EUR 4497 e

COMMISSION OF THE EUROPEAN COMMUNITIES

COSTAX - BOIL

A COMPUTER PROGRAMME OF THE COSTANZA SERIES FOR THE AXIAL DYNAMICS OF BWR AND PWR NUCLEAR REACTORS

by

G. FORTI

1970

Joint Nuclear Research Center
Ispra Establishment - Italy
Reactor Physics Department
Reactor Theory and Analysis

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Doppler and void reactivity feedback are accounted for pointwise. A flexible input allows representation of reactivity transients, flow recirculation or inlet enthalpy transients, or an arbitrary mixture of them, including control rod bank movement. No pressure variation is possible in the present version The programme is intended for the analysis of intermediate accidents or severe operational transients in which a detailed spatial reprensentation is essential.

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ABSTRACT

Costax-Boil is a FORTRAN programme for transient analysis of BWR in the time domain. It couples the two velocity groups neutron diffusion kinetic calculations (up to 10 delayed neutron groups) in one dimension (axial) with the heat conduction equations in the fuel rods and a two phase flow dynamics calculation for the typical coolant channel. Doppler and void reactivity feedback are accounted for pointwise. A flexible input allows representation of reactivity transients, flow recirculation or inlet enthalpy transients, or an arbitrary mixture of them, including control rod bank movement. No pressure variation is possible in the present version The programme is intended for the analysis of intermediate accidents or severe operational transients in which a detailed spatial reprensentation is essential.

KEYWORDS

FORTRAN
ANALYSIS
BWR
NEUTRON
DIFFUSION
DOPPLER EFFECT
TRANSIENTS
COOLANT LOOPS

Contents

1 - Purpose *)

The Costax-Boil programme has been developed for the analysis of those transients of thermal nuclear power reactors for which the spatial effects in the axial direction are of essential importance, either because of neutronic behaviour in itself (high reactivity accidents) or because of localized reactivity feedbacks such as void feedback for BWR or PWR in accident situations. It is built by coupling the neutronic spatial kinetics in plane geometry and two energy groups to the thermal conduction equations in the fuel elements and the two phase flow thermohydrodynamics of the typical coolant channel by means of Doppler, void, and liquid coolant temperature feedback evaluated pointwise.
Any kind of transient problem may be analized by the code, except those that imply a relevant variation of the general pressure level of the reactor core, as the thermohydraulic model is limited to constant physical properties of the coolant in the present version. The input allows scheduled time variations of general or local reactivity, or control rod insertion, freely combined with scheduled coolant flow rate and inlet temperature variations. The assumption that coolant physical properties are independent of space and time limits the applicability of the programme to those reactors in which the pressure drop across the core is not relevant compared to the general pressurization level. This condition is generally fairly met by PWR and BWR power plants.

Manuscript received on 22 April 1970

2 - Structure of the programme

Each transient problem treated is started from an initial condition of equilibrium in which the reactor is critical in some configuration, keeping into account all the power feedbacks in the stationary state. Then time dependent perturbations are introduced in any of the available input parameters and the dynamic calculation is started and goes on up to a specified final time.
Therefore at the beginning of each problem the programme enters a starting up procedure that is articulated as follows:

a) After the reading out of the data and some preliminary calculations, assuming a flat power distribution, a stationary calculation of the average coolant channel is performed, and the map of the results is printed; the fuel temperatures, coolant temperatures and void distribution are used to calculate pointwise the feedback for neutron equations.

b) A fixed number of time steps in neutron diffusion kinetics (without delayed neutrons) are taken, starting from flat fluxes and using the neutronic constants given in input modified by the feedbacks obtained in a). The fluxes are normalized to give the prescribed initial power. This allows a first rough shaping of the fluxes. This first map of fluxes is printed.

c) The criticality search is made, varying a chosen parameter (see options). Each iteration consists of a kinetic time step corresponding to the same time increment Δt used in b), after which a new channel stationary calculation is performed with the new power distribution, and the new feedback is evaluated. A number of time steps (up to 10) are then taken in the new condition to obtain a stable period in the new configuration; the reciprocal of the period is the objective value that has to be reduced to zero during the search by varying the parameter. The search is started with the parameter equal to zero, and the second iteration with a guess value given in input. In the following iterations the parameter is varied on the basis of the last two values obtained of the reciprocal of the period by linear interpolation or extrapolation, until the reciprocal of the period is smaller than a given criterium in absolute value. The converged fluxes are then utilized to calculate the delayed neutron precursors concentrations at equilibrium condition and the complete stationary conditions for the cooling channels, including pressure drops in the channel and the riser. A final complete print of stationary results is made and this concludes the static part of the problem which may be utilized also in itself.

Then the dynamic calculation begins. Time step after time step in the neutronic calculation the current value of the nuclear perturbation parameters are interpolated in the input tables, and the same applies, whenever a thermohydraulic step is called for after a fixed number of neutronic steps, to the inlet velocity and subcooling variables when it is the case. The last current distribution of fluxes is the source for the power generation in the fuel rods at each thermal step, and the last values of the temperature and void distribution give the feedback for all the neutronic steps between two successive thermal steps. A flexible printing pattern is available for synthetic or detailed output of the results along the time.

3 - Physical and numerical models and available options of the programme

The physical model for the neutronic part is fundamentally unchanged from the last published code of the Costanza series, (EUR 3633 e) not considering minor improvements. The heat conduction and hydrodinamic model is illustrated in EUR 4052 e and the corresponding computer programme is EUR 4241 e.
The feedback is represented locally pointwise as a reactivity factor that multiplies the neutron production cross section (fast and thermal) in the form $\nu\Sigma_f = (1+\delta k)\,\nu\Sigma_f$ nominal

δk is given as the sum of three contributions

$$\delta k = \delta k_D + \delta k_\alpha + \delta k_{T_l}$$

δk_D is the Doppler feedback and is given as function of the average fuel temperature (three functional forms are possible, see input key) and of the void fraction

$$\delta k_D = f(T_f, T_{ref})\, e^{a\alpha}$$

(α is defined as the volume fraction of the coolant channel occupied by vapour)

δk_α is given as a quadratic function of the void fraction $\delta k_\alpha = a\alpha + b\alpha^2$ or may be given as a tabulated function of α

δk_{T_l} is a quadratic function of the liquid coolant temperature $\delta k_{T_l} = a\,(T_l - T_{l\,ref}) + b\,(T_l - T_{l\,ref})^2$

A multiple option is available for the criticality search. The search parameter may be a factor for all the $\nu\Sigma_f$ cross section, giving a conventional k_{eff} search (the k_{eff} found at convergence will be printed in the output in this case). Alternatively the search parameter may be chosen as a poison absorption cross section to be added in any region of the reactor or in any combination of regions; a fixed ratio between thermal and epithermal poison cross section is to be given in input, so that the search is performed, as it must. on a single parameter. As a third alternative, the search parameter may be the depth of insertion of a control rod bank. In this case the bank is represented by a specified thermal and epithermal cross sections and the direction of the rod insertion (parallel or antiparallel to the coolant flow) is specified at will. In the steady state channel calculation, different options are available on fuel geometry, and on other matters. We omit here the details, as they are easily understood from the analytical input description in appendix; they reproduce essentially the features of the FRANCESCA code (EUR 4241 e) except that no coolant inlet velocity search is admitted, so that coolant flow rate must be given either directly or indirectly by specifying the output quality in the steady state condition.

The nuclear perturbation during transient is given as a time table. A double alternative of options is available. As for the nature of the perturbation, this is either a poison absorption cross sections insertion or a δk insertion, by the latter meaning that a factor $(1 + \delta k)$ effects the $\nu \Sigma f$ cross sections. The modality of the perturbation may be a diffused insertion in any zone or combination of zones (obtained by zone weighting of the perturbation) or a bank rod movement represented as a shifting boundary.
In the latter case the direction of insertion for the rod bank is specified at will.

In the dynamic channel calculation, the same features are present that in the already mentioned FRANCESCA code. The main option concerns the inlet flow rate of coolant, that may be either given as a time schedule, or calculated by the programme as it follows from the dynamic conditions taking into account the specifications for the driving pressure. For the details here also the reader is referred to the analytic description of the input (and to the quoted report EUR 4241 e).

4- Directions and suggestions for the user of the code

The whole programme, aiming to provide a practical tool for calculations is, as it happens in such cases, a rather intricate machinery, and the author is unable to give a complete description of its working that, to be useful, should be more readable that the FORTRAN listing itself. A real know how of its functioning and possibilities can best be gained by using it in practical cases. The input key given in appendix should be the essential guide to the use of the code; as however the author is well aware that many items may not be clear to the user, care was taken in framing the input, so that whenever a puzzled user omits an indicator, or even a parameter whose definition looks obscure, the code automatically selects what in the author's opinion is best or more convenient in the majority of cases. Of course no sensible answer can be expected if essential logical or numerical information is missing.
A specific direction is given now about the use of DATA (1700). In a problem implying a rod drop, a scram or anyway the movement

of a bank of rods, it may be important to represent the rod starting from a specified position, inside the core. On the other hand, the programme is so conceived that it must start from an equilibrium condition; therefore the time zero insertion value has in the programme a double effect: a rod specified as the negative counterpart of the rod to be moved is positioned permanently at the position specified, while the actual rod is set in the same position to be subsequently moved. The net effect at time zero is nil, as it should be, and a net effect will appear only when the rod is moved. If the user wants to represent the sudden appearance, of a rod in a given position at the time zero, he should give DATA (1700) as zero and give the wanted position as DATA (1701) corresponding to a successive time smaller than the calculation time step, as this will produce the desired effect.
Some observations on the general use of the programme follow. When in a problem one tries to represent an actual transient in a real reactor, one will find always some difficulty in adapting the one dimensional model to the real case. In our opinion the best way of proceeding should be the following. First the best guess at the reactor starting configuration should be worked out, and the problem run as a stationary one with δk search. Observing the results will permit to adjust, if it is required, the poison cross sections or the boundaries of the regions to have a better matching with the real situation. A stationary problem will generally take less than one minute of machine time on a IBM 360/65. When satisfactory results are obtained for the stationary situation the time dependent perturbation should be introduced, and the complete transient calculated.

Sometimes it may even be useful to run a short transient without any perturbation, to check the equilibrium condition. In normal siatuations, everything should stay constant, or change irrelevantly. A fluctuation however will not necessarily indicate that something in the calculation is wrong; it may happen that the system is physically in an unstable situation, and in this case the numerical errors are sufficient to start an oscillation. The reader must be aware the convergence of the iteration process that leads to the equilibrium condition is not theoretically proved; all that can be safely said is that we always found it to converge when the physical problem was a sound one. Starting from an initial configuration which is very far from critical, it may happen that the iteration process produces negative fluxes. When this happens, no recovery of the iteration process is possible and the programme will be stopped by some diagnostic (typical is the square root of a negative number, occurring in the feedback calculation because of negative fuel temperature). In such cases, the first thing to do is a careful scrutiny of the input, to detect unphysical conditions (negative absorption cross sections, wrong order of magnitude of nuclear data, inconsistent geometry, and so on). If everything is all right, but the reactor is too far from criticality, altering beforehand the $\nu\Sigma_f$ data by a common factor, so that the problem becomes more manageable is a good move, and the following one is to decrease the time increment Δt for initialization (DATA 11). A better second guess for criticality parameter is also helpful. In our experience a physically well posed problem has always converged satisfactorily, sometimes after some trials. The convergence is easier for δk search, it may be more difficult when control rod insertion is the search parameter. This is easy to understand, if it is considered that in BWR problems it may very well happen that two rod positions are critical at the same time, because of the interaction between flux shape and voids, through void coefficients. In this case the iteration process may succeed in finding one of the two equilibrium positions or it may oscillate among the two, or even diverge. In such cases the rod position should be fixed in input (utilizing region constants definition) and the search made on δk.

Generally, when a problem is well posed, the number of iterations for criticality search should be below 50, very often below 20. When a small Δt has been used, it may happen that the maximum number of iterations is exceeded. The solution often is nevertheless good, but in this case the trial of an unperturbed dynamic run is advisable. Should the results be unsatisfactory, the static problem may be repeated altering the $\nu \Sigma f$ cross sections and with a wider time step for initialization.

A warning is also given against the tentation to use always the full capacity of the programme (100 mesh points). This is most of the time a pure waste of machine time, and may make things more difficult. In our experience, 50 mesh points in most cases is all what is needed, and very often 30 give a more than adequate representation. The reader should bear in mind that, also when the static problem is used for its own sake, the goal is to reach a fair representation of flux shape and heat fluxes, and by no means the exact determination of k_{eff}, for which a one dimensional tool is clearly insufficient. Very often a mesh size of the order of 10 cm has been found quite adequate for power reactors.

5 - Output

The output of the programme is largely selfexplanatory. The input data are first printed. Then the delayed neutron groups composition is shown.

A summary of the coolant channel characteristics follows with the results of the thermal calculation corresponding to a flat distribution of power; the pressure drop appears as zero, as the calculation is not yet performed at this stage.

Then the first map of fluxes is printed, which corresponds to the first initialization step, performed with the feedback corresponding to the flat thermal calculation. The power column is normalized to the average value of the power and the average is given in watt per cm of height of one single average channel. The averages appearing in the DK columns are weighted on the square of power, for best comparison with point models.

Then the criticality search results are printed; a complete map of the neutronic and thermal results for the equilibrium state is given. Then the output of the dynamic calculation follows: the printing pattern is freely chosen by the user among three possibilities: complete maps of values, average on regions and global values. In the print of region values FLM1 indicates average fast flux in the region, FLM2 average thermal flux and AVPO average power in regions relative to mean power. By PINT is indicated the total integrated power in Joule. The map of channel results gives for each axial mesh the following items: Power/cm POW, Heat flux FI, vapour quality Q, void fraction VF, temperature of the cladding surface TSUR, inner temperature of the cladding TICL, average temperature of the fuel AVTF, maximum (central point) temperature of the fuel TMAXF and liquid coolant temperature TL. If a riser is present, the void fraction is given, while the quality is printed as zero, because it is not memorized.

The Sample problem output in appendix is an illustrative case of a reactor which is not boiling in the nominal condition. There is no perturbation, and the dynamic calculation shows practical equilibrium, up to 0.5 seconds, then a pump trip is simulated, followed by a scram.

6 - Input form

Many problems may be executed in one run. For every problem the first input card is a title card, in which any alphamerical information may appear in columns from 7 to 70 included. This title will appear in the output - a 1 in column 6 means that the problem is the last of the run.
A vector of 3500 memory positions DATA (1) to DATA (3500) contains all the data in floating point form (Internal conversion is performed by the code when needed). Since entire groups of memory positions are zero, it is possible to read different sets of significant data; each set must be preceded by a card containing the integers Ki_1, Ki_2 defining the first and last datum of the set. Ki_1 and Ki_2 are given in integer form adjusted to the right at columns 12 and 24. The last set of a problem is indicated by -1 in columns 1 and 2. The data of each set are all in floating form (FORTRAN FORMAT E 12.8). Any number of problems may be run in sequence and only the data changing from the preceding problem need to be given. A title card must be present for each problem. The key to the input is given in appendix A.

7 - Computer specifications and programme's performance

The programme has been assembled at the CETIS computing center at Ispra on IBM 360/65 in FORTRAN H 360 optimization level 2, except the routine FUELS, for which the optimization level 0 has been employed, as it was found that level 2 gave unexplained execution errors due to bad compilation. The programme will be available at the CETIS nuclear code group - Ispra. The running time is somewhat difficult to assess, as it depends on many items. An average problem of 50 mesh points will require of the order of the minute on 360/65 for every 1000 neutronic time steps and about 2 minutes for every 1000 thermal steps. The stationary calculation will generally require less than 1 minute in the whole. A typical problem may require in total around 5 minutes.

The programme has been extensively tested and used by the author in many different ways, and no logical mistake has ever been detected. As the combination of available options is unusually large, no absolute statement can be made that the code will work correctly in all the possible consistent uses, but the author is pretty confident it should. Physically, the inner consistency has been carefully checked; the neutronic part of the calculation have been tested in straight-forward cases where the analytical solution may be calculated with nearly perfect agreement. The channel calculations had also been checked at it was mentioned in the FRANCESCA code report (EUR 4241 e). The code has been used for the calculation of an experimental pump trip case for the Lingen BWR power plant built by AEG for which the data were available, with surprisingly good agreement.

We want here to thank Dr. Wolff of the AEG and the methods group of AEG headed by Dr. Schmidt for the helpful suggestions and criticism and the opportunity of access to real plant data and problems in the frame of a fruitful collaboration.

References

EUR 3633 e "The codes COSTANZA for the dynamics of liquid-cooled nuclear reactors"

G.FORTI and E.VINCENTI, 1967.

EUR 4052 e "A dynamic model for the cooling channels of a boiling nuclear reactor with forced circulation and high pressure level"

G.FORTI, 1968.

EUR 4241 e "FRANCESCA, A dynamic program for boiling cooling channels"

G.FORTI, 1969.

APPENDIX A

COSTAX - BOIL

INPUT KEY

Title card (bbbbbb any title) a 1 in column 6 means that the problem is the last of the run.

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
1	DELT	Δt for transient calculation	sec	1/15 of minimum expected period generally gives good results.
2	DZ	ΔZ mesh width	cm	
3	IMAX	Number of mesh points	-	up to 100
4	NREG	Number of regions	-	up to 12
5	NRIT	Number of delayed neutron groups		up to 10
6	IDST	Number of steps for initialization	-	30 is suggested
7	ITCR	Put always 1	-	
8	IDIR	Search indicator - 1 Search for δK_{eff} 0 Poison search 1 Control rods inserted from top (entry of the coolant) 2 Control rods inserted from bottom	-	
9	SI	Area of the core cross section	cm^2	This value is employed to normalize the neutronic fluxes to the given total power for the whole reactor.
10	BU	Transversal Buckling	cm^{-2}	
11	DELT	Δt for initialization	sec	10^{-4} is suggested
12	POWER	Steady state power of the reactor	watt	
13	ICAN	Number of channels in the core The power given to the average channel will be PØWER/ICAN	-	Put 0 if no channel calculation is wanted
14	KPC	Thermal calculation will be made every KPC neutronic time steps	-	Omit of no channel is represented

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
15	IDOP	Doppler feedback indicator 0 $\delta K_D = b(e^{a(\sqrt{T}-\sqrt{T_o})}-1)e^{(DATA(19)\times\alpha)}$ -1 $\delta K_D = a(T-T_o)+b(T-T_o)^2$ +1 $\delta K_D = a(\sqrt{T}-\sqrt{T_o})$	-	
16	TDOPP	Reference temperature T_o of the fuel for Doppler feedback	Kelvin	°C may also be employed if IDOP = -1
17	TREF	Reference temperature for liquid coolant temperature feedback	Kelvin	All temperature should be given in the same unit, so °C may be used if the square root formulae are not employed for Doppler feedback
19		Coefficient in void dependent Doppler feedback (see DATA (15))		
31-40	BETA	β_i Delayed neutrons precursors yield per fission	-	
41-50	DLI	λ_i Delayed neutron precursors decay constants	sec^{-1}	
61-73	I1, I2	Region boundary mesh numbers	-	The first value must be 1 and the last IMAX

REGIONS CONSTANTS

First region

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
81	D1	D_f Fast group diffusion coefficient	cm	
82	SR	$\Sigma_r = \Sigma_{sd} + \Sigma_{af}$ Total removal cross section from fast group	cm^{-1}	
83	SSD	Σ_{sd} Slowing down cross section from fast to thermal	cm^{-1}	
84	SF1	$\nu\Sigma_{f_1}$ Fast neutron production cross section	cm^{-1}	
85	W	Fast group neutron velocity	cm/sec	
86	PFAC1	$E_1 \Sigma_{f_1}$ Fission energy production cross section for group 1	joule/cm	
87	D2	D_{th} Thermal group diffusion coefficient	cm	
88	SA	Σ_{a_2} Thermal group absorption cross section	cm^{-1}	
89	SF	$\nu\Sigma_{f_2}$ Thermal neutron production cross section	cm^{-1}	
90	V	Thermal group neutron velocity	cm/sec	
91	$PFAC_2$	$E_2 \Sigma_{f_2}$ Fission energy production cross section - group 2	joule/cm	
92	-	Not used		
93-104		Same constants for second region etc...		

Only for ICAN>0
Omit if no coolant channel is present-Neutronic calculation will be executed without feedback.

Feed-back coefficients

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
300	ICI	If 0 the feedback coefficients are equal in all the regions. If 1 they are given regionwise		
301	ALDOP	a in Doppler feedback formula		see Data (15)
302	BEDOP	b in Doppler feedback formula		Units depend on formula-Temperature in Kelvin or °C
303	AVOID	a in void feedback formula $\delta k_v = a\alpha + b\alpha^2$		May be omitted, if the void feedback is given as a table (see DATA (1000))
304	BVOID	b in void feedback formula		
305	ACOCO	a in liquid coolant temperature feedback $\delta k_T = a(T-TREF) + b(T-TREF)^2$	$°C^{-1}$	
306	BCOCO	b in coolant feedback formula	$°C^{-2}$	
307–312		Same for 2nd region etc..		Only if DATA (300)>0

450	ICORE	Mesh number of the beginning of the core	-	First node of the active channel, if channel is present If omitted, the code will take 1
451	NCORE	Mesh number of the end of the core		If omitted, the code will take IMAX

Integer channel data

Only if ICAN > 0

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
452	NF	Number of radial meshes in the fuel for thermal conduction		up to 10
453	IP1	Full print of thermal data every IP1 restricted prints		
454	ISTD	If 1. Standard formulae for water are selected		
455	ITIPO	0. Cylindrical fuel element 1. Slab element -1. General geometry		
456	IVAR	0. Thermal parameters in fuel are constant 1. Variable parameters (functions of temperature)		
457	JPØW	0. → Constant power density along the thickness of the fuel element 1. → Power in radial zones given in input -1. → Power is the same in all radial zones		
458	IOR	0. → No operation 1. → Orificing at the inlet of the channel is calculated to match a given pressure drop in the steady state		
459	IVIN	0. Inlet velocity of the channel is calculated by the code during the transient 1. Inlet velocity is tabulated as a function of time		

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
460	IEX	0. Driving pressure is a function of the inlet velocity $\Delta p=\Delta p_0+a(v-v_0)+b(v-v_0)^2$ 1. Driving pressure is tabulated as function of time		Only if IVIN = 0
461	IFRIC	Two phase friction multiplier selector 0. $TPM=1+ax+bx^2$ (x=vapour quality) -1. $TPM=1+a\alpha+b\alpha^2$ (α =void fraction) +1. $TPM=1.+a\chi+b\chi^2$ (χ =TMART $\frac{x}{1-x}$) +2. $TPM=1.+a\chi^{-1}+b\chi^{-2}$		
462	IRIS	Number of meshes in the riser (put zero if no riser)		up to 10
463-465	KRIS	Index of the riser meshes where local friction loss is present		
466		leave blank		
467	IDF	Geometry indicator 0. Radial zones in fuel have constant area 1. Uniform radial mesh -1. Radii of fuel zones given in input		
468	ITET	0.→Θ calculated by the code 1. Θ given in input		
469-478	KKC(I)	Indexes of the active meshes where local friction losses are present		
479-500	-	Dummy - leavy blank		

Floating channel data

Only if ICAN = 1

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
501	A	Coolant cross section area	cm^2	
502	DIAF	Fuel diameter (or thickness)	cm	
503	GAPTH	Gap thickness	cm	
504	CLTH	Cladding thickness	cm	
505	ROF	Fuel density	g/cm^3	
506	CPF	Fuel specific heat	$\frac{joule}{gr°C}$	
507	AKF	Thermal conductivity of the fuel	watt/cm°C	
508	RGAP	Gap thermal resistance	$\frac{cm^2 °C}{watt}$	
509	ROCL	Cladding density	g/cm^3	
510	CPCL	Cladding specific heat	$\frac{joule}{gr°C}$	
511	AKCL	Thermal conductivity of the cladding	watt/cm°C	
512	SWID	Fuel element width	cm	Only for slab geometry
513	TINER	Total inertia of the channel	cm	The inertia is expressed as the equivalent length of a channel of constant cross section A with the same inertia of the actual channel. May be omitted if IVIN = 0
514	RGFAC	Factor for gravity pressure drop in in the riser (if omitted, the code will take 1. Give h/l otherwise)		
515	FRDF	Ratio of the power directly added to the liquid coolant (γ rays and neutron moderation) the total power produced.		

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
516	PS	Printing time interval (restricted print) for thermal output		
517-518		Dummy		
519	HINLET	Inlet temperature of the coolant for steady state	Kelvin (or °C)	
520	VINLET	Inlet velocity of the coolant for the steady state	cm/sec	May be omitted if the exit quality is given
521	FFK	Friction coefficient in the active channel $\Delta p = FFK . \Delta z . \frac{1}{2} \rho (G/\rho)^2$	cm^{-1}	
522	FFRK	Friction coefficient in the riser Same formula	cm^{-1}	
523	XOUT	Imposed exit quality for steady state	-	If omitted it will be calculated by the code
524	DPEQ	Imposed pressure drop for the steady state	bar	If omitted it will be calculated by the code
525	TSAT	Saturation temperature	Kelvin (or °C)	
526	RO	Liquid coolant density	gr/cm^3	
527	ROVAP	Vapour density	gr/cm^3	
528	CP	Coolant specific heat	$\frac{joule}{gr°C}$	
529	HLAT	Latent heat of vaporization	$\frac{joule}{gr}$	

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
530	HC	Convective heat transfer coefficient	$\frac{watt}{cm°C}$	Omit if standard formula for water is selected (ISTD=1)
531	HB	Boiling heat transfer constant (ϕ =HB ΔT^n)	$\frac{watt}{cm°C^n}$	Omit if standard
532	AN	Exponent in the boiling heat transfer correlation ϕ =HB T^n		Omit if standard
533	TAU	Bowring ratio of heat transmitted through vapour bubbles to total heat transmitted by boiling mechanism	-	Omit if standard
534	AK	Bankoff's slip constant	-	Omit if standard
535	ZE	Relaxation parameter for void profile in diabatic two phase flow	cm	Omit lacking better information
536	R1	Recondensation time constant for subcooled boiling	$(sec°C)^{-1}$	Omit lacking information
537	R2	Vaporization time constant for superheated liquid (put zero if no overheating is wanted)	$(sec°C)^{-1}$	Omit lacking information
538	AFRIC	Coefficients for two phase flow friction multiplier	-	See DATA (461)
539	BFRIC			
540	ALOC	Coefficient for two phase flow friction multiplier for local losses		
541	BLOC	TPM local = 1.+ALOCx+BLOCx^2		
542	TMART	Coefficient in Lockhart-Martinelli parameter χ = TMART $\frac{x}{1-x}$	-	Needed only if IFRIC = 1,2 May be omitted also if standard formula is used (see DATA (604))

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
543	COEF 1	Coefficient for momentum flow of liquid at outlet	-	Omit lacking better information. They will be taken as 1.
544	COEF 2	Same for vapour	-	
545	COEF 3	Same for inlet liquid	-	
546	ZIN	Inlet pipe height	cm	
547	CFFI	Inlet friction coefficient $\Delta p = CFFI \frac{\rho V^2}{2}$	-	
548	ZR	Riser length	cm	
549	ARIS	Riser flow area	cm^2	
550	GRAV	Gravity direction cosinus (+1. for upwards flow)	-	
551		Dummy		
552				
553	APEX	Coefficient for external driving pressure $DPEX = \Delta p_o (1.+APEX \cdot \Delta v + BPEX \cdot \Delta v^2)$	sec/cm	Needed only of IVIN = 0 and IEX = 0
554	BPEX		$(sec/cm)^2$	
555	TKF	T_o in formula $K = k_o + a(T-T_o) + b(T-T_o)^2$ for fuel variable heat conductivity	Kelvin (°C)	Only if IVAR = 1. if TKF is omitted the parameter will be kept constant
556	AKF1	a		
557	AKF2	b		

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
558	TCPF	To } in the same formula for fuel specific heat		
559	CPF1	a		
560	CPF2	b		
561	TKCL	To } same for cladding thermal conductivity		
562	CPCL1	a		
563	CPCL2	b		
564	TCCL	To } same for cladding specific heat		
565	CPCL1	a		
566	CPCL2	b		
567 to 569	CFRF (I)	Values for local pressure drop coefficients in riser $\Delta pi = CFRZ\ (I) \cdot \frac{1}{2} \varrho\ (G/\varrho)^2$		
570 to 579	CKFF(I)	Same for active channel (same formula)		
580 to 589	RFØ(I)	Radii of successive regions in the fuel pellet	cm	Only of IDF = -1
590 to 599	PFAC(I)	Corresponding power factors (relative values normalization performed by the code)	-	Only if JPØW = 1
600	TINPUT	θ value	°C	Only if ITET = 1

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
601	PRESS	Average pressure	bar	Needed only when ISTD = 1 (Standard formulae for water)
602	VISC	Viscosity of liquid coolant	poise	Only if ISTD=1 and/or if IFRIC=1,2 and TMART=0
603	WCON	Water conductivity	$\frac{\text{watt}}{\text{cm°C}}$	Only if ISTD=1
604	VISCV	Viscosity of vapour (it is needed to evaluate Martinelli parameter TMART if not given in input. Formula employed is $\chi = \frac{x}{1-x} \left(\frac{\mu_w}{\mu_{vap}}\right)^{0.143} \left(\frac{\rho_{vap}}{\rho_{water}}\right)^{0.571}$		Only if IFRIC = 1,2
605	DIAH	Hydraulic diameter of the channel (appears in Colburn formula for $h_c = 0.023 \frac{K_W}{D_n} Rev^{0.8} Pr^{0.4}$	cm	Only if ISTD = 1
606	-	Not employed		
607	ELSUR	Area of the heating surface per cm of height	cm	Only for general geometry (ITIPO =-1)
608	CLCAP	Thermal capacity of the cladding per cm of height	$\frac{\text{joule}}{\text{cm°C}}$	Same
609	ACØNCL	Thermal conductance of the cladding per cm of height	watt/cm°C	Same
610 to 619	FMASS(1)	Mass/cm in every zone in the fuel element	gr/cm	Same
620 to 629	CAP(I)	Thermal capacities in the fuel element zones per unit height	$\frac{\text{joule}}{\text{cm°C}}$	Same

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
630 to 639	CONF(I)	Thermal conductivities from one zone to the following in the outer direction (per unit height)	$\frac{watt}{cm°C}$	same

Tabulations for the channel

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
640 to 648	TIMEV(I)	Times for the inlet velocity tabulation	sec	Only when the corresponding options are checked
650 to 658	VVAL(I)	Values for inlet velocity	cm/sec	First time in each table is always zero. If the first value is zero, the steady state is kept
660 to 668	TIMEH(I)	Times for inlet temperature tabulation	sec	After the last value of time the values are kept constant to the last value of the Table
670 to 678	HVAL(I)	Values for inlet temperature	Kelvin (or°C)	Therefore if no DATA are entered in a table, the values are kept constant to the steady state value if the tabulation option is checked.
680 to 688	TIMEPR(I)	Times for external driving pressure tabulation	sec	
690 to	PRE(I)	Values of driving pressure	bar	

Void feedback tabulations

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
1000	-	If greater than zero, void feed back is tabulated (10 values)		
1001 to 1012	-	Give ten values of δk corresponding to x = 0.1, 0.2...1.0		Omit if DATA (1000) is zero the quadratic formula will be employed
1013 to 1024 etc	-	Same for 2[nd] region, if DATA (300) > 0		

Criticality search parameters

DATA N°	NAME	DESCRIPTION	UNIT	REAMRKS
1600	LF	Maximum number of trials for search		50 is suggested
1601	DAPF	Convergence criterium for search (10^{-3}) Reciprocal of period will be less than DAPF		
1602	SPRG	Second guess of control parameter for search (Σa_2, cm of rod insertion, or δ k)		First guess is zero
1603	SPB	Σ_{p2} corresponding to control rods	cm^{-1}	Only if banked rods (IDIR=1,2)
1604	RFAST	Ratio Σ_{p1}/Σ_{p2} for poison		Not used if IDIR = -1 (K_{eff} search)
1605 to 1616	KV(I)	I if poison is present in region I 0 if it is not		Only when diluted poisons search is done (IDIR = 0)

Nuclear perturbation parameters

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
1617	IDKF	0 perturbation is given as absorption cross sections -1 perturbation given as δk		
1618	IDIR	0 perturbation is diffused 1 banked rod perturbation from top 2 banked rod perturbation from bottom		
1619	RFAST	Ratio Σ_{P1}/Σ_{P2} for absorption perturbation		Only if IDKF = 0
1620	SPB	Control rod Σ_{P2} (or δk if IDKF=-1) for perturbation	cm^{-1} or δk	Only if IDIR = 1,2
1621 to 1699	TBAR	Successive times for perturbation insertion	sec	
1700	VBAR	Time zero insertion for perturbation parameter		The parameter may represent depth of insertion (cm) of rods, or Σ_{P2}, or δk, according to the options checked. See directions and suggestions page of the text.
1701 to 1779	VBAR	Insertion values for successive times		
1781 to 1792		Factors which multiply the value VBAR(t) in each region I		Considered only if IDIR = 0

Criticality search parameters

DATA N°	NAME	DESCRIPTION	UNIT	REAMRKS
1600	LF	Maximum number of trials for search		50 is suggested
1601	DAPF	Convergence criterium for search (10^{-3}) Reciprocal of period will be less than DAPF		
1602	SPRG	Second guess of control parameter for search (Σa_2, cm of rod insertion, or δ k)		First guess is zero
1603	SPB	Σ_{p2} corresponding to control rods	cm^{-1}	Only if banked rods (IDIR=1,2)
1604	RFAST	Ratio Σ_{p1}/Σ_{p2} for poison		Not used if IDIR = -1 (K_{eff} search)
1605 to 1616	KV(I)	I if poison is present in region I 0 if it is not		Only when diluted poisons search is done (IDIR = 0)

Nuclear perturbation parameters

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
1617	IDKF	0 perturbation is given as absorption cross sections -1 perturbation given as δk		
1618	IDIR	0 perturbation is diffused 1 banked rod perturbation from top 2 banked rod perturbation from bottom		
1619	RFAST	Ratio Σ_{P1}/Σ_{P2} for absorption perturbation		Only if IDKF = 0
1620	SPB	Control rod Σ_{P2} (or δk if IDKF=-1) for perturbation	cm^{-1} or δk	Only if IDIR = 1,2
1621 to 1699	TBAR	Successive times for perturbation insertion	sec	
1700	VBAR	Time zero insertion for perturbation parameter		The parameter may represent depth of insertion (cm) of rods, or Σ_{P2}, or δk, according to the options checked . See directions and suggestions page of the text.
1701 to 1779	VBAR	Insertion values for successive times		
1781 to 1792		Factors which multiply the value VBAR(t) in each region I		Considered only if IDIR = 0

Printing specifications

DATA N°	NAME	DESCRIPTION	UNIT	REMARKS
1851+6n	KTP	Number of time step for the n^{th} printing pattern		n = 0, 1, etc.. As many cards as wanted may be given, allowing successive printing patterns.
1852+6n	I1P	Number of time steps for the more frequent type of print		
1853+6n	I1S	Type of more frequent output 1. only power, average fluxes and period 2. complete map of fluxes and delayed neutron precursors concentration 3. same as 1 plus region averages 4.5 no print		After the last is completed the calculation stops and a final print is done. Then the control is transferred to the beginning of the programme to start a new problem, unless the title card contains a positive integer in column 1-6, in which case the run is stopped
1854+6n	I2P	Number of time steps for the less frequent type of print (must be multiple of I1P and divisor of KTP)		
1855+6n	I2S	Same as I1S for less frequent output		
1856+6n	-	Not used		

END of DATA

Appendix B

Data and output listing for the sample problem.

INPUT LIST

1 12 24 36 48 60 72

SAMPLE PROBLEM COSTAX BOIL

1	17				
0.01	18.39	25.	3.	6.	30.
1.	-1.	77500.	0.00016	0.001	2. +08
4477.	5.	-1.	640.	262.5	
31	36				
30. -05	83. -05	269. -05	131. -05	145. -05	21. -05
41	46				
3.	1.13	0.301	0.111	0.0305	0.0124
61	64				
1.	3.	23.	25.		
81	116				
1.319	0.008655	0.0077627	0.	5. +06	
0.939	0.00392	0.004788	270000.	6.19 -14	
1.319	0.008655	0.0077627	0.	5. +06	
0.939	0.00392	0.004788	270000.	6.19 -14	
1.319	0.008655	0.0077627	0.	5. +06	
0.939	0.00392	0.004788	270000.	6.19 -14	
301	306				
-1.3 -05	0.	0.0066	0.	-0.6 -05	
450	451				
3.	23.				
452	462				
3.	2.	1.	0.	0.	0.
1.		1.		0.	
501	530				
0.92	1.08	0.005	0.04	10.35	0.335
0.0334	2.	6.55	0.335	0.159	0.
367.8	0.	0.	0.5		
251.5	398.	0.0171			2.5
297.	0.865	0.05	5.18	1275.	
538	539				
50.	-65.				
547	550				
30.			1.		
601	605				
86.8	1.15 -03	5.22 -03		0.313	
680	682				
0.	0.499	0.5			
690	692				
2.5	2.5	1.			
1600	1602				
50.	0.001	0.001			
1617	1620				
-1.	2.	0.	-0.0785		
1621	1622				
2.	2.5				
1701	1702				
	402.				
-1					
1851	1856				
300.	50.	3.	100.	2.	

COSTAXIA AXIAL-BOILING CHANNEL
T.C.R. EURATOM ISPRA

SAMPLE PROBLEM COSTAX BOIL

1	0.100000E-01	2	0.133000E 02	3	0.250000E 02	4	0.300000E 01	5	0.600000E 01	6	0.300000E 02
7	0.100000E 01	8	-0.100000E 01	9	0.776000E 05	10	0.160000E-03	11	0.100000E-02	12	0.200000E 09
13	0.447700E 04	14	0.500000E 01	15	-0.100000E 01	16	0.640000E 03	17	0.262500E 03		
31	0.300000E-03	32	0.330000E-03	33	0.269000E-02	34	0.131000E-02	35	0.145000E-02	36	0.210000E-03
41	0.300000E 01	42	0.113000E 01	43	0.301000E 00	44	0.111000E 00	45	0.305000E-01	46	0.124000E-01
61	0.100000E 01	62	0.300000E 01	63	0.230000E 02	64	0.250000E 02				
81	0.131900E 01	82	0.365500E-02	83	0.776270E-02	84	0.0	85	0.500000E 07	86	0.0
87	0.939000E 00	88	0.392000E-02	89	0.473800E-02	90	0.270000E 06	91	0.619000E-13	92	0.0
93	0.131900E 01	94	0.365500E-02	95	0.776270E-02	96	0.0	97	0.500000E 07	98	0.0
99	0.939000E 00	100	0.392000E-02	101	0.473800E-02	102	0.270000E 06	103	0.619000E-13	104	0.0
105	0.131900E 01	106	0.365500E-02	107	0.776270E-02	108	0.0	109	0.500000E 07	110	0.0
111	0.939000E 00	112	0.392000E-02	113	0.478800E-02	114	0.270000E 06	115	0.619000E-13	116	0.0
301	-0.130000E-04	302	0.0	303	0.660000E-02	304	0.0	305	-0.600000E-05	306	0.0
450	0.300000E 01	451	0.230000E 02								
452	0.300000E 01	453	0.200000E 01	454	0.100000E 01	455	0.0	456	0.0	457	0.0
458	0.100000E 01	459	0.0	460	0.100000E 01	461	0.0	462	0.0		
501	0.920000E 00	502	0.108000E 01	503	0.500000E-02	504	0.400000E-01	505	0.103500E 02	506	0.335000E 00
507	0.334000E-01	508	0.200000E 01	509	0.655000E 01	510	0.335000E 00	511	0.159000E 00	512	0.0
513	0.367800E 03	514	0.0	515	0.0	516	0.500000E 00	517	0.0	518	0.0
519	0.251500E 03	520	0.398000E 03	521	0.171000E-01	522	0.0	523	0.0	524	0.250000E 01
525	0.297000E 03	526	0.365000E 00	527	0.500000E-01	528	0.518000E 01	529	0.127500E 04	530	0.0
538	0.500000E 02	539	-0.650000E 02								
547	0.300000E 02	548	0.0	549	0.0	550	0.100000E 01				
601	0.830000E 02	602	0.115000E-02	603	0.522000E-02	604	0.0	605	0.813000E 00		
680	0.0	681	0.499000E 00	682	0.500000E 00						
690	0.250000E 01	691	0.250000E 01	692	0.100000E 01						
1600	0.500000E 02	1601	0.100000E-02	1602	0.100000E-02						
1617	-0.100000E 01	1618	0.200000E 01	1619	0.0	1620	-0.785000E-01				
1621	0.200000E 01	1622	0.250000E 01								
1701	0.0	1702	0.400000E 03								
1851	0.300000E 03	1852	0.500000E 02	1853	0.300000E 01	1854	0.100000E 03	1855	0.200000E 01	1856	0.0

BETA	LAMBDA
0.30000E-03	0.30000E 01
0.83000E-03	0.11300E 01
0.26900E-02	0.30100E 00
0.13100E-02	0.11100E 00
0.14500E-02	0.30500E-01
0.21000E-03	0.12400E-01

FUEL DATA

FUEL RADIUS	DENSITY	MASS/CM	CLAD RADIUS	EXT.RADIUS
0.54000E 00	0.10330E 02	0.94815E 01	0.54500E 00	0.58500E 00

3 REGIONS IN FUEL

RADII

0.31177	0.44091	0.54000

RELATIVE POWER

0.33333	0.33333	0.33333

TEMPERATURE INDEPENDENT CONSTANTS

CPF	KF	CPCL	KCL
0.330000E 00	0.334000E-01	0.335000E 00	0.159000E 00

STATIC CALCULATION

CHANNEL DATA
HEIGHT 367.8 CM SECTION 0.920 CM2 COOLANT DENSITY 0.86500 G/CM3 GRAVITY= 980.000 CM/SEC**2
INLET PIPE HEIGHT 0.0
NO RISER
TOTAL CHANNEL POWER IN FUEL 0.446730 05WATT
TOTAL CHANNEL POWER IN COOLANT 0.0 WATT

OPTIONS

IMPOSED PRESSURE DROP 2.500000 BAR
SEARCH FOR INLET ORIFICING FOR= 0.0

INLET VELOCITY /VINLET/= 393.000 CM/SEC
EXIT QUALITY /XOUT/= -0.07423
AVERAGE VOID FRACTION /AVF/= 0.0
POWER FLUX TO COOLANT /TNF/= 0.44673E 05WATT
POWER OUTPUT 0.44673E 05

PRESSURE DROP 2.50000 BAR

INLET	0.0	CHANNEL	0.74267	RISER	0.0
FRICTION	0.45038	GRAVITY	0.31178	SPACE ACCEL.	0.0

HEAT TRANSFER CONSTANTS

HC	0.31716E 01	HS	0.63273E-01	AN	4.000	TAU	0.43500
TETA	2.26	TETAF	3.91	K	0.873	ZE	0.0

41

I	PDW	FI	Q	VF	TSUR	TICL	AVTF	TMAXF	TL
1	0.12146E 03	0.33044E 02	0.0	0.0	0.26328E 03	0.27189E 03	0.51119E 03	0.63542E 03	0.25286E 03
2	0.12146E 03	0.33044E 02	0.0	0.0	0.26464E 03	0.27325E 03	0.51255E 03	0.63678E 03	0.25422E 03
3	0.12146E 03	0.33044E 02	0.0	0.0	0.26600E 03	0.27461E 03	0.51391E 03	0.63814E 03	0.25558E 03
4	0.12146E 03	0.33044E 02	0.0	0.0	0.26736E 03	0.27597E 03	0.51527E 03	0.63951E 03	0.25695E 03
5	0.12146E 03	0.33044E 02	0.0	0.0	0.26873E 03	0.27733E 03	0.51663E 03	0.64087E 03	0.25831E 03
6	0.12146E 03	0.33044E 02	0.0	0.0	0.27009E 03	0.27869E 03	0.51799E 03	0.64223E 03	0.25967E 03
7	0.12146E 03	0.33044E 02	0.0	0.0	0.27145E 03	0.28006E 03	0.51936E 03	0.64359E 03	0.26103E 03
8	0.12146E 03	0.33044E 02	0.0	0.0	0.27281E 03	0.28142E 03	0.52072E 03	0.64495E 03	0.26239E 03
9	0.12146E 03	0.33044E 02	0.0	0.0	0.27417E 03	0.28278E 03	0.52208E 03	0.64631E 03	0.26375E 03
10	0.12146E 03	0.33044E 02	0.0	0.0	0.27553E 03	0.28414E 03	0.52344E 03	0.64767E 03	0.26511E 03
11	0.12146E 03	0.33044E 02	0.0	0.0	0.27689E 03	0.28550E 03	0.52480E 03	0.64904E 03	0.26648E 03
12	0.12146E 03	0.33044E 02	0.0	0.0	0.27826E 03	0.28686E 03	0.52616E 03	0.65040E 03	0.26784E 03
13	0.12146E 03	0.33044E 02	0.0	0.0	0.27962E 03	0.28822E 03	0.52752E 03	0.65176E 03	0.26920E 03
14	0.12146E 03	0.33044E 02	0.0	0.0	0.28098E 03	0.28959E 03	0.52889E 03	0.65312E 03	0.27056E 03
15	0.12146E 03	0.33044E 02	0.0	0.0	0.28234E 03	0.29095E 03	0.53025E 03	0.65448E 03	0.27192E 03
16	0.12146E 03	0.33044E 02	0.0	0.0	0.28370E 03	0.29231E 03	0.53161E 03	0.65584E 03	0.27328E 03
17	0.12146E 03	0.33044E 02	0.0	0.0	0.28506E 03	0.29367E 03	0.53297E 03	0.65720E 03	0.27464E 03
18	0.12146E 03	0.33044E 02	0.0	0.0	0.28642E 03	0.29503E 03	0.53433E 03	0.65857E 03	0.27601E 03
19	0.12146E 03	0.33044E 02	0.0	0.0	0.28779E 03	0.29639E 03	0.53569E 03	0.65993E 03	0.27737E 03
20	0.12146E 03	0.33044E 02	0.0	0.0	0.28915E 03	0.29775E 03	0.53705E 03	0.66129E 03	0.27873E 03

FUEL TEMPERATURE MAP

1	635.42	499.00	399.14
2	636.78	500.36	400.50
3	638.14	501.73	401.86
4	639.51	503.09	403.22
5	640.87	504.45	404.59
6	642.23	505.81	405.95
7	643.59	507.17	407.31
8	644.95	508.53	408.67
9	646.31	509.90	410.03
10	647.67	511.26	411.39
11	649.04	512.62	412.75
12	650.40	513.98	414.11
13	651.76	515.34	415.48
14	653.12	516.70	416.84
15	654.48	518.06	418.20
16	655.84	519.43	419.56
17	657.20	520.79	420.92
18	658.57	522.15	422.28
19	659.93	523.51	423.65
20	661.29	524.87	425.01

TIME 0.0 IT 0 POWER 0.20000E 09

	FLUX1	FLUX2	POWER	ROD VALUE	DKFBACK	DKVOID
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.10355D 14	0.20275D 14	0.0	0.0	0.0	0.0
3	0.21551D 14	0.40191D 14	0.43981E 00	0.0	0.17324E-02	0.0
4	0.31633D 14	0.59337D 14	0.60455E 00	0.0	0.17065E-02	0.0
5	0.41574D 14	0.77492D 14	0.75825E 00	0.0	0.16807E-02	0.0
6	0.50533D 14	0.94181D 14	0.89813E 00	0.0	0.16548E-02	0.0
7	0.58534D 14	0.10913D 15	0.10221E 01	0.0	0.16289E-02	0.0
8	0.65597D 14	0.12224D 15	0.11280E 01	0.0	0.16031E-02	0.0
9	0.72466D 14	0.13316D 15	0.12145E 01	0.0	0.15772E-02	0.0
10	0.76155D 14	0.14130D 15	0.12801E 01	0.0	0.15513E-02	0.0
11	0.79453D 14	0.14303D 15	0.13241E 01	0.0	0.15255E-02	0.0
12	0.81452D 14	0.15177D 15	0.13460E 01	0.0	0.14996E-02	0.0
13	0.82111D 14	0.15293D 15	0.13454E 01	0.0	0.14737E-02	0.0
14	0.81591D 14	0.15134D 15	0.13225E 01	0.0	0.14479E-02	0.0
15	0.79515D 14	0.14778D 15	0.12775E 01	0.0	0.14220E-02	0.0
16	0.75911D 14	0.14145D 15	0.12110E 01	0.0	0.13961E-02	0.0
17	0.71225D 14	0.13275D 15	0.11240E 01	0.0	0.13703E-02	0.0
18	0.65527D 14	0.12175D 15	0.10177E 01	0.0	0.13444E-02	0.0
19	0.58303D 14	0.10867D 15	0.89381E 00	0.0	0.13185E-02	0.0
20	0.50263D 14	0.93524D 14	0.75415E 00	0.0	0.12927E-02	0.0
21	0.41520D 14	0.77354D 14	0.60106E 00	0.0	0.12668E-02	0.0
22	0.31659D 14	0.59035D 14	0.43717E 00	0.0	0.12409E-02	0.0
23	0.21415D 14	0.39946D 14	0.0	0.0	0.0	0.0
24	0.10799D 14	0.20149D 14	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0
AVER.	0.52421D 14	0.97592D 14	0.12145E 01		0.14870E-02	0.0

TIME 0.0 POWER RATIO 0.10000E 01

POWER 0.20000E 09 WATT PHI 0.52421D 14 PHI2 0.97692D 14 PER 0.77782E-01 PINT 0.0

FLUX1

0.10322E 14 0.80755E 14 0.10755E 14

FLUX2

0.20136E 14 0.11522E 15 0.20055E 14

AVPO

0.0 0.10000E 01 0.0

SPRS = 0.10000E-02 DAPF = 0.10000E-02 LF = 50 ITCR = 1

ITERATIONS	PM2	REP	SPCR
6	0.97698D 14	-0.47050E-03	-0.11325E-01

KEFF 1.011454

TIME 0.0 IT 0 POWER 0.20000E 09

	FLUX1	FLUX2	POWER	ROD VALUE	DKFBACK	DKVOID
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.10782D 14	0.20329D 14	0.0	0.0	0.0	0.0
3	0.21400D 14	0.40316D 14	0.44119E 00	0.0	0.36235E-02	0.0
4	0.31641D 14	0.59374D 14	0.60631E 00	0.0	0.30533E-02	0.0
5	0.41260D 14	0.77701D 14	0.76002E 00	0.0	0.25174E-02	0.0
6	0.50101D 14	0.94376D 14	0.89970E 00	0.0	0.20251E-02	0.0
7	0.58022D 14	0.10933D 15	0.10231E 01	0.0	0.15840E-02	0.0
8	0.64906D 14	0.12233D 15	0.11285E 01	0.0	0.12009E-02	0.0
9	0.70653D 14	0.13319D 15	0.12144E 01	0.0	0.88125E-03	0.0
10	0.75133D 14	0.14175D 15	0.12795E 01	0.0	0.62945E-03	0.0
11	0.78451D 14	0.14795D 15	0.13231E 01	0.0	0.44882E-03	0.0
12	0.80405D 14	0.15163D 15	0.13446E 01	0.0	0.34171E-03	0.0
13	0.81027D 14	0.15281D 15	0.13439E 01	0.0	0.30947E-03	0.0
14	0.80512D 14	0.15145D 15	0.13209E 01	0.0	0.35251E-03	0.0
15	0.78271D 14	0.14760D 15	0.12760E 01	0.0	0.47027E-03	0.0
16	0.74932D 14	0.14130D 15	0.12098E 01	0.0	0.66126E-03	0.0
17	0.70540D 14	0.13262D 15	0.11232E 01	0.0	0.92298E-03	0.0
18	0.64555D 14	0.12169D 15	0.10174E 01	0.0	0.12519E-02	0.0
19	0.57660D 14	0.10867D 15	0.89399E 00	0.0	0.16433E-02	0.0
20	0.49751D 14	0.93714D 14	0.75471E 00	0.0	0.20916E-02	0.0
21	0.40943D 14	0.77134D 14	0.60173E 00	0.0	0.25896E-02	0.0
22	0.31330D 14	0.59116D 14	0.43776E 00	0.0	0.31290E-02	0.0
23	0.21227D 14	0.39999D 14	0.0	0.0	0.0	0.0
24	0.10693D 14	0.20155D 14	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0
AVER.	0.51830D 14	0.97693D 14	0.12146E 03		0.97478E-03	0.0

	C1	C2	C3	C4	C5	C6
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.97357D 07	0.71493D 08	0.36988D 09	0.11487D 10	0.46275D 10	0.16484D 10
3	0.19303D 08	0.14173D 09	0.17251D 10	0.22781D 10	0.91769D 10	0.32691D 10

4	0.28524D 08	0.2095[illegible]D 09	0.23491D 10	0.33863D 10	0.13561D 11	0.49307D 10
5	0.37203D 08	0.27326D 09	0.33248D 10	0.43906D 10	0.17687D 11	0.63005D 10
6	0.45187D 08	0.33190D 09	0.40383D 10	0.53329D 10	0.21482D 11	0.76526D 10
7	0.5234[illegible]D 08	0.33[illegible]49D 09	0.46781D 10	0.61778D 10	0.24886D 11	0.88650D 10
8	0.58570D 08	0.43021D 09	0.52343D 10	0.69123D 10	0.27845D 11	0.99191D 10
9	0.63779D 08	0.46[illegible]D 09	0.56991D 10	0.75260D 10	0.30317D 11	0.10800D 11
10	0.67374D 08	0.49[illegible]D 09	0.60659D 10	0.80104D 10	0.32268D 11	0.11495D 11
11	0.70350D 08	0.5[illegible]D 09	0.63300D 10	0.83592D 10	0.33673D 11	0.11995D 11
12	0.72[illegible]D 08	0.5[illegible]D 09	0.64882D 10	0.85681D 10	0.34515D 11	0.12295D 11
13	0.73[illegible]D 08	0.557[illegible]D 09	0.65387D 10	0.86548D 10	0.34783D 11	0.12391D 11
14	0.72[illegible]D 08	0.55[illegible]D 09	0.64809D 10	0.85585D 10	0.34476D 11	0.12281D 11
15	0.70[illegible]73D 08	0.51910D 09	0.63159D 10	0.83407D 10	0.33599D 11	0.11969D 11
16	0.67[illegible]D 08	0.4[illegible]91D 09	0.60460D 10	0.79342D 10	0.32162D 11	0.11457D 11
17	0.6[illegible]497D 08	0.46[illegible]D 09	0.56747D 10	0.74938D 10	0.30187D 11	0.10754D 11
18	0.58[illegible]D 08	0.42797D 09	0.52071D 10	0.68764D 10	0.27700D 11	0.98675D 10
19	0.5[illegible]D 08	0.3[illegible]17D 09	0.46499D 10	0.61406D 10	0.24736D 11	0.88117D 10
20	0.44[illegible]D 08	0.3[illegible]37D 09	0.40111D 10	0.52970D 10	0.21338D 11	0.76012D 10
21	0.3[illegible]D 08	0.271[illegible]D 09	0.33005D 10	0.43586D 10	0.17558D 11	0.62546D 10
22	0.28[illegible]D 08	0.2[illegible]7[illegible]D 09	0.25296D 10	0.33405D 10	0.13456D 11	0.47935D 10
23	0.19[illegible]D 08	0.240[illegible]D 09	0.17115D 10	0.22602D 10	0.91047D 10	0.32434D 10
24	0.9[illegible]67D 07	0.70[illegible]D 08	0.85301D 09	0.11397D 10	0.45909D 10	0.16354D 10
25	0.0	0.0	0.0	0.0	0.0	0.0

TIME 0.0 POWER RATIO 0.10000E 01

POWER 0.20000E 09 WATT PH1 0.[illegible]D 14 PH2 0.97[illegible]93D 14 PER-0.21254E 04 PINT 0.0
FLM1
0.[illegible]7[illegible] 1[illegible] 0.[illegible] 14 0.1[illegible] 14
FLM2
0.[illegible] 1[illegible] 0.[illegible]322 13 0.2[illegible] 14
A[illegible]
0.0 0.[illegible]E 01 0.0

STATIC CALCULATION

CHANNEL DATA
HEIGHT 367.8 CM SECTION C.020 CM2 COOLANT DENSITY 0.86500 G/CM3 GRAVITY= 980.000 CM/SEC**2
INLET PIPE HEIGHT 0.0
NO RISER
TOTAL CHANNEL POWER IN FUEL 0.44573E 05WATT
TOTAL CHANNEL POWER IN COOLANT 0.0 WATT

OPTIONS

IMPOSED PRESSURE DROP 2.500000 BAR
SEARCH FOR INLET ORIFICING FOR= -4.34909

INLET VELOCITY /VINLET/= 393.000 CM/SEC
EXIT QUALITY /XOUT/= -0.07423
AVERAGE VOID FRACTION /AVF/= 0.0
POWER FLUX TO COOLANT /TWF/= 0.44573E 05WATT
POWER OUTPUT 0.44573E 05

PRESSURE DROP 2.50000 BAR
INLET 2.03329 CHANNEL 0.74267 RISER -0.00000
FRICTION 2.43617 GRAVITY 0.31178 SPACE ACCEL. 0.0

HEAT TRANSFER CONSTANTS
HC 0.31710E 01 HB 0.63273E-01 AN 4.000 TAU 0.43500
TETA 2.25 TETAF 3.01 K 0.873 ZE 0.0 46

I	TSUR		TICL		AVTF		TMAXF		TL	
1	0.25670E	03	0.26049E	03	0.36607E	03	0.42099E	03	0.25210E	03
2	0.25924E	03	0.26446E	03	0.40955E	03	0.48487E	03	0.25293E	03
3	0.26133E	03	0.26842E	03	0.45029E	03	0.54471E	03	0.25396E	03
4	0.26456E	03	0.27230E	03	0.48760E	03	0.59938E	03	0.25519E	03
5	0.26724E	03	0.27604E	03	0.52089E	03	0.64800E	03	0.25653E	03
6	0.26937E	03	0.27959E	03	0.54965E	03	0.68985E	03	0.25811E	03
7	0.27242E	03	0.28287E	03	0.57347E	03	0.72434E	03	0.25977E	03
8	0.27484E	03	0.28585E	03	0.59204E	03	0.75099E	03	0.26151E	03
9	0.27710E	03	0.28848E	03	0.60510E	03	0.76947E	03	0.26331E	03
10	0.27915E	03	0.29072E	03	0.61249E	03	0.77954E	03	0.26514E	03
11	0.28097E	03	0.29254E	03	0.61413E	03	0.78100E	03	0.26697E	03
12	0.28253E	03	0.29390E	03	0.60999E	03	0.77409E	03	0.26877E	03
13	0.28380E	03	0.29478E	03	0.60013E	03	0.75865E	03	0.27051E	03
14	0.28476E	03	0.29517E	03	0.58468E	03	0.73499E	03	0.27215E	03
15	0.28539E	03	0.29505E	03	0.56384E	03	0.70338E	03	0.27368E	03
16	0.28567E	03	0.29443E	03	0.53790E	03	0.66439E	03	0.27507E	03
17	0.28560E	03	0.29329E	03	0.50723E	03	0.61829E	03	0.27629E	03
18	0.28518E	03	0.29167E	03	0.47227E	03	0.56593E	03	0.27731E	03
19	0.28440E	03	0.28958E	03	0.43359E	03	0.50835E	03	0.27813E	03
20	0.28329E	03	0.28706E	03	0.39181E	03	0.44620E	03	0.27873E	03

I	POW		FI		Q	VF
1	0.53386E	02	0.14579E	02	0.0	0.0
2	0.73544E	02	0.20035E	02	0.0	0.0
3	0.92311E	02	0.25114E	02	0.0	0.0
4	0.10923E	03	0.29750E	02	0.0	0.0
5	0.12427E	03	0.33309E	02	0.0	0.0
6	0.13707E	03	0.37292E	02	0.0	0.0
7	0.14750E	03	0.40123E	02	0.0	0.0
8	0.15541E	03	0.42280E	02	0.0	0.0
9	0.16070E	03	0.43722E	02	0.0	0.0
10	0.16352E	03	0.44452E	02	0.0	0.0
11	0.16325E	03	0.44407E	02	0.0	0.0
12	0.16043E	03	0.43543E	02	0.0	0.0
13	0.15498E	03	0.42164E	02	0.0	0.0
14	0.14594E	03	0.39777E	02	0.0	0.0
15	0.13543E	03	0.37156E	02	0.0	0.0
16	0.12393E	03	0.33532E	02	0.0	0.0
17	0.10833E	03	0.29341E	02	0.0	0.0
18	0.91557E	02	0.24939E	02	0.0	0.0
19	0.73392E	02	0.19985E	02	0.0	0.0
20	0.53171E	02	0.14465E	02	0.0	0.0

FUEL TEMPERATURE MAP

1	420.99	359.76	316.64
2	484.87	402.16	341.61
3	544.71	441.05	365.13
4	599.38	475.64	386.79
5	648.00	513.42	406.24
6	689.85	535.90	423.20
7	724.34	553.53	437.49
8	750.99	570.45	448.67
9	769.47	583.98	455.35
10	779.54	593.11	461.83
11	781.00	597.76	463.55
12	774.09	593.90	461.99
13	758.65	584.58	457.16
14	734.99	569.94	449.12
15	703.38	550.16	437.99
16	664.39	525.50	423.90
17	618.29	496.34	407.06
18	565.93	463.38	387.71
19	508.35	425.26	366.16
20	446.20	386.43	342.76

DYNAMIC CALCULATION

OPTIONS

VINLET CALCULATED
PRESSURE DROP GIVEN IN INPUT

TIME 0.0 0.50 0.50
P.DROP 0.250E 07 0.250E 07 0.100E 07

TIME STEP FOR THERMAL CALCULATION 0.05000

DKINF PERTURBATION
BANKED RODS PERTURBATION
INSERTION FROM OUTLET

PERTURBATION TIME TABLE
TIMES
0.0 2.000 2.000
VALUES
0.0 0.0 0.400000E 03

TO = 0.010 VBAR = 0.0

TIME 0.500 SEC
POWER 0.44565E 05 TMF 0.44673E 05 AVF 0.0 XOUT -0.07423

VINLET 593.000 PDROP 1.000

AVERAGE FUEL TEMPERATURE 524.132
MAX.FUEL TEMP. 731.079 IN NODE 11
MAX.CLAD TEMP. 295.172 IN NODE 14
MAX.HEAT FLUX 44.432 IN NODE 10

FIRST BOILING NODE 21
EXIT LIQUID SUPERHEAT -13.271

TIME 0.5000 POWER RATIO 0.99934E 00

POWER 0.19997E 09 WATT PH1 0.51322D 14 PH2 0.97683D 14 PER-0.15515E 05 PINT 0.22334E 05
FLM1
0.10774E 14 0.50005E 14 0.10665E 14
FLM2
0.20244E 14 0.11322E 15 0.21033E 14
AVPD
0.0 0.10000E 01 0.0

TIME 1.000 SEC
POWER 0.44435E 05 TMF 0.41370E 05 AVF 0.0 XOUT -0.05807

VINLET 123.211 PDROP 1.000

AVERAGE FUEL TEMPERATURE 524.357
MAX.FUEL TEMP. 731.051 IN NODE 11
MAX.CLAD TEMP. 306.510 IN NODE 14
MAX.HEAT FLUX 41.255 IN NODE 10

FIRST BOILING NODE 21
EXIT LIQUID SUPERHEAT -14.294

I	POW	FI	Q	VF	TSUR	TICL	AVTF	TMAXF	TL
1	0.55500E 02	0.14010E 02	0.0	0.0	0.25954E 03	0.26319E 03	0.36633E 03	0.42097E 03	0.25252E 03
2	0.73333E 02	0.19167E 02	0.0	0.0	0.26348E 03	0.26849E 03	0.40993E 03	0.49496E 03	0.25388E 03
3	0.91349E 02	0.23913E 02	0.0	0.0	0.26752E 03	0.27377E 03	0.45078E 03	0.54469E 03	0.25554E 03
4	0.10334E 03	0.23164E 02	0.0	0.0	0.27155E 03	0.27892E 03	0.48820E 03	0.59935E 03	0.25744E 03
5	0.11377E 03	0.31920E 02	0.0	0.0	0.27549E 03	0.28385E 03	0.52158E 03	0.64797E 03	0.25951E 03

6	0.13551E 03	0.55374E 02	0.0	0.0	0.27027E 03	0.28346E 03	0.55043E 03	0.69982E 03	0.26170E 03
7	0.14639E 03	0.57511E 02	0.0	0.0	0.28260E 03	0.29267E 03	0.57433E 03	0.72431E 03	0.26396E 03
8	0.15479E 03	0.59499E 02	0.0	0.0	0.28603E 03	0.29641E 03	0.59295E 03	0.75096E 03	0.26625E 03
9	0.16003E 03	0.40722E 02	0.0	0.0	0.28891E 03	0.29962E 03	0.60606E 03	0.76944E 03	0.26852E 03
10	0.16262E 03	0.41263E 02	0.0	0.0	0.29140E 03	0.30226E 03	0.61348E 03	0.77951E 03	0.27073E 03
11	0.16233E 03	0.41120E 02	0.0	0.0	0.29344E 03	0.30427E 03	0.61512E 03	0.78105E 03	0.27285E 03
12	0.15974E 03	0.40299E 02	0.0	0.0	0.29502E 03	0.30564E 03	0.61097E 03	0.77405E 03	0.27483E 03
13	0.15451E 03	0.38309E 02	0.0	0.0	0.29609E 03	0.30633E 03	0.60109E 03	0.75962E 03	0.27666E 03
14	0.14630E 03	0.35572E 02	0.0	0.0	0.29665E 03	0.30634E 03	0.58560E 03	0.73494E 03	0.27829E 03
15	0.13383E 03	0.33016E 02	0.0	0.0	0.29668E 03	0.30565E 03	0.56470E 03	0.70335E 03	0.27969E 03
16	0.12304E 03	0.30381E 02	0.0	0.0	0.29617E 03	0.30427E 03	0.53869E 03	0.66427E 03	0.28086E 03
17	0.10311E 03	0.26713E 02	0.0	0.0	0.29513E 03	0.30222E 03	0.50794E 03	0.61826E 03	0.28176E 03
18	0.91268E 02	0.22371E 02	0.0	0.0	0.29357E 03	0.29953E 03	0.47289E 03	0.56601E 03	0.28237E 03
19	0.72775E 02	0.17623E 02	0.0	0.0	0.29151E 03	0.29622E 03	0.43410E 03	0.50833E 03	0.28269E 03
20	0.52940E 02	0.12347E 02	0.0	0.0	0.28909E 03	0.29237E 03	0.39221E 03	0.44619E 03	0.28271E 03

TIME 1.0000 POWER RATIO 0.99584E 00

POWER 0.19913E 03 WATT PM1 0.51604D 14 PM2 0.97275D 14 PER-0.67568E 02 PINT 0.44631E 05

FLM1

0.10702E 14 0.59792E 14 0.10512E 14

FLM2

0.20158E 14 0.11278E 15 0.19993E 14

AVPD

0.0 0.10000E 01 0.0

TIME 1.00001 IT 100 POWER 0.19913E 03

	FLUX1	FLUX2	POWER	ROD VALUE	DKFBACK	DKVOID
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.10749D 14	0.20249D 14	0.0	0.0	0.0	0.0
3	0.21315D 14	0.40156D 14	0.41356E 00	0.0	0.36176E-02	0.0
4	0.31513D 14	0.59356D 14	0.60652E 00	0.0	0.30426E-02	0.0
5	0.41094D 14	0.77337D 14	0.76025E 00	0.0	0.25015E-02	0.0
6	0.49895D 14	0.93991D 14	0.89993E 00	0.0	0.20038E-02	0.0
7	0.57762D 14	0.10833D 15	0.10234E 01	0.0	0.15573E-02	0.0
8	0.64634D 14	0.12132D 15	0.11237E 01	0.0	0.11692E-02	0.0
9	0.70553D 14	0.13262D 15	0.12145E 01	0.0	0.84495E-03	0.0
10	0.74864D 14	0.14115D 15	0.12795E 01	0.0	0.58913E-03	0.0
11	0.78110D 14	0.14729D 15	0.13231E 01	0.0	0.40515E-03	0.0
12	0.80051D 14	0.15097D 15	0.13445E 01	0.0	0.29542E-03	0.0
13	0.80567D 14	0.15215D 15	0.13433E 01	0.0	0.26135E-03	0.0
14	0.79953D 14	0.15079D 15	0.13297E 01	0.0	0.30335E-03	0.0
15	0.77912D 14	0.14597D 15	0.12758E 01	0.0	0.42092E-03	0.0
16	0.74594D 14	0.14065D 15	0.12095E 01	0.0	0.61253E-03	0.0
17	0.70021D 14	0.13201D 15	0.11230E 01	0.0	0.87568E-03	0.0
18	0.64253D 14	0.12114D 15	0.10173E 01	0.0	0.12068E-02	0.0
19	0.57299D 14	0.10813D 15	0.89385E 00	0.0	0.16013E-02	0.0
20	0.49325D 14	0.93133D 14	0.75460E 00	0.0	0.20532E-02	0.0
21	0.40764D 14	0.76735D 14	0.60170E 00	0.0	0.25556E-02	0.0
22	0.31243D 14	0.58835D 14	0.43771E 00	0.0	0.31001E-02	0.0

23	0.21132D 14	0.39320D 14	0.0	0.0	0.0	0.0
24	0.10643D 14	0.20070D 14	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	-0.30250E-01	0.0	0.0
AVER.	0.51604D 14	0.97273D 14	0.12093E 03		0.93437E-03	0.0

TIME 1.500 SEC
POWER 0.44207E 05 THF 0.41402E 05 AVF 0.0 XOUT -0.03414

WINLET 223.200 PUMP 1.000

AVERAGE FUEL TEMPERATURE 325.326
MAX.FUEL TEMP. 730.775 IN NODE 11
MAX.CLAD TEMP. 311.299 IN NODE 14
MAX.HEAT FLUX 41.545 IN NODE 10

FIRST BOILING NODE 21
EXIT LIQUID SUPERHEAT -3.402

TIME 1.5000 POWER RATIO 0.33945E 00

POWER 0.19789E 00 WATT PN1 0.51233D 14 PN2 0.96669D 14 PER-0.79294E 02 PINT 0.65798E 05
FLM1
0.10614E 14 0.59142E 14 0.10314E 14
FLM2
0.20053E 14 0.11200E 15 0.19355E 14
AVPJ
0.0 0.10000E 01 0.0

TIME 2.000 SEC
POWER 0.43293E 05 THF 0.41241E 05 AVF 0.05106 XOUT -0.01111

WINLET 219.311 PUMP 1.000

AVERAGE FUEL TEMPERATURE 326.063
MAX.FUEL TEMP. 731.250 IN NODE 11
MAX.CLAD TEMP. 312.430 IN NODE 13
MAX.HEAT FLUX 42.200 IN NODE 10

FIRST BOILING NODE 13
EXIT LIQUID SUPERHEAT -7.132

I	PWI	FI	Q	VF	TSUR	TICL	AVTF	TMAXF	TL
1	0.54000E 02	0.21129E 02	0.0	0.0	0.25934E 03	0.26354E 03	0.36675E 03	0.42087E 03	0.25257E 03
2	0.74221E 02	0.19583E 02	0.0	0.0	0.26509E 03	0.26707E 03	0.41058E 03	0.49487E 03	0.25404E 03
3	0.99533E 02	0.24473E 02	0.0	0.0	0.26331E 03	0.27465E 03	0.45169E 03	0.54472E 03	0.25587E 03
4	0.21018E 03	0.25394E 02	0.0	0.0	0.27270E 03	0.28019E 03	0.48936E 03	0.59940E 03	0.25803E 03
5	0.22533E 03	0.32763E 02	0.0	0.0	0.27710E 03	0.29560E 03	0.52301E 03	0.64903E 03	0.26046E 03
6	0.23329E 03	0.35023E 02	0.0	0.0	0.28142E 03	0.29077E 03	0.55211E 03	0.68990E 03	0.26313E 03

7	0.14333E 03	0.33342E 02	0.0	0.0	0.28550E 03	0.29562E 03	0.57626E 03	0.72449E 03	0.26597E 03
8	0.15695E 03	0.40574E 02	0.0	0.0	0.28955E 03	0.30007E 03	0.59511E 03	0.75109E 03	0.26894E 03
9	0.16241E 03	0.41792E 02	0.0	0.0	0.29320E 03	0.30405E 03	0.60843E 03	0.76959E 03	0.27198E 03
10	0.16520E 03	0.42291E 02	0.0	0.0	0.29650E 03	0.30743E 03	0.61604E 03	0.77967E 03	0.27502E 03
11	0.16523E 03	0.42361E 02	0.0	0.0	0.29933E 03	0.31030E 03	0.61784E 03	0.78123E 03	0.27801E 03
12	0.16257E 03	0.41110E 02	0.0	0.0	0.30173E 03	0.31246E 03	0.61382E 03	0.77426E 03	0.28090E 03
13	0.15740E 03	0.41265E 02	-0.54841E-01	0.32251E-01	0.30196E 03	0.31247E 03	0.60398E 03	0.75894E 03	0.28293E 03
14	0.14952E 03	0.37795E 02	-0.[illegible]E-01	0.91530E-01	0.30135E 03	0.31163E 03	0.58837E 03	0.73519E 03	0.28432E 03
15	0.13909E 03	0.34263E 02	-0.39915E-01	0.15261E 00	0.30175E 03	0.31087E 03	0.56740E 03	0.70360E 03	0.28572E 03
16	0.12522E 03	0.31324E 02	-0.27091E-01	0.19407E 00	0.30154E 03	0.30985E 03	0.54133E 03	0.66453E 03	0.28695E 03
17	0.11109E 03	0.27407E 02	-0.20513E-01	0.18722E 00	0.30143E 03	0.30862E 03	0.51053E 03	0.61952E 03	0.28798E 03
18	0.93903E 02	0.22593E 02	-0.15533E-01	0.21184E 00	0.30127E 03	0.30719E 03	0.47544E 03	0.55625E 03	0.28883E 03
19	0.74947E 02	0.17467E 02	-0.12547E-01	0.20759E 00	0.30100E 03	0.30555E 03	0.43662E 03	0.50855E 03	0.28946E 03
20	0.54549E 02	0.11315E 02	-0.11113E-01	0.20427E 00	0.30055E 03	0.30371E 03	0.39470E 03	0.44639E 03	0.28987E 03

TJ = 2.000 VBAR = 0.0

TIME 2.0000 POWER RATIO 0.10143E 01

POWER 0.20296E 09 WATT PM1 0.52509D 14 PM2 0.99157D 14 PER 0.12135E 02 PINT 0.89103E 05

FLM1

0.10333E 14 0.30133E 14 0.10033E 14

FLM2

0.20412E 14 0.11403E 15 0.23333E 14

AVPJ

0.0 0.10000E 01 0.0

TIME 2.00000 IT 200 POWER 0.20296E 09

	FLUX1	FLUX2	POWER	ROD VALUE	DKFBACK	DKVOID
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.10870D 14	0.20490D 14	0.0	0.0	0.0	0.0
3	0.21575D 14	0.40640D 14	0.43835E 00	0.0	0.36118E-02	0.0
4	0.31903D 14	0.60170D 14	0.60249E 00	0.0	0.30332E-02	0.0
5	0.41603D 14	0.78361D 14	0.75535E 00	0.0	0.24878E-02	0.0
6	0.50534D 14	0.95100D 14	0.89433E 00	0.0	0.19851E-02	0.0
7	0.58533D 14	0.11030D 15	0.10174E 01	0.0	0.15332E-02	0.0
8	0.65504D 14	0.12340D 15	0.11225E 01	0.0	0.11388E-02	0.0
9	0.71334D 14	0.13430D 15	0.12033E 01	0.0	0.80787E-03	0.0
10	0.75951D 14	0.14321D 15	0.12741E 01	0.0	0.54489E-03	0.0
11	0.79300D 14	0.14955D 15	0.13185E 01	0.0	0.35354E-03	0.0
12	0.81342D 14	0.15341D 15	0.13412E 01	0.0	0.23634E-03	0.0
13	0.82055D 14	0.15470D 15	0.13420E 01	0.0	0.19493E-03	0.0
14	0.81435D 14	0.15359D 15	0.13210E 01	0.0	0.22993E-03	0.0
15	0.79495D 14	0.14992D 15	0.12782E 01	0.0	0.35855E-03	0.21296E-03
16	0.76250D 14	0.14373D 15	0.12143E 01	0.0	0.11430E-02	0.50278E-03
17	0.71742D 14	0.13512D 15	0.11295E 01	0.0	0.16798E-02	0.87524E-03
18	0.65932D 14	0.12432D 15	0.10252E 01	0.0	0.22189E-02	0.10929E-02

19	0.59040D 14	0.11122D 15	0.90225E 00	0.0	0.27658E-02	0.12356E-02
20	0.51023D 14	0.95365D 14	0.76260E 00	0.0	0.33134E-02	0.13322E-02
21	0.42051D 14	0.79155D 14	0.60874E 00	0.0	0.38523E-02	0.13701E-02
22	0.32253D 14	0.60712D 14	0.44505E 00	0.0	0.43728E-02	0.13482E-02
23	0.22015D 14	0.41990D 14	0.0	0.0	0.0	0.0
24	0.10933D 14	0.20720D 14	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	-0.39265E-01	0.0	0.0
AVER.	0.52509D 14	0.99157D 14	0.12526E 03		0.11576E-02	0.27744E-03

TIME 2.500 SEC
POWER 0.54275E 04   TMF 0.40523E 03   AVF 0.05955   XOUT 0.00036

VINLET 224.336   PUMP 1.000

AVERAGE FUEL TEMPERATURE 515.513
MAX.FUEL TEMP. 738.255 IN NODE 11
MAX.CLAD TEMP. 312.372 IN NODE 13
MAX.HEAT FLUX 46.737 IN NODE 10

FIRST BOILING NODE 14
EXIT LIQUID SUPERHEAT -6.515

TS = 2.500   VBAR = 0.40000E 03

TIME 2.5000 POWER RATIO 0.75506E-01

POWER 0.15101E 03 WATT PN1 0.39254D 15   PN2 0.73989D 15   PER-0.59414E 00   PINT 0.10910E 06
FLM1
0.10055E 15   0.45555E 15   0.78105E 12
FLM2
0.15555E 15   0.35455E 15   0.14745E 15
AVPJ
0.0   0.20405E 01   0.0

TIME 3.000 SEC
POWER 0.29275E 04   TMF 0.55944E 03   AVF 0.05874   XOUT -0.00453

VINLET 223.625   PUMP 1.000

AVERAGE FUEL TEMPERATURE 505.435
MAX.FUEL TEMP. 744.970 IN NODE 11
MAX.CLAD TEMP. 319.155 IN NODE 13
MAX.HEAT FLUX 37.437 IN NODE 10

FIRST BOILING NODE 17
EXIT LIQUID SUPERHEAT -5.514

I	POW	FI	Q	VF	TSUR	TICL	AVTF	TMAXF	TL
1	0.59479E 01	0.12520E 02	0.0	0.0	0.25372E 03	0.26196E 03	0.35664E 03	0.40965E 03	0.25244E 03
2	0.52155E 01	0.17196E 02	0.0	0.0	0.26156E 03	0.26681E 03	0.39667E 03	0.46949E 03	0.25374E 03
3	0.65404E 01	0.21525E 02	0.0	0.0	0.26617E 03	0.27174E 03	0.43421E 03	0.52524E 03	0.25539E 03
4	0.73603E 01	0.25341E 02	0.0	0.0	0.27010E 03	0.27668E 03	0.46862E 03	0.57624E 03	0.25735E 03
5	0.82659E 01	0.28373E 02	0.0	0.0	0.27403E 03	0.28154E 03	0.49935E 03	0.62156E 03	0.25961E 03
6	0.90404E 01	0.31764E 02	0.0	0.0	0.27804E 03	0.28525E 03	0.52594E 03	0.66054E 03	0.26211E 03
7	0.95711E 01	0.34217E 02	0.0	0.0	0.28102E 03	0.29073E 03	0.54801E 03	0.69262E 03	0.26482E 03
8	0.10244E 02	0.35343E 02	0.0	0.0	0.28506E 03	0.29491E 03	0.56524E 03	0.71735E 03	0.26769E 03
9	0.10454E 02	0.36946E 02	0.0	0.0	0.28929E 03	0.29873E 03	0.57743E 03	0.73445E 03	0.27068E 03
10	0.10596E 02	0.37467E 02	0.0	0.0	0.29247E 03	0.30212E 03	0.58441E 03	0.74369E 03	0.27373E 03
11	0.10567E 02	0.37226E 02	0.0	0.0	0.29544E 03	0.30504E 03	0.58612E 03	0.74498E 03	0.27678E 03
12	0.10567E 02	0.37063E 02	0.0	0.0	0.29804E 03	0.30743E 03	0.58254E 03	0.73833E 03	0.27979E 03
13	0.10000E 02	0.34901E 02	0.0	0.0	0.30029E 03	0.30919E 03	0.57357E 03	0.72391E 03	0.28270E 03
14	0.94719E 01	0.32349E 02	0.0	0.0	0.30175E 03	0.31018E 03	0.55927E 03	0.70162E 03	0.28539E 03
15	0.87355E 01	0.29472E 02	0.0	0.0	0.30225E 03	0.30993E 03	0.54013E 03	0.67215E 03	0.28749E 03
16	0.79561E 01	0.26247E 02	0.0	0.0	0.30178E 03	0.30365E 03	0.51652E 03	0.63590E 03	0.28861E 03
17	0.69598E 01	0.23299E 02	-0.11832E-01	0.15071E 00	0.30130E 03	0.30736E 03	0.48878E 03	0.59310E 03	0.28869E 03
18	0.59000E 01	0.19355E 02	-0.17355E-01	0.18140E 00	0.30119E 03	0.30614E 03	0.45732E 03	0.54471E 03	0.28963E 03
19	0.47037E 01	0.15006E 02	-0.38517E-02	0.21000E 00	0.30035E 03	0.30476E 03	0.42262E 03	0.49138E 03	0.29027E 03
20	0.34205E 01	0.10320E 02	-0.45525E-02	0.23274E 00	0.30051E 03	0.30320E 03	0.38524E 03	0.43400E 03	0.29069E 03

TIME 3.0000 POWER RATIO 0.53333E-01

POWER 0.13077E 03 WATT PHI 0.54000D 13 PHI 0.54043D 13 PER-0.43122E 01 PINT 0.10165E 06

FLU1
0.54366E 12 0.59273E 13 0.63233E 12

FLU2
0.15473E 13 0.74022E 13 0.12333E 13

AVPO
0.0 0.10000E 01 0.0

TIME 3.00000E IT 300 POWER 0.13077E 03

	FLUX1	FLUX2	POWER	ROD VALUE	DKFBACK	DKVOID
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.66375D 12	0.15755D 13	0.0	0.0	0.0	0.0
3	0.15551D 13	0.50373D 13	0.49591E 00	-0.93502E-02	0.37441E-02	0.0
4	0.21173D 13	0.45055D 13	0.65530E 00	-0.73500E-01	0.32159E-02	0.0
5	0.28035D 13	0.55375D 13	0.79634E 00	-0.73500E-01	0.27180E-02	0.0
6	0.35083D 13	0.63057D 13	0.92453E 00	-0.73500E-01	0.22588E-02	0.0
7	0.33651D 13	0.72949D 13	0.10388E 01	-0.73500E-01	0.18458E-02	0.0
8	0.42317D 13	0.77077D 13	0.11559E 01	-0.73500E-01	0.14851E-02	0.0
9	0.46297D 13	0.87355D 13	0.12150E 01	-0.73500E-01	0.11820E-02	0.0
10	0.49055D 13	0.92509D 13	0.12745E 01	-0.73500E-01	0.94066E-03	0.0
11	0.50973D 13	0.95170D 13	0.13135E 01	-0.73500E-01	0.75436E-03	0.0
12	0.52037D 13	0.96270D 13	0.13313E 01	-0.73500E-01	0.65527E-03	0.0
13	0.52355D 13	0.98305D 13	0.13270E 01	-0.73500E-01	0.61475E-03	0.0
14	0.51700D 13	0.97754D 13	0.13025E 01	-0.73500E-01	0.54323E-03	0.0

15	0.50530D 13	0.95336D 13	0.12564E 01	-0.78500E-01	0.74240E-03	0.0
16	0.48130D 13	0.90339D 13	0.11897E 01	-0.78500E-01	0.91211E-03	0.0
17	0.45177D 13	0.85224D 13	0.11035E 01	-0.78500E-01	0.11483E-02	0.0
18	0.41432D 13	0.78143D 13	0.99920E 00	-0.78500E-01	0.14486E-02	0.0
19	0.37033D 13	0.69757D 13	0.87783E 00	-0.78500E-01	0.28034E-02	0.99470E-03
20	0.31933D 13	0.60162D 13	0.74103E 00	-0.78500E-01	0.34093E-02	0.11972E-02
21	0.26233D 13	0.49517D 13	0.59080E 00	-0.78500E-01	0.40454E-02	0.13960E-02
22	0.20142D 13	0.37942D 13	0.42964E 00	-0.78500E-01	0.46788E-02	0.15361E-02
23	0.13610D 13	0.25557D 13	0.0	-0.78500E-01	0.0	0.0
24	0.66513D 12	0.12932D 13	0.0	-0.78500E-01	0.0	0.0
25	0.0	0.0	0.0	-0.78500E-01	0.0	0.0
AVER.	0.34000D 13	0.64043D 13	0.79414E 01		0.13581E-02	0.10119E-03

TIME 0.00001 IT 500 POWER 0.13077E 03

	FLUX1	FLUX2	POWER	ROD VALUE	DKFBACK	DKVOID
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.86573D 12	0.15750D 13	0.0	0.0	0.0	0.0
3	0.15631D 13	0.30373D 13	0.49591E 00	-0.98502E-02	0.37441E-02	0.0
4	0.23173D 13	0.43333D 13	0.65530E 00	-0.78500E-01	0.32159E-02	0.0
5	0.28635D 13	0.55975D 13	0.79654E 00	-0.78500E-01	0.27180E-02	0.0
6	0.35333D 13	0.65957D 13	0.92483E 00	-0.78500E-01	0.22588E-02	0.0
7	0.39651D 13	0.72979D 13	0.10585E 01	-0.78500E-01	0.18458E-02	0.0
8	0.42617D 13	0.80717D 13	0.11553E 01	-0.78500E-01	0.14851E-02	0.0
9	0.46277D 13	0.87333D 13	0.12150E 01	-0.78500E-01	0.11820E-02	0.0
10	0.49655D 13	0.92533D 13	0.12745E 01	-0.78500E-01	0.94066E-03	0.0
11	0.50970D 13	0.96170D 13	0.13135E 01	-0.78500E-01	0.76436E-03	0.0
12	0.52037D 13	0.98179D 13	0.13313E 01	-0.78500E-01	0.65527E-03	0.0
13	0.52355D 13	0.98303D 13	0.13275E 01	-0.78500E-01	0.61475E-03	0.0
14	0.51799D 13	0.97734D 13	0.13025E 01	-0.78500E-01	0.64323E-03	0.0
15	0.50573D 13	0.95386D 13	0.12564E 01	-0.78500E-01	0.74240E-03	0.0
16	0.48133D 13	0.90339D 13	0.11897E 01	-0.78500E-01	0.91211E-03	0.0
17	0.45177D 13	0.85224D 13	0.11035E 01	-0.78500E-01	0.11483E-02	0.0
18	0.41432D 13	0.78143D 13	0.99920E 00	-0.78500E-01	0.14486E-02	0.0
19	0.37033D 13	0.69757D 13	0.87783E 00	-0.78500E-01	0.28034E-02	0.99470E-03
20	0.31933D 13	0.60162D 13	0.74103E 00	-0.78500E-01	0.34093E-02	0.11972E-02
21	0.26233D 13	0.49517D 13	0.59080E 00	-0.78500E-01	0.40454E-02	0.13960E-02
22	0.20142D 13	0.37942D 13	0.42964E 00	-0.78500E-01	0.46788E-02	0.15361E-02
23	0.13610D 13	0.25557D 13	0.0	-0.78500E-01	0.0	0.0
24	0.66513D 12	0.12932D 13	0.0	-0.78500E-01	0.0	0.0
25	0.0	0.0	0.0	-0.78500E-01	0.0	0.0
AVER.	0.34000D 13	0.64043D 13	0.79414E 01		0.13581E-02	0.10119E-03

	C1	C2	C3	C4	C5	C6
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.13775D 07	0.54922D 03	0.71282D 09	0.10067D 10	0.45338D 10	0.15348D 10

4	0.55409D 07	0.10175D 09	0.20352D 10	0.31239D 10	0.13284D 11	0.47993D 10
5	0.66567D 07	0.13200D 09	0.27164D 10	0.40725D 10	0.17324D 11	0.62476D 10
6	0.82115D 07	0.15960D 09	0.32954D 10	0.49445D 10	0.21039D 11	0.75899D 10
7	0.93044D 07	0.18309D 09	0.38123D 10	0.57252D 10	0.24369D 11	0.87897D 10
8	0.10386D 08	0.20434D 09	0.42604D 10	0.64023D 10	0.27263D 11	0.98343D 10
9	0.11174D 08	0.22133D 09	0.46319D 10	0.69675D 10	0.29679D 11	0.10707D 11
10	0.11747D 08	0.23475D 09	0.49222D 10	0.74113D 10	0.31584D 11	0.11395D 11
11	0.12104D 08	0.24347D 09	0.51278D 10	0.77295D 10	0.32954D 11	0.11890D 11
12	0.12245D 08	0.24734D 09	0.52465D 10	0.79173D 10	0.33771D 11	0.12187D 11
13	0.12174D 08	0.24816D 09	0.52772D 10	0.79732D 10	0.34027D 11	0.12281D 11
14	0.11902D 08	0.24422D 09	0.52202D 10	0.78970D 10	0.33720D 11	0.12171D 11
15	0.11433D 08	0.23627D 09	0.50763D 10	0.76901D 10	0.32855D 11	0.11860D 11
16	0.10793D 08	0.22449D 09	0.48497D 10	0.73557D 10	0.31443D 11	0.11352D 11
17	0.99969D 07	0.20914D 09	0.45422D 10	0.68985D 10	0.29506D 11	0.10654D 11
18	0.90513D 07	0.19048D 09	0.41591D 10	0.63251D 10	0.27069D 11	0.97755D 10
19	0.79785D 07	0.16638D 09	0.37061D 10	0.56433D 10	0.24167D 11	0.87285D 10
20	0.67962D 07	0.14459D 09	0.31903D 10	0.48647D 10	0.20843D 11	0.75289D 10
21	0.55511D 07	0.11617D 09	0.26199D 10	0.39999D 10	0.17147D 11	0.61946D 10
22	0.41972D 07	0.90022D 08	0.20044D 10	0.30635D 10	0.13139D 11	0.47472D 10
23	0.28163D 07	0.60634D 08	0.13542D 10	0.20716D 10	0.88886D 10	0.32118D 10
24	0.14124D 07	0.30453D 08	0.68210D 09	0.10442D 10	0.44814D 10	0.16194D 10
25	0.0	0.0	0.0	0.0	0.0	0.0

TIME 5.000 SEC
POWER 0.29293E 04 THF 0.36343E 05 AVF 0.03874 XOUT -0.00453

VINLET 223.025 PUMP 1.000

AVERAGE FUEL TEMPERATURE 505.430
MAX.FUEL TEMP. 744.977 IN NODE 11
MAX.CLAD TEMP. 310.133 IN NODE 14
MAX.HEAT FLUX 57.407 IN NODE 10

FIRST BOILING NODE 17
EXIT LIQUID SUPERHEAT -6.314

I	POW	FI	Q	VF	TSUR	TICL	AVTF	TMAXF	TL
1	0.39332E 01	0.12529E 02	0.0	0.0	0.25872E 03	0.26196E 03	0.35664E 03	0.40965E 03	0.25244E 03
2	0.52039E 01	0.17196E 02	0.0	0.0	0.26235E 03	0.26681E 03	0.39667E 03	0.45949E 03	0.25374E 03
3	0.63264E 01	0.21525E 02	0.0	0.0	0.26617E 03	0.27174E 03	0.43421E 03	0.52524E 03	0.25539E 03
4	0.73444E 01	0.25540E 02	0.0	0.0	0.27010E 03	0.27668E 03	0.46862E 03	0.57624E 03	0.25735E 03
5	0.82478E 01	0.28378E 02	0.0	0.0	0.27406E 03	0.28154E 03	0.49935E 03	0.62155E 03	0.25961E 03
6	0.90207E 01	0.31784E 02	0.0	0.0	0.27804E 03	0.28625E 03	0.52594E 03	0.66054E 03	0.26211E 03
7	0.96490E 01	0.34117E 02	0.0	0.0	0.28192E 03	0.29073E 03	0.54801E 03	0.69262E 03	0.26482E 03
8	0.10122E 02	0.35345E 02	0.0	0.0	0.28566E 03	0.29491E 03	0.56524E 03	0.71736E 03	0.26769E 03
9	0.10451E 02	0.36945E 02	0.0	0.0	0.28919E 03	0.29873E 03	0.57743E 03	0.73445E 03	0.27068E 03
10	0.10573E 02	0.37407E 02	0.0	0.0	0.29247E 03	0.30212E 03	0.58441E 03	0.74369E 03	0.27373E 03
11	0.10543E 02	0.37226E 02	0.0	0.0	0.29544E 03	0.30504E 03	0.58612E 03	0.74498E 03	0.27678E 03
12	0.10344E 02	0.35403E 02	0.0	0.0	0.29804E 03	0.30743E 03	0.58254E 03	0.73833E 03	0.27979E 03
13	0.99771E 01	0.34002E 02	0.0	0.0	0.30029E 03	0.30919E 03	0.57357E 03	0.72381E 03	0.28270E 03
14	0.94431E 01	0.32549E 02	0.0	0.0	0.30175E 03	0.31013E 03	0.55927E 03	0.70162E 03	0.28539E 03
15	0.87542E 01	0.29457E 02	0.0	0.0	0.30225E 03	0.30993E 03	0.54013E 03	0.67215E 03	0.28749E 03
16	0.79350E 01	0.25249E 02	0.0	0.0	0.30175E 03	0.30356E 03	0.51652E 03	0.63589E 03	0.28861E 03
17	0.69711E 01	0.22290E 02	-0.21432E-01	0.15071E 00	0.30130E 03	0.30736E 03	0.48878E 03	0.59319E 03	0.28869E 03
18	0.53343E 01	0.19959E 02	-0.14333E-01	0.18140E 00	0.30110E 03	0.30614E 03	0.45732E 03	0.54471E 03	0.28963E 03

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Alfred Nobel

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