  1.4955D+05
 8.1843D+05  1.0608D+06  1.1775D+06  1.2366D+06  1.2570D+06  1.2447D+06  1.1983D+06  1.1183D+06  1.0088D+06  8.9348D+05

    LOG(DENSITY  (KG/M**3) *  1.000000D+00 )
 5.48316     5.51442     5.53503     5.56245     5.59943     5.62313     5.66860     5.85661     6.04685     6.18404
 6.25507     6.17805     6.17581     6.18541     6.19611     6.39584     6.25731     5.76006     4.12087     2.99516
 2.47313     2.06452     1.68950     1.31648     0.92978     0.51142     0.04023    -0.50932    -1.18711    -2.73662

    LOG(HYDRODYNAMIC PRESSURE  (JOULE/M**3) *  1.000000D+00 )
18.23207    18.22980    18.23604    18.26423    18.29652    18.34998    18.48171    18.72574    18.93620    19.08316
19.13496    19.03903    19.02836    19.02103    19.00319    19.18118    18.95743    17.90906    15.27380    14.48276
13.99945    13.59708    13.22346    12.85025    12.46286    12.04325    11.57118    11.02033    10.34118     8.78986

    LOG(ION TEMPERATURE (DEGREE K) *  1.000000D+00 )
 9.05587     9.00122     8.97439     8.97128     8.95823     9.00252     9.13262     9.21147     9.24008     9.25468
 9.23363     9.21374     9.20630     9.18816     9.15049     9.11896     9.00308     7.96709     7.33075     7.50231
 7.36052     7.21023     7.06568     6.91972     6.76974     6.61035     6.43277     6.22727     5.97566     5.18860

    LOG(ELECTRON TEMPERATURE (DEGREE K) *  1.000000D+00 )
 8.76498     8.76735     8.77230     8.77900     8.78649     8.79445     8.80200     8.80591     8.80472     8.80096
 8.79137     8.78032     8.76887     8.75742     8.74515     8.73652     8.71126     8.52346     7.33493     7.78732
 7.89661     7.93949     7.96342     7.97862     7.98884     7.99583     8.00057     8.00365     8.00547     8.00703

    RELEASED THERMONUCLEAR ENERGY (ELECTRON) 5.32538D+01
 1.9108D-03  1.4510D-02  4.1193D-02  8.4417D-02  1.4986D-01  2.3430D-01  3.6098D-01  7.3773D-01  1.4838D+00  2.5378D+00
 3.7112D+00  3.6466D+00  4.3535D+00  5.1662D+00  6.5649D+00  1.2743D+01  1.1206D+01  2.1526D-01  6.5721D-05  2.9322D-05
 2.2650D-06  1.7251D-07  1.2150D-08  0.0         0.0         0.0         0.0         0.0         0.0         0.0

    RELEASED THERMONUCLEAR ENERGY (ION)         7.89655D+01
 2.8983D-03  2.2171D-02  6.3771D-02  1.3290D-01  2.4046D-01  3.8312D-01  5.9952D-01  1.2356D+00  2.4791D+00  4.2060D+00
 6.0250D+00  5.7763D+00  6.7209D+00  7.7735D+00  9.6142D+00  1.8324D+01  1.5184D+01  1.8161D-01  3.6032D-06  4.8207D-06
 4.7879D-07  4.0237D-08  2.9934D-09  0.0         0.0         0.0         0.0         0.0         0.0         0.0

    RELEASED NEUTRONS D-D REACTION              1.37520D+12
 4.4131D+07  3.0568D+08  8.3164D+08  1.7106D+09  2.9856D+09  5.0680D+09  9.7827D+09  2.2659D+10  4.7411D+10  8.2425D+10
 1.1600D+11  1.0927D+11  1.2728D+11  1.4516D+11  1.7205D+11  3.1658D+11  2.1423D+11  1.4119D+09  2.8793D+05  1.3449D+05
 1.1276D+04  9.1940D+02  6.9087D+01  0.0         0.0         0.0         0.0         0.0         0.0         0.0

    RELEASED NEUTRONS D-T REACTION              2.24649D+14
 8.1851D+09  6.2512D+10  1.7900D+11  3.7062D+11  6.6590D+11  1.0525D+12  1.6322D+12  3.3467D+12  6.7161D+12  1.1425D+13
 1.6503D+13  1.5979D+13  1.8782D+13  2.1956D+13  2.7478D+13  5.2810D+13  4.5001D+13  6.8141D+11  1.1891D+08  5.8586D+07
 4.7068D+06  3.6483D+05  2.5959D+04  0.0         0.0         0.0         0.0         0.0         0.0         0.0
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    RELEASED ENERGY D-D REACTION (NEUTRON)    5.42112D-01
1.7397D-05  1.2050D-04  3.2784D-04  6.7432D-04  1.1769D-03  1.9978D-03  3.8564D-03  8.9324D-03  1.8690D-02  3.2492D-02
4.5726D-02  4.3076D-02  5.0176D-02  5.7222D-02  6.7822D-02  1.2480D-01  8.4451D-02  5.5657D-04  1.1350D-07  5.3015D-08
4.4450D-09  3.6243D-10  2.7234D-11  0.0         0.0         0.0         0.0         0.0         0.0         0.0

    RELEASED ENERGY D-T REACTION (NEUTRON)    5.09659D+02
1.8569D-02  1.4182D-01  4.0609D-01  8.4082D-01  1.5107D+00  2.3877D+00  3.7030D+00  7.5925D+00  1.5237D+01  2.5920D+01
3.7440D+01  3.6251D+01  4.2612D+01  4.9810D+01  6.2338D+01  1.1981D+02  1.0209D+02  1.5459D+00  2.6978D-04  1.3291D-04
1.0678D-05  8.2768D-07  5.8892D-08  0.0         0.0         0.0         0.0         0.0         0.0         0.0

    FIRST COLLISION SLOWED DOWN NEUTRON       9.20113D+13
2.2484D+10  2.3167D+10  2.3885D+10  1.5655D+11  1.6177D+11  1.6745D+11  1.3742D+12  1.4969D+12  1.6407D+12  7.3457D+12
7.6075D+12  8.2567D+12  1.5503D+13  1.6449D+13  1.7146D+13  6.3955D+12  6.9896D+12  9.1781D+11  2.7479D+11  3.5373D+10
1.1507D+10  5.4067D+09  2.8934D+09  1.6278D+09  !.6600D+08  4.2587D+08  2.2449D+08  1.0779D+08  4.4098D+07  3.2129D+07

    SECOND COLLISION SLOWED DOWN NEUTRON      5.47675D+13
9.0889D+09  9.3710D+09  9.6647D+09  6.2367D+10  6.4447D+10  6.6723D+10  7.7742D+11  8.4714D+11  9.2857D+11  4.7843D+12
4.9465D+12  5.3582D+12  1.0170D+13  1.0780D+13  1.1265D+13  2.0150D+12  2.2079D+12  3.3775D+11  1.0112D+11  1.6217D+10
5.2754D+09  2.4787D+09  1.3264D+09  7.4625D+08  3.5118D+08  1.9524D+08  1.0292D+08  4.9416D+07  2.0217D+07  1.4729D+07

    FIRST COLLISION DEPOSIT NEUTRON ENERGY    8.28686D+01
2.0263D-02  2.0878D-02  2.1525D-02  1.4112D-01  1.4582D-01  1.5094D-01  1.2400D+00  1.3507D+00  1.4805D+00  6.6115D+00
6.8471D+00  7.4315D+00  1.3929D+01  1.4779D+01  1.5406D+01  5.8064D+00  6.3458D+00  8.3706D-01  2.5061D-01  3.2262D-02
1.0495D-02  4.9311D-03  2.6388D-03  1.4846D-03  6.9862D-04  3.8841D-04  2.0474D-04  9.8306D-05  4.0219D-05  2.9303D-05

    SECOND COLLISION DEPOSIT NEUTRON ENERGY  2.95100D+01
4.7260D-03  4.8729D-03  5.0257D-03  3.2536D-02  3.3621D-02  3.4808D-02  4.1225D-01  4.4923D-01  4.9241D-01  2.5883D+00
2.6759D+00  2.8986D+00  5.4954D+00  5.8252D+00  6.0875D+00  1.0625D+00  1.1643D+00  1.7574D-01  5.2616D-02  8.7377D-03
2.8424D-03  1.3355D-03  7.1470D-04  4.0208D-04  1.8922D-04  1.0520D-04  5.5454D-05  2.6626D-05  1.0893D-05  7.9363D-06

    FIRST COLLISION NEUTRON ENERGY LOSS       8.28665D+01
1.5797D-03  1.2065D-02  3.4546D-02  7.1512D-02  1.2849D-01  2.0307D-01  5.1186D-01  1.0495D+00  2.1059D+00  5.5538D+00
8.0233D+00  7.7690D+00  9.0951D+00  1.0631D+01  1.3306D+01  1.3149D+01  1.1206D+01  1.3923D-02  2.4296D-06  3.8937D-08
3.1282D-09  2.4247D-10  1.7253D-11  0.0         0.0         0.0         0.0         0.0         0.0         0.0

    SECOND COLLISION NEUTRON ENERGY LOSS      2.95099D+01
3.8030D-03  3.9185D-03  4.0400D-03  2.6137D-02  2.7007D-02  2.7956D-02  3.4752D-01  3.7855D-01  4.1493D-01  2.6012D+00
2.6939D+00  2.9238D+00  5.4790D+00  5.8131D+00  6.0596D+00  1.2817D+00  1.4008D+00  1.7489D-02  5.2361D-03  2.1104D-05
6.8652D-06  3.2257D-06  1.7262D-06  9.7115D-07  1.6565D-08  9.2094D-09  4.8545D-09  2.3309D-09  9.5362D-10  6.9963D-11

    ESCAPE NEUTRON SPECTRUM BY GROUP          1.83762D+14
1.3262D+14  1.1274D+13  9.4313D+12  7.7419D+12  6.3119D+12  5.1787D+12  4.2294D+12  2.7765D+12  1.8345D+12  1.3636D+12
1.0022D+12  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
0.0         0.0

    TOTAL NEUTRON SPECTRUM BY GROUP  . 1.83762D+14
1.3262D+14  1.1274D+13  9.4313D+12  7.7419D+12  6.3119D+12  5.1787D+12  4.2294D+12  2.7765D+12  1.8345D+12  1.3636D+12
1.0022D+12  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
0.0         0.0

    TOTAL RELEASED NEUTRON                    2.26024D+14
8.2292D+09  6.2818D+10  1.7983D+11  3.7233D+11  6.6889D+11  1.0575D+12  1.6420D+12  3.3693D+12  6.7635D+12  1.1507D+13
1.6619D+13  1.6088D+13  1.8910D+13  2.2101D+13  2.7650D+13  5.3127D+13  4.5216D+13  6.8282D+11  1.1920D+08  5.8720D+07
4.7181D+06  3.6575D+05  2.6028D+04  0.0         0.0         0.0         0.0         0.0         0.0         0.0

    TOTAL RELEASED NEUTRON ENERGY             5.10201D+02
1.8587D-02  1.4194D-01  4.0642D-01  8.4149D-01  1.5119D+00  2.3897D+00  3.7068D+00  7.6015D+00  1.5255D+01  2.5952D+01
3.7485D+01  3.6294D+01  4.2662D+01  4.9868D+01  6.2406D+01  1.1993D+02  1.0218D+02  1.5465D+00  2.6989D-04  1.3297D-04
1.0683D-05  8.2804D-07  5.8919D-08  0.0         0.0         0.0         0.0         0.0         0.0         0.0

    TOTAL SLOWED DOWN NEUTRON                 9.20113D+13
2.2484D+10  2.3167D+10  2.3885D+10  1.5655D+11  1.6177D+11  1.6745D+11  1.3742D+12  1.4969D+12  1.6407D+12  7.3457D+12
7.6075D+12  8.2567D+12  1.5503D+13  1.6449D+13  1.7146D+13  6.3955D+12  6.9896D+12  9.1781D+11  2.7479D+11  3.5373D+10
1.1507D+10  5.4067D+09  2.8934D+09  1.6278D+09  7.6600D+08  4.2587D+08  2.2449D+08  1.0779D+08  4.4098D+07  3.2129D+07
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TOTAL DEPOSIT NEUTRON ENERGY 1.12379D+02

2.4989D-02	2.5751D-02	2.6551D-02	1.7365D-01	1.7944D-01	1.8575D-01	1.6522D+00	1.7999D+00	1.9729D+00	9.1998D+00
9.5231D+00	1.0330D+01	1.9425D+01	2.0604D+01	2.1493D+01	6.8689D+00	7.5101D+00	1.0128D+00	3.0323D-01	4.0999D-02
1.3337D-02	6.2666D-03	3.3535D-03	1.8867D-03	8.8784D-04	4.9361D-04	2.6019D-04	1.2493D-04	5.1112D-05	3.7239D-05

TOTAL NEUTRON ENERGY LOSS 1.12376D+02

5.3827D-03	1.5983D-02	3.8586D-02	9.7648D-02	1.5549D-01	2.3103D-01	8.5938D-01	1.4281D+00	2.5209D+00	8.1550D+00
1.0717D+01	1.0693D+01	1.4574D+01	1.6445D+01	1.9366D+01	1.4431D+01	1.2607D+01	3.1412D-02	5.2385D-03	2.1143D-05
6.8684D-06	3.2259D-06	1.7262D-06	9.7115D-07	1.6565D-08	9.2094D-09	4.8545D-09	2.3309D-09	9.5362D-10	6.9963D-11

ESCAPE NEUTRON PROBABILITY BY GROUP

7.8529D-01	7.8530D-01	6.4996D-01	4.6212D-01	4.6669D-01	7.2313D-01	9.7749D-01	9.9927D-01	9.9997D-01	1.0000D+00
7.3828D-01	7.3976D-01	5.8879D-01	3.9896D-01	4.0316D-01	6.7513D-01	9.7180D-01	9.9910D-01	9.9997D-01	1.0000D+00
7.0360D-01	7.0649D-01	5.4684D-01	3.5963D-01	3.6356D-01	6.4170D-01	9.6738D-01	9.9897D-01	9.9996D-01	1.0000D+00
6.6338D-01	6.6829D-01	5.0140D-01	3.2023D-01	3.2388D-01	6.0475D-01	9.6200D-01	9.9882D-01	9.9996D-01	1.0000D+00
6.2213D-01	6.2955D-01	4.5823D-01	2.8536D-01	2.8876D-01	5.6879D-01	9.5625D-01	9.9865D-01	9.9995D-01	9.9999D-01
5.9164D-01	6.0114D-01	4.2829D-01	2.6256D-01	2.6592D-01	5.4291D-01	9.5170D-01	9.9852D-01	9.9994D-01	9.9999D-01
5.7193D-01	5.8292D-01	4.0984D-01	2.4891D-01	2.5221D-01	5.2672D-01	9.4870D-01	9.9843D-01	9.9994D-01	9.9999D-01
5.6394D-01	5.7562D-01	4.0269D-01	2.4352D-01	2.4666D-01	5.2083D-01	9.4764D-01	9.9840D-01	9.9994D-01	9.9999D-01
5.6059D-01	5.7268D-01	3.9996D-01	2.4116D-01	2.4402D-01	5.1939D-01	9.4751D-01	9.9840D-01	9.9994D-01	9.9999D-01
5.5423D-01	5.6710D-01	3.9481D-01	2.3677D-01	2.3909D-01	5.1667D-01	9.4724D-01	9.9839D-01	9.9994D-01	9.9999D-01
5.4673D-01	5.6053D-01	3.8879D-01	2.3171D-01	2.3343D-01	5.1352D-01	9.4693D-01	9.9839D-01	9.9994D-01	9.9999D-01