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L'ÉNERGIE ATOMIQUE
DU CANADA LIMITÉE

SPORTS (VERSION 1) USERS' GUIDE

Manuel des utilisateurs de SPORTS (version 1)

V. CHATOORGOON and P.R. THIBEAULT

Chalk River Nuclear Laboratories

Laboratoires nucléaires de Chalk River

Chalk River, Ontario

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Résumé

SPORTS est un code thermohydraulique, transitoire et unidimensionnel, ayant été formulé à partir des équations de conservation non linéaires dépendant du temps. Ce code a été conçu pour étudier la stabilité des écoulements diphasiques. Le manuel des utilisateurs de SPORTS donne quelques caractéristiques du code, un aperçu de l'accès au programme et des conditions de son utilisation et une description des données d'entrée avec un problème-exemple.

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ABSTRACT

SPORTS is a transient one-dimensional thermalhydraulic code formulated from the non-linear time dependent conservation equations and designed to investigate two-phase flow stability. The SPORTS Users' Guide contains som features of the code, a brief description of the program environment and access, and a description of the input data complete with a sample problem.

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Revision Level

1985 March Original Release

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The SPORTS Code

1.0 INTRODUCTION

SPORTS (Special Predictions of Reactor Thermalhydraulics and Stability) was conceived out of the need for a swift, yet accurate, code for investigating two-phase instability. The choice to develop a non-linear code, as opposed to one based on the linearized approach, was influenced by many factors, notwithstanding the most important one being the development of a novel, but simple, scheme that permits efficient solution of the unabridged conservation equations. The reasons that led to the choice of a non-linear solution, and the particular solution scheme, are detailed in Reference 1.

SPORTS is based on a one-dimensional formulation of the time-dependent inviscid conservation equations and can calculate steady-state and time history transients. It is equipped with an optional fuel model, a point source six group neutron-kinetic model, subcooled boiling and has the ability to do both forced convection and natural convection flows. While it is presently applicable only to homogeneous flows, it will be extended at some later time to include a drift-flux model.

The purpose of this document is to acquaint the user with the SPORTS code and explain how to implement the code, with the minimum of effort and difficulty, to investigate two-phase flow stability.

1.1 Assumptions

The following are the assumptions used in the formulation of the governing equations.

1. One-dimensionality of vapour and liquid flow (no radial distribution in vapour is allowed).
2. Homogeneity between vapour and liquid.
3. No local slip between vapour and liquid.
4. Non-equilibrium between vapour and liquid is permitted.
5. The geometry is comprised of constant area sections connected together so that area changes occur abruptly.
6. The neutron-kinetic model is a point source model that uses the mean values in the heated region.
7. The fuel model assumes the temperature profile within the fuel is parabolic.
8. The inlet and outlet pressure and temperature boundary conditions are assumed constant during the transient.

1.2 Governing Equations

Mass $$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho u)}{\partial x} = 0$$

Momentum $$\frac{\partial(\rho u)}{\partial t} + \frac{\partial(\rho u^2)}{\partial x} + \frac{\partial p}{\partial x} + C_k \rho u^2 + \rho g = 0$$

Energy $$\frac{\partial}{\partial t}\left[\rho\left(h + \frac{u^2}{2} \right) \right] + \frac{\partial}{\partial x}\left[\rho u\left(h + \frac{u^2}{2} \right)\right] + \rho u g = \frac{\partial p}{\partial t} + q_w$$

State $$\rho = f(p,h)$$

where ρ is two-phase density
u is flow velocity
p is pressure
h is enthalpy
g is gravity
C_k is friction coefficient
q_w is applied heat per unit volume of flow

2.0 GENERAL FEATURES OF SPORTS

2.1 Geometry

The geometry must be a one dimensional confined flow path operating between known boundary conditions. For input the path is divided into regions and sections. These are defined as follows:

region	- A different region is assigned to each part of the geometry where the flow area, the inclination, and section lengths are constant. The user must specify the exact number of regions.
section	- Each region is divided into sections of equal length. The user must specify the number of sections in each region.

The inclination factor is the angle the region makes with the horizontal. When this angle is zero, the flow is horizontal, and when the angle is 90 degrees, the flow is vertically upwards.

2.2 Steam-Water Package

SPORTS uses the STPH steam-water property package [2] developed at WNRE. It was found, however, that saturation temperature and viscosity in the pressure range 1 to 2 atmospheres were inaccurate. This was corrected within the code by using TSATLW, a light water saturation temperature function and VISLW, a light water viscosity function from AELIB, which is an AECL library of FORTRAN-callable routines [3].

2.3 Boiling and Heat Transfer Relations

Subcooled Boiling

SPORTS is equipped with the following quasi-steady correlation, which may be only valid for the low pressure SLOWPOKE reactor:

$$\frac{\alpha}{1-\alpha} = 1.964 \left(e^{3.99E-6\phi} - 1\right) e^{-\left(2.04\mu + 0.2506\left(T_{sat} - T_{bulk}\right)\right)}$$

where $\mu = 0.65$ m/s if $u < 0.65$ m/s.

and ϕ is the heat flux in W/m^2

Subcooled boiling calculation is controlled by the NSUBC option. When NSUBC is set to zero, no subcooled boiling calculation is done and when NSUBC is set to 1, subcooled boiling calculation is done.

Film Heat-Transfer Coefficients

SPORTS is equipped with the Dittos-Boelter correlation for forced convection single-phase flow and the McAdams correlation for nucleate boiling.

Dittos-Boelter

$$Nu = 0.023\ Re^{0.8}\ Pr^{0.4}$$

McAdams

$$q = 2.253\ (T_{wall} - T_{sat})^{3.86} \quad w.m^{-2}$$

2.4 Fuel and Neutron-Kinetics Model

The fuel is modelled by a first order ordinary differential equation derived by assuming a parabolic temperature profile within the fuel[4]. The equation is

$$\frac{d\theta}{dt} = \frac{-8\lambda/\rho c a^2}{[1+4/C]}\ (\theta - T_o) + q/\rho c$$

where
θ - mean fuel temperature
ρ - mean fuel density
c - mean specific heat
a - fuel radius
T_o - coolant temperature
λ - mean fuel conductivity
q - mean source density
h - mean heat transfer coefficient
C - ah/λ

The fuel transient calculation is only done when the neutron-kinetic option, NOPT, is set to 1.

SPORTS is equipped with a point source, six group neutron-kinetic model. Therefore, the fuel and coolant properties are integrated over the heated length to provide mean values for the variables of the subroutine. The six group, point source neutron kinetic equations are of the following form:

$$\frac{dn}{dt} = \frac{\delta k}{\ell^*}\ n - \frac{\gamma \beta k}{\ell^*}\ n + \gamma \sum_{i=1}^{6} \lambda_i C_i$$

and

$$\frac{dC_i}{dt} = \frac{\beta_i k}{\ell^*}\ n - \lambda_i C_i$$

where
n is the neutron density,
δk is reactivity,
k is defined as $1+\delta k$,
ℓ^* is the neutron generation time
γ is the relative effectiveness of the delayed neutrons,
β_i is the fission yield of the i^{th} group,

β is defined as $\sum_{i=1}^{6} \beta_i$,

λ_i is the decay constant of the i^{th} group, and

C_i is the density of the i^{th} delayed neutron group.

Provision is made to simulate reactivity effects due to coolant void, coolant temperature and fuel temperature. The reactivity for each of these effects must be described by an eight coefficient polynomial. If less than an eight coefficient polynomial is used, the remaining data fields must be set equal to zero.

Coolant Void:

$$\delta k_V = \sum_{i=1}^{8} a_i V^i \qquad \text{(mk)}$$

Coolant Temperature:

$$\delta k_T = \sum_{i=1}^{8} a_i \{(T - T_{REF}) - (T_{SS} - T_{REF})\} \qquad \text{(mk)}$$

Fuel Temperature:

$$\delta k_F = \sum_{i=1}^{8} a_i \{(\sigma - \sigma_{REF})^i - (\sigma_{SS} - \sigma_{REF})^i\} \qquad \text{(mk)}$$

where the reference coolant temperature, T_{REF}, and the reference fuel temperature, σ_{REF}, must be input by the user. The initial steady-state values of the coolant temperature, T_{SS}, and the fuel temperature, σ_{SS}, are calculated internally.

2.5 Stability and Transient Simulations

Because SPORTS is based on a real time solution of the conservation equations, it can also do transient simulations of systems where stability is not a concern. A transient simulation is accomplished by specifying the correct value of final power, FPOW, with the transient option, ITR,equal to one. For a stability run, FPOW must be set equal to the initial power, POW, with ITR equal to one. When this is done, SPORTS automatically inputs a perturbation.

In a simulation run, the power change is accomplished in a time-linear manner. The user must specify the final power, FPOW, and time span, RAMP, over which the power is to be changed. When the neutron-kinetic option, NOPT,is equal to one there is no need to specify a value of FPOW; the final value of reactivity insertion, DELKF, must be specified instead.

2.6 Time Step

The SPORTS code permits time-steps in the range:

$$\Delta t > \Delta x / 2a$$

where: Δt is the time-step,
Δx is the section length, and
a is the speed of sound.

The above time-step range is satisfactory for most practical systems; however, care should be exercised in choosing the time-step. Some systems possess multiple modes of oscillation and all modes with a period less than the chosen time-step will be suppressed. On the other hand, if too small a time-step is chosen and the system happens to have multiple modes, a higher mode may be picked up instead of the fundamental mode. An optimum time-step is roughly the material transit time through an average length section. A default time-step, based on the average transit time across a node, is built into SPORTS, and the user can activate this by setting the time-step, DT, equal to zero in the input data.

2.7 Boundary Conditions

For convenience, SPORTS offers a variety of possible boundary conditions, which are controlled by the input data for PIN, the inlet pressure, and PEX, the external reference pressure.

If the flow-rate, FLOW, is known, the user must specify PEX equal to zero in the input data and the known FLOW. If PIN and/or PEX is known, the correct value must be specified in the data. If PIN and/or PEX is not known, but must be calculated from a static head of water, PIN and/or PEX must be set equal to one, and a value of ZIN must be specified, where ZIN is the height of the static head of water in metres. It is assumed that the static head of water is open to atmosphere. This case is appropriate for natural-circulation systems and pool-type reactors.

For all cases, the inlet temperature, TIN, must also be specified in degrees Celsius.

2.8 Power

The user must specify an average applied power and also the heat-flux profile. (Care should be taken to ensure the heat-flux profile averages out to unity. If the heat-flux profile does not average out to unity, the code will adjust it to do so.) This does not include heat removed due to heat-exchangers, or other heat losses.

2.9 Friction Factor

SPORTS is equipped with very basic equations for the friction factor. They are:

$$\text{Smooth Pipe}\quad f = 0.188 / Re^2 \tag{1}$$

$$\text{Rough Pipe}\quad f = 0.25*(\ln(\varepsilon/(3.7*D_e)+2.51/(Re*\mathrm{sqrt}(f))))^2 \tag{2}$$

where: Re is the Reynold's number
ε is the roughness factor and
D_e is the equivalent diametre.

Other equations can be inserted by the user if necessary. Restriction loss coefficients are provided in the input data.

2.10 Two-Phase Multiplier

The two-phase multiplier is of the following form:

$$\phi^2 = \left[1 + \frac{\alpha(\rho_L - \rho_g)}{(1-\alpha)\rho_L + \alpha\rho_g} \right] \left[1 + \frac{\alpha\rho_g}{(1-\alpha)\rho_L + \alpha\rho_g} \left(\frac{\mu_L - \mu_g}{\mu g} \right) \right]^{-1/4}$$

where α is the void
ρ is density
μ is viscosity

3.0 THE SPORTS PROGRAM ENVIRONMENT

The relationship between the user and the SPORTS program environment is illustrated in Figure 1. The program environment is conveniently divided into two parts; the **user interface** and the **program file set.**

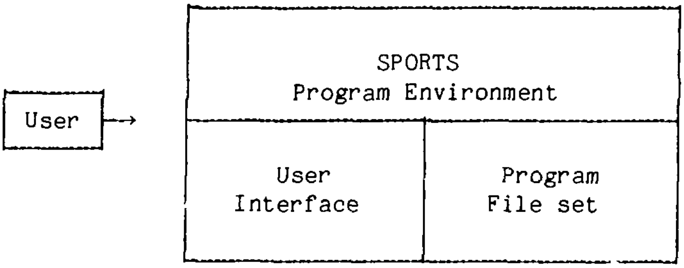

Figure 1: SPORTS Program Environment

The **program file set** is a collection of permanent files which are accessed via the user interface. These files contain user bulletins, SPORTS program source and test problem input data decks. The **user interface** provides access to the latest news about SPORTS, permits the user to run standard test problems, to solve user-defined problems, and to modify selected SPORTS routines as required.

3.1 SPORTS Control Statement

The user interface consists of a SPORTS control statement having the following syntax:

SPORTS,function,$p_1=v_1,p_2=v_2,\ldots p_n=v_n$.

where: function = one of five valid SPORTS functions - LSTBULL, GETPROB, RUNPROG, LSTPROG, and MODPROG
p_i = control statement parameter i
v_i = value assigned to parameter i

3.2 LSTBULL Function

A call to this function causes SPORTS user bulletin(s) to be copied to the user output file. This recognizes two parameters:

O = file to which user bulletins are to be copied (default:OUTPUT)
V = SPORTS version identifier (default:V1R1)

3.3 GETPROB Function

A call to this function gets SPORTS sample problem input from a library of sample problems, Table 1. This function recognizes three parameters:

TP = test problem identifier (default:SLOWPK3)
O = file to which test problem data are written (default:OUTPUT)
V = SPORTS version identifier (default:V1R1)

Identifier	Description
SLOWPK3	SLOWPOKE-3 Reactor
LEU2	SLOWPOKE-2 Low Enriched Uranium
HEU2	SLOWPOKE-2 High Enriched Uranium

Table 1: SPORTS Sample Problems

3.4 RUNPROG Function

A call to this function causes either the CRNL version or a user modified version of SPORTS to run. This function recognizes seven parameters:

I = SPORTS input data file (default:INPUT)
O = user output file (default:OUTPUT)
PL = user output file print limit in lines (default:20000)
X = file containing a user modified version of SPORTS (default:SPORTSX)
V = SPORTS version identifier (default:V1R1)
NODEMX = number of nodes in the model
($\sum$sections + # of $|$area changes$|$ + 1) (default:66)
NREGMX = number of regions in the model (default:10)

3.5 LSTPROG Function

A call to this function causes a list of specific SPORTS subprograms to be generated. This function recognizes four parameters:

O = file to which printable output is to be written (default:OUTPUT)
SP = name(s) of subprogram(s) to be listed (default:SPORTS)
LO = FTN5 reference map control parameter (default:$0/S$)
V = SPORTS version identifier (default:V1R1)

3.6 MODPROG Function

A call to this function allows the user to produce a modified version of SPORTS which can be executed by a subsequent call to the RUNPROG function. This procedure recognizes seven parameters:

I = user input file which contains user modifications in CDC UPDATE utility format (default:INPUT)
O = file to which printable output is to be written (default:OUTPUT)
PL = output file print limit in lines (default:20000)
LO = FTN5 reference map control parameter (default:O/S)
OPT = FTN5 optimization level specification (default:2)
X = file to which modified version of SPORTS is to be written (default:SPORTSX)
V = SPORTS version identifier (default:V1R1)

3.7 Using the User Interface Functions

To perform any one of the user functions, the user must include control statements similar to the following in the job deck:

```
LIBRARY,APPLICS.
SPORTS,LSTBULL,O=BULL.
```

Executing the LIBRARY control statement makes the SPORTS control statement available. In this case, when the SPORTS control statement is processed, the current SPORTS user bulletins are copied to the local file BULL. Other user functions require additional input data supplied by the user. In particular, the RUNPROG function requires a data deck consisting of information described in the following section.

4.0 INPUT DESCRIPTION

The user input process has been streamlined to make it as error-free as possible and except for the fixed format case title card, the user input is unformatted.

The input data are divided into six groups; the case identification, geometric data, boundary conditions, transient data, fuel model data and neutron kinetics data. These groups and their items are presented in an input summary table in Appendix A. This input summary will assist the user in preparing the input data sheet provided in Appendix B and will further reduce user errors.

4.1 Group 1: Case Identification

The first group is the case identification and option data. Card 01 is the title in A80 format. Card 02 describes the case options IOUT, IPLOT, NSUBC, ITR, and NOPT. These options control the output, the plotting, the subcooled boiling calculations, the transient calculations, and the neutron kinetics calculations respectively. They are all binary switches where 1 activates the option and 0 deactivates the option.

4.2 Group 2: Geometric Data

Group 2 is the geometric data. Card 03 to card 07 define arrays RLEN, A, DE, ANGLE, and NSECT. These are total length per region, flow area per region, equivalent diameter per region, angle with the horizontal per region, and number of sections per region respectively.

Card 08 defines the sections per region and is repeated until all sections are covered. The items IRPT, NCOD, TFA, TRK, and TRUFF are a repeat flag, the section identifier, the power profile factor per section, the restriction loss coefficient per section, and the roughness factor per section respectively. The repeat flag, IRPT, is used to indicate that the corresponding values of NCOD, TFA, TRK, and TRUFF define IRPT number of adjacent sections within the same region. The IRPT flag must not overlap regions. The power profile factors, TFA, must average out to unity. This option was incorporated to permit a non-uniform power profile. If the power profile factors do not average out to unity, the code will adjust the profile so that it does. The restriction loss coefficient, TRK, is as defined by the equation:

$$\frac{dP}{dx} = -\left(R_k + \frac{fL}{D}\right) * \frac{\rho u^2}{2}$$

where: R_k is equivalent to TRK,

$\frac{dp}{dx}$ is the pressure drop per unit length,

f is the friction factor defined by equations (1) and (2),

L is the section length,

D is diameter,

ρ is density,

and u is velocity.

The roughness factor, TRUFF, is ε in equation (2).

4.3 Group 3: Boundary Conditions

There are six options of boundary conditions, and these are specified on card 09. The necessary inputs for card 09 are POW, TIN, FLOW, PIN, and PEX, which are the average applied power, inlet temperature, actual or estimated flow, inlet pressure, and outlet pressure repectively. There is a special provision for pool-type reactors and this is activated by setting PIN=1. When this is done, the code assumes the inlet pressure must be calculated from a static head of water that is open to the atmosphere, and therefore ZIN, the height of the the static head of water in metres, must be inserted in card 10. Otherwise, the actual value of PIN must be specified.

If the flow-rate, FLOW, is known, then PEX must be set equal to 0 and the correct flow inserted in the data. If, however, the flow-rate is not known, as in natural-circulation systems, an estimate of the flow must be inserted. Then PEX must be set either to 1, if the outlet pressure must be calculated from a static head of water, or to the actual value of the outlet pressure. If PEX is set equal to 1, ZIN must be inserted in card 10.

4.4 Group 4: Transient Data

Group 4 is the transient data. Card 11 defines FSDT, DT, RAMP, and FPOW or DELKF. These are the final time of the transient, the transient time step, the rate of change of reactor power when NOPT=0 or the rate of reactivity change when NOPT=1, and the final power of the transient when NOPT=0 or the final value of reactivity insertion when NOPT=1 respectively.

4.5 Group 5: Fuel Model Data

Group 5 is the fuel model data. Card 12 defines NFPINS, PINLEN, and RADS which are the number of fuel pins, the fuel pin length, and the radius of the sheath respectively. Card 13 defines RADG, RADF, CPF, DENF, HG, THCF, THCS, RCTEMP, and RFTEMP. These items are the radius of the sheath-fuel gap, the radius of the fuel pins, the specific heat of the fuel, fuel density, heat transfer coefficient of the gap, the fuel thermal conductivity, sheath thermal conductivity, the reference coolant temperature, and the reference fuel temperature respectively. Because the subcool boiling model requires the items on card 12, it is necessary to include card 12 for all cases.

4.6 Group 6: Neutron Kinetics Data

Group 6 describes the neutron kinetics data required if NOPT=1. On card 14 LSTAR and GAMMA are the mean neutron generation time and the effectiveness of delayed neutrons respectively.

Card 15 to card 18 describe arrays that are fixed in length for a six group neutron kinetic model. Unused array elements must be set equal to zero. Card 15 is the array LAMDA, the decay constants; card 16 is the array BETA, the fission yield of delayed neutrons; card 17 is the array AKALFA, the reactivity coefficients of void; card 18 is the array AKTEMP, the reactivity coefficients of coolant temperature; card 19 is the array AKFUEL, the reactivity coefficients of fuel temperature.

5.0 OUTPUT DESCRIPTION

The SPORTS output listing and/or plots may be suppressed by setting the output flag, IOUT and the plotting flag, IPLOT, equal to 0.

Setting IOUT equal to 1 provides a detailed listing of all the flow variables for the steady-state solution and, if the transient option equals 1, a summary line for each time step of the transient as well as all the flow variables at the end of the transient. If using small time steps, the user may limit the volume of output by setting IOUT equal to n, where a summary line will be printed only every nth time step of the transient.

If the pl t option is set equal to 1, time history plots of inlet mass flow rate, outlet coolant temperature, and power are provided.

The numerical scheme used in SPORTS is not suitable for negative flow. If the system, in its dynamic motion, goes through negative or zero velocity, the code stops and provides a listing and/or plots, if requested, up to the time the negative or zero velocity was encountered.

Appendix C is an example of the input data sheet, the job deck, the listing and plots of a typical SLOWPOKE simulation case.

6.0 REFERENCES

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[3] L.E. Evans, E.A. Okazaki, "AELIB Users' Manual", AECL-6076, revision D, June 1983.

[4] W.N. Selander, "A Simple Method for Computing Mean Fuel Temperatures During a Reactor Transient", AECL-8777.

7.0 ACKNOWLEDGEMENT

We wish to thank R.A. Judd for his assistance in supplying the interface for the installation and development of the SPORTS code.

Appendix A: Input Data Table

This table describes the input data items in terms of their order, their type (real, integer, or alphanumeric), the units, the default values if any, and defines these items and their options. The table is a guide to completing the input data sheets in appendix B.

CARD	ITEM	TYPE	UNITS	DEFAULT	DESCRIPTION
Case Identification					
01	TITLE	A			Run description.
02	IOUT	I			Print option, IOUT=0 inhibits output and IOUT=n prints a transient summary line every nth time step and all the flow variables at the end of the steady-state and/or the transient.
	IPLOT	I			Plot option, IPLOT=0 inhibits any plotting and IPLOT=1 turns on the plot flag.
	NSUBC	I			Subcooled boiling option, NSUBC=0 turns off subcooled boiling calculations and NSUBC=1 turns on subcooled boiling calculations.
	ITR	I			Transient option. When ITR=0, only steady-state calculations are done; when ITR=1, transient calculations are done.
	NOPT	I			Neutron kinetic options. When NOPT=0, power change is specified by the user. When NOPT=1, a value of final reactivity insertion must be specified.
Geometric Data					
03	RLEN	R	m		Length of each region.
04	A	R	m^2		Flow area per region.
05	DE	R	m		Equivalent diameter per region. (4*flow area / wetted perimeter)
06	ANGLE	R	degrees		Angle of region with horizontal.
07	NSECT	I			Number of sections per region.

CARD	ITEM	TYPE	UNITS	DEFAULT	DESCRIPTION
08	IRPT	I			Repeat flag - indicates the number of adjacent sections within the same region that have the same values of NCOD, TFA, TRK and TRUFF.
	NCOD	I			Section identifier.

NCOD	Identifier
1	Heated sec
2	(reserved)
3	Riser
4	Heat exch.
5	Feeder in
6	Feeder out
7	Header
8	Unheated

CARD	ITEM	TYPE	UNITS	DEFAULT	DESCRIPTION
	TFA	R			Power profile data.
	TRK	R			Restriction loss coefficient data.
	TRUFF	R			Roughness factor.

(repeat card 08 for all sections)

Boundary Conditions

CARD	ITEM	TYPE	UNITS	DEFAULT	DESCRIPTION
09	POW	R	kW		Average applied power over entire geometry.
	TIN	R	°C		Inlet temperature.
	FLOW	R	kg/s		Actual or estimated flow rate.
	PIN	R	kPa		Inlet pressure. If PIN=1., estimate PIN and inlet density until density converges. If PIN is defined, calculated inlet enthalpy.
	PEX	R	kPa		External reference pressure. If PEX=0., FLOW is known and external pressure iteration is not necessary. If PEX=1., FLOW is estimated and external pressure is calculated internally. If PEX is defined, FLOW is estimated.

CARD	ITEM	TYPE	UNITS	DEFAULT	DESCRIPTION
10	ZIN	R	m		Height of static head of water at inlet, used when PIN and/or PEX=1.

Transient Data

11	FSDT	R	s		Final value of run time.
	DT	R	s		Time step.
	RAMP	R	s	DT	Rate of change of reactor power when NOPT=0, or rate of reactivity change when NOPT=1.
	FPOW	R	kW		Final average applied power.(NOPT=0)
	or/DELKF	R	mk	0.0	Final value of reactivity insertion. (NOPT=1)

Fuel Model Data

12	NFPINS	I			Number of fuel pins.
	PINLEN	R	m		Fuel pin length.
	RADS	R	m		Radius of the sheath.
13	RADG	R	m		Radius of sheath-fuel gap.
	RADF	R	m		Radius of the fuel pins.
	CPF	R	J/kg K		Specific heat of the fuel.
	DENF	R	kg/m^3		Density of the fuel.
	HG	R	W/m^2 K		Heat transfer coefficient of the gap.
	THCF	R	W/m °C		Fuel thermal conductivity.
	THCS	R	W/m °C		Sheath thermal conductivity.
	RCTEMP	R	°C		Reference coolant temperature.
	RFTEMP	R	°C		Reference fuel temperature.

Neutron Kinetics Data

14	LSTAR	R	s		Mean neutron generation time.
	GAMMA	R			Effectiveness of delayed neutrons.

CARD	ITEM	TYPE	UNITS	DEFAULT	DESCRIPTION
15	LAMDA	R	s^{-1}		Decay constants.[1]
16	BETA	R			Fission yield of delayed neutrons.[1]
17	AKALFA	R	mk		Reactivity coefficients of void.[1]
18	AKTEMP	R	mk		Reactivity coefficients of coolant temperature.[1]
19	AKFUEL	R	mk		Reactivity coefficients of fuel temperature.[1]

[1] Unused array elements **must** be set equal to zero.

Appendix B: Input Data Sheets

These sheets are provided to assist the user in making up an input deck. Except for the title card, the data is unformatted and all items must be separated by a comma or a blank. The card numbers are only a guide to the order of the data, and not the number of cards required.

CARD ITEMS

Case Identification

01 TITLE
A80

02 IOUT IPLOT NSUBC ITR NOPT
*(Free format)

Geometric Data

03 $RLEN_1, RLEN_2, \ldots RLEN_{NREGMX}$[1]
*

04 $A_1, A_2, \ldots A_{NREGMX}$[1]
*

05 $DE_1, DE_2, \ldots DE_{NREGMX}$[1]
*

06 $ANGLE_1, ANGLE_2, \ldots ANGLE_{NREGMX}$[1]
*

07 $NSECT_1, NSECT_2, \ldots NSECT_{NREGMX}$[1]
*

CARD ITEMS

08 IRPT NCOD TFA TRK TRUFF (repeat for all sections)
*

08 IRPT NCOD TFA TRK TRUFF
*

08 IRPT NCOD TFA TRK TRUFF
*

08 IRPT NCOD TFA TRK TRUFF
*

08 IRPT NCOD TFA TRK TRUFF
*

08 IRPT NCOD TFA TRK TRUFF
*

08 IRPT NCOD TFA TRK TRUFF
*

08 IRPT NCOD TFA TRK TRUFF
*

```
CARD   ITEMS

 08    IRPT NCOD TFA TRK TRUFF
       *

 08    IRPT NCOD TFA TRK TRUFF
       *

 08    IRPT NCOD TFA TRK TRUFF
       *

 08    IRPT NCOD TFA TRK TRUFF
       *

 08    IRPT NCOD TFA TRK TRUFF
       *

 08    IRPT NCOD TFA TRK TRUFF
       *

 08    IRPT NCOD TFA TRK TRUFF
       *

 08    IRPT NCOD TFA TRK TRUFF
       *
```

CARD ITEMS

Boundary Conditions

09 POW TIN FLOW PIN PEX
*

10 ZIN
*

Transient Data

11 FSDT DT RAMP FPOW/DELKF
*

Fuel Model Data

12 NFPINS PINLEN RADS
*

13 RADG RADF CPF DENF HG THCF RCTEMP RFTEMP
*

Neutron Kinetics Data

14 LSTAR GAMMA
*

15 $LAMDA_1, LAMDA_2, \ldots LAMDA_6$[2]
*

CARD ITEMS

16 BETA_1, BETA_2, ... BETA_6[2]
*

17 AKALFA_1, AKALFA_2, ... AKALFA_8[2]
*

18 AKTEMP_1, AKTEMP_2, ... AKTEMP_8[2]
*

19 AKFUEL_1, AKFUEL_2, ... AKFUEL_8[2]
*

---

[1] Arrays dimensioned by NREGMX must be **exactly** dimensioned and defined.

[2] Unused array elements must be set equal to 0.

Appendix C: Sample Case

This is a sample case for the SLOWPOKE-2 reactor for a 6.25 mk step insertion of reactivity. The transients were performed for 200 seconds. Since this is a pool type reactor, PIN and PEX were set equal to 1 to calculate the inlet pressure and the external reference pressure respectively, and ZIN, the height of the static head of water at inlet is also defined by the user. It was assumed that the pool temperature remained constant throughout the transient at 20°C. Desirable neutron kinetic and subcooled boiling effects are calculated by setting NOPT and NSUBC equal to 1.

The user controls the type and volume of output with the IOUT and IPLOT options. The IOUT option is set to print the steady-state solution, a transient summary line at every tenth time step, and the transient solution. The IPLOT is set equal to 1 for plots.

```
CASE OPTIONS
------------

SUBCOOLING OPTION              :  1       OUTPUT OPTION               : 10
TRANSIENT  OPTION              :  1       PLOT OPTION                 :  1
NEUTRON KINETIC OPTION         :  1

BOUNDARY CONDITIONS :
-------------------

AVERAGE POWER (KW)             : .100000E+00
AVERAGE POWER PROFILE FACTOR   :  .10000E+01
INLET TEMPERATURE (DEG C)      : .200000E+02
CALCULATE INLET PRESSURE FOR POOL TYPE REACTOR
CALCULATE REF. EXT. PRESSURE FOR POOL TYPE REACTOR
EST. INLET MASS FLOW (KG/S)    : .500000E-01

TRANSIENT DATA
--------------

TIME STEP OF TRANSIENT (S)     : .200000E+00
FINAL TIME OF TRANSIENT (S)    : .200000E+03
POWER CHANGE IS DUE TO NEUTRON-KINETIC EFFECT AND REACTIVITY INSERTION
```

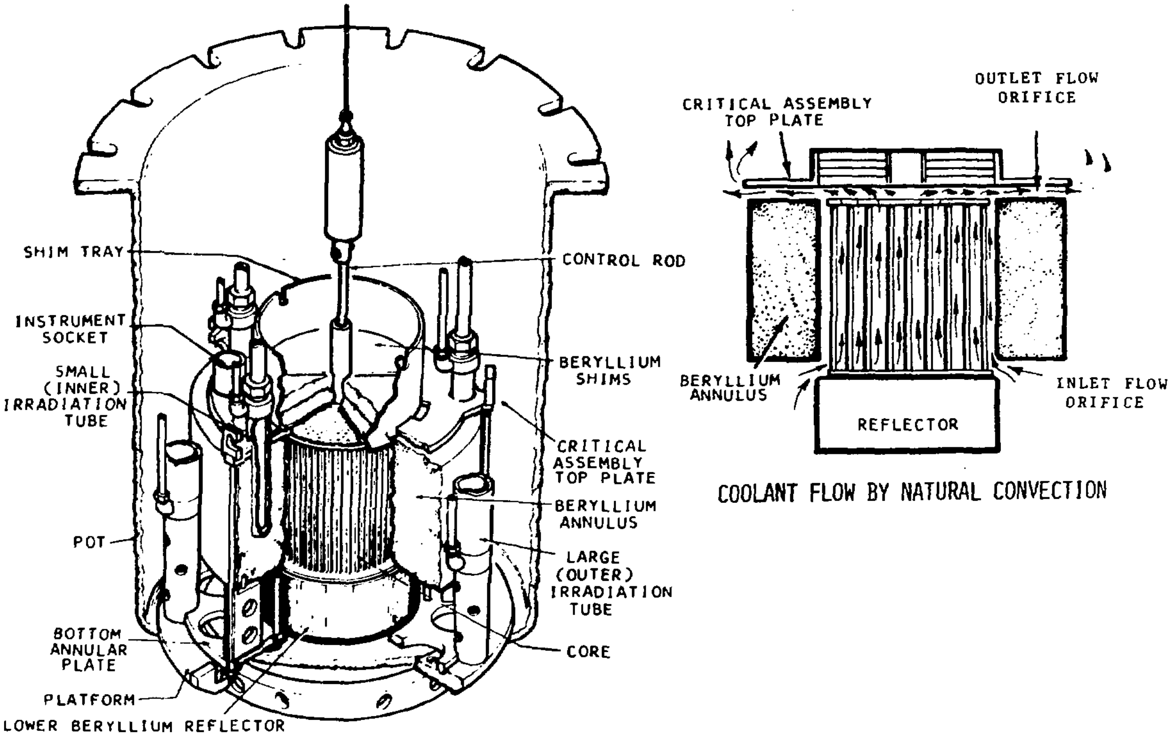


Figure 2: Core Region of SLOWPOKE-2

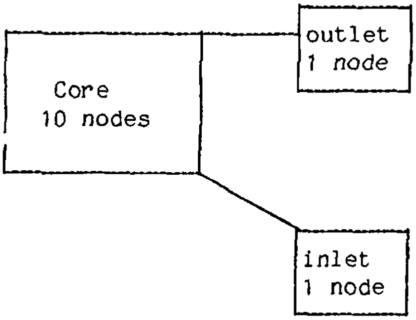


Figure 3: Nodal Diagram of SLOWPOKE-2 in Sample Case

```
/JOB
/NOSEQ
LEU2,B####-#####,T200,IO100.  SLOWPOKE 2 SIMULATION
ROUTE,PLOT,DC=PL,TID=##,DEF.
LIBRARY,APPLICS.
SPORTS,RUNPROG,NODEMAX=15,NREGION=3.
/EOR
/CASE IDENTIFICATION
/TITLE
   SPORTS SIMULATION PACKAGE - LEU SLOWPOKE-2 TRANSIENTS
/OPTIONS DATA
/IOUT IPLOT NSUBC ITR NOPT
 10 1 1 1 1
/GEOMETRY DATA
/RLEN, LENGTH OF EACH REGION
 0.016  0.2278  0.114
/A, FLOW AREA PER REGION
 0.00387  34.4445E-3  0.00441
/DE, EQUIVALENT DIAMETER AREA PER REGION
 0.07267  0.1628  0.06513
/ANGLE, REGION ANGLE WITH THE HORIZONTAL
 30.  90.  0.
/NSECT, NUMBER OF SECTIONS PER REGION
 1 10 1
/IRPT  NCOD  TFA  TRK  TRUFF  - REPEAT FOR ALL SECTIONS
  1  3  0.0000   0.90  0.0
  1  1  0.8580   0.00  0.0
  1  1  0.80485  0.00  0.0
  1  1  0.9985   0.00  0.0
  1  1  1.13895  0.00  0.0
  1  1  1.1997   0.00  0.0
  1  1  1.1997   0.00  0.0
  1  1  1.13895  0.00  0.0
  1  1  0.9985   0.00  0.0
  1  1  0.80485  0.00  0.0
  1  1  0.8580   0.00  0.0
  1  3  0.0000   3.60  0.0
/BOUNDARY CONDITIONS
/POW  TIN  FLOW  PIN  PEX
 0.1 20.0 0.05 1.0 1.0
/IF PIN AND/OR PEX EQUALS 1, THEN READ ZIN
 4.4964
```

```
/TRANSIENT DATA
/DT FSDT RAMP (FPOW OR DELKF)
 0.1 200.0 0.0 6.25
/FUEL MODEL DATA
/NFPINS PINLEN RADS
 180 .2278 2.6289E-3
/RADG RADF CPF DENF HG THCF THCS RCTEMP RFTEMP
 2.1209E-3 2.0828E-3 236.4 10.6E3 5000. 4.67 12.6 20. 20
/NEUTRON KINETIC DATA
/LSTAR GAMMA
 7.65E-5 1.173
/LAMDA(1),LAMDA(2)...LAMDA(6)
 .01272 .03174 .116 .311 1.40 3.87
/BETA(1),BETA(2)...BETA(6)
 .0002601 .0014572 .0027845 .0008759 .0001778
/AKALFA(1),AKALFA(2)...AKALFA(8)
 -.242427E1 -.6662E-1 .150717E-1 -.274285E-2
 .280277E-3 -.162731E-4 .499322E-6 -.627403E-8
/AKTEMP(1),AKTEMP(2)...AKTEMP(8)
 -.504244E-1 -.133402E-2 .941701E-5 -.110905E-5
 .652472E-7 -.169802E-8 .202431E-10 -.906002E-13
/AKFUEL(1),AKFUEL(2)...AKFUEL(8)
 -.912139E-2 .737004E-5 -.434446E-7 .530476E-9
 -.357810E-11 .123747E-13 -.209559E-16 .137182E-19
```

Figure 4: Sample User's Job Deck

```
******************************************************
*                                                    *
*                                                    *
*                      SPORTS                        *
*                                                    *
*           SPECIAL PREDICTIONS OF REACTOR           *
*          THERMALHYDRAULICS AND STABILITY           *
*                                                    *
*                                                    *
*        SPORTS IS A SWIFT AND ACCURATE CODE FOR     *
*       INVESTIGATING THE STABILITY OF TWO-PHASE     *
*       FLOWS.  IT IS BASED ON A SIMPLE ALGORITHM    *
*       THAT PERMITS EFFICIENT SOLUTION OF THE       *
*       UNABRIDGED CONSERVATIONS EQUATIONS CAST IN   *
*       FINITE-DIFFERENCE FORM.                      *
*                                                    *
*       LARGE TIME-STEPS ARE ALLOWED AND THE PRO-    *
*       GRAM DETERMINES STEADY-STATE AS WELL AS THE  *
*       TIME-HISTORY OF ONE-DIMENSIONAL TRANSIENT    *
*       FLOWS.  THE OUTPUT CONSISTS OF TABULATED     *
*       RESULTS OF ALL THE FLOW VARIABLES AND TIME-  *
*       HISTORY PLOTS OF INLET VELOCITY AND POWER.   *
*                                                    *
*                                                    *
*                 SPORTS - VERSION 1                 *
*                                                    *
*               USERS' GUIDE - AECL-8752             *
*           V. CHATOORGOON, P.R. THIBEAULT           *
*                                                    *
*                                                    *
*                    PROPERTY OF                     *
*                                                    *
*           ATOMIC ENERGY OF CANADA LIMITED          *
*           CHALK RIVER NUCLEAR LABORATORIES         *
*             APPLIED MATHEMATICS BRANCH             *
*                        1985                        *
*                                                    *
*                                                    *
******************************************************
```

Figure 5: SPORTS Output - Banner

```
                                  ++++++++++++++++++++++++++++++++++
                                  +        SPORTS PACKAGE          +
                                  +  COPY OF USER INPUT TO SPORTS  +
                                  ++++++++++++++++++++++++++++++++++

 CARD                                                                             CARD
NUMBER                                  CARD IMAGE                               NUMBER
       1        10        20        30        40        50        60        70        80
.......V.........V.........V.........V.........V.........V.........V.........V.........V........
*****  /CASE IDENTIFICATION                                                       *****
*****  / TITLE                                                                    *****
00001     SPORTS THERMALHYDRAULIC STABILITY CODE - SLOWPOKE-2 TRANSIENT           00001
*****  /OPTIONS DATA                                                              *****
*****  /IOUT IPLOT NSUBC  ITR  NOPT                                               *****
00002   10 1 1 1 1                                                                00002
*****  /GEOMETRY DATA                                                             *****
*****  /RLEN, LENGTH OF EACH REGION                                               *****
00003   0.016  0.2278  0.114                                                      00003
*****  /A, FLOW AREA PER REGION                                                   *****
00004   0.00387  34.4445E-3  0.00441                                              00004
*****  /DE, EQUIVALENT DIAMETER AREA PER REGION                                   *****
00005   0.07267  0.1628  0.06513                                                  00005
*****  /ANGLE, REGION ANGLE WITH THE HORIZONTAL                                   *****
00006   30.  90.  0.                                                              00006
*****  /NSECT, NUMBER OF SECTIONS PER REGION                                      *****
00007   1 10 1                                                                    00007
*****  /IRPT  NCOD  TFA   TRK  TRUFF  - REPEAT FOR ALL SECTIONS                   *****
00008    1  3  0.0000   0.90  0.0                                                 00008
00009    1  1  0.8580   0.00  0.0                                                 00009
00010    1  1  0.80485  0.00  0.0                                                 00010
00011    1  1  0.9985   0.00  0.0                                                 00011
00012    1  1  1.13895  0.00  0.0                                                 00012
00013    1  1  1.1997   0.00  0.0                                                 00013
00014    1  1  1.1997   0.00  0.0                                                 00014
00015    1  1  1.13895  0.00  0.0                                                 00015
00016    1  1  0.9985   0.00  0.0                                                 00016
00017    1  1  0.80485  0.00  0.0                                                 00017
00018    1  1  0.8580   0.00  0.0                                                 00018
00019    1  3  0.0000   3.60  0.0                                                 00019
*****  /BOUNDARY CONDITIONS                                                       *****
*****  /POW  TIN  FLOW  PIN  PEX                                                  *****
00020    0.1 20.0 0.05 1.0 1.0                                                    00020
*****  /IF PIN AND/OR PEX EQUALS 1, THEN READ ZIN                                 *****
00021   4.4964                                                                    00021
*****  /TRANSIENT DATA                                                            *****
*****  /DT  FSDT  RAMP  (FPOW OR DELKF)                                           *****
00022   0.2 200.0 0.0 6.25                                                        00022
```

Figure 6: SPORTS Output - Card Image of User's Job Deck

```
*****  /FUEL MODEL DATA                                                                  *****
*****  /NFPINS PINLEN RADS                                                               *****
00023   180 .2278 2.6289E-3                                                              00023
*****  /RADG RADF CPF DENF HG THCF THCS RCTEMP RFTEMP                                    *****
00024   2.1209E-3 2.0828E-3 236.4 10.6E3 5000. 4.67 12.6 20. 20.                         00024
*****  /NEUTRON KINETIC DATA                                                             *****
*****  /LSTAR GAMMA                                                                      *****
00025   7.65E-5 1.173                                                                    00025
*****  /LAMDA(1),LAMDA(2)...LAMDA(6)                                                     *****
00026   .01272  .03174  .116  .311  1.40  3.87                                           00026
*****  /BETA(1),BETA(2)...BETA(6)                                                        *****
00027   .0002601  .0014572  .0012863  .0027845  .0008759  .0001778                       00027
*****  /AKALFA(1),AKALFA(2)...AKALFA(8)                                                  *****
00028   -.242427E1 -.666200E-1 .150717E-1 -.274285E-2                                    00028
00029   .280277E-3 -.162731E-4 .499322E-6 -.627403E-8                                    00029
*****  /AKTEMP(1),AKTEMP(2)...AKTEMP(8)                                                  *****
00030   -.504244E-1 -.133402E-2 .941701E-5 -.110905E-5                                  00030
00031   .652472E-7 -.169802E-8 .202431E-10 -.906002E-13                                  00031
*****  /AKFUEL(1),AKFUEL(2)...AKFUEL(8)                                                  *****
00032   -.912139E-2 .737004E-5 -.434446E-7 .530476E-9                                    00032
00033   -.357810E-11 .123747E-13 -.209559E-16 .137182E-19                                00033
```

Figure 6: SPORTS Output - Card Image cont'd

```
SUMMARY OF INPUT DATA :    SPORTS THERMALHYDRAULIC STABILITY CODE - SLOWPOKE-2 TRANSIENT
---------------------

 NODE      AREA       LENGTH      POWER    RESTRICTION    GRAVITY SECTION SECTION
NUMBER      M2          M      DISTRIBUTION LOSS COEF.     INDEX    CODE   NAME


00001 .38700E-02  .16000E-01 0.           .90000E+00 .50000E+00  00003  RISER
00002 .38700E-02 0.          0.          0.           .50000E+00  00002  BOUNDARY
00003 .34445E-01  .22780E-01  .85800E+00 0.           .10000E+01  00001  HEATED SEC
00004 .34445E-01  .22780E-01  .80485E+00 0.           .10000E+01  00001  HEATED SEC
00005 .34445E-01  .22780E-01  .99850E+00 0.           .10000E+01  00001  HEATED SEC
00006 .34445E-01  .22780E-01  .11390E+01 0.           .10000E+01  00001  HEATED SEC
00007 .34445E-01  .22780E-01  .11997E+01 0.           .10000E+01  00001  HEATED SEC
00008 .34445E-01  .22780E-01  .11997E+01 0.           .10000E+01  00001  HEATED SEC
00009 .34445E-01  .22780E-01  .11390E+01 0.           .10000E+01  00001  HEATED SEC
00010 .34445E-01  .22780E-01  .99850E+00 0.           .10000E+01  00001  HEATED SEC
00011 .34445E-01  .22780E-01  .80485E+00 0.           .10000E+01  00001  HEATED SEC
00012 .34445E-01  .22780E-01  .85800E+00 0.           .10000E+01  00001  HEATED SEC
00013 .34445E-01 0.          0.          0.           .10000E+01  00002  BOUNDARY
00014 .44100E-02  .11400E+00 0.          .36000E+01 0.           00003  RISER
00015 .44100E-02 0.          0.          0.          0.           00002  BOUNDARY
```

Figure 7: SPORTS Output - Input Data Summary

```
   SPORTS THERMALHYDRAULIC STABILITY CODE - SLOWPOKE-2 TRANSIENT

 CASE OPTIONS
 ------------

 SUBCOOLING OPTION           :  1                OUTPUT OPTION                          : 10
 TRANSIENT  OPTION           :  1                PLOT OPTION                            :  1
 NEUTRON KINETIC OPTION      :  1

 BOUNDARY CONDITIONS :
 -------------------

 AVERAGE POWER (KW)           : .100000E+00
 AVERAGE POWER PROFILE FACTOR :  .10000E+01
 INLET TEMPERATURE (DEG C)    : .200000E+02
 CALCULATE INLET PRESSURE FOR POOL TYPE REACTOR
 CALCULATE REF. EXT. PRESSURE FOR POOL TYPE REACTOR
 EST. INLET MASS FLOW (KG/S)  : .500000E-01

 TRANSIENT DATA
 --------------

 TIME STEP OF TRANSIENT (S)   : .200000E+00
 FINAL TIME OF TRANSIENT (S)  : .200000E+03
 POWER CHANGE IS DUE TO NEUTRON-KINETIC EFFECT AND REACTIVITY INSERTION

 FUEL MODEL DATA
 ---------------

 NUMBER OF FUEL PINS                          :  180
 FUEL PIN LENGTH (M)                          : .227800E+00
 RADIUS OF SHEATH (M)                         : .262890E-02
 RADIUS OF GAP (M)                            : .212090E-02
 RADIUS OF FUEL (M)                           : .208280E-02
 SPECIFIC HEAT OF FUEL (J/KG K)               : .236400E+03
 DENSITY OF FUEL (KG/M3)                      : .106000E+05
 HEAT TRANSFER COEFFICIENT OF GAP (W/M2 K)    : .500000E+04
 FUEL CONDUCTIVITY (W/M C)                    : .467000E+01
 SHEATH CONDUCTIVITY (W/M C)                  : .126000E+02
 REFERENCE COOLANT TEMP. (DEG C)              : .200000E+02
 REFERENCE FUEL TEMP. (DEG C)                 : .200000E+02

 NEUTRON KINETIC DATA
 --------------------

 FINAL VALUE OF REACTIVITY INSERTION (MK)     : .625000E+01
 RATE OF REACTIVITY INSERTION (S)             :  .20000E+00
 DECAY CONSTANT (S-1)                         : .127200E-01 .317400E-01 .116000E+00 .311000E+00 .140000E+01 .387000E+01
 NEUTRON GENERATION TIME (S)                  : .765000E-04
 FISSION YIELD OF DELAYED NEUTRON             : .260100E-03 .145720E-02 .128630E-02 .278450E-02 .875900E-03 .177800E-03
 EFFECTIVENESS OF DELAYED NEUTRONS            : .117300E+01
```

Figure 7: SPORTS Output - Input Data Summary cont'd

```
SPORTS THERMALHYDRAULIC STABILITY CODE - SLOWPOKE-2 TRANSIENT                   85-02-21    17.31.49.

===================================================================================================

    STEADY-STATE CONDITIONS :

    NUMBER OF POUT ITERATIONS =                               2
    NUMBER OF NODES =                                    15
    OUTLET PRESSURE =                               .143024E+03    KPA
    REFERENCE EXT. PRESS. =                         .143024E+03    KPA
    CONVERGED FLOW RATE =                               .04        KG/S
    AVERAGE CORE VOID =                               .00000       FRACTION
    AVERAGE CORE TEMP. =                              20.28663     DEG C
    APPLIED POWER =                                 .10000E+00     KW

===================================================================================================

NODE   DENSITY     VELOCITY    PRESSURE     DELTA P      ENTHALPY  TEMPERATURE     VOID        NAME
        KG/M3        M/S        PASCAL       PASCAL        J/KG      DEG. C

  1  .99826E+03  .10785E-01  .14533E+06 -.78397E+02  .84087E+05  .20000E+02 0.              RISER
  2  .99826E+03  .10785E-01  .14525E+06  .20822E-01  .84087E+05  .20000E+02 0.              BOUNDARY
  3  .99826E+03  .12118E-02  .14525E+06 -.22307E+03  .84087E+05  .20000E+02 0.              HEATED SEC
  4  .99825E+03  .12118E-02  .14503E+06 -.22307E+03  .84293E+05  .20049E+02  .39049E-13   HEATED SEC
  5  .99824E+03  .12118E-02  .14481E+06 -.22307E+03  .84486E+05  .20095E+02  .37484E-13   HEATED SEC
  6  .99823E+03  .12118E-02  .14459E+06 -.22307E+03  .84725E+05  .20153E+02  .47724E-13   HEATED SEC
  7  .99822E+03  .12118E-02  .14436E+06 -.22307E+03  .84998E+05  .20218E+02  .55979E-13   HEATED SEC
  8  .99820E+03  .12119E-02  .14414E+06 -.22307E+03  .85286E+05  .20287E+02  .60688E-13   HEATED SEC
  9  .99819E+03  .12119E-02  .14392E+06 -.22306E+03  .85574E+05  .20355E+02  .62461E-13   HEATED SEC
 10  .99817E+03  .12119E-02  .14369E+06 -.22306E+03  .85847E+05  .20421E+02  .60977E-13   HEATED SEC
 11  .99816E+03  .12119E-02  .14347E+06 -.22306E+03  .86086E+05  .20478E+02  .54860E-13   HEATED SEC
 12  .99815E+03  .12119E-02  .14325E+06 -.22306E+03  .86279E+05  .20524E+02  .45254E-13   HEATED SEC
 13  .99814E+03  .12119E-02  .14302E+06 -.17703E-01  .86485E+05  .20573E+02  .49412E-13   BOUNDARY
 14  .99814E+03  .94658E-02  .14302E+06 -.16903E+00  .86485E+05  .20573E+02 0.              RISER
```

Figure 8: SPORTS Output - Steady-State Solution

```
      SPORTS THERMALHYDRAULIC STABILITY CODE - SLOWPOKE-2 LEU DATA          85-05-13    16.07.52.

 TRANSIENT AT     .20S INLET FLOW  .042KG/S  OUTLET CORE TEMP  20.6° C  APPLIED POWER .10721E+00KW
 TRANSIENT AT    2.20S INLET FLOW  .042KG/S  OUTLET CORE TEMP  20.6° C  APPLIED POWER .55172E+00KW
 TRANSIENT AT    4.20S INLET FLOW  .042KG/S  OUTLET CORE TEMP  20.7° C  APPLIED POWER .47127E+01KW
 TRANSIENT AT    6.20S INLET FLOW  .049KG/S  OUTLET CORE TEMP  21.5° C  APPLIED POWER .25268E+02KW
 TRANSIENT AT    8.20S INLET FLOW  .091KG/S  OUTLET CORE TEMP  24.5° C  APPLIED POWER .82168E+02KW
 TRANSIENT AT   10.20S INLET FLOW  .193KG/S  OUTLET CORE TEMP  29.9° C  APPLIED POWER .13866E+03KW
 TRANSIENT AT   12.20S INLET FLOW  .308KG/S  OUTLET CORE TEMP  37.1° C  APPLIED POWER .15669E+03KW
 TRANSIENT AT   14.20S INLET FLOW  .399KG/S  OUTLET CORE TEMP  46.6° C  APPLIED POWER .15311E+03KW
 TRANSIENT AT   16.20S INLET FLOW  .465KG/S  OUTLET CORE TEMP  57.2° C  APPLIED POWER .14217E+03KW
 TRANSIENT AT   18.20S INLET FLOW  .503KG/S  OUTLET CORE TEMP  70.4° C  APPLIED POWER .13256E+03KW
 TRANSIENT AT   20.20S INLET FLOW  .520KG/S  OUTLET CORE TEMP  79.9° C  APPLIED POWER .12774E+03KW
 TRANSIENT AT   22.20S INLET FLOW  .520KG/S  OUTLET CORE TEMP  89.2° C  APPLIED POWER .12744E+03KW
 TRANSIENT AT   24.20S INLET FLOW  .508KG/S  OUTLET CORE TEMP  94.0° C  APPLIED POWER .13143E+03KW
 TRANSIENT AT   26.20S INLET FLOW  .491KG/S  OUTLET CORE TEMP  92.3° C  APPLIED POWER .13969E+03KW
 TRANSIENT AT   28.20S INLET FLOW  .484KG/S  OUTLET CORE TEMP  88.9° C  APPLIED POWER .14832E+03KW
 TRANSIENT AT   30.20S INLET FLOW  .489KG/S  OUTLET CORE TEMP  86.8° C  APPLIED POWER .15372E+03KW
 TRANSIENT AT   32.20S INLET FLOW  .500KG/S  OUTLET CORE TEMP  86.7° C  APPLIED POWER .15604E+03KW
 TRANSIENT AT   34.20S INLET FLOW  .510KG/S  OUTLET CORE TEMP  87.9° C  APPLIED POWER .15669E+03KW
 TRANSIENT AT   36.20S INLET FLOW  .519KG/S  OUTLET CORE TEMP  89.7° C  APPLIED POWER .15690E+03KW
 TRANSIENT AT   38.20S INLET FLOW  .524KG/S  OUTLET CORE TEMP  91.4° C  APPLIED POWER .15740E+03KW
 TRANSIENT AT   40.20S INLET FLOW  .526KG/S  OUTLET CORE TEMP  92.5° C  APPLIED POWER .15858E+03KW

------------::------------::------------::------------::------------::------------::------------::----------

 TRANSIENT AT  160.20S INLET FLOW  .575KG/S  OUTLET CORE TEMP  97.4° C  APPLIED POWER .18616E+03KW
 TRANSIENT AT  162.20S INLET FLOW  .575KG/S  OUTLET CORE TEMP  97.4° C  APPLIED POWER .18624E+03KW
 TRANSIENT AT  164.20S INLET FLOW  .575KG/S  OUTLET CORE TEMP  97.4° C  APPLIED POWER .18632E+03KW
 TRANSIENT AT  166.20S INLET FLOW  .575KG/S  OUTLET CORE TEMP  97.4° C  APPLIED POWER .18639E+03KW
 TRANSIENT AT  168.20S INLET FLOW  .575KG/S  OUTLET CORE TEMP  97.4° C  APPLIED POWER .18646E+03KW
 TRANSIENT AT  170.20S INLET FLOW  .575KG/S  OUTLET CORE TEMP  97.4° C  APPLIED POWER .18652E+03KW
 TRANSIENT AT  172.20S INLET FLOW  .575KG/S  OUTLET CORE TEMP  97.4° C  APPLIED POWER .18659E+03KW
 TRANSIENT AT  174.20S INLET FLOW  .576KG/S  OUTLET CORE TEMP  97.4° C  APPLIED POWER .18665E+03KW
 TRANSIENT AT  176.20S INLET FLOW  .576KG/S  OUTLET CORE TEMP  97.4° C  APPLIED POWER .18672E+03KW
 TRANSIENT AT  178.20S INLET FLOW  .576KG/S  OUTLET CORE TEMP  97.4° C  APPLIED POWER .18677E+03KW
 TRANSIENT AT  180.20S INLET FLOW  .576KG/S  OUTLET CORE TEMP  97.5° C  APPLIED POWER .18683E+03KW
 TRANSIENT AT  182.20S INLET FLOW  .576KG/S  OUTLET CORE TEMP  97.5° C  APPLIED POWER .18688E+03KW
 TRANSIENT AT  184.20S INLET FLOW  .576KG/S  OUTLET CORE TEMP  97.5° C  APPLIED POWER .18693E+03KW
 TRANSIENT AT  186.20S INLET FLOW  .576KG/S  OUTLET CORE TEMP  97.5° C  APPLIED POWER .18698E+03KW
 TRANSIENT AT  188.20S INLET FLOW  .576KG/S  OUTLET CORE TEMP  97.5° C  APPLIED POWER .18704E+03KW
 TRANSIENT AT  190.20S INLET FLOW  .576KG/S  OUTLET CORE TEMP  97.5° C  APPLIED POWER .18708E+03KW
 TRANSIENT AT  192.20S INLET FLOW  .577KG/S  OUTLET CORE TEMP  97.5° C  APPLIED POWER .18712E+03KW
 TRANSIENT AT  194.20S INLET FLOW  .577KG/S  OUTLET CORE TEMP  97.5° C  APPLIED POWER .18717E+03KW
 TRANSIENT AT  196.20S INLET FLOW  .577KG/S  OUTLET CORE TEMP  97.5° C  APPLIED POWER .18721E+03KW
 TRANSIENT AT  198.20S INLET FLOW  .577KG/S  OUTLET CORE TEMP  97.5° C  APPLIED POWER .18725E+03KW
```

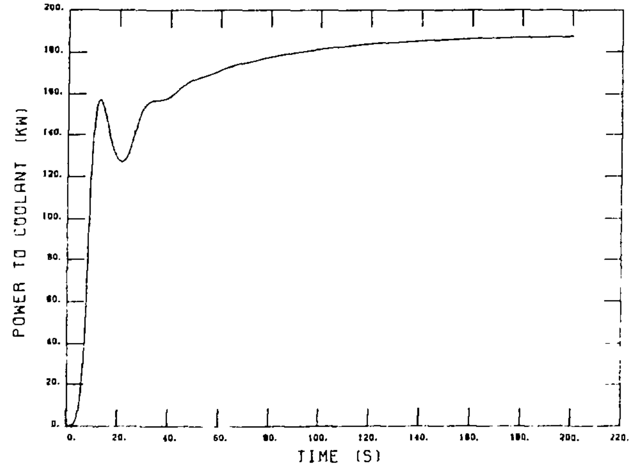
Figure 9: SPORTS Output - Transient Summary

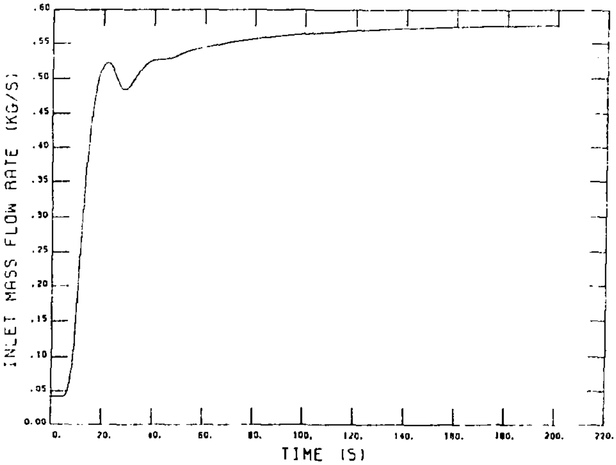
```
SPORTS THERMALHYDRAULIC STABILITY CODE - SLOWPOKE-2 TRANSIENT                85-02-21    18.18.55.

=================================================================================================

      RESULT OF TRANSIENT RUN :

      TIME LAPSE =                                  200.20000   SECONDS
      TIME STEP =                                      .20000   SECONDS
      INLET FLOW RATE =                              .58        KG/S
      AVERAGE CORE VOID =                          .00259       FRACTION
      AVERAGE CORE TEMP. =                        58.80084      DEG C
      APPLIED POWER =                           .18730E+03      KW

=================================================================================================

NODE   DENSITY     VELOCITY     PRESSURE    DELTA P       ENTHALPY  TEMPERATURE     VOID      NAME
        KG/M3        M/S         PASCAL     PASCAL          J/KG      DEG. C

  1  .99826E+03  .14935E+00  .14533E+06 -.88436E+02  .84087E+05  .20000E+02 0.             RISER
  2  .99826E+03  .14935E+00  .14524E+06  .39928E+01  .84087E+05  .20000E+02 0.             BOUNDARY
  3  .99826E+03  .16780E-01  .14525E+06 -.22291E+03  .84087E+05  .20000E+02 0.             HEATED SEC
  4  .99666E+03  .16807E-01  .14503E+06 -.22251E+03  .11194E+06  .26657E+02  .63819E-09  HEATED SEC
  5  .99475E+03  .16840E-01  .14480E+06 -.22199E+03  .13806E+06  .32908E+02  .28043E-08  HEATED SEC
  6  .99194E+03  .16887E-01  .14458E+06 -.22126E+03  .17047E+06  .40667E+02  .27855E-07  HEATED SEC
  7  .98823E+03  .16951E-01  .14436E+06 -.22032E+03  .20743E+06  .49520E+02  .32407E-06  HEATED SEC
  8  .98353E+03  .17032E-01  .14414E+06 -.21925E+03  .24637E+06  .58834E+02  .37109E-05  HEATED SEC
  9  .97868E+03  .17116E-01  .14392E+06 -.21807E+03  .28531E+06  .68146E+02  .38709E-04  HEATED SEC
 10  .97291E+03  .17218E-01  .14370E+06 -.21671E+03  .32227E+06  .76954E+02  .32435E-03  HEATED SEC
 11  .96654E+03  .17331E-01  .14349E+06 -.21508E+03  .35467E+06  .84671E+02  .18109E-02  HEATED SEC
 12  .95836E+03  .17479E-01  .14327E+06 -.21060E+03  .38079E+06  .90891E+02  .61688E-02  HEATED SEC
 13  .92633E+03  .18084E-01  .14306E+06 -.35106E+01  .40863E+06  .97522E+02  .35170E-01  BOUNDARY
 14  .96007E+03  .13628E+00  .14306E+06 -.32471E+02  .40863E+06  .97522E+02 0.             RISER
```

Figure 10: SPORTS Output - Transient Solution at End of Transient

SPORTS - STABILITY/SIMULATION CODE

INITIAL POWER(KW)=.10000E+00 REACTIVITY(MK)= 6.25 HC(W/M2.K)=.50000E+04





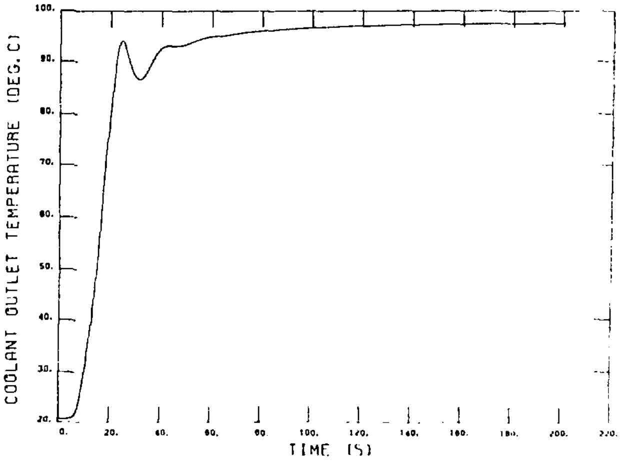


Figure 11: Optional Plots

Appendix D: SPORTS Linkage and Flowchart

This appendix shows linkage diagrams of the subroutines, functions, and the common blocks of the SPORTS code. The SPORTS flowchart is also included.

```
<CALL MAP>

                                 CALLING SUBPROGRAM

    CALLED     B S A C F F I O P P P P R R S S S T Z    NO. OF
  SUBPROGRAM   A P R O R U N W E H O O F H O T U S P    TIMES
      OR       N O C N C E P T X I W W A O L P B N L    CALLED
 ENTRY POINT   N R O V T L U P C S C E L C V R C O O
               E T   H N M T U H Q O Q S H E O O T T
               R S   I   D   T E   R N I E   P O
                     N   L     K   R     K     L

BANNER                     X                           001
SPORTS                                                 000<
ARCO                                     X             001
CONVHIN                  X                             001
FRCTN                                    X             001
FUELMDL                                    X           001
> FUELNXT                          X                   001
INPUT            X                                     001
OWTPUT                                     X           001
PEXCHEK                                    X           001
PHISQ                                    X             001
POWCORR                                    X           001
POWEQN                             X                   001
RFALSI                   X                             001
RHOCHEK                  X                             001
SOLVE            X                                     001
STPROP               X           X         X X         004
SUBCOOL                                  X             001
TSNOT                    X                             001
ZPLOT                                      X           001

NUMBERX100     0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 OF X10        0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
CALLSX1        0 2 1 0 0 1 1 0 4 0 2 0 0 5 6 0 0 0 0
```

Figure 12: SPORTS Linkage -- Subprogram Call Map

```
<COMMON BLOCK MAP>

-----------------------------------------------------------------------
|            |                     SUBPROGRAM                |NO.OF   |
|            |                                               |        |
|            | B S A C F F I O P P P P R R S S S T Z         |TIMES   |
|  COMMON    | A P R O R U N W E H O O F H O T U S P         |REF D   |
|  BLOCK     | N O C N C E P T X I W W A O L P B N L         |        |
|            | N R O V T L U P C S C E L C V R C O O         |        |
|            | E T   H N M T U H Q O Q S H E O O T T         |        |
|            | R S   I   D   T E   R N I E   P O             |        |
|            |       N   L     K   R     K     L             |        |
-----------------------------------------------------------------------
| CSTPHM     |   X                                           |  001   |
| NEUTKIN    |   X       X X       X       X   X   X         |  007   |
| OPTIONS    |   X X       X X X   X     X X X X   X         |  011   |
| CONSTNT    |   X X X X X X X X X X     X X X X   X         |  015   |
| FACTLIM    |   X X X X   X   X         X X                 |  008   |
| CSTPHS     |       X                       X               |  002   |
| CSTPH3     |       X                       X               |  002   |
| TSOCOM     |           X                       X           |  002   |
| CSTPHL     |           X                   X               |  002   |
| CSTPHV     |                               X               |  001   |
| SCALES     |                                     X         |  001   |
| FORMAT     |                                     X         |  001   |
-----------------------------------------------------------------------
| NO. OFX100 | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0         |        |
| COMMONX10  | 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0         |        |
| BLOCKSX1   | 0 5 3 4 2 4 4 2 3 1 3 0 0 3 4 6 3 1 5         |        |
-----------------------------------------------------------------------
```

Figure 13: SPORTS Linkage - Common Block Map

<HIERARCHICAL DIAGRAM>

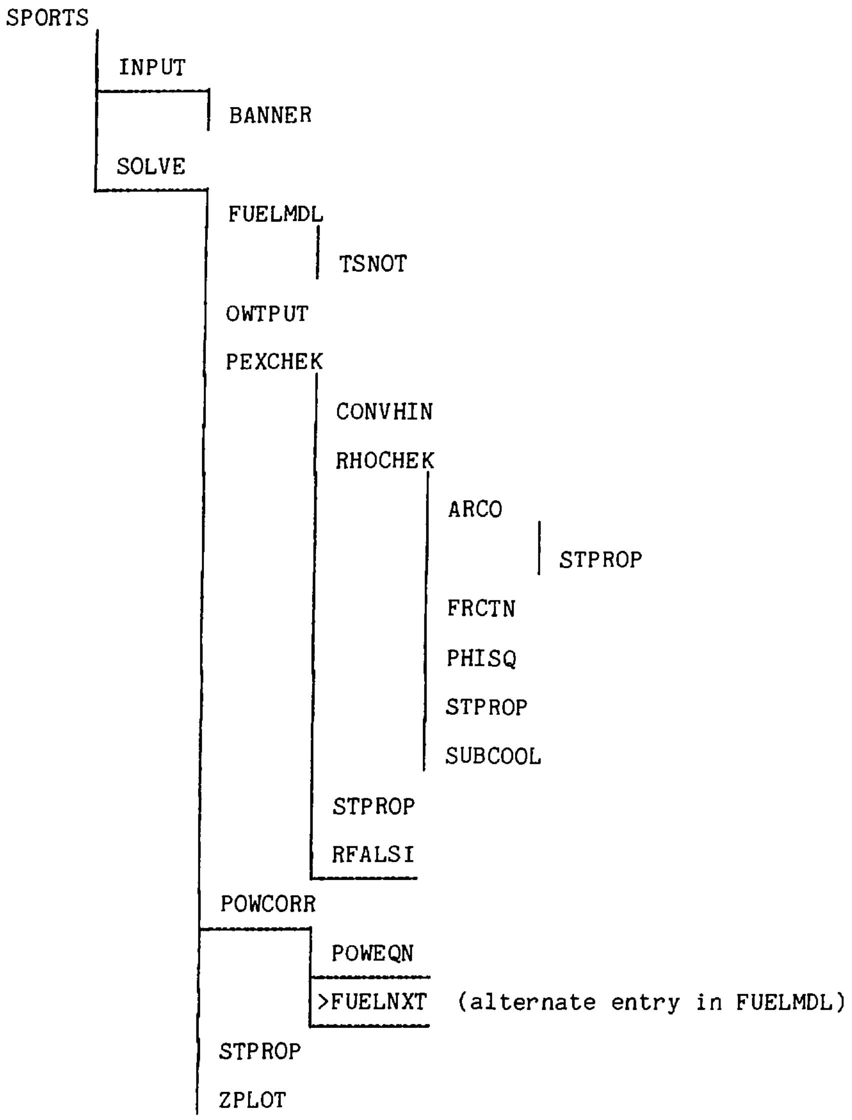


Figure 14: SPORTS Linkage - Hierarchical Diagram

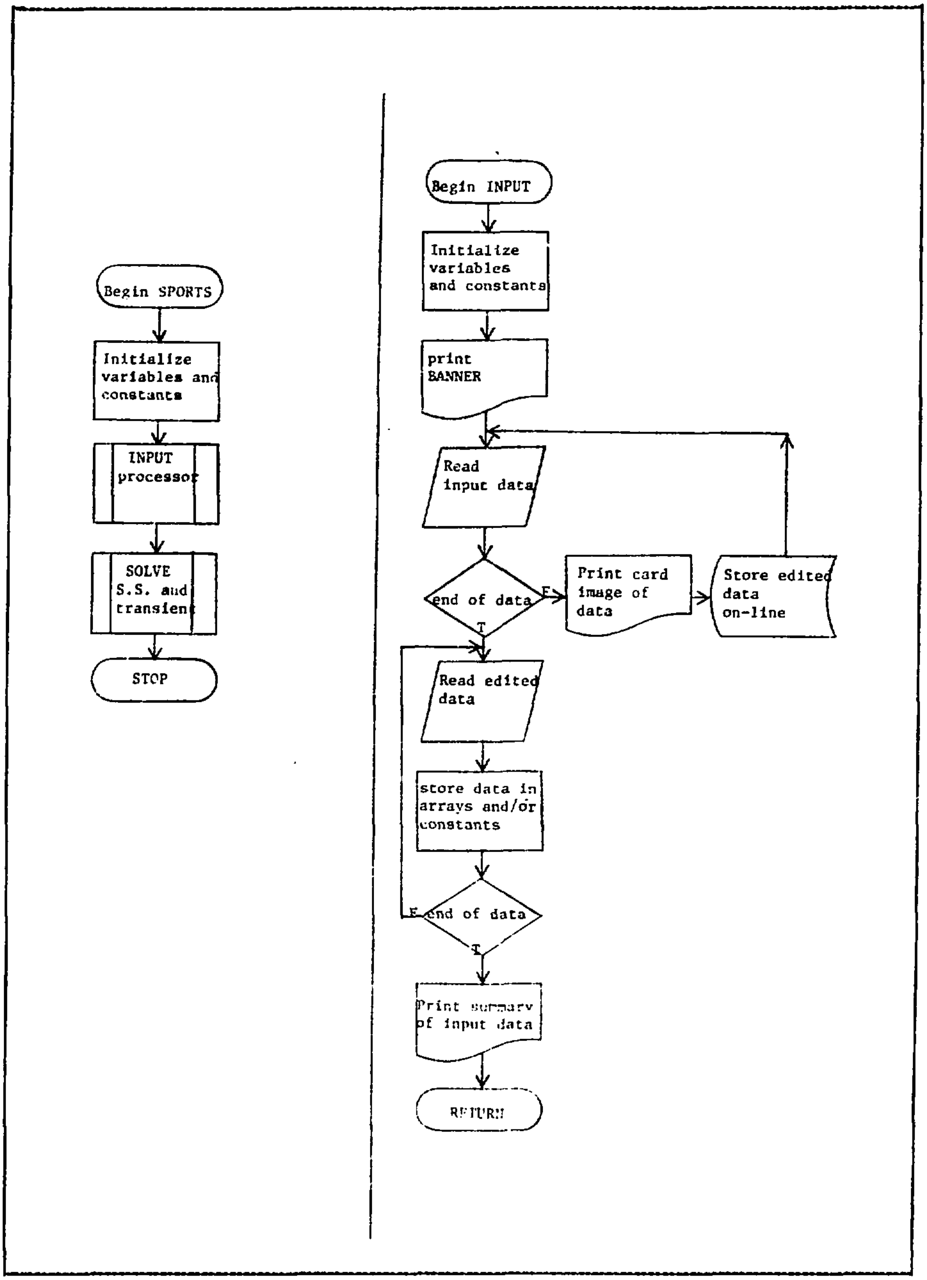


Figure 15: SPORTS Flowchart

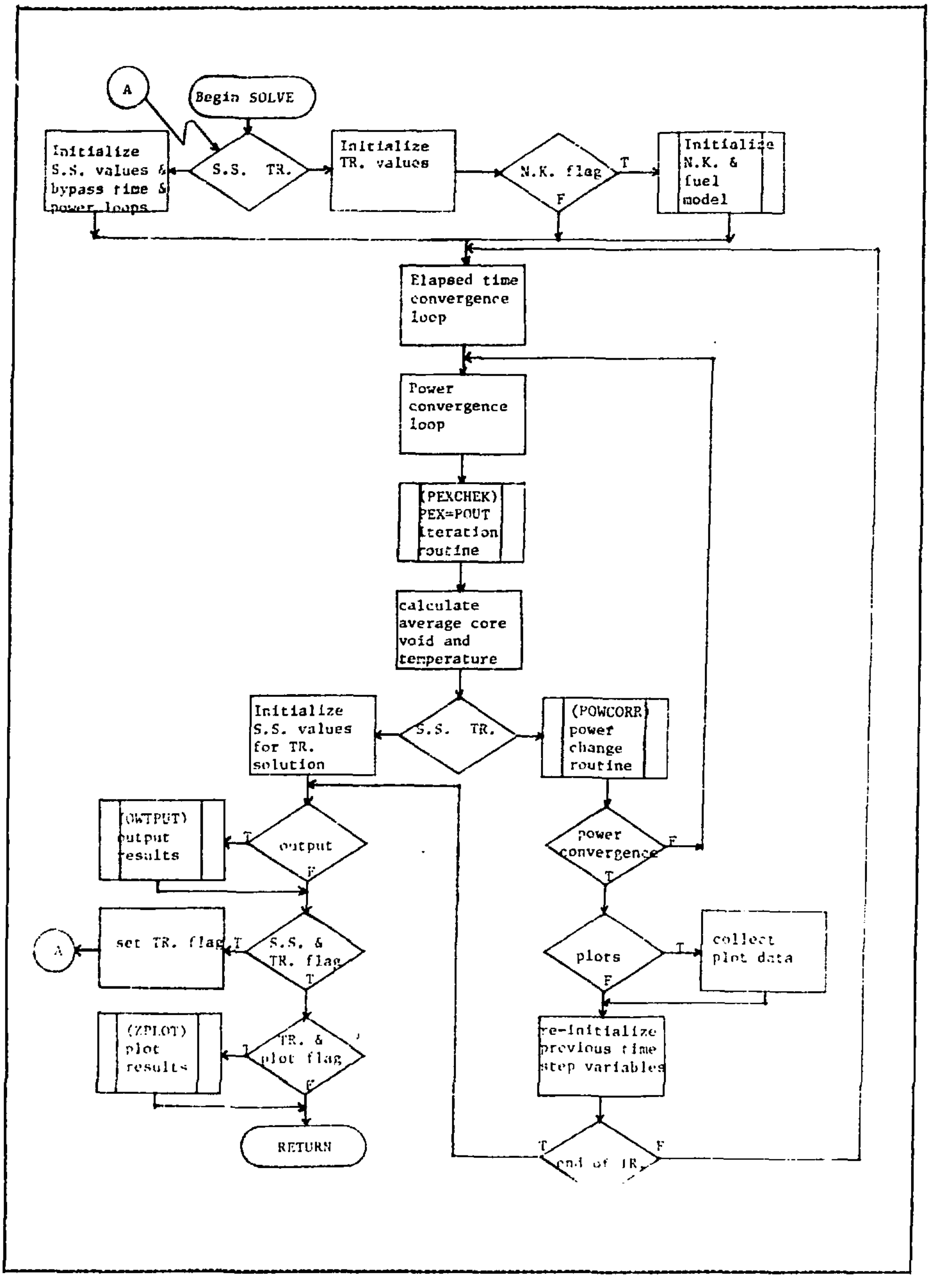


Figure 15: SPORTS Flowchart cont'd

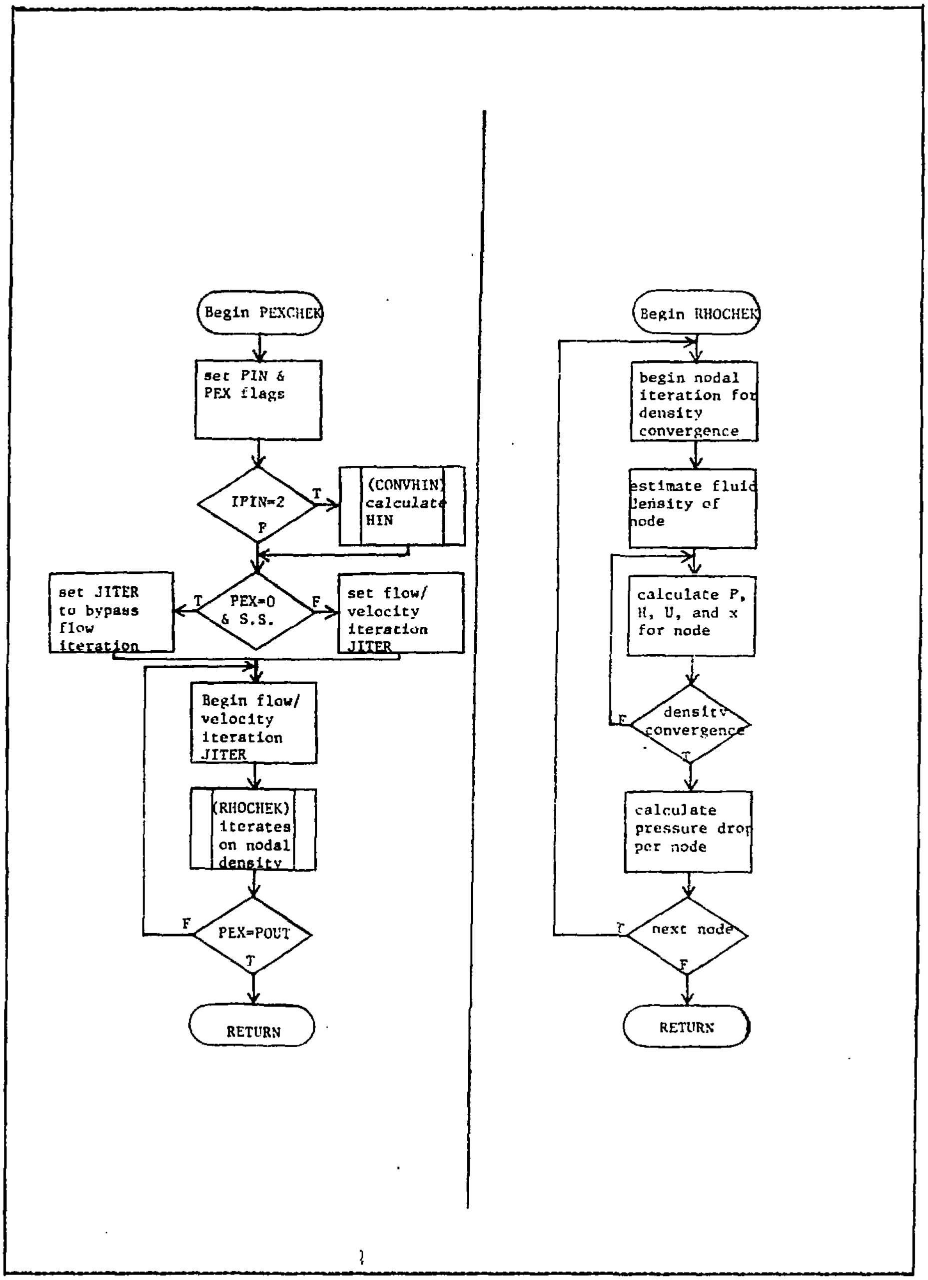


Figure 15: SPORTS Flowchart cont'd

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