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Advanced Neutron Source Dynamic Model (ANSDM) Code Description and User Guide

Jose March-Leuba

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Advanced Neutron Source

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ADVANCED NEUTRON SOURCE DYNAMIC MODEL (ANSDM) CODE DESCRIPTION AND USER GUIDE

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ACRONYMS AND INITIALISMS

ACSL	Advanced Continuous Simulation Language
ANS	Advanced Neutron Source
ANSDM	Advanced Neutron Source Dynamic Model
BOC	beginning of cycle
CHF	critical heat flux
EOC	end of cycle
LOCA	loss-of-coolant accident

ABSTRACT

A mathematical model is designed that simulates the dynamic behavior of the Advanced Neutron Source (ANS) reactor. Its main objective is to model important characteristics of the ANS systems as they are being designed, updated, and employed; its primary design goal, to aid in the development of safety and control features. During the simulations the model is also found to aid in making design decisions for thermal-hydraulic systems. Model components, empirical correlations, and model parameters are discussed; sample procedures are also given. Modifications are cited, and significant development and application efforts are noted focusing on examination of instrumentation required during and after accidents to ensure adequate monitoring during transient conditions.

1. INTRODUCTION

The Advanced Neutron Source Dynamic Model (ANSDM) is a mathematical model that simulates the dynamic behavior of the Advanced Neutron Source (ANS) reactor in a personal computer. The main objective was to model important characteristics of the ANS systems as they were being designed, updated, and employed. The primary ANSDM design goal was to aid the development of safety and control features, but it also has aided in making design decisions for thermal-hydraulic systems. The model has been modified to evaluate possible design changes, to study the performance of control algorithms, and to support safety analyses. Significant ANSDM development and application efforts have been focused on examining the instrumentation required during and after accidents to ensure adequate monitoring during transient conditions.

The most important limitations of this model are:

- Point kinetics for the neutron dynamics in the core region. The power is distributed among different components (i.e, upper and lower fuel elements, reflector, bypass region) based on steady-state power fraction distributions that have been estimated for the specific ANS conditions. This is not such a bad approximation because most transients result in a reactor scram within the first few milliseconds and then the power is determined by a decay heat correlation.
- Incompressible flow. The model is limited to liquid-phase state; when a transient results in saturated boiling, the simulation fails. Note that the core typically is damaged (owing either to critical heat flux or to flow excursion instabilities) well before saturated boiling can be established; thus, this approximation is fairly accurate except when acoustic wave propagation is a relevant effect such as during large-break loss-of-coolant accidents (LOCAs).
- Single loop flow dynamics. All three active loops are simulated by one effective loop. Because of this approximation, the model is not able to simulate imbalances between loops (e.g., we cannot model directly the shutdown of one pump while the other two remain on). These imbalances must be simulated by, for example, reducing the pump speed to 80% to simulate a one-out-of-three pump trip.
- Poor reverse flow model. The model fails to compute enthalpies properly if reverse flow is established. Note, however, that reverse flow occurs only in the hot leg during large-break LOCAs, and the hot leg enthalpy is fairly irrelevant during these transients. The reverse flow model in ANSDM is designed to "ride through" short (i.e., a few milliseconds) flow reversals that may occur during severe transients, which do not affect significantly the later evolution of the event.

2. MODEL COMPONENTS

The ANSDM has been programmed in the Advanced Continuous Simulation Language, giving it fairly good flexibility of operation at run time. This model was designed for testing and defining control and plant protection system design requirements; it also has been used to evaluate reactivity events in the Conceptual Safety Analysis Report and other transient events to evaluate different design options. The model is composed of a collection of modules, most of which are reused throughout the model.

2.1 CORE AND CORE PRESSURE BOUNDARY TUBE REGIONS

The power generation in the core is estimated from the addition of two components: (1) the core neutronics (modeled using point kinetics) with delayed neutrons (including photo-delayed neutrons) and (2) decay heat (based on an ANS-specific correlation).

ANSDM models the average channel fuel and coolant dynamics. The average channel determines the average core outlet conditions. A single axial node is used for this calculation. The dynamics of the hot streak of the upper and lower element are simulated separately from the average channel calculation. The lower element is typically limited at beginning of cycle (BOC); the upper element, at end of cycle (EOC). Thus, in our model we use the BOC axial power shape and hot streak factors for the lower element hot channel and the EOC conditions for the upper element. The two hot channels are divided into up to 50 axial nodes (typically, we use 27) where local temperatures, pressures, and heat fluxes are estimated to determine its margin to incipient boiling, critical heat flux, and flow excursion instability.

A single bypass region simulates the flow of heavy water that bypasses the fuel elements inside the pressure vessel. This coolant is typically colder than the core outlet coolant such that when it mixes, the vessel outlet temperature (which is computed dynamically) is lower than the core outlet temperature.

2.2 REFLECTOR REGION

A reflector region is modeled with a very simplified one-node approach. The reflector provides some (but not much) reactivity feedback to the core owing to the direct neutron and gamma heating. ANSDM does not model the reflector coolant systems. The main purpose of this node is to provide for an estimate of the reflector temperature feedback.

2.3 COOLING SYSTEMS

Cooling system pipes are modeled, and they release heat to the appropriate surrounding light water pools. Whenever parallel flows exists (i.e., multiple hot legs), ANSDM uses a single pipe with an effective flow area and equivalent diameter.

Containment light water pools (i.e., the main reactor pool, the pipe chase pool, the heat exchangers pool) are modeled. These pools take heat from the reactor piping according to their relative temperature and based on natural convection heat transfer coefficients. The heat exchanger pool also cools the emergency heat exchanger secondary side by natural circulation.

The main heat exchanger is modeled with the primary flow in the shell side and with the secondary flow in the tube side. Heat transfer characteristics are adjustable by varying the tube diameter and surface area; typically, values include a fouling heat transfer resistance factor.

The emergency heat exchanger is modeled in series with the main heat exchanger. Primary flow is in the shell side, and secondary flow is on the tube side. The shell side (primary) assumes "turbulizers" so that the flow is never laminar regardless of Reynolds number. The tube's diameter is designed to be about 0.05 m (2 in.) so that the Reynolds number will be large enough to ensure turbulent flow even at the low natural circulation flow rates. The secondary side of the emergency heat exchanger is connected to the heat exchanger pool and allowed to flow by natural circulation.

Main circulation pumps are modeled according to the head-flow characteristic curve. The characteristic curve scales the flow directly proportional to the pump rotational speed; the pump head is proportional to the square of the pump speed; and the power required is proportional to the cube of the speed. Pump coast-down is modeled based on a conservation of angular momentum; the resulting differential equation that is solved by the model is:

$$\frac{dn}{dt} = \frac{n^2 - n_0^2}{\tau} , \tag{1}$$

where n is the pump rotational speed, n_0 is the desired equilibrium speed (e.g., $n_0 = 10\%$ if a reduction to pony flow is desired), and τ is the pump half speed time constant. The coast-down flow and pump head are computed by scaling the characteristic pump curve using the calculated speed, n.

2.4 GAS ACCUMULATORS

The gas accumulator is assumed to follow the ideal gas law ($P\,V^\gamma$ = constant). The default values in ANSDM assume that the accumulators expand isothermally (i.e., $\gamma = 1.0$), but a model parameter (KGCGAC) can be changed to 1.4 for an adiabatic expansion. The initial gas-to-liquid ratio is such that the liquid level will not reach the bottom of the accumulator after the gas has expanded to the depressurized condition; for a 2.0-MPa core outlet pressure, the liquid-to-gas ratio is 20 to 1.

2.5 MAKEUP AND LETDOWN SYSTEMS

The reactor pressure is maintained high by a makeup flow. The model simulates this flow with a pump module (i.e., the pressurizer pump) with a suction in a constant pressure tank (i.e., the letdown system tank). The makeup pump speed is maintained constant unless a coast-down (e.g., loss of off-site power) is required. During normal operation the makeup flow adjusts itself to the system pressure (e.g., as the system pressure lowers, the makeup flow increases). These changes, however, are not sufficient to maintain constant pressure. The pressure regulation is accomplished by modulating the flow through the letdown valves. The letdown valves are modeled as a pressure drop with variable coefficient (according to valve opening); the letdown flow is collected in the letdown tank. The model does not simulate the low-pressure cleanup system, and this tank is assumed to have an infinite supply of D_2O such that makeup can always be maintained. Makeup supply problems can be simulated at any time by tripping the makeup pump that is simulated with a perfect (i.e, no reverse flow) check valve.

2.6 SECONDARY COOLING SYSTEMS

The secondary side of the ANS cooling system is represented by:

- the secondary side of the main heat exchanger in the tube side,

- the secondary hot leg,
- main cooling towers and the cooling towers basin,
- the secondary circulation pump, and
- the secondary cold leg.

All these components use approximations similar to those in the primary system.

2.7 CONTROL SYSTEMS

A preliminary control system, simulated in the model, includes:

- control rod position based on the measured power-to-flow ratio,
- pressure control that actuates the letdown valve based on hot-leg pressure measurements, and
- core inlet temperature control that actuates on the secondary flow based on the temperature measured at the heat exchanger outlet.

2.8 INSTRUMENTATION

Sensor dynamics are modeled as first-order lag systems. The required time constants have been determined through simulation of control and plant protection system challenges. The time constants currently in the model are those required to satisfy most design basis events requirements.

2.9 BREAKS

Breaks are simulated as a flow through an orifice (of the break effective diameter) from the inside of the main piping system to the light water pools. The leak flow, W_{lk}, is estimated from the orifice relation as

$$W_{lk} = \frac{C_v}{\sqrt{1-\left(\frac{D_b}{D}\right)^4}} \frac{\pi D^2}{4} \sqrt{2\rho(P-P_{lk})} \; , \tag{2}$$

where P_{lk} is the pool pressure, P is the system pressure, C_v is the orifice coefficient (taken as 0.6 for a sharp orifice), D_b is the break effective diameter, and D is the pipe diameter.

Breaks are opened exponentially over a finite period of time, τ, following the expression

$$D(t) = D_b \, (e^{\frac{t}{\tau} \ln 2} - 1) \quad \text{if } 0 \le t \le \tau \; , \tag{3}$$

and

$$D(t) = D_b \quad \text{if } t \ge \tau \; , \tag{4}$$

where $D(t)$ is the effective break diameter, D_b is the final break size, and τ is the break time constant (typically 250 ms). ANSDM does not model the compressibility of D_2O such that the effective speed of sound is infinite. Therefore, ANSDM cannot model fast-opening large breaks where the pressure perturbations are large and speed-of-sound effects are relevant.

3. MODELS AND EMPIRICAL CORRELATIONS

This section documents the empirical correlations used in ANSDM. Unless otherwise stated, the units for all correlations are SI, energy is in joules, temperature is in degrees Celsius, length is in meters, and time is in seconds.

3.1 HEAVY WATER PROPERTIES

ANSDM uses the standard ANS D_2O correlations that define some D_2O properties required by ANSDM as a function of known parameters. Appendix A documents the specific correlation parameters and units used in ANSDM; the actual FORTRAN Program used is shown.

3.2 FRICTION FACTORS

Appendix B lists the actual FORTRAN coding used to estimate the friction factor. Figure 1 shows the friction factor calculated by ANSDM following a scram and complete loss of pumping power (i.e., natural circulation). This section discusses some of the approximations used.

3.2.1 Turbulent Regime

In the turbulent regime (*Re* > 4240), ANSDM uses two different correlations to estimate the Darcy friction factor: the Filonenko correlation in the core region and the Colebrook and White correlation for the piping sections. If a relative roughness other than zero is input, ANSDM uses the Colebrook and White correlation; otherwise, it uses the Filonenko correlation.

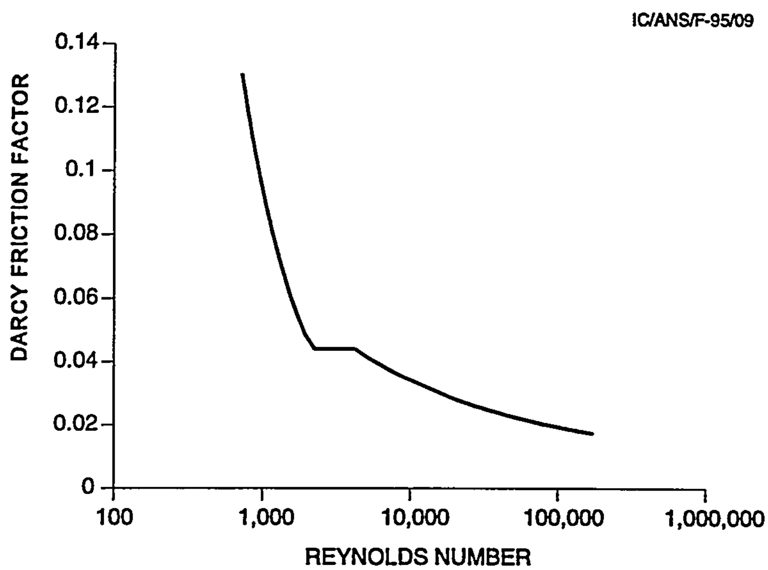

Fig. 1. Friction factor calculated by the Advanced Neutron Source Dynamic Model after scram and transition to natural circulation.

The Filonenko correlation used for ANS design applies to smooth surfaces. When a correction for rectangular channels and coolant properties is included, the correlation takes the form.

$$f_D = \frac{1.0875 - 0.1125\ (b/s)}{\left(1.82\ \log_{10} Re_b - 1.64\right)^2} \left[\frac{7 - \left(\mu_b/\mu_w\right)}{6}\right] . \qquad (5)$$

ANSDM does not use this form of the correlation. It uses the following approximation:

$$f_D = \frac{1.0836}{\left(1.82\ \log_{10} Re_b - 1.64\right)^2} . \qquad (6)$$

ANSDM collapses both the upper and lower fuel elements into a single average channel; thus, it uses an average of the span-to-gap aspect ratio (*b/s*) for the upper and lower elements, resulting in the term 1.8036, which includes an average aspect ratio for both cores.

The last term in Eq. (5) is a correction proposed by Petukhov to account for the effect of heated fluids, which have lower viscosity near the wall. ANSDM ignores this term to avoid the need for iterative solutions that involve the fuel temperature. The effect of this term is fairly small. For instance, the core average coolant outlet temperature is 85°C, and the average fuel wall temperature is 121°C. With these numbers, the error introduced by neglecting the second term in Filonenko's correlation is about 7% (ANSDM estimates higher friction than the actual one). This error is partly offset by the fact that ANSDM estimates the pressure drop based on the outlet conditions of a single axial node in the core region. We estimate the error caused by this single-node approximation to be about 10% (the friction factor at 85°C is 0.0174 and at 45°C is 0.0209; the average is 0.0191, or about 10% higher than ANSDM estimates). Thus, ANSDM assumes that the 7% error introduced by ignoring the second term in Filonenko's correlation is partially offset by the 10% error caused by the single-node approximation. The error caused by these two approximations diminishes as the power is decreased (e.g., following scram). Because of these approximations, the pressure-drop estimate accuracy in ANSDM is assumed to be ±10% but is probably lower owing to cancellation of errors.

In the piping region the Filonenko correlation is not applicable because the pipes have an appreciable roughness factor, ϵ. In this region ANSDM uses the Colebrook and White correlation. The friction factor is estimated by direct iteration from the following implicit equation:

$$\sqrt{f_D/4} = \frac{1}{3.48 - 1.7372\ \ln\left(\dfrac{\epsilon}{2D_e} + \dfrac{9.35}{Re\sqrt{f_D/4}}\right)} . \qquad (7)$$

To initiate the iteration, ANSDM uses the Moody correlation as the initial guess:

$$f_D/4 = 0.001375\left[1 + 21.544\left(\frac{\epsilon}{2D_e} + \frac{100}{R_e}\right)^{\frac{1}{3}}\right] . \qquad (8)$$

3.2.2 Laminar Regime

In the laminar regime ANSDM uses the standard laminar friction factor correlation:

$$f_D = 4 \, \frac{23.532}{Re} \; . \tag{9}$$

3.2.3 Transition Regime

To avoid possible numerical instabilities, the transition regime is modeled at Reynolds numbers lower than 4240 by selecting the higher of two numbers: the laminar friction factor at the actual Reynolds number or the turbulent friction factor at $Re = 4240$. This approximation results in a constant friction factor for Reynolds numbers between 2300 and 4240. In this way, a smooth transition between laminar and turbulent is achieved.

3.3 HEAT TRANSFER COEFFICIENTS

3.3.1 Core Region

Appendix C documents the actual FORTRAN coding for heat flux and heat transfer correlations. In the fully developed turbulent regime ($Re > 2300$) ANSDM uses the Petukhov correlation to estimate the heat transfer between the fuel plates and the core coolant. This correlation takes the form

$$h_{\text{turbulent}} = \frac{k}{D_e} \, \frac{\left(f_D/8\right) Re_b \, Pr_b \left(\mu_b/\mu_w\right)^{0.11}}{\left(1 + 3.4 f_D\right) + \left(11.7 + \dfrac{1.8}{Pr^{1/3}}\right) \sqrt{f_D/8} \left(Pr^{2/3} - 1\right)} \; . \tag{10}$$

In the laminar regime ($Re < 2300$) ANSDM uses a constant Nusselt number of 7.627 with a correction for heated fluid. The actual correlation takes the form

$$h_{\text{laminar}} = \frac{k}{D_e} \, 7.627 \left(\mu_b/\mu_w\right)^{0.11} \; . \tag{11}$$

3.3.2 Piping Region

ANSDM estimates the heat lost to the containment light-water pools. The heat transfer coefficient inside the circular pipes is estimated using the following correlations:

$$h_{\text{turbulent}} = \frac{k}{D_e} \left[6.3 + \frac{0.079 \sqrt{f_D/8} \; Re \; Pr}{\left(1 + P_r^{0.8}\right)^{5/6}} \right] , \tag{12}$$

and

$$h_{\text{laminar}} = \frac{k}{D_e} \, 4.364 \; . \tag{13}$$

The heat transfer coefficient outside of the pipes is input manually, and it is maintained constant during all transients.

3.4 INCIPIENT BOILING

ANSDM uses an incipient boiling correlation based on local conditions at the hot spot. The correlation used is that of Bergles and Rosenhow. The incipient boiling flux is estimated by iteration between the two following equations:

$$Q_{IB} = 0.9 \times 1.7978 \times 10^{-6} \times P^{1.156} \times \left[1.8 \left(T_w - T_b\right)\right]^{\left(2.8285/P^{0.0234}\right)} \ , \tag{14}$$

and

$$Q_{IB} = h\left(T_w - T_b\right) \ , \tag{15}$$

where h is the local heat transfer coefficient estimated using the Petukhov correlation.

3.5 CRITICAL HEAT FLUX

ANSDM estimates the critical heat flux (CHF) using the Gambill additive CHF correlation, the Weatherhead correlation for CHF wall temperature, and the Petukhov heat transfer coefficient correlation. The flowing equations are used:

$$Q_{\text{pool}} = 0.18 \ h_{fg} \rho_v \left(\sigma g \frac{\rho_l - \rho_v}{\rho_v^{\ 2}} \right)^{\frac{1}{4}} \left(1 + \left[\frac{\rho_l}{\rho_v} \right]^{\frac{3}{4}} c_p \ \frac{T_{\text{sat}} - T_{\text{bulk}}}{9.8 \ h_{fg}} \right) \ , \tag{16}$$

and

$$Q_{\text{crit}} = Q_{\text{pool}} + h \left(T_{\text{wall}} - T_{\text{bulk}}\right) \ , \tag{17}$$

where h is the local heat transfer coefficient estimated using the Petukhov correlation, and T_{wall} (i.e., the critical wall temperature) is estimated from the following equation:

$$T_{\text{wall}} = T_{\text{sat}} + \left(47.7 - 0.127 \ T_{\text{sat}}\right) \left(\frac{Q_{\text{crit}}}{3.1546E6} \right)^{\frac{1}{4}} \ . \tag{18}$$

Because T_{wall} depends on the critical flux, Q_{crit}, the solution of the above equation requires an iteration procedure. To initiate the iteration, T_{wall} is estimated without the Weatherhead correction using the following equation:

$$T_{\text{wall}} = T_{\text{sat}} + 84.96 - 0.1313 \left(T_{\text{sat}} + 273.16\right) \ . \tag{19}$$

3.6 FLOW EXCURSION

Flow excursion is a special case of critical heat flux that is caused by a flow instability rather than by a change in boiling regime. ANSDM uses the Costa correlation to estimate this critical heat flux:

$$Q_{\text{crit}} = \frac{\left(T_{\text{sat}} - T_{\text{bulk}}\right) \sqrt{u}}{12.8E\text{-}6} \ . \tag{20}$$

4. MODEL PARAMETERS

All model variables are accessible at run time for display, and they can also be modified at any time. In this way, different power levels or reactor configurations can be input at run time with simple "set" commands that can be prepared in a command file for multiple uses or that can be input from the keyboard. The variable nomenclature, thus, is important. This section describes this nomenclature, and Appendix F lists all variables and their nominal values.

An ACSL variable name has up to six characters. In ANSDM the first one, two, or three characters describe the type of parameter, and the last three or four characters describe the location on the model. For example, the variable *TCORO* represents the temperature (variable type = *T*) at the core outlet (location = *CORO*). Table 1 documents the interpretation of the first two characters, Table 2 documents the model nodes (i.e., three character locations that relate to node-average variables), and Table 3 documents the interconnection locations (i.e., four character locations that relate to node-boundary variables).

Table 1. Interpretation of the first two characters of Advanced Neutron Source Dynamic Model variable names

Characters	Variable type	Units	Characters	Variable type	Units
CFR	Critical heat flux ratio (Gambill correlation)	Adimensional	P	Pressure	Pa
CIR	Critical heat flux ratio (incipient boiling)	Adimensional	PS	Saturation pressure	Pa
CSR	Critical heat flux ratio (flow excursion)	Adimensional	PR	Prandtl number	Adimensional
CK	Coolant conductivity	$W/(m \cdot K)$	Q	Heat flux	W/m^2
CP	Heat capacity	$J/(kg \cdot K)$	R	Coolant density	kg/m^3
F	Neutron flux	n/m^2		or reactivity	Dollars
	(also) friction coefficient	Adimensional	RE	Reynolds number	Adimensional
H	Heat transfer coefficient	$W/(m^2 \cdot K)$	T	Temperature	C
J	Power	W	TS	Saturation temperature	C
K	Constant parameter. Type depends on next character		U	Velocity	m/s
MU	Viscosity	$kg/(s \cdot m)$	V	Control variable. Type depends on next character	
MCR	Minimum critical heat flux ratio along all channels	Adimensional	W	Mass flow rate	kg/s
MIR	Minimum incipient boiling ratio along channel	Adimensional	X	Position	m
MSR	Minimum flow excursion ratio along all channels	Adimensional	Z	Internal node variable. Type depends on next character	
N	Angular speed (for pumps)	Normalized			

Table 2. Interpretation of the node characters in Advanced Neutron Source Dynamic Model variable names

Node	Module[a]	Description
TRA	1	Externally imposed transients
ANS	1	Main ANSDM module
DET	2	Detectors
CON	2	Controls
PPS	2	Plant protection system
SCRAM	3	Scram module
ICR	2	Inner control rod
OCR	2	Outer control rod
VES	2	CPBT and core region
REF	3	Reflector region
IPR	3	Inlet plenum region
COR	3	Core region
CPG	4	Core power generation
CDH	5	Core decay heat
CNT	5	Core neutronics
POI	5	Neutron poisons model
ACC	4	Average channel coolant
ACF	4	Average channel fuel
ACH	4	Average channel
BYP	4	Bypass
HCL	4	Hot channel lower core
HCU	4	Hot channel upper core
HLC	4	Hot channel lower core coolant
HLF	4	Hot channel lower core fuel
HUC	4	Hot channel upper core coolant
HUF	4	Hot channel upper core fuel
OPR	4	Outlet plenum region
CCS	2	Coolant cooling systems
CIL	3	Core inlet leak
CLR	3	Cold leg riser
COL	3	Core outlet leak
EHX	3	Emergency heat exchange
EPP	3	Emergency heat exchanger primary side
ESP	3	Emergency heat exchanger secondary
GAC	3	Gas accumulator
HLR	3	Hot leg riser
HXP	3	Heat exchangers pool
LDS	3	Letdown system
MCL	3	Main cold leg (horizontal part)
MCP	3	Main coolant pump
MCS	3	Storage (controls pressure dynamics)
MHL	3	Main hot leg (horizontal part)
MHP	3	Main heat exchanger primary side
MHX	3	Main heat exchange
MRP	3	Main reactor pool
MUS	3	Makeup system
PCH	3	Pipe chase pool
POL	3	Pump outlet leak module
SHP	3	Main heat exchanger secondary side
SCC	3	Secondary cooling circuits
CTB	4	Cooling towers basin
TCL	4	Secondary cold leg (tower to MHX)
THL	4	Secondary hot leg (MHX to tower)

[a]Numbers indicate parent module sequence.

Table 3. Interpretation of the node interface characters in Advanced Neutron Source Dynamic Model variable names

Node interface	Description
ACHI	Average channel inlet
ACHO	Average channel outlet
AREA	Accident reactivity
BYPI	Bypass inlet
BYPO	Bypass outlet
CILC	Core inlet leak at containment side
CLRI	Cold leg riser inlet
CLRO	Cold leg riser outlet
CNFX	Core neutron flux
COLC	Core outlet leak at containment side
CORO	Core outlet at outlet plenum
CROD	Control rods (inner + outer)
CTBI	Cooling towers basin inlet (hot leg)
CTBO	Cooling towers basin outlet (cold leg)
DHFX	Core gamma flux
DHFX	Decay heat fluxes
ESCL	Secondary cold leg at emergency heat exchanger inlet
ESHL	Secondary hot leg at emergency heat exchanger outlet
HCLI	Hot channel lower core inlet
HCLO	Hot channel lower core outlet
HCUI	Hot channel upper core inlet
HCUO	Hot channel upper core outlet
HLRI	Hot leg riser inlet
HLRO	Hot leg riser outlet
HSFC	Hot spot coolant
HXPI	Heat exchangers pool coolant flow inlet (cold)
HXPO	Heat exchangers pool coolant flow outlet (hot)
IPCI	Inlet plenum outlet at core inlet
LDSI	Letdown system inlet
MCLI	Main cold leg inlet (at pump outlet leak location)
MCLX	Emergency heat exchanger outlet (cold leg inlet)
MCPI	Main coolant pump inlet
MCPO	Main coolant pump outlet
MCSO	Main cold leg at storage module outlet
MHLA	Main hot leg at accumulator outlet
MHLL	Main hot leg at letdown outlet
MHLO	Main hot leg outlet
MHXO	Main heat exchanger outlet
MRPI	Main reactor pool coolant flow inlet (cold)
MRPO	Main reactor pool coolant flow outlet (hot)
MUSO	Makeup system outlet
PCHI	Pipe chase pool coolant flow inlet (cold)
PCHO	Pipe chase pool coolant flow outlet (hot)
POLC	Pump outlet leak at containment side
REFC	Reflector-core interface
REFI	Reflector inlet
REFO	Reflector outlet
SCLX	Secondary cold leg at main heat exchanger inlet
SHLX	Secondary hot leg at main heat exchanger outlet
TCLI	Secondary cold leg inlet at tower
TCLO	Secondary cold leg outlet at MHX
THLO	Secondary hot leg outlet at towers
VESI	CPBT inlet
VESO	CPBT outlet
XESM	Neutron poisons

5. SAMPLE PROCEDURES

Within the ACSL the user can define macros to execute procedures in a consistent manner. Appendix D shows the standard ANSDM macro file (ANS.CMD) that defines the most common procedures that can be exercised with ANSDM. In this we show and describe an example procedure to run a natural circulation transient.

Either at ACSL run time or by loading a command file, the user defines the following procedure, called *natcir*, that sets a transition to natural circulation by tripping the pump at the beginning of the transient. The procedure is defined as follows:

```
proced natcir
    set hvdprn=.true.
    ! Pry pump speed will be set to 0 (natural circulation) at time 0
    set hvdprn=.false.
    action /var = 0., /val = 0., /loc = zn0mcp
    p2off
end     ! of procedure natcir
```

The first line defines the name of the procedure; this is further defined by the lines that follow and is delimited by the *end* statement. Comments following an exclamation mark (*!*) are ignored. Variable *hvdprn* is an internal ACSL variable that controls the high-volume display to the screen; it is originally set to *.true.* to output the comment to the screen and then set to *.false.* to avoid unnecessary screen I/O. The *action* statement instructs ACSL to set variable *zn0mcp* (i.e., the main coolant pump speed setpoint) to zero (*/val = 0.*) at time zero (*/var = 0.*). The final statement *p2off* executes a procedure (or macro) that has been defined previously in file ANS.CMD (see Appendix D); this procedure trips the secondary cooling circuit pumps and resets the temperature control parameters.

To execute a transition to natural circulation, the user must invoke the *natcir* procedure and then start the simulation. In ACSL run time language, the following steps are performed:

```
ACSL> natcir
ACSL> start
```

After the simulation is completed, the user may print or plot any of the variables that have been prepared (or saved). Appendix D lists the standard variables prepared automatically by ANS.CMD. Appendix E shows nominal operating conditions predicted by ANSDM.

Appendix A

HEAVY WATER CORRELATIONS

APPENDIX A. HEAVY WATER CORRELATIONS

```
c
c **  Physical properties of D2O
c **  Official ANS correlations as of September 30
1991
c **  Memo from Moshw Siman-Tov to D.G. Selby
c
c **  Note: Some correlations here use different
units
c **  than in the "official" correlations in the
memo
c
c
----------------------------------------------------
--------------
c
****************************************************
**********
c
----------------------------------------------------
--------------
c D2O Saturation Temperature
c     INPUT :
c           P      Pressure (Pa)
c     OUTPUT :
c           D_TSAT      Saturation temperature (C)
c
----------------------------------------------------
--------------
      real function D_TSAT(P)
        real      P
        real      a0, a1, a2, a3
        data      a0/5.194927982/,
a1/2.36771673e-1/,
     >            a2/-2.615268e-3/, a3/1.708386e-3/

        x    = alog(ABS(P)/1.e6)
        D_TSAT= exp(a0 + a1*x + a2*x**2 + a3*x**3)
        return
      end
c
c
----------------------------------------------------
--------------
c
****************************************************
**********
c
----------------------------------------------------
--------------
c D2O Liquid Density
c     INPUT :
c           T      Temperature (C)
c     OUTPUT :
c           D_RHOL      Liquid density (kg/m3)
c
----------------------------------------------------
--------------
      real function D_RHOL(T)
        real      T
        real      a0, a1, a2
        data      a0/1.117772605e3/,
a1/-7.7855e-2/,
     >            a2/-8.42e-4/

        x    = 32. + 1.8*T
        D_RHOL= a0 + a1*x + a2*x**2
        return
      end
c
```

```
c
----------------------------------------------------------
---------------
c
**********************************************************
**********
c
----------------------------------------------------------
---------------
c D2O Saturated Liquid Thermal Conductivity
c     INPUT :
c           T     Temperature (C)
c     OUTPUT :
c           D_K   Liquid Conductivity (W/m/K)
c
----------------------------------------------------------
---------------
      real function D_K(T)
        real      T
        real      a0, a1, a2, a3
        data      a0/-4.521496e-1/,
a1/3.60743280e1/,
     >            a2/-3.579973221e2/,
a3/9.240219962e2/,
     >            conv/1.729577/

        x   = (491.67 + 1.8*T)/1.e4
        D_K = a0 + a1*x + a2*x**2 + a3*x**3
        return
      end
c
c
----------------------------------------------------------
---------------
c
**********************************************************
**********
```

```
c
----------------------------------------------------------
---------------
c D2O Saturated Liquid Specific Heat
c Note: "Official" correlation uses energy in KJ.
Use conv for J
c     INPUT :
c           T     Temperature (C)
c     OUTPUT :
c           D_CP  Liquid Specific Heat (J/kg/K)
c
----------------------------------------------------------
---------------
      real function D_CP(T)
        real      T
        real      a0, a1, a2, a3
        data      a0/2.237124/,
a1/1.22217151e2/,
     >            a2/-2.303384060e3/,
a3/1.3555737878e4/,
     >            conv/1.e3/

        x   = (491.67 + 1.8*T)/1.e4
        D_CP     = conv*(a0 + a1*x + a2*x**2 +
a3*x**3)
        return
      end
c
c
----------------------------------------------------------
---------------
c
**********************************************************
**********
c
----------------------------------------------------------
---------------
```

```
c D2O Surface Tension
c     INPUT :
c           T     Temperature (C)
c     OUTPUT :
c           D_SIG Surface Tension (N/m)
c
----------------------------------------------------
--------------
      real function D_SIG(T)
        real       T
        real       a, b, c
        data       a/2.44835759e-1/, b/1.269/,
     >             c/-6.660709649e-1/

        x    = (371.49 - T)/644.65
        D_SIG      = a * ABS(x)**b * (1. + c*x)
        return
      end
c
c
----------------------------------------------------
--------------
c
****************************************************
**********
c
----------------------------------------------------
--------------
c D2O Latent Heat of Vaporization
c Note: "Official" correlation uses energy in KJ.
Use conv for J
c     INPUT :
c           T     Temperature (C)
c     OUTPUT :
c           D_HFG Latent Heat of Vaporization
(J/kg)
c
----------------------------------------------------
--------------
      real function D_HFG(T)
        real       T
        real       a0, a1, a2
        data       a0/5.080936669e5/,
a1/1.7006921765e4/,
     >             a2/-1.1009078e1/, conv/1.e3/

        x    = 371.49 - T
        D_HFG      = conv*sqrt(ABS(a0 + a1*x +
a2*x**2))
        return
      end
c
c
----------------------------------------------------
--------------
c
****************************************************
**********
c
----------------------------------------------------
--------------
c D2O Saturated Vapor Density
c     INPUT :
c           T     Temperature (C)
c     OUTPUT :
c           D_RHOV      Saturated Vapor Density
(kg/m3)
c
----------------------------------------------------
--------------
      real function D_RHOV(T)
        real       P
        real       a0, a1, a2, b0, b1, b2
        data       a0/-5.456208705/,
```

```
a1/6.0526809e-2/,
     >             a2/-1.11360e-4/,  b0/1.0/,
     >             b1/2.386228e-3/,  b2/-1.15778e-5/

        D_RHOV = exp((a0 + a1*T + a2*T**2) / (b0 +
b1*T + b2*t**2))
        return
      end
c
c
---------------------------------------------------
--------------
c
***************************************************
**********
c
---------------------------------------------------
--------------
c D2O Liquid Dynamic Viscosity
c     INPUT :
c           T     Temperature (C)
c     OUTPUT :
c           D_MU  Liquid Dynamic Viscosity (Pa s)
c
---------------------------------------------------
--------------
      real function D_MU(T)
        real       T
        real       a0, a1, b1, b2
        data       a0/-1.111606e-4/, a1/9.46e-8/
     >             b1/8.873655375e-2/,
b2/4.111103409e-1/

        x    = 32. + T*1.8
        D_MU = a0 + a1*x + b1/x + b2/x**2
        return
      end
c
c
---------------------------------------------------
--------------
c
***************************************************
**********
c
---------------------------------------------------
--------------
c
c D2O Derivative of Liquid Density wrt Enthalpy
c Note: "Official" correlation uses energy in KJ.
Use conv for J
c     INPUT :
c           T     Temperature (C)
c     OUTPUT :
c           D_RH  Deriv Liquid Density/ Enthalpy
(kg/m3)/(J/kg)
c
---------------------------------------------------
--------------
      real function D_RH(T)
        real       T
        real       a0, a1, a2, a3
        data       a0/-5.5574282e-2/,
a1/-8.9497e-4/,
     >             b/-5.16987e-3/,
c/6.521616293e1/,
     >             conv/1.e-3/

        D_RH       = conv*(a0 + a1*T + b*sqrt(T) +
c/T**2)
        return
      end
c
c
```

```
----------------------------------------------------
--------------
c
****************************************************
**********
c
----------------------------------------------------
--------------
c
c D2O Liquid Specific Heat as function of enthaly
c Note: "Official" correlation uses energy in KJ.
Use conv for J
c     INPUT :
c           H     Enthalpy (J/kg)
c     OUTPUT :
c           D_CP_H      Liquid Specific Heat
(J/kg/K)
c
----------------------------------------------------
--------------
      real function D_CP_H(H)
        real      H
        real      a0, a1, a2, a3
        data      a0/4.303528320/,
a1/-4.09143e-4/,
     >            a2/-2.037e-7/,
a3/8.6071287e-10/,
     >            conv/1.e3/

          x = H/1.e3
        D_CP_H= conv*(a0 + a1*x + a2*x**2 +
a3*x**3)
        return
      end
c
c
----------------------------------------------------
```

```
--------------
c
****************************************************
**********
c
----------------------------------------------------
--------------
c
c D2O Saturation Pressure
c     INPUT :
c           T     Temperature (C)
c     OUTPUT :
c           D_PSAT      Saturation Pressure (Pa)
c
----------------------------------------------------
--------------
      real function D_PSAT(T)
        real      T
        real      a0, a1, a2, a3, conv
        data      a0/9.5720020e1/,  a1/1.2010e-2/
     >            b1/-8.439470752e3/,
c1/-1.3496506e1/
     >            conv/1.e6/

          x = 273.16 + T
        D_PSAT= conv*exp(a0 + a1*x + b1/x +
c1*alog(x))
        return
      end
```

Appendix B

COOLANT-RELATED CORRELATIONS

APPENDIX B. COOLANT-RELATED CORRELATIONS

```
      SUBROUTINE CPROPH(CL, H_CL,
     >               CP_CL, T_CL, R_CL, RH_CL, MU_CL,
CK_CL, PS_CL)
C
C
C---------------------------------------------------
-------------
C
C***************************************************
*************
C
C---------------------------------------------------
-------------
C
C     This subroutine computes coolant properties
that depend
C     on the enthalpy.
C     See MACRO CPROP (File CPROP.M10) for a
description of all
C     the variables
C
C
C---------------------------------------------------
-------------
C
C***************************************************
*************
C
C---------------------------------------------------
-------------
C
      CHARACTER *4 CL
      REAL H_CL, CP_CL, T_CL, R_CL, RH_CL, MU_CL,
CK_CL
      DATA HMAX/1.2E6/, HMIN/4.E4/
C
C
C---------------------------------------------------
-------------
C
C***************************************************
*************
C
C---------------------------------------------------
-------------
C
C            ! AVOID OVERFLOWS IF H_CL UNDEFINED
      H = H_CL
      IF(H_CL .GT. PMAX .OR. H_CL .LT. PMIN) THEN
C       WRITE(*,'('' <CPROP::'', A4,''>  ERROR.  H
= ''
C     >             , G15.5)') CL, H
        IF(H.LT.HMIN) H = HMIN
        IF(H.GT.HMAX) H = HMAX
      ENDIF

      CP_CL = D_CP_H(H)
      T_CL  = H/CP_CL
      R_CL  = D_RHOL(T_CL)
      RH_CL = D_RH(T_CL)
      MU_CL = D_MU(T_CL)
      CK_CL = D_K(T_CL)
      PS_CL = D_PSAT(T_CL)
      RETURN
      END
C
C
C
```

```
      SUBROUTINE CPROPW(CL, W_CL, R_CL, KA_CL,
CP_CL,
     >         MU_CL, CK_CL, KD_CL, KE_CL,
     >         U_CL, PR_CL, RE_CL, F_CL, HW_CL)
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C
C     This subroutine computes coolant properties
that depend
C     on the flow.
C     See MACRO CPROP (File CPROP.M10) for a
description of all
C     the variables
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C
      CHARACTER *4 CL
      REAL W_CL, R_CL, KA_CL, CP_CL, MU_CL, CK_CL,
KD_CL, KE_CL,
     >          U_CL, PR_CL, RE_CL, F_CL, HW_CL
      DATA RE_TUR/4240./
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C
      U_CL  = W_CL / R_CL / KA_CL
      PR_CL = ABS(CP_CL * MU_CL / CK_CL)
      RE_CL = MAX(ABS(U_CL*KD_CL*R_CL/MU_CL),
1.E-4)
C                 ! Core friction correlation
      IF(KE_CL .LE. 0.) THEN
C               ! If smooth use Filonenko (for
core)
        IF(RE_CL .GT. RE_TUR) THEN
          F_CL    = F_FILO(CL, RE_CL, KE_CL, KD_CL)
        ELSE
          F_MIN   = F_FILO(CL, RE_TUR, KE_CL,
KD_CL)
          F_L     = F_LAM(CL, RE_CL, KE_CL, KD_CL)
          F_CL    = MAX(F_MIN, F_L)
        ENDIF
C               ! IF KE_CL<0 USE AS FUDGING FACTOR
          IF(KE_CL .LT. 0.) F_CL = F_CL*ABS(KE_CL)
      ELSE
C               ! Else use Colebrook and White
        IF(RE_CL .GT. RE_TUR) THEN
          F_CL    = F_CW(CL, RE_CL, KE_CL, KD_CL)
        ELSE
          F_MIN   = F_CW(CL, RE_TUR, KE_CL, KD_CL)
          F_L     = F_LAM(CL, RE_CL, KE_CL, KD_CL)
          F_CL    = MAX(F_MIN, F_L)
```

```
          ENDIF
        ENDIF
C
C **   Heat transfer coefficients
C                          ! Inside tube
        XNUL = 4.364
        XNUT = 6.3 +
0.079*SQRT(ABS(F_CL)/8.)*RE_CL*PR_CL /
     >             (1. + PR_CL**0.8)**(5./6.)

        IF(RE_CL .LT. 2200) THEN
          XNU = XNUL
        ELSE
          XNU = XNUT
        ENDIF

C            ! This corr may give problem if
variables undefined
C     XNU  = ( XNUL**10 + ( EXP(
(2200.-RE_CL)/365.)/XNUL**2 +
C     >                         XNUT**(-2)  )**(-5)
)**0.1
        HW_CL = CK_CL*XNU/KD_CL
C                          ! Outside tube
C       HW_CL = R_CL * U_CL * CP_CL * 0.03 /
RE_CL**0.2 /
C     >             PR_CL**(2./3.)

        RETURN
        END
C
C
C
        SUBROUTINE CPROPP(CL, P_CL,
     >          TS_CL)
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C
C     This subroutine computes coolant tproperties
that depend
C     on the pressure.
C     See MACRO CPROP (File CPROP.M10) for a
description of all
C     the variables
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C
        CHARACTER *4 CL
        REAL P_CL, TS_CL
        DATA PMIN/0.03E6/, PMAX/8.4E6/
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
```

```
-----------------------------------------------------
-------------
C
      P     = P_CL
      IF(P_CL.LT.PMIN .OR. P_CL.GT.PMAX) THEN
C       WRITE(*,'('' <CPROP::'', A4,''>  ERROR  P =
''
C     >           , G15.5)') CL, P_CL
        IF(P.LT.PMIN) P = PMIN
        IF(P.GT.PMAX) P = PMAX
      ENDIF

      TS_CL = D_TSAT(P)

      RETURN
      END
C
C
C
      FUNCTION F_LAM(CL, RE_CL, KE_CL, KD_CL)
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C
C   This function estimates the laminar friction
coefficient
C   This function returns 4*f
C
C     CL     C*4    Coolant node
C     RE_CL R*4    Reynolds number
C     KE_CL R*4    Pipe roughness (m)
C     KD_CL R*4    Pipe diameter (m)
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C
      CHARACTER *4 CL
      REAL RE_CL, KE_CL, KD_CL
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C
      F_LAM = 4.*23.532/RE_CL
      RETURN
      END
C
C
C
      FUNCTION F_FILO(CL, RE_CL, KE_CL, KD_CL)
C
C
-----------------------------------------------------
-------------
```

```
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C
C   This function estimates the turbulent friction
coefficient
C   based on teh Filonenko correlation for ANS core
C   This function returns 4*f
C
C     CL     C*4    Coolant node
C     RE_CL R*4    Reynolds number
C     KE_CL R*4    Pipe roughness (m)
C     KD_CL R*4    Pipe diameter (m)
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C
      CHARACTER *4 CL
      REAL RE_CL, KE_CL, KD_CL
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C
      F_FILO = 4.*0.2709/(1.82*ALOG10(RE_CL) -
1.64)**2
      RETURN
      END
C
C
C
      FUNCTION F_CW(CL, RE_CL, KE_CL, KD_CL)
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C
C   This function estimates the turbulent friction
coefficient
C   based on Colebrook and White correlation for
circular pipes
C   This function returns 4*f
C
C     CL     C*4    Coolant node
C     RE_CL R*4    Reynolds number
C     KE_CL R*4    Pipe roughness (m)
C     KD_CL R*4    Pipe diameter (m)
C
C
-----------------------------------------------------
-------------
C
```

```
*****************************************************
**************
C
-----------------------------------------------------
-------------
C
      CHARACTER *4 CL
      REAL RE_CL, KE_CL, KD_CL
      DATA ERROR/0.001/
C
C
-----------------------------------------------------
-------------
C
*****************************************************
**************
C
-----------------------------------------------------
-------------
C
      C1 = KE_CL/(KD_CL/2.)
      C2 = 9.35/RE_CL

C                  ! Moody correlation (f/4) for first
guess
      F_M    = 1.375E-3*(1. + 21.544*(C1 +
100/RE_CL)**(1./3.))
      SF     = SQRT(F_M)

      NITER = 20
      DO 100 I = 1, NITER
        SFO = SF
        SF  = 1./(3.48 - 1.7372*ALOG(C1 + C2/SF))
        SFERR     = ABS((SF - SFO)/SFO)
        IF(SFERR .LT. ERROR) NITER = 0
  100 CONTINUE
      F_CW = 4.*SF**2

      IF(NITER .EQ. 20)
     >         WRITE(*,'('' <'', A4,
     >         ''> F_COLEBRROK&WHITE DID NOT
CONVERGE.  F = '', G20.5)')
     >         CL, F_CW
      RETURN
      END
```

Appendix C

HEAT TRANSFER AND CRITICAL HEAT FLUX CORRELATIONS

APPENDIX C. HEAT TRANSFER AND CRITICAL HEAT FLUX CORRELATIONS

```
      SUBROUTINE CMFUEL(NODE, T, Q, UCL, TCL, PCL
     >          , HL, DE, CHFTYP
     >          , QI, QC, QS, TW, PW, H)
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C **    MFUEL.F10       04-NOV-88       J M-L
C
C **    This subroutine is called by MACRO CMFUEL.
It checks for
C **    parameters out of bounds.  (Melting,
superheating...)
C **  And calculates critical heat fluxes and wall
temperature
C **    See MACRO MFUEL for more details.
C INTERCONNECTING VARIABLES :
C   INPUT :
C       NODE    : Node name (R*4 as C*4)
C       T       : Actual temperature (melting
included)  (C)
C       Q       : Fuel/coolant heat flux (w/m2)
C       UCL     : Coolant velocity (m/s)
C       TCL     : Coolant temperature (C)
C       PCL     : Coolant pressure (Pa)
C       HL      : Heated length (m)
C       DE      : Equivalent diameter (m)
C     CHFTYP      : Type of CHF correlation
0-Bernath  1-Gambill  2-Costa
C
C   OUTPUTS :
C     QI     : Incipient boiling heat flux (W/m2)
C     QC     : Critical heat flux (W/m2)
C     QS     : Flow      stability (COSTA) heat flux
(W/m2)
C     TW     : Fuel wall temperature (C)
C     PW     : Press. required to avoid incipient
boiling (Pa)
C     H      : Wal heat transfer coefficient
(W/m2/C)
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C
      REAL NODE, T, Q
C                                      ! Pure Al data
      DATA TMELT/660.2/, HMELT/397061.6/,
CP/920.48/
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
```

```
C
------------------------------------------------------
-------------
C
c        IF(T .GE. TMELT)
c     >        WRITE(*,'('' <'',A4,''> FUEL TEMP >
MELTING '')') NODE

C ------------ Heat transfer coeff (W/m2/C)
C               Iterate to find T_Wall
        TW = (D_TSAT(PCL) + TCL)/2.
        ICOUNT = 0
   10   CONTINUE
        CALL HANS(UCL, TCL, TW, PCL, DE, HL, H,
H_LAM, H_TUR)

C ------------ Fuel wall temperatue (C)
          TWO = TW
          TW  = TCL + Q/H
          ICOUNT = ICOUNT + 1
          IF(ICOUNT.GT.20)  STOP 'T-WALL ITERATION
FAILED'
        IF(ABS(TWO - TW).GT.1.) GOTO 10
      CALL HANS(UCL, TCL, TW, PCL, DE, HL, H,
H_LAM, H_TUR)

C ------------ Critical
COSTA-flow-excursion-instability power
      ITYPE = 2
        CALL QCRIT(ITYPE, UCL, TCL, PCL, H_TUR, QS,
TS)

C        IF(CSR .LE. 1.0)
C     >        WRITE(*,'('' <'',A4,''> FLOW
EXCURSION INSTABILITY'')') NODE

C ------------ Critical heat flux (W/m2)
      ITYPE = INT(CHFTYP)
        CALL QCRIT(ITYPE, UCL, TCL, PCL, H_TUR, QC,
TC)

C        IF(CFR .LE. 1.0)
C     >        WRITE(*,'('' <'',A4,''> CRITICAL HEAT
FLUX REACHED'')') NODE

C ------------ Pressure required to avoid incipient
boiling
      PW    = D_PSAT(TW)

C ------------ Incipient boiling heat flux (W/m2)
      ITYPE = 3
        CALL QCRIT(ITYPE, UCL, TCL, PCL, H_TUR, QI,
TI)

C        IF(CIR .LE. 1.0)
C     >        WRITE(*,'('' <'',A4,''> INCIPIENT
BOILING'')') NODE

        RETURN
        END
C
C
C
      SUBROUTINE HANS(U, TB, TW, P, DE, HL, H,
H_LAM, H_TUR)
C
C
------------------------------------------------------
----------------
C
******************************************************
****************
C
------------------------------------------------------
```

```
----------------
C
C **    This subroutine computes the heat transfer
coefficient
C **    in W/m2 based on ANS-specific correlation.
C **  Laminar corr for Re<2300 Nu=7.627
C **  Petukhov corr for Re>2300
C
C   INPUTS
C **    U       R*4     Coolant velocity (m/s)
C **    TB      R*4     Coolant bulk temperature
(C)
C **    TW      R*4     Fuel surface velocity (C)
C **    P       R*4     Coolant bulk pressure (Pa)
C **    DE      R*4     Equivalent diameter (m)
C **    HL      R*4     Heated length (m)
C   OUTPUT
C **  H     R*4   Film heat transfer coeff W/m2/K
C **  H_LAM R*4   Laminar film heat transfer coeff
W/m2/K
C **  H_TUR R*4   Turbulent film heat transfer
coeff W/m2/K
C
C
--------------------------------------------------
----------------
C
**************************************************
****************
C
--------------------------------------------------
----------------
C
      REAL U, TB, TW, P, DE, HL, H, H_LAM, H_TUR
C
C **    Channel gap (B) and Span (S) (Avg of
lower&upper)
C
        REAL B, S
        DATA B/0.00127/, S/0.07882/
C
C
--------------------------------------------------
----------------
C
**************************************************
****************
C
--------------------------------------------------
----------------
C
C                             ! Saturation temp (C)
      TSAT  = D_TSAT(P)
C                             ! Coolant density (Kg/s)
        C_RHO     = D_RHOL(TB)
C                             ! Coolant viscosity
(Kg/s/m)
        C_MUB     = D_MU(TB)
C                             ! Coolant viscosity
@Wall (Kg/s/m)
        TWALL   = MAX(TB, MIN(TW, TSAT))
        C_MUW   = D_MU(TWALL)
C                             ! Coolant conductivity
(W/m/K)
        C_K = D_K(TB)
C                             ! Coolant heat capacity
(J/Kg/K)
        C_CP      = D_CP(TB)
C
C
--------------------------------------------------
----------------
C
**************************************************
```

```
*****************
C
------------------------------------------------------------
----------------
C
C                                    ! Prandtl number
        PR   = C_CP*C_MUB/C_K
C                                    ! Reynolds number
        RE   = ABS(U)*DE*C_RHO/C_MUB

C ** Laminar Flow (Nu = 7.627)
      H_LAM = (C_K/DE) * 7.627 *
(C_MUB/C_MUW)**0.11

C ** Transition + Turbulent Flow (Petukhov)
C **    Friction factor Filonenko
C **    Filonenko not corrected for temp for use
with Petukhov
      F     = (1.0875 -
0.1125*B/S)/(1.82*ALOG10(Re) - 1.64)**2
C     >              * (7. - C_MUB/C_MUW)/6.
c     H_TUR = ( (C_K/DE) * (F/8.) * RE * PR *
(C_MUB/C_MUW)**0.11 )
c     >            / ( (1. + 3.4*F) + (11.7 +
1.8/PR**0.333)
c     >                * SQRT(F/8.) * (PR**0.666 -
1.) )
        H_NUM   = (C_K/DE) * (F/8.) * RE * PR *
(C_MUB/C_MUW)**0.11
        H_D1    = (1. + 3.4*F)
        H_D2    = (11.7 + 1.8/PR**0.333)
        H_D2    = H_D2*SQRT(F/8.)
        H_D2    = H_D2*(PR**0.666 - 1.)
        H_TUR   = H_NUM/(H_D1+H_D2)
C
      IF(RE .LT. 2300) THEN
        H   = H_LAM
      ELSE
        H   = H_TUR
      ENDIF

        RETURN
        END
C
C
C
        SUBROUTINE QCRIT(itype, U, T, P, H_TUR, QC,
TC)
C
C
------------------------------------------------------------
----------------
C
************************************************************
*****************
C
------------------------------------------------------------
----------------
C
C **    This function returns the critical heat
flux in w/m2
C
C   INPUTS
C **  itype I*4   if 0 - Bernath
C **              If 1 - Gambill/Weatherhead
C **              If 2 - Costa
C **    U       R*4     Coolant velocity (m/s)
C **    T       R*4     Coolant bulk temperature
(C)
C **    P       R*4     Coolant bulk pressure (Pa)
C **  H_TUR R*4   Turbulent heat transfer coeff
(W/m2/K)
C   OUTPUT
C **  QC    R*4   Critical heat flux W/m2
```

```
C **  TC    R*$   Critical fuel surface (Wall)
temperature (C)
C
C
--------------------------------------------------------
----------------
C
*******************************************************
****************
C
--------------------------------------------------------
----------------
C
C                 ! Default is Gambill/Weatherhead
      IF(ITYPE.LT.0 .OR. ITYPE.GT.3) ITYPE = 1

C ** Bernath (Critical Heat Flux)
      IF(ITYPE .EQ. 0) THEN
        PM  = P/1.E6
        TC  = 571.76 - 273.16 + 60.*ALOG(PM)
     >             - 80.8*(PM/(PM+0.0931)) -
U*0.8202
          QC       = H_TUR*(TC - T)
        RETURN
      ENDIF

C ** Gambill/Weatherhead (Critical Heat Flux)
      IF(ITYPE .EQ. 1) THEN
        QC  = QC_GW(P, T, H_TUR)
        TC  = T + QC/H_TUR
        RETURN
      ENDIF

C ** Costa (Flow excursion instability)
C **    Note: "Official" correlations are in
KJ/s/m2.  Here I use W/m2
C **    Thus, the factor of 1.E3 when fluxes are
multiplied or divided
      IF(ITYPE .EQ. 2) THEN
        TSAT      = D_TSAT(P)
        QC  = SQRT(U)*(TSAT - T)/12.8E-6
        TC  = T + QC/H_TUR
        RETURN
      ENDIF

C ** Bergles and Rosenhow (Incipient boiling)
      IF(ITYPE .EQ. 3) THEN
        QC  = QC_BR(P, T, H_TUR)
        TC  = T + QC/H_TUR
        RETURN
      ENDIF

      QC    = 1.E-32
      WRITE(*,'('' Selected correlation out of
range''/
     >          '' SET CHFTYP     0 - Bernath''/
     >          ''              1 - Gambill
Weatherhead''
     >          ''              2 - Costa''
     >          ''              3 - Bergles &
Rosenhow'')')

        RETURN
        END
C
C
C
      REAL FUNCTION QC_GW(P, T, H)
C
C
--------------------------------------------------------
--------------
C
*******************************************************
```

```
**************
C
--------------------------------------------------
-------------
C
C **  Gambill/Weatherhead critical heat flux
correlation
C **    Note: "Official" correlations are in
KJ/s/m2.  Here I use W/m2
C **    Thus, the factor of 1.E3 when fluxes are
multiplied or divided
C
C **  INPUT
C           P     Coolant bulk pressure (Pa)
C           T     Coolant bulk temperature (C)
C           H     Film heat transfer coeff
(Pethukov) (W/m2/K)
C **  OUTPUT
C           QC_GW Crit heat flux (W/m2)
C
C
--------------------------------------------------
-------------
C
**************************************************
**************
C
--------------------------------------------------
-------------
C
      DATA  G/9.81/,    CONV/1.E-3/,
     >            ITERMX/20/
C
C
--------------------------------------------------
-------------
C
**************************************************
**************
C
--------------------------------------------------
-------------
C
C·**  D2O Properties
C           HFG   Latent heat of vaporization
(J/kg)
C           RHOL  Liquid density at bulk coolant
pressure (kg/m3)
C           RHOG  Vapor density at bulk coolant
pressure (kg/m3)
C           CP    Specific heat (J/kg/K)
C           SIG   Surface tension (N/m)
C           TSAT  Coolant saturation temp @bulk
pressure (C)
C
      TSAT  = D_TSAT(P)
      HFG   = D_HFG(TSAT)
      RHOL  = D_RHOL(TSAT)
      RHOV  = D_RHOV(TSAT)
      CP    = D_CP(TSAT)
      SIG   = D_SIG(TSAT)
c
c **  Correlation is only valid for subcooled flow
c
      IF(T .GE. TSAT) THEN
        QC_GW     = -1.E32
        RETURN
      ENDIF
c                 ! pool crit heat flux in W/m2
      Q_POOL      =
0.18*HFG*RHOV*(SIG*G*(RHOL-RHOV)/RHOV**2)**0.25
     >            *(1. + (RHOL/RHOV)**0.75 *
CP*(TSAT-T)/9.8/HFG)
```

```
C ! initial guess use crit t_wall without
Weatherhead correction
      TW    = TSAT + 84.96 - 0.1313*(TSAT + 273.16)
      QC    = Q_POOL + H*(TW - T)
      ITER  = 0

   10 CONTINUE
      ITER  = ITER + 1
      TW    = (47.7 -
0.127*TSAT)*ABS(QC/3.1546E6)**0.25 + TSAT
      OLD_QC      = QC
      QC    = Q_POOL + H*(TW - T)

      IF(ITER.GT.ITERMX) THEN
        WRITE(*,'('' !! ERROR in crit heat flux
iteration'')')
        QC_GW     = -1.E32
        RETURN
      ENDIF

      IF(ABS((QC - OLD_QC)/QC).GT.CONV) GOTO 10

      QC_GW = QC

      RETURN
      END
C
C
C
      REAL FUNCTION QC_BR(P, T, H)
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C
C **  Bergles & Rohsenow Incipient boiling heat
flux correlation
C **    Note: "Official" correlations are in
KJ/s/m2.  Here I use W/m2
C **    Thus, the factor of 1.E3 when fluxes are
multiplied or divided
C
C **  INPUT
C           P     Coolant bulk pressure (Pa)
C           T     Coolant bulk temperature (C)
C           H     Film heat transfer coeff
(Pethukov) (W/m2/K)
C **  OUTPUT
C           QC_BR Incipient boiling heat flux
(W/m2)
C
C
-----------------------------------------------------
-------------
C
*****************************************************
*************
C
-----------------------------------------------------
-------------
C
      DATA  CONV/1.E3/, ITERMX/20/
C
C
-----------------------------------------------------
-------------
C
*****************************************************
```

```
**************
C
-----------------------------------------------------
-------------
C
C **  D2O Properties
C            TSAT  Coolant saturation temp @bulk
pressure (C)
C
C
C
-----------------------------------------------------
-------------
C
*****************************************************
**************
C
-----------------------------------------------------
-------------
C
      TSAT  = D_TSAT(P)
c     C1    =
3.1546*0.98*15.6*((P/6.8948E3)**1.156)
c     C2    = (2.3/(P/6.8948E3)**0.0234)
        C1       = CONV * 0.9 * 1.7978E-6 *
(P)**1.156
        C2       = 2.8285/(P)**0.0234
      TC    = TSAT + 10.
      TW    = TC

      NITER = 0
   10 NITER = NITER + 1
        QC  = C1*(1.8*ABS(TW - TSAT))**C2
        TC  = T + QC/H
        F   = TW - TC
        DFDT     = 1. - C1*C2/H * 1.8 *
(1.8*ABS(TW - TSAT))**(C2 - 1.)
        DT  = -F/DFDT

        IF(NITER .LT. ITERMX) THEN
          IF(ABS(DT) .GT. 0.01) THEN
            TW    = TW + DT
            IF(TW .LT. TSAT) TW = TSAT + 1.
            GOTO 10
          ENDIF
        ELSE
          WRITE(*,'('' Incipient boiling iteration
not converged'')')
          QC      = -1.E32
        ENDIF

      QC_BR = QC
      RETURN
      END
```

Appendix D

STANDARD MACRO DEFINITION FILE (ANS.CMD) FOR THE ADVANCED NEUTRON SOURCE DYNAMIC MODEL

APPENDIX D. STANDARD MACRO DEFINITION FILE (ANS.CMD) FOR ANSDM

```
set hvdpm = .true.
! Delete after rebuilding 11/8/94 (fixed anomalus OCR worth value)
  set kwrocr(6) = -4
! Delete after rebuild 4/8/94 (Updated reactivity coefficients)
  set kracor=7.4
  set krfcor=-1.25e-3
  set kgtcor=0.5e-3
  set kktcon=1

set hvdpm = .false.
set ftsplt = .true.     ! Flyback trace suspension
set cjvitg = .false.    ! No check Jacob validity
set ecsitg = .false.    ! Relative error based on MAX value
set rxeitg = .false.    ! Eval deriv before communication intrvl
set weditg = .false.    ! No scheduled events info
set wesitg = .false.    ! No error control info
set nstp  = 10000
set tjnitg = 1.e32      ! Jacobian nonlinearity threshold
s grdcpl=.false.        ! No grids on plots

! Restoring binary data ...
! RESTOR

proced settim
s hvdpm=.t.
! Actions for standard time intervals set
s hvdpm=.f.
  s tstop = 604800.                           ! 1 week
  s cint  = 1.e-3
  action 'var'=0.02,'val'=0.01,'loc'=cint
  action 'var'=0.2,'val'=0.1,'loc'=cint
  action 'var'=2.,'val'=1.,'loc'=cint
  action 'var'=20.,'val'=10.,'loc'=cint
  action 'var'=200.,'val'=100.,'loc'=cint
  action 'var'=1800.,'val'=1800.,'loc'=cint
  action 'var'=86400.,'val'=21600.,'loc'=cint
end
settim

proced locat
s hvdpm=.t.
! Actions for LOCA time intervals set
s hvdpm=.f.
  s tstop = 604800.                           ! 1 week
  s cint  = 1.e-3
  action 'var'=0.02,'val'=0.01,'loc'=cint
  action 'var'=2.,'val'=0.1,'loc'=cint
  action 'var'=20.,'val'=1.,'loc'=cint
  action 'var'=200.,'val'=10.,'loc'=cint
  action 'var'=1800.,'val'=1800.,'loc'=cint
  action 'var'=86400.,'val'=21600.,'loc'=cint
end

proced relapt
s hvdpm=.t.
! Actions for RELAP time intervals set
s hvdpm=.f.
  s cint = 2.e-4
  s tstop= 25.
  action 'var'=0.01,'val'=0.001,'loc'=cint
  action 'var'=0.05,'val'=0.033,'loc'=cint
  action 'var'=0.974,'val'=0.026,'loc'=cint
  action 'var'=1.0,'val'=0.33,'loc'=cint
  action 'var'=4.96,'val'=0.04,'loc'=cint
  action 'var'=5.0,'val'=1.65,'loc'=cint
  action 'var'=24.8,'val'=0.2,'loc'=cint
end

prepar 'clear',t
prepar pvesl,pveso,pmcpl,pmcpo
prepar wacho,tacho,tacf,tbypo,uacho
prepar thcuo,thclo,thuf,thlf
prepar mcrhcu,xcrhcu,mlrhcu,xlrhcu,msrhcu,xsrhcu
prepar mcrhcl,xcrhcl,mlrhcl,xlrhcl,msrhcl,xsrhcl
prepar tveso,thlro
prepar tmcpl,tmcpo,tclrl,tvesl
prepar fcnfx,jcpg,fdhfx,jrefc
prepar wmuso,wgac,wldsl,wclic,wcolc
prepar wsctx,tsctx,tshlx
prepar rxesm, rxpol, rspol
prepar xicr, ricr

! ------------ start
proced go
  set error=.false.,nrwitg=.false., abort=.false.
  set nstp=100, t=0., cint=1.e-3
  start
end

! ------------ multiple runs
proced next
  set error=.false.,nrwitg=.true.,abort=.false.
  set nstp=100, t=0., cint = 1.e-3
  start
end

proced logplt
plot 'xlo'=1.e-3,'xlog',fcnfx,'type'=222,wacho,'type'=333,pveso,'type'=444
end

proced STEADY
s hvdpm=.t.
! Steady State Run
s hvdpm=.f.
  s tstop = 0
  start
s hvdpm=.t.
! Fine tunning steady state...
s hvdpm=.f.
  s tstop = 100.
  contin              ! Find steady state
  s t = 0
  s cint = 1.e-3
  s tstop = 0
  contin              ! Reset time to 0
  s tstop = 604800.
end

proced ppsoff
s hvdpm=.t.
! Plant protection system off.
s hvdpm=.f.
  set oseisc = .f., oseosc = .f.
end

proced ppson
s hvdpm=.t.
! Plant protection system on
s hvdpm=.f.
  set oseisc = .t., oseosc = .t.
end

proced norcon
! Rods will not move
  set kvsicr =0., kvficr = 0.
end

proced roff
set hvdpm=.t.
! External reactivity set to zero
set hvdpm=.f.
  set kartra(1)  = 0.,  0.,  0.,  0.,  0.,  0.,  0.
  set kartra(11) = 0., 1.e10, 1.e10, 1.e10, 1.e10, 1.e10, 1.e10
end

proced ron
set hvdpm=.t.
! External reactivity set to 1.0 dol step (in 1 ms)
set hvdpm=.f.
  set kartra(1)  = 0., 1.0, 1.0
  set kartra(11) = 0., 0.001, 1.e10
end

proced p2off
set hvdpm=.t.
! Secondary pump speed will trip to nat circ. at t=0
! Control pars KKTCON and KTNCON have been changed.
set hvdpm=.f.
  action 'var'=0,'val'=0.0,'loc'=kn0con
  s kktcon = 0.
  s ktncon = 5.
end

proced pony
set hvdpm=.t.
! Pump speed will be set to pony speed (10%) at time 0
set hvdpm=.f.
  action 'var'=0,'val'=0.1,'loc'=zn0mcp
  p2off
end

proced natcir
set hvdpm=.t.
! Pry pump speed will be set to 0 (natural circulation) at time 0
```

```
set hvdpm=.f.
  action 'var'=0,'val'=0.,'loc'=zn0mcp
  p2off
end

proced nopres
set hvdpm=.t.
! pressure dynamics turned off
set hvdpm=.f.
  s offgac = .t.
  s kpmmcs = 0.
  s kwiccs = 0.
end

proced no2con
set hvdpm = .t.
! No secondary control
set hvdpm=.f.
  s kktcon = 0.
  s kbncom = 0.
  s kbxcon = 0.
  s kwncom = 1.
  s kwxcon = 1.
end

proced lonhs
set hvdpm=.t.
! Loss of normal heat sink.  Main heat exchangers disabled at time 0
set hvdpm=.f.
  action 'var'=0., 'val'=0., 'loc'=kaemhx    ! No heat trf area in MHX
  action 'var'=0., 'val'=0., 'loc'=kofscc    ! No heat sink @ tower
end

proced lotow
set hvdpm=.t.
! Loss of normal heat sink.  Tower cooling disabled at time 0
set hvdpm=.f.
  action 'var'=0., 'val'=0., 'loc'=kofscc    ! No heat sink @ tower
end

proced mhxoff
  set hvdpm=.t.
! Eliminate main heat exchanger (set HT area=0) at time 0
  set hvdpm=.f.
  action 'var'=0., 'val'=0., 'loc'=zaemhx    ! MHX off
end

proced ehxoff
  set hvdpm=.t.
! Eliminate Emergency heat exchanger (set HT area=0) at time 0
  set hvdpm=.f.
  action 'var'=0., 'val'=0., 'loc'=zaeehx    ! MHX off
end

proced isolat
  set hvdpm=.t.
! Containment will be isolated at time 0
! Loss: MHX, all pool cooling, makeup flow
  set hvdpm=.f.
  action 'var'=0., 'val'=1.E-3, 'loc'=wmrpo          ! RX pool cooling
off
  action 'var'=0., 'val'=1.E-3, 'loc'=wpcho          ! Pipe chase
cooling off
  action 'var'=0., 'val'=1.E-3, 'loc'=whxpo ! HX pool cooling off
  mhxoff
 MHX off
  s kofmus = .true.
 Turn makeup off
 end

proced nohw
  set hvdpm=.t.
! Disable pipe heat losses to pools
  set hvdpm=.f.
  s khwhlr = 0.
  s khwmhl = 0.
  s khwihl = 0.
  s khwpcl = 0.
  s khwmcl = 0.
  s khwclr = 0.
end

proced hw
  set hvdpm=.t.
! Set heat losses to pool het transfer coeff
  set hvdpm=.f.
  s khwhlr = 250.   ! W/m2/K
  s khwmhl = 250.
  s khwihl = 250.
  s khwpcl = 250.
  s khwmcl = 250.
  s khwclr = 250.
end

proced loahs
  set hvdpm=.t.
! Loss of all heat sinks. Containment will be isolated at time 0
! Cooling tower basin will still be available
  set hvdpm=.f.
  action 'var'=0., 'val'=0.,    'loc'=kofscc
  action 'var'=0., 'val'=0.,    'loc'=wmrpo
  action 'var'=0., 'val'=0.,    'loc'=wpcho
  action 'var'=0., 'val'=0.,    'loc'=whxpo
!  s kwiccs = 0.
!  s kwmcon = 0.
  s kofmus=.true.   !Turn off makeup injection
end

proced loop2
  set hvdpm=.t.
! Approximate 1 loop operation with 2 HX will be set at time 0
  set hvdpm=.f.
  action 'var'=0., 'val'=1.65,  'loc'=kcvmhl
  action 'var'=0., 'val'=0.164, 'loc'=kfamhl
  action 'var'=0., 'val'=14.36, 'loc'=ksamhl

  action 'var'=0., 'val'=1.65,  'loc'=kcvmcl
  action 'var'=0., 'val'=0.164, 'loc'=kfamcl
  action 'var'=0., 'val'=14.36, 'loc'=ksamcl

  action 'var'=0., 'val'=1.32,  'loc'=kcvclr
  action 'var'=0., 'val'=0.164, 'loc'=kfaclr
  action 'var'=0., 'val'=11.49, 'loc'=ksaclr

  action 'var'=0., 'val'=3000., 'loc'=kaemhx
  action 'var'=0., 'val'=20.,   'loc'=kcvmhp
  action 'var'=0., 'val'=1.25,  'loc'=kfamhp
  action 'var'=0., 'val'=116.75,'loc'=ksamhp
  action 'var'=0., 'val'=20.,   'loc'=kcvshp
  action 'var'=0., 'val'=1.15,  'loc'=kfashp

  action 'var'=0., 'val'=250.,  'loc'=kaeehx

  action 'var'=0., 'val'=12.,   'loc'=kcvthl
  action 'var'=0., 'val'=0.59,  'loc'=kfathl

  action 'var'=0., 'val'=12.,   'loc'=kcvtcl
  action 'var'=0., 'val'=0.59,  'loc'=kfatcl

  action 'var'=0., 'val'=3000., 'loc'=kcvctb

  action 'var'=0., 'val'=150.,  'loc'=kcvpch

  set knpisc = 0.05         ! Pony speed (10%/2) after scram

 end

proced scram
  set hvdpm=.t.
! Reactor scram request set at 1 ms.  Delay still active
  set hvdpm=.f.
  s kssisc = 0.001
end

proced nolim
  set hvdpm=.t.
! Control rod limits of servo motion removed
  set hvdpm=.f.
  s kosicr = 1.e10
end

proced nolpol
  s kipol = 0.  ! No initial Iodine
  s kxpol = 0.  ! No initial Xenon
end

proced digcon
  set hvdpm = .t.
! Digital control active.  DTFCON, DTPCON, DTTCON set sampling
time
  set hvdpm = .f.
  set odccon = .true.
  set DTFCCN = 0.01    ! Power (flux) control sampling time
  set DTPCON = 0.5     ! Pressure control sampling time
  set DTTCCN = 0.5     ! Temperature control sampling time
  d dtfcon, dtpcon, dttcon
end

PROCED U95
  set hvdpm=.t.
! 95/95 Uncertainties (FAX DGM-JML 4/23/92 11:00)
! Not valid if CHF limit is at inlet or outlet (use kugcor=1.631)
  set hvdpm=.f.

  s khucor = 1.074                  ! Hot streak uncertainty
  s kugcor = 1.554                  ! Hot spot unc. for CHF
  s kuccor = 1.305                  ! Hot spot unc. for FE
END
```

```
PROCED U99
  set hvdpm=.t.
! 99.9/99 Uncertainties (FAX DGM-JML 4/23/92 11:00)
! Not valid if CHF limit is at inlet or outlet (use kugcor=1.995)
  set hvdpm=.f.

  s khucor = 1.113                    ! Hot streak uncertainty
  s kugcor = 1.899                    ! Hot spot unc. for CHF
  s kuccor = 1.592                    ! Hot spot unc. for FE ???
END

PROCED UMULT
  set hvdpm=.t.
! Multiplicative uncertainties (Old HFIR type) used JM-L pg 72
  set hvdpm=.f.

  s khucor = 1.259                    ! Hot streak uncertainty
  s kugcor = 1.46                     ! Hot spot unc. for CHF
  s kuccor = 1.46                     ! Hot spot unc. for FE ???
END

PROCED UPS2
  set hvdpm=.t.
! SQRT(SUM_var) uncertainties (PS2 type) used JM-L pg 72. I1 Grade
  set hvdpm=.f.

  s khucor = 1.144                    ! Hot streak uncertainty
  s kugcor = 1.32                     ! Hot spot unc. for CHF
  s kuccor = 1.32                     ! Hot spot unc. for FE ???
END

PROCED UNO
  set hvdpm=.t.
! No uncertainties used.
  set hvdpm=.f.

  s khucor = 1.0                      ! Hot streak uncertainty
  s kugcor = 1.0                      ! Hot spot unc. for CHF
  s kuccor = 1.0                      ! Hot spot unc. for FE ???
END

PROCED I1BOC
  set hvdpm=.t.
! Beginning of cycle detailed power shapes (27 nodes)
  set hvdpm=.f.

! Lower core BOC. I1
  s kplcor   = 1.319
  s knnhcl   = 27
  s kpshcl   = 1.215, 1.368, 1.407, 1.391, 1.386, 1.382, 1.396,...
                         1.374, 1.373, 1.364, 1.372, 1.373, 1.382,
1.386,...
                         1.394, 1.397, 1.401, 1.402, 1.350, 1.289,
1.279,...
                         1.219, 1.164, 1.114, 1.038, 0.926, 0.793

! Upper core BOC. I1
  s kpucor   = 0.641
  s knnhcu   = 27
  s kpshcu   = 0.761, 0.834, 0.890, 0.919, 0.890, 0.877, 0.855,...
                         0.880, 0.792, 0.699, 0.679, 0.658, 0.637,
0.614,...
                         0.597, 0.579, 0.563, 0.547, 0.525, 0.500,
0.487,...
                         0.467, 0.459, 0.453, 0.426, 0.380, 0.366
END

PROCED I1EOC
  set hvdpm=.t.
! End of cycle detailed power shapes (27 nodes)
  set hvdpm=.f.

! Lower core EOC. I1
  s kplcor   = 0.992
  s knnhcl   = 27
  s kpshcl   = 0.463, 0.502, 0.529, 0.520, 0.500, 0.483, 0.474,...
                         0.441, 0.427, 0.412, 0.406, 0.399, 0.399,
0.396,...
                         0.403, 0.407, 0.415, 0.423, 0.416, 0.412,
0.423,...
                         0.431, 0.431, 0.452, 0.482, 0.552, 0.627

! Upper core EOC. I1
  s kpucor   = 1.258
  s knnhcu   = 27
  s kpshcu   = 0.877, 1.119, 1.281, 1.419, 1.426, 1.434, 1.430,...
             1.555, 1.418, 1.281, 1.288, 1.286, 1.283, 1.270,...
                         1.264, 1.252, 1.241, 1.229, 1.199, 1.165,
1.140,...
                         1.117, 1.120, 1.143, 1.147, 1.207, 1.339
END

PROCED I1
  set hvdpm=.t.
! I1 Grade. BOC power shape for lower core, EOC for upper.
  set hvdpm=.f.

! Upper core EOC. I1
  s kpucor   = 1.258 ! EOC
  s knnhcu   = 27
  s kpshcu   = 50*0.
  s kpshcu   = 0.877, 1.119, 1.281, 1.419, 1.426, 1.434, 1.430,...
             1.555, 1.418, 1.281, 1.288, 1.286, 1.283, 1.270,...
                         1.264, 1.252, 1.241, 1.229, 1.199, 1.165,
1.140,...
                         1.117, 1.120, 1.143, 1.147, 1.207, 1.339

! Lower core BOC. I1
  s kplcor   = 1.319 ! BOC
  s knnhcl   = 27
  s kpshcl   = 50*0.
  s kpshcl   = 1.215, 1.368, 1.407, 1.391, 1.386, 1.382, 1.396,...
             1.374, 1.373, 1.364, 1.372, 1.373, 1.382, 1.386,...
                         1.394, 1.397, 1.401, 1.402, 1.350, 1.289,
1.279,...
                         1.219, 1.164, 1.114, 1.038, 0.926, 0.793
END

PROCED I3
  set hvdpm=.t.
! I3 Grade. EOC
  set hvdpm=.f.

! Upper core EOC. I3
  s kpucor   = 1.53176 ! EOC. To agree with RELAP MW/m2
  s knnhcu   = 5
  s kpshcu   = 50*0.
  s kpshcu   = 1.362, 1.614, 1.566, 1.517, 1.517

! Lower core EOC. I3
  s kplcor   = 0.96658 ! EOC. To agree with RELAP MW/m2
  s knnhcl   = 5
  s kpshcl   = 50*0.
  s kpshcl   = 1.109, 1.034, 0.963, 0.901, 0.864
END

PROCED M1
  set hvdpm=.t.
! M1 core power distributions.
  set hvdpm=.f.

  s kpucor = 1.417174
  s knnhcu = 35
  s kpshcu =...
   .143363E+01, .144865E+01, .150306E+01, .171713E+01,
.168831E+01,...
   .152097E+01, .142640E+01, .140383E+01, .145661E+01,
.141338E+01,...
   .155626E+01, .158702E+01, .155000E+01, .159092E+01,
.156396E+01,...
   .161399E+01, .158341E+01, .162455E+01, .158724E+01,
.162086E+01,...
   .157873E+01, .144618E+01, .140452E+01, .152382E+01,
.148467E+01,...
   .121482E+01, .122511E+01, .124843E+01, .122010E+01,
.128158E+01,...
   .105417E+01, .988099E+00, .102623E+01, .953287E+00,
.986873E+00

! Lower core BOC  M1
  s kplcor = 1.46936
  s knnhcl = 35
  s kpshcl =...
   .198589E+01, .199858E+01, .182327E+01, .197119E+01,
.195061E+01,...
   .192650E+01, .191143E+01, .191442E+01, .193013E+01,
.195302E+01,...
   .199781E+01, .184419E+01, .189851E+01, .179257E+01,
.183855E+01,...
   .189571E+01, .195197E+01, .163039E+01, .167774E+01,
.151195E+01,...
   .154781E+01, .138763E+01, .140760E+01, .120902E+01,
.119860E+01,...
   .980262E+00, .963091E+00, .936532E+00, .776620E+00,
.737582E+00,...
   .705939E+00, .529689E+00, .499613E+00, .579974E+00,
.535297E+00

END

PROCED L7
  set hvdpm=.t.
! L7 Grade. BOC power shape for lower core, EOC for upper.
  set hvdpm=.f.

! Upper core EOC. L7
  s kpucor = 1.49 ! EOC Upper Core relative power
  s knnhcu = 23
  s kpshcu = 50*0.
```

```
s kpshcu = ...
        1.26, 1.32, 1.38, 1.45, 1.51,...
        1.51, 1.54, 1.58, 1.64, 1.67,...
        1.70, 1.75, 1.75, 1.74, 1.71,...
        1.68, 1.57, 1.49, 1.43, 1.26,...
        1.16, 1.06, 1.03

! Lower core BOC. L7
 s kplcor = 1.70 ! BOC Lower Core relative power
 s knnhcl = 23
 s kpshcl = 50*0.
 s kpshcl = ...
        2.31, 2.29, 2.28, 2.27, 2.25,...
        2.24, 2.21, 2.18, 2.12, 2.08,...
        2.02, 1.88, 1.80, 1.71, 1.61,...
        1.39, 1.29, 1.12, 1.04, 0.89,...
        0.80, 0.73, 0.67
END


PROCED L7N5
 set hvdpm=.t.
! 5-node L7 Grade. BOC power shape for lower core, EOC for upper.
 set hvdpm=.f.

! Upper core EOC. L7
 s kpucor = 1.49 ! EOC Upper Core relative power
 s knnhcu = 5
 s kpshcu = 50*0.
 s kpshcu = 1.384, 1.588, 1.720, 1.543, 1.133

! Lower core BOC. L7
 s kplcor = 1.70 ! BOC Lower Core relative power
 s knnhcl = 5
 s kpshcl = 50*0.
 s kpshcl = 2.280, 2.166, 1.804, 1.21, 0.773
END

PROCED GRODS
 set hvdpm=.t.
! Gravity outer rods. Inner rods disabled
 set hvdpm=.f.

 s oseisc    = .false.
 s kkfcon    = 0.
 s kasocr    = 9.81, 9.81, 9.81
END

PROCED HERODS
 set hvdpm=.t.
! He3 shutdown system, 3 dollars worth
 set hvdpm=.f.
 s kwrocr    = 0., 0., -3., -3.
 s kwrocr(22)          = -1.e10, -0.4, 1., 1.e10
 s kasocr    = 1.e3, 1.e3, 1.e3
END

PROCED HRODS
 set hvdpm=.t.
! Hydraulic outer rods (20m, 1inch, P0=2MPa, Tvalv=50ms)
 set hvdpm=.f.
 s kasocr = 5, 25, 25, 0, 0.01, 10
END
```

```
PROCED P335
 set hvdpm=.t.
! 335 MWf, 3.0 MPa @fuel_element_inlet, 25 m/s, PS2 uncert, M1
grade
 set hvdpm=.f.
 s kjncor=335.e6, kj0cor=335.e6, kpcccs=3.15e6, kwcccs=2144
 UPS2
 M1
END

PROCED RELAP1
 set hvdpm=.t.
! RELAP5 Benchmark Parameters for 10/91 (See RELAP2 10/92)
 set hvdpm=.f.

 I3                                          ! I3 Grading used
in RELAP
 s khucor = 1.14                  ! Hot streak uncertainty
SQRT(SUM **2)
 s khshcu = 1.395, 1.217, 1.204, 1.243, 1.312 ! Hot spot unc. upper
core
 s khshcl = 1.394, 1.406, 1.374, 1.352, 1.243 ! Hot spot unc. lower
core
 s kjncor = 350.e6                ! Core fission power (W)
 s kj0cor = 350.e6                ! Core fission power (W)
 s kfacor = 0.0692247
 s kdecor = 0.002489
 s kercor = 2.0e-6
 s kerves = 2.0e-6
 s kwcccs = 2462.9
 s kkccll = 1.69624       !For RELAP benchmark only.  WRONG #!!!
 s kkclfd = 0.            !For RELAP benchmark only.  WRONG #!!!
 s kbwcor = 0.1664636
 s kgfgac = 0.025
 s kcflhl = 1.2           ! Match RELAP P @ accumulator
 s kcfpcl = 1.                    ! Match RELAP P @
accumulator
 s kcfmcl = 1.                    ! Match RELAP P @
accumulator
 s kcfclr = 1.                    ! Match RELAP P @
accumulator
 s kcflfd = 0.5           ! Match RELAP P @ accumulator
 s kz0gac = 3.7
END

PROCED RELAP2
 set hvdpm=.t.
! RELAP5 Benchmark Parameters for 10/92 (Close to CDR config)
 set hvdpm=.f.

 L7                                          ! L7 Grading
used in RELAP
 U95                   ! 95% uncertainties
 s kjncor = 330.e6                ! Core nominal fission power
(W)
 s kj0cor = 343.86e6              ! Initial power (W) (104.2%)
 s kdecor = 0.002489       ! Avg eq diam UC LC (m)
! s kercor = 0.14e-6         C-W eff roughness (m)
! s kerves = 0.14e-6         C-W eff roughness (m)
 s kwcccs = 1994.2         ! Total primary flow (kg/s)
 s kbwcor = 0.0965         ! To agree with RELAP flow splits
 s kwlccs = 15.0          ! Letdown flow (kg/s)
 s kcfmcl = 5.           ! Extra dP to fudge chk vlv
```

```
 s kgfgac = 3.02          ! Initial gas fraction 0.1:5 m3
 s kvagac = 15.           ! 3 accumulators 5 m3 each
 s kgcgac = 1.0           ! Isothermal accumulator
 s kz0gac = 3.7
 s kplcon = 0.15e6          ! Letdown valve downstream Press
 s kdrcor = kfrcor        ! RELAP decay heat distrib
 s kdbcor = kbfcor         ! RELAP decay heat distrib
END

PROCED RELAP3
 set hvdpm=.t.
! RELAP5 Benchmark Parameters for 10/92 (200 MW (104.2%), 17.0
m/s)
 set hvdpm=.f.

 RELAP2
 s kjncor = 200.e6                 ! Core nominal fission power
(W)
 s kj0cor = 208.4e6                ! Initial power (W) (104.2%)
 s kwcccs = 1336.          ! Total primary flow (kg/s)
 s kpcccs = 2.39e6         ! ~core inlet pressure (Pa)

 s kpfisc = 0.85          ! P is 95%nom, trip at 80%nom
 s kfscon = 1.042          ! Conrol power at 104.2%
END
        !

PROCED RELAP4
 set hvdpm=.t.
! RELAP5 Benchmark Parameters for 10/92 (Almost CDR config)
 set hvdpm=.f.

 RELAP2

 s kgfgac = 0.069          ! Initial gas fraction 0.52:7.52 m3
 s kvagac = 22.56          ! 3 accumulators 7.52 m3 each

 s kercor = -1.13         ! Force agreement with RELAP P-out

 s kpfisc = 0.85          ! P is 95%nom, trip at 80%nom
 s kfscon = 1.042          ! Conrol power at 104.2%
END


proced RNC
 set hvdpm=.t.
! RELAP5 Benchmark - Nat Circ (10/92)
 set hvdpm=.f.

! This is a strange (very) station blackout. If I understand
! the RELAP data correctly, At time=0 they isolate the secondary
! (10 seconds for 0 sec. flow) and trip the makeup pump (5 s)
! but the primary pumps keep running untill scram
! also, secondary side natural circulation is disabled (they
! assume total isolation
! The letdown valve is also assumed fully open

! This macro does not really do all that, it makes some approx

 action 'clear'
```

```
prepar 'clear', t, jcpg, thclo, tvesl, tveso, twhlf, zqwhcl(23)
prepar      plpcl, zipopr, nmcp, uacho
prepar      wmcpo, wshlx, wmuso, wgac
prepar      csrhcl(23), cfrhcl(23), zqshcl(23), csrhcl(23)

RELAP3          ! 200 MW, 17 m/s core

s ktcmcp = 3.     ! Try to match RELAP costdown
s knplsc = -0.15   ! Trip MC Pumps to nat circ on LP scram
!                set speed to -15% to fudge RELAPs friction

s kklcon = 0.      ! Keep letdown valve at current position

s kofmus = .t.     ! Trip makeup pump at t=0
s ktimus = 2.      ! Makeup coasts down as e(-t/2)

s kktcon = 0.      ! Trip secondary coolant pump
s ktncon = 2.      ! Trip secondary pump as e-(t/2)
! ans cut down all heaty transfer at time 10 s
 action 'var'=10, 'val'=0, 'loc'=kaemhx
! s kdhthl = 0.1
! s kdhtcl = -0.1     to limit nat circ in sec (isolation)

s tstop = 400
s cint = 1.
s maxt = 1.
action 'var'= 6.,'val'=0.1,'loc'=cint
action 'var'=10.,'val'=1.0,'loc'=cint
action 'var'=50.,'val'=10.,'loc'=cint

! Modified 6/21/93 to fudge old pump trip with scram function
  s knpmcp = -0.15
  s kptmcp = 6.91    ! To trip at approx same time as core

start

print t, jcpg, thclo, tvesl, tveso, twhlf, zqwhcl(23)
print t, plpcl, zipopr, nmcp, uacho
print t, wmcpo, wshlx, wmuso, wgac
print t, csrhcl(23), cfrhcl(23)
print t, zqwhcl(23), zqshcl(23), csrhcl(23)


end

PROCED R60C
 set hvdpm=.t.
! RELAP5 Benchmark - 60 CENT REACTIVITY STEP
 set hvdpm=.f.

 action 'clear'
 RELAP4

! set kbecor = 0.008   ! CSAR values, use new one : 0.0078
! set kgtcor = 0.5e-3  ! CSAR values, use new one : 1.3 ms
 set kartra(1) = 0., 0.6, 0.6
 set kartra(11) = 0., 0.001, 1.e10

prepar 'clear', t, fcnfx, jacho, jcpg, msrhcl, mcrhcl
prepar xicr, ricr, xocr, rocr
prepar pcoro, phclo, tcoro, thclo, thcuo
prepar tshclo, uhclo, phclo, zqshcl(23), csrhcl(23)
```

```
s tstop=0.5,cint=0.002
start

print t, fcnfx, jacho, jcpg, msrhcl, mcrhcl
print t, xicr, ricr, xocr, rocr
print t, pcoro, phclo, tcoro, thclo, thcuo
print tshclo, uhclo, phclo, zqshcl(23), csrhcl(23)

END

PROCED RTD
 set hvdpm=.t.
! RELAP5 Benchmark - CI 14inch DEG break 1.1 s (11/92)
 set hvdpm=.f.

 action 'clear'
 RELAP4

s kbdcil = kdecil    ! 14 inches ID
s kgbcil = .true.    ! DEG break (doubles flow)
s kticil = 1.1
prepar 'clear', t, plpcl, zipopr, wveso, wcilc, pdet
prepar qsfff, zqshcl(23), csrhcl(23), msrhcl, mcrhcl
prepar pveso, phiro, pmhlo, pgac, pmcpl, pmcpo


s tstop=1,cint=0.01
start

print t, plpcl, zipopr, wveso, wcilc, pdet
print t, qsfff, zqshcl(23), csrhcl(23), msrhcl, mcrhcl
print t, pveso, phiro, pmhlo, pgac, pmcpl, pmcpo


END

PROCED R2B
 set hvdpm=.t.
! RELAP5 10/91Benchmark. 2 inch, sharp edge, 250 ms CPBT break
 set hvdpm=.f.

 RELAP1

s knplsc = 1.e10                 ! Do not trip main pumps
s knslsc = 1.e10                 ! Do not trip secondary pumps
s kpflsc = 0.86           ! Scram @86% nominal press (1.41MPa)
s kpccol = 0.211e6        ! RELAPs pool pressure
s kbdcol = 0.0508         ! 2 inch
s kticol = 0.25           ! 250 ms time constant
s kwiccs = 30             ! letdown flow
s kgcgac = 1.4            ! Adiabatic accumulator
s kticon = 100.           ! To close letdown vlv in ~1.5 s

prepar 'clear', t
prepar wcolc, wvesl, whiro, widsl, wmuso, wgac
prepar jcpg, fcnfx, fdhfx
prepar qhuf, qchuf, qshuf, ztwhcu(5), zqwhcu(5)
prepar qhlf, qchlf, qshlf, ztwhcl(5), zqwhcl(5)
prepar zipipr, zipopr, pgac

action 'clear'
relapt
action 'var'=5., 'val'= 68., 'loc'=wmuso  !standby pump
```

```
s cint = 0.0002
start

print t, wcolc, wvesl, whiro, widsl, wmuso, wgac
print t, jcpg,  fcnfx, fdhfx
print t, qhuf, qchuf, qshuf, ztwhcu(5), zqwhcu(5)
print t, qhlf, qchlf, qshlf, ztwhcl(5), zqwhcl(5)
print t, zipipr, zipopr, pgac
END

PROCED SSPAR
! Parameters fudged to agree with Gradys SS code
! Set by hand the inlet/outlet pressure (KPCCCS=2.77E6)
 s kfvcor = 0.0315     ! Heat flux area accounts for unheated
 s kercor=-0.96        ! Filonenko friction -4%
END

proced CSARF
s hvdpm=.t.
! CSAR Full power initial conditions
! (includes measurement+operational uncert)
s hvdpm=.f.
!  restor 'csar'

 s kj0cor = 343.992e6  ! Set initial power at 104.24%
 s kwcccs = 2122.56    ! Set initial flow at 99%
 s kfscon = 1.0424     ! Control power at 104.24%
 s ktscon = 45.6       ! Control temperature at 101.41%
! Parameters to agree with s.s. code conservative assumptions
 s kpcccs = 2.77e6     ! To set P-inlet = 2.85
 s kpscon = 1.433e6    ! To set P_outlet = 1.61
 s kercor = -0.96      ! To fudge core dp = 1.25
 s kfvcor = 0.0315     ! To agree on IB limit 329MWth 95/95
end

proced CSARL
s hvdpm=.t.
! CSAR Low power initial conditions
! (includes measurement+operational uncert)
s hvdpm=.f.

!  restor 'csar'

 s kj0cor = 33.e3      ! Set initial power at 1.e-4
 s kwcccs = 2122.56    ! Set initial flow at 99%
 s ktscon = 45.6       ! Control temperature at 101.41%
 s kwsccs = 100.       ! Initial guess for secondary flow
 s kfscon = 1.0424     ! Control power at 104.24%
! Parameters to agree with s.s. code conservative assumptions
 s kpcccs = 2.77e6     ! To set P-inlet = 2.85
 s kpscon = 1.433e6    ! To set P_outlet = 1.61
 s kercor = -0.96      ! To fudge core dp = 1.25
 s kfvcor = 0.0315     ! To agree on IB limit 329MWth 95/95
end

proced Newrod
s hvdpm=.t.
! Rod worths set to 1 dolar per 50 mm, max -10 dol
s hvdpm=.f.
! Assume 50 mm to insert 1 dol conservative to account for 1-rod failure
! actual 3-rod number vary from 22.3 mm to 36.3 mm
! Assumed criticality at centerline, and linear worth around it
! Not the real total worth, only differential woth relevant
```

```
 s kwricr(1) =20.0,10.0, 0.0,-10.0, -10.0
 s kwricr(5) =-10.0, -10.0, -10.0, -10.0, -10.0
 s kwricr(10)=-10.0, -10.0, -10.0, -10.0, -10.0
 s kwricr(15)=-1.0,-0.5,-0.0, 0.5, 1.0
 s kwricr(20)= 2.0, 3.0, 4.0, 5.0, 6.0
 s kwricr(25)= 7.0, 8.0, 9.0, 10., 11.

 s kx0icr = 0.
end

PROCED h
set hvdpm=.true.
!The following procedures have been defined :
! PPSOFF - Plant protection system OFF
! RON       - Reactivity ramp ON.  Set KARTRA to alter
! ROFF  - Reactivity ramp OFF
! PONY  - Transition to pony motor flow
! NATCIR - Transition to natural circulation
! P2OFF  - Trip secondary pumps
! NOPRES - Eliminate pressure dynamics
! LOAHS  - Loss of all heat sinks.  Main+Emergency HXs disabled
! LONHS  - Loss of normal heat sink.  Main HX disabled
! LOTOW  - Loss of towers heat sink
! ISOLAT - Isolate containment.  Close all flows
! MHXOFF - Isolate main heat exchanger (HT area=0)
! EHXOFF - Isolate emergency heat exchanger (HT area=0)
! LOOP2  - One loop operation 2 HX
! Power Shapes:   I1BOC, I1EOC, I1, M1
! Uncertainties:  U95, UMULT, UPS2, UNO
set hvdpm=.f.
END

h
```

Appendix E

NOMINAL ADVANCED NEUTRON SOURCE OPERATING CONDITIONS PREDICTED BY THE ADVANCED NEUTRON SOURCE DYNAMIC MODEL

APPENDIX E. NOMINAL ANS OPERATING CONDITIONS PREDICTED BY ANSDM

```
==================================================
======================
 --------------------------- ANS DYNAMIC MODEL
---------------------------
 ---

 --- Current Simulation Time : 0.00000E+00 PAGE :
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==================================================
======================


==================================================
======================
 ---------- Powers (MW)

--------------------------------------------------
----------------------
 Nominal Fission          : 330.00        Total
Fission          : 330.00
 Active_Core (Fuel+Cool): 303.01
Active_Core_Fuel        : 303.01
 Reflector                : 15.325        Bypass
          : 11.661


==================================================
======================
 ---------- Mass Flow Rates (Kg/s)
```

```
--------------------------------------------------
----------------------
 Nominal_Total @Pump      : 2144.0
Actual_Total @Pump      : 2144.0
 Hot_Channel upper core : 1543.1        Active Core
          : 1790.2
 Main_HX Secondary        : 2800.0        Hot_Channel
lower core : 1547.4
 Letdown                  : 14.600        Makeup
          : 14.600
 Bypass                   : 353.76        Reflector
          : 200.00


==================================================
======================
 ---------- Pressures (MPa)

--------------------------------------------------
----------------------
 Core Inlet               : 3.1991        Core Outlet
          : 1.8103
 Pressurizer              : 1.5864
Letdown/Makup           : 1.6904
 Main_HX Primary Inlet    : 1.6904        Main_HX
Primary Outlet : 1.6702
 Pump Inlet               : 1.6513        Pump Outlet
          : 3.2931
 Main HX Secondary Inlet:0.26209
          :


==================================================
```

```
======================
 ---------- Coolant Temperatures (C)

--------------------------------------------------------
----------------------
 Core Inlet              : 44.443        Core Outlet
           : 85.645
 Hot_Chan Up Core Outlet: 120.84        Hot_Chan Lo
Core Outlet: 131.14
 Bypass Outlet           : 52.438        Reflector
Outlet       : 67.597
 Main_HX Primary Inlet  : 79.623        Main_HX
Primary Outlet : 43.959
 Main HX Scdry inlet    : 29.930        Main HX
Scdry outlet   : 56.900
 Pump Inlet              : 43.810        Pump Outlet
           : 44.484
 Pressurizer             : 39.687        Makeup Flow
Temp        :0.00000E+00
```

```
======================================================
======================
 ---------------------------- ANS DYNAMIC MODEL
---------------------------
 ---

 --- Current Simulation Time : 0.00000E+00 PAGE :
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======================================================
======================


======================================================
======================
 ---------- Fuel Temperatures (C)

------------------------------------------------------
----------------------
 Avg_Channel Avg_Temp    : 205.38       Avg_Channel
@Wall       : 121.58
 Hot_Chan Up Core Avg_T : 266.99       Hot_Chan Lo
Core Avg_T : 296.37


======================================================
======================
 ---------- Fuel Heat Fluxes (MW/m2)

------------------------------------------------------
----------------------
 Avg_Channel Actual     : 5.7096       Avg_Channel
Critical    : 33.257
```

```
 Hot_Chan Up Core Actual: 9.1369        Hot_Chan Up
Core Crit. : 28.004
 Hot_Chan Lo Core Actual: 10.425        Hot_Chan Lo
Core Crit. : 26.277


==================================================
======================
 ---------- Critical Heat Flux Ratios

--------------------------------------------------
----------------------
 Min CFR Upper Core     :0.10000E+11    Min CFR
Lower Core     :0.10000E+11
 Location CFR Upper Core:0.10000E+11    Location
CFR Lower Core:0.10000E+11
 Min CSR Upper Core     :0.10000E+11    Min CSR
Lower Core     :0.10000E+11
 Min IBLR Upper Core    :0.55555E+34    Min IBLR
Lower Core     :0.55555E+34


==================================================
======================
 ---------- Vessel Inlet (Cold Leg) Coolant

--------------------------------------------------
----------------------
 Saturation_Temp (C)     : 235.88        Density
(Kg/m3)          : 1098.5
 Prandtl Number          : 4.9956        Reynolds
Number        :0.63264E+07
 Velocity (m/s)          : 21.021        Friction
Coefficient   :0.14280E-01

==================================================
======================
 ---------- Avg_Ch Outlet Coolant Properties

--------------------------------------------------
----------------------
 Saturation_Temp (C)     : 204.63        Density
(Kg/m3)          : 1074.1
 Prandtl Number          : 2.6009        Reynolds
Number        :0.17278E+06
 Velocity (m/s)          : 25.015        Friction
Coefficient   :0.17397E-01


==================================================
======================
 ---------- Hot_Ch Upper Core Outlet Coolant Prop

--------------------------------------------------
----------------------
 Saturation_Temp (C)     : 204.61        Density
(Kg/m3)          : 1045.9
 Prandtl Number          : 1.7970        Reynolds
Number        :0.21415E+06
 Velocity (m/s)          : 24.603        Friction
Coefficient   :0.16672E-01
```

```
****************************************************
**********************
 --------------------------- ANS DYNAMIC MODEL
---------------------------
 ---

 --- Current Simulation Time : 0.00000E+00 PAGE :
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****************************************************
**********************


****************************************************
**********************
 ---------- Hot_Ch Lower Outlet Coolant Prop

----------------------------------------------------
----------------------
 Saturation_Temp (C)      : 204.61        Density
(Kg/m3)          : 1036.4
 Prandtl Number           : 1.6483        Reynolds
Number         :0.23505E+06
 Velocity (m/s)           : 24.897        Friction
Coefficient    :0.16372E-01


****************************************************
**********************
 ---------- Bypass Outlet Coolant Properties

----------------------------------------------------
----------------------
 Saturation_Temp (C)      : 236.39        Density
(Kg/m3)          : 1094.5
 Prandtl Number           : 4.2820        Reynolds
Number         :0.14760E+07
 Velocity (m/s)           : 8.9238        Friction
Coefficient    :0.11788E-01


****************************************************
**********************
 ---------- Vessel Outlet (Hot Leg) Coolant

----------------------------------------------------
----------------------
 Saturation_Temp (C)      : 208.28        Density
(Kg/m3)          : 1077.9
 Prandtl Number           : 2.7904        Reynolds
Number         :0.11541E+08
 Velocity (m/s)           : 8.0660        Friction
Coefficient    :0.82541E-02


****************************************************
**********************
 ---------- Main Heat Exchanger Primary Side Outlet

----------------------------------------------------
----------------------
 Saturation_Temp (C)      : 203.55        Density
(Kg/m3)          : 1098.7
 Prandtl Number           : 5.0455        Reynolds
Number         : 18767.
 Velocity (m/s)           :0.78054        Friction
Coefficient    :0.31526E-01
```

```
*********************************************************************
**********************
 ---------- Main Heat Exchanger Secondary Side
Outlet

---------------------------------------------------------------------
----------------------
 Saturation_Temp (C)     : 176.81        Density
(Kg/m3)         : 1092.1
 Prandtl Number          : 3.9569        Reynolds
Number         : 55312.
 Velocity (m/s)          : 2.3308        Friction
Coefficient    :0.29564E-01
```

```
*********************************************************************
**********************
 ---------------------------- ANS DYNAMIC MODEL
---------------------------
 ---

 --- Current Simulation Time : 0.00000E+00 PAGE :
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*********************************************************************
**********************


*********************************************************************
**********************
 ---------- Core Properties

---------------------------------------------------------------------
----------------------
 Active Fuel Volume (m3):0.33700E-01     Act Coolant
Volume (m3):0.33700E-01
 Active Fuel Height (m) :0.52700         Fuel
Thickness (m)      :0.12700E-02
 Fuel Density (Kg/m3)   : 3870.0         Heat
Capacity (J/Kg/K) :0.52700
 Ef Ht Trf Coef (W/K/m2):0.00000E+00     Core Flow
Area (m2)      :0.66630E-01
 Ch. Equiv. Diameter (m):0.25400E-02     Hot_Ch Eq.
Diameter (m):0.00000E+00
 Loc Press Loss (v_head): 1.0000         Channel
Flow Length (m):0.52700
 Bypass Volume (m3)     :0.33700E-01     Bypass Flow
Area (m2)   :0.36220E-01
```

```
==================================================
======================
 ---------- Core Neutronics

--------------------------------------------------
----------------------
 Core react coeff $/dr/r: 7.4000        Bypass reac
coef $/dr/r: 9.1000
 Fuel Doppler coef ($/K):-.12500E-02    Reflec reac
coef $/dr/r: 29.000
 Eff Beta (delayed neut):0.77400E-02    Eff
Generation Time (s):0.50000E-03

 --- Delayed Neutron Fractions
 0.42748E-03 0.14662E-02 0.13113E-02 0.33248E-02
0.77441E-03 0.27879E-03

 --- Delayed Neutron Time Constants (s-1)
 0.14300E-01 0.30500E-01 0.11100     0.29600
1.1300      3.0000


==================================================
======================
 ---------- Decay Heat Model

--------------------------------------------------
----------------------
 Fraction in Bypass (%) : 26.360        Fraction in
Reflector %: 8.6400


 Time (s) = 0.10000E-09 Decay Heat (%) =  5.7544
 Time (s) =  1.0000     Decay Heat (%) =  5.7544
 Time (s) =  10.000     Decay Heat (%) =  4.7863
 Time (s) =  100.00     Decay Heat (%) =  3.2359
 Time (s) =  1000.0     Decay Heat (%) =  1.7783
 Time (s) =  10000.     Decay Heat (%) = 0.87096
 Time (s) = 0.10000E+06 Decay Heat (%) = 0.30200
 Time (s) = 0.10000E+07 Decay Heat (%) = 0.10233
```

```
==================================================
======================
 --------------------------- ANS DYNAMIC MODEL
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 ---

 --- Current Simulation Time : 0.00000E+00 PAGE :
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==================================================
======================
 ---------- Hot Leg Riser

--------------------------------------------------
---------------------
 Volume (m3)              : 3.7582        Flow Area
(m2)          :0.24660
 Height (m)               : 12.500        Flow Length
(m)         : 15.240
 Equiv. Diameter (m)      :0.56040        Loc Press
Loss (v_head): 1.0000


==================================================
======================
 ---------- Hot Leg (Horizontal Run)

--------------------------------------------------
---------------------
 Volume (m3)              : 3.7631        Flow Area
(m2)          :0.24660
 Height (m)               :0.00000E+00    Flow Length
(m)         : 15.260
 Equiv. Diameter (m)      :0.56040        Loc Press
Loss (v_head): 1.0000


==================================================
======================
 ---------- Main Heat Exchanger Primary Side

--------------------------------------------------
---------------------
 Volume (m3)              : 29.100        Flow Area
(m2)          : 2.5000
 Height (m)               :0.00000E+00    Flow Length
(m)         : 40.000
 Equiv. Diameter (m)      :0.16000E-01    Loc Press
Loss (v_head): 1.0000
 Eff. H.T. coeff (W/K)    :0.17412E+08    Film H.T.
coeff(W/m2/K): 6792.9


==================================================
======================
 ---------- Main Heat Exchanger Secondary Side

--------------------------------------------------
---------------------
 Volume (m3)              : 29.100        Flow Area
(m2)          : 1.1000
 Height (m)               :0.00000E+00    Flow Length
(m)         : 12.200
 Equiv. Diameter (m)      :0.12700E-01    Loc Press
```

```
Loss (v_head): 1.0000
 Total foul. res (m2K/W):0.26000E-03    Film H.T.
coeff(W/m2/K): 10493.


==================================================
======================
 ---------- Cold Leg (Horizontal Run)

--------------------------------------------------
----------------------
 Volume (m3)                : 4.7086        Flow Area
(m2)          :0.24966
 Height (m)                 :0.00000E+00    Flow Length
(m)         : 18.860
 Equiv. Diameter (m)        :0.32550        Loc Press
Loss (v_head): 1.0000


==================================================
======================
 ---------- Cold Leg Riser

--------------------------------------------------
----------------------
 Volume (m3)                : 2.5116        Flow Area
(m2)          :0.24966
 Height (m)                 :-13.570        Flow Length
(m)         : 10.060
 Equiv. Diameter (m)        :0.32550        Loc Press
Loss (v_head): 1.0000

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 --------------------------- ANS DYNAMIC MODEL
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 --- Current Simulation Time : 0.00000E+00 PAGE :
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======================
 ---------- Pools

--------------------------------------------------
----------------------
 RX Pool volume (m3)     : 500.00        Heat load
(MW)         :0.12345E+07
 Pipe Chase Pool Vol(m3): 300.00        Heat load
(MW)         :0.16143E+07
 HX Pool volume (m3)     : 1200.0        Heat load
(MW)         :0.21258E+07


==================================================
======================
 ---------- Main Circulation Pumps

--------------------------------------------------
```

```
 Flow (Kg/s)              : 2144.0        Power (MW)
         :0.00000E+00
 Head (MPa)               : 1.6418        Coastdown
Tim Const (s): 2.0000

 --- Normalized Pump Head vs Flow     ---
Normalized Pump Power vs Head
 Flow = 0.00000E+00 Head = 1.1200     Head =
-1.0000      Power = 1.1200
 Flow = 0.20000     Head = 1.1500     Head =
0.00000E+00 Power = 1.1200
 Flow = 0.40000     Head = 1.1600     Head =
0.84000      Power = 1.0400
 Flow = 0.60000     Head = 1.1400     Head =
1.0000      Power = 1.0000
 Flow = 0.80000     Head = 1.0900     Head =
1.1000      Power =0.96000
 Flow =  1.0000     Head = 1.0000     Head =
1.1800      Power =0.93000
 Flow =  1.2000     Head =0.89000     Head =
1.2300      Power =0.87000
 Flow =  1.4000     Head =0.74000     Head =
1.2600      Power =0.80000
 Flow =  1.6000     Head =0.59000     Head =
1.2800      Power =0.72000
 Flow =  1.8000     Head =0.44000     Head =
1.3000      Power =0.00000E+00
 Flow =  2.4000     Head =0.00000E+00 Head =
2.0000      Power =0.00000E+00
```

```
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======================
 ---------------------------- ANS DYNAMIC MODEL
---------------------------
 ---

 --- Current Simulation Time : 0.00000E+00 PAGE :
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======================
 ---------- Reflector Region

--------------------------------------------------
---------------------
 Volume (m3)            : 15.000        Flow Area
(m2)         : 1.0000
 Height (m)             :0.00000E+00    Flow Length
(m)        :0.00000E+00
 Equiv. Diameter (m)    :0.15000        Loc Press
Loss (v_head):0.00000E+00


==================================================
======================
 ---------- Gas Accumulator

--------------------------------------------------
 Total Volume (m3)        : 21.000        Gas Volume
Fraction     :0.74000E-01
 Level (m)                : 4.6300        Mass Flow
Rate (Kg/s)  :0.00000E+00
 Outlet Pipe Length (m) : 5.0000         Otlt Pipe
Flow Area(m2):0.24966
 Equiv. Diameter (m)     :0.32550        Loc Press
Loss (v_head): 1.0000
 Effective L/A            : 10.000
         :


==================================================
======================
 ---------- Leak Effective Diameters (m)

--------------------------------------------------
---------------------
 @Core Inlet             :0.00000E+00    @Core
Outlet           :0.00000E+00
```

```
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 --------------------------- ANS DYNAMIC MODEL
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 ---

 --- Current Simulation Time : 0.00000E+00 PAGE :
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======================
 ---------- Friction Pressure Drops (MPa)

--------------------------------------------------
----------------------
 Across Active Core     : 1.2130        Across Main
HX          :0.26379E-01
 Across Main Pump       : 1.6418        Across
Emergency HX     :0.18623E-01



==================================================
======================
 ---------- Inner Control Rod Scram System

--------------------------------------------------
----------------------
 Flux/Flow Setpoint (%) : 115.00        Flux rate
Setpoint      :0.20000
 Flow Setpoint (%)    : 8.0000          Pressure
Setpoint (MPa): 1.3584
 Inlet Temp Setpoint (C): 55.000        Scram Delay
Time (s)    :0.30000E-01
 Init C_Rod Position (m):-.15000        Max. C_Rod
Insertion(m):0.60000

 --- Control Rod Acceleration vs Position (z = 0
==> Top of Active Core)
 z = 0.00 m,    accel = 58.860    m/s
 z = 0.15 m,    accel = 9.8100    m/s
 z = 1.00 m,    accel = 9.8100    m/s

 --- Control Rod Worth vs Position (z = 0  ==> Top
of Active Core)
 z = 0.00 m,    worth = 9.1900    $
 z = 0.10 m,    worth = 9.1900    $
 z = 0.20 m,    worth = 7.7300    $
 z = 0.30 m,    worth = 6.6100    $
 z = 0.40 m,    worth = 3.6600    $
 z = 0.60 m,    worth = 2.1400    $
 z = 1.00 m,    worth =-.18000    $
 z = 0.00 m,    worth =-1.5000    $
 z = 0.00 m,    worth =-4.9500    $
 z =-0.25 m,    worth =-8.1500    $
 z =-2.02 m,    worth =-11.580    $
 z =-3.11 m,    worth =-14.030    $
 z =-4.00 m,    worth =-15.210    $
 z =-4.60 m,    worth =-15.210    $
 z =-6.58 m,    worth =-1.0000    $
 z =-8.53 m,    worth =-.60000    $
 z =-8.53 m,    worth =-.50000    $
 z =-1.00 m,    worth =-.40000    $
 z =-0.80 m,    worth =-.30000    $
 z =-0.60 m,    worth =-.20000    $
 z =-0.50 m,    worth =-.10000    $
```

```
***************************************************
**********************
 ---------- Detector Time delays (s)

---------------------------------------------------
----------------------
 Neutron flux           :0.25000E-01    Pressure
         :0.30000E-01
 Temperature            : 2.0000        Flow
         :0.25000
```

Appendix F

LIST OF ALL ADVANCED NEUTRON SOURCE DYNAMIC MODEL VARIABLES AND THEIR NOMINAL VALUES

APPENDIX F. LIST OF ALL ANSDM MODEL VARIABLES AND THEIR NOMINAL VALUES

State Variables	Derivatives
Initial Conditions	
DNDET 0.	DDNDET 0.
ZDNDET 0.	
ECPG 0.	JCPG 3.3000E+08
ZIECPG 0.	
FCNFX 1.00000000	DNCNT-2.7057E-07
ZINCNT 1.00000000	
FDET 1.00000000	DFDET 0.
ZIFDET 1.00000000	
HACHO 357191.000	ZDDACC 150.256000
ZIHACC 357191.000	
HBYPO 220896.000	ZDDBYP 14.2309000
ZIHBYP 220896.000	
HCLRI 187863.000	ZDDMCL-0.40749600
ZIHMCL 187863.000	
HCLRO 187783.000	ZDDCLR-0.50672300
ZIHCLR 187783.000	
HCORO 357191.000	ZDDOPR 0.
ZIHOPR 357191.000	
HCTBO 127200.000	ZDDCTB-1.2745E-06
ZIHCTB 127200.000	
HEHXO 185213.000	ZDDEPP 23.7187000
ZIHEPP 185213.000	
HESHL 155891.000	ZDDESP 0.00466240
ZIHESP 155891.000	
HHCLO 545474.000	ZDDHLC 2699.44000
ZIHHLC 545474.000	
HHCUO 502162.000	ZDDHUC 238.107000
ZIHHUC 502162.000	
HHLRO 334207.000	ZDDHLR-0.46265300
ZIHHLR 334207.000	
HHXPO 148200.000	ZDDHXP-0.71966300
ZIHHXP 148200.000	

HIPCI 187933.000	ZDDIPR-608.837000
ZIHIPR 187933.000	
HLHLO 333542.000	ZDDLHL-0.43457300
ZIHLHL 333542.000	
HMCPI 185153.000	ZDDPCL-0.00150202
ZIHPCL 185153.000	
HMHLO 333929.000	ZDDMHL-0.25996300
ZIHMHL 333929.000	
HMHXO 185769.000	ZDDMHP 25.1418000
ZIHMHP 185769.000	
HMRPO 148200.000	ZDDMRP 0.00579261
ZIHMRP 148200.000	
HPCHO 148200.000	ZDDPCH 0.01194720
ZIHPCH 148200.000	
HREFO 283287.000	ZDDREF-1.5506E-05
ZIHREF 283287.000	
HSHLX 239306.000	ZDDSHP 61.9591000
ZIHSHP 239306.000	
HTCLO 127200.000	ZDDTCL 0.
ZIHTCL 127200.000	
HTHLO 239306.000	ZDDTHL 0.
ZIHTHL 239306.000	
HVESI 187783.000	ZDDIFD 0.
ZIHIFD 187783.000	
IPOI 1.00000000	ZDIPOI-1.1830E-12
ZIIPOI 1.00000000	
MMCS 0.	ZDMMCS 0.06835940
ZIMMCS 0.	
PCIL 3.4001E+06	ZDPCIL 0.
ZIPCIL 3.4001E+06	
PCOL 1.8414E+06	ZDPCOL 0.
ZIPCOL 1.8414E+06	
PDET 1.6980E+06	DPDET 8125.00000
ZIPDET 1.6980E+06	
PPOI 1.00000000	ZDPPOI 8.2641E-15

```
ZIPPOI 1.00000000
      SPOI 1.00000000     ZDSPOI 3.1914E-13
ZISPOI 1.00000000
      TACF 205.381000     ZDTACF 0.10249800
ZITACF 205.381000
     TCDET 44.4839000     DTCDET-3.2425E-05
ZTCDET 44.4839000
     THDET 80.0271000     DTHDET 0.
ZTHDET 80.0271000
      THLF 296.366000     ZDTHLF-0.76695700
ZITHLF 296.366000
      THUF 266.990000     ZDTHUF 0.17215000
ZITHUF 266.990000
      VICR 0.             ZDVICR 0.
ZIVICR 0.
     VLGAC 19.4460000     ZDVGAC 0.
ZIVGAC 19.4460000
      VOCR 0.             ZDVOCR 0.
ZIVOCR 0.
      WDET 2144.00000      DWDET-0.27441400
ZIWDET 2144.00000
      WGAC 0.              DWGAC 0.
ZIWGAC 0.
     WMCPI 2144.00000     DWMCPI 0.
ZIWMCP 2144.00000
     WTHLO 2800.00000     ZDWSCC-0.01437500
ZIWSCC 2800.00000
      XICR-0.15000000     ZDXICR 0.
ZIXICR-0.15000000
      XOCR-0.80000000     ZDXOCR 0.
ZIXOCR-0.80000000
      XPOI 1.00000000     ZDXPOI 2.4224E-11
ZIXPOI 1.00000000
    Z99840 104.000000     Z99839-0.24569400
ZWECCS 104.000000
    Z99873 1.00000000     Z99872-8.6018E-04
ZINCON 1.00000000
```

```
    ZDPMCP 1.00000000     ZDDMCP-0.15059900
Z99838 1.00000000
    ZFFGAC 0.             ZDFGAC 0.
Z99842 0.
    ZFFMUS 0.             ZDFMUS 6.8100E-05
Z99841 0.
     ZNMCP 1.00000000     ZDNMCP 0.
ZINMCP 1.00000000
 ZPCCNT(1) 59.7868000  ZDCCNT(1)-2.4470E-08
ZICCNT(1) 59.7868000
 ZPCCNT(2) 96.1457000  ZDCCNT(2) 3.9262E-09
ZICCNT(2) 96.1457000
 ZPCCNT(3) 23.6277000  ZDCCNT(3) 9.6127E-08
ZICCNT(3) 23.6277000
 ZPCCNT(4) 22.4650000  ZDCCNT(4) 8.6625E-08
ZICCNT(4) 22.4650000
 ZPCCNT(5) 1.37064000  ZDCCNT(5)-9.7346E-09
ZICCNT(5) 1.37064000
 ZPCCNT(6) 0.18585900  ZDCCNT(6) 1.6823E-08
ZICCNT(6) 0.18585900
 ZPCCNT(7) 2853.59000  ZDCCNT(7)-7.4055E-09
ZICCNT(7) 2853.59000
    ZPIGAC 0.             ZDPGAC-0.15578700
Z99843 0.
    ZWLCIL 0.             DWCILC 0.
Z99827 0.
    ZWLCOL 0.             DWCOLC 0.
Z99844 0.
    ZXLCON 0.             ZDXCON-0.01537870
ZIXCON 0.

  Algebraic Variables

 Common Block /ZZCOMU
     ABORT    F            CFRACF 5.82486000
CFRACH(50) 5.5555E+33
CFRHCL(50) 5.5555E+33 CFRHCU(50) 5.5555E+33
```

```
CFRHLF 2.52038000
    CFRHUF 3.03794000     CIRACF 3.74292000
CIRACH(50) 5.5555E+33
CIRHCL(50) 5.5555E+33 CIRHCU(50) 5.5555E+33
CIRHLF 1.48056000
    CIRHUF 1.82997000     CKACHO 0.63335200
CKBYPO 0.61842000
    CKCLRI 0.61279700     CKCLRO 0.61278300
CKCORO 0.63335200
    CKCTBO 0.60042600     CKEHXO 0.61231200
CKESCL 0.60500800
    CKESHL 0.60660700      CKGAC 0.60903800
CKHCLO 0.63328400
    CKHCUO 0.63524500     CKHLRI 0.63179500
CKHLRO 0.63175700
    CKHXPO 0.60500800     CKIFDI 0.61278300
CKIPCI 0.61281000
    CKLHLO 0.63170500     CKMCPI 0.61230100
CKMCPO 0.61281300
    CKMHLL 0.63170500     CKMHLO 0.63173500
CKMHXI 0.63170500
    CKMHXO 0.61241500     CKMRPO 0.60500800
CKPCHO 0.60500800
    CKREFO 0.62689800     CKSCLX 0.60042600
CKSHLX 0.62121300
    CKTCLO 0.60042600     CKTHLO 0.62121300
CKVESI 0.61278300
    CKVESO 0.63179500     CPACHO 4170.62000
CPBYPO 4212.49000
    CPCLRI 4225.18000     CPCLRO 4225.21000
CPCORO 4170.62000
    CPCTBO 4249.96000     CPEHXO 4226.23000
CPESCL 4241.22000
    CPESHL 4238.06000      CPGAC 4233.12000
CPHCLO 4159.44000
    CPHCUO 4155.70000     CPHLRI 4176.04000
CPHLRO 4176.17000
    CPHXPO 4241.22000     CPIFDI 4225.21000
CPIPCI 4225.16000
    CPLHLO 4176.34000     CPMCPI 4226.25000
CPMCPO 4225.15000
    CPMHLL 4176.34000     CPMHLO 4176.24000
CPMHXI 4176.34000
    CPMHXO 4226.01000     CPMRPO 4241.22000
CPPCHO 4241.22000
    CPREFO 4190.84000     CPSCLX 4249.96000
CPSHLX 4205.75000
    CPTCLO 4249.96000     CPTHLO 4205.75000
CPVESI 4225.21000
    CPVESO 4176.04000     CSRACF 5.82486000
CSRACH(50) 5.5555E+33
CSRHCL(50) 5.5555E+33 CSRHCU(50) 5.5555E+33
CSRHLF 2.52038000
    CSRHUF 3.03794000     DCFCON      14
DCPCON      15
    DCTCON      16        DHTCDH      12
DWACHI 0.
    DWACHO 0.             DWBYPI 0.
DWBYPO 0.
    DWCLRI 0.             DWCLRO 0.
DWCORO 0.
    DWCTBI 0.             DWCTBO 0.
DWEHXO 0.
    DWESCL 0.             DWESHL 0.
DWHCLI 0.
    DWHCLO 0.             DWHCUI 0.
DWHCUO 0.
    DWHLRI 0.             DWHLRO 0.
DWHXPI 0.
    DWHXPO 0.             DWIFDI 0.
DWIPCI 0.
    DWLHLO 0.             DWMCLI 0.
DWMCPO 0.
    DWMHLA 0.             DWMHLL 0.
```

```
DWMHLO 0.
    DWMHXI 0.            DWMHXO 0.
DWMRPI 0.
    DWMRPO 0.            DWMUSO 0.
DWPCHI 0.
    DWPCHO 0.            DWREFI 0.
DWREFO 0.
    DWSCLX 0.            DWSHLX 0.
DWTCLI 0.
    DWTCLO 0.            DWTHLO 0.
DWVESI 0.
    DWVESO 0.            ERROR    F
ESCICR     10
    ESCOCR     11        FACHO 0.01739690
FBYPO 0.01178800
    FCLRI 0.01314660     FCLRO 0.01314680
FCON 1.00000000
    FCORO 0.01003460     FCTBO 0.00983458
FDHFX 0.05754400
    FEHXO 0.02117430     FESCL 0.17391900
FESHL 0.03622640
    FGAC 941280.000      FHCLO 0.01637210
FHCUO 0.01667240
    FHLRI 0.01171540     FHLRO 0.01171570
FHXPO 0.02986810
    FIFDI 0.01314680     FIPCI 0.01089630
FLHLO 0.01300280
    FMCPI 0.01315080     FMCPO 0.01314650
FMHLL 0.01300430
    FMHLO 0.01171580     FMHXI 0.01300280
FMHXO 0.03152640
    FMRPO 0.03454270     FPCHO 0.03211220
FREFO 0.02122350
    FSCISC      2        FSCLX 0.01281110
FSHLX 0.02956350
    FTCLO 0.01228130     FTHLO 0.01180590
FVESI 0.01428000
    FVESO 0.00825411     HACF 159027.000
HACHI 187933.000
    HBYPI 187933.000     HCILC 187783.000
HCOLC 334703.000
    HCTBI 239306.000     HESCL 148200.000
HFFF 175180.000
    HGAC 168000.000      HHCLI 187933.000
HHCUI 187933.000
    HHLF 178292.000      HHLRI 334703.000
HHUF 173687.000
    HHXPI 127200.000     HIFDI 187783.000
HLDSI 333542.000
    HMCLI 187951.000     HMCPO 187951.000
HMHLA 333542.000
    HMHLL 333542.000     HMHXI 333542.000
HMRPI 127200.000
    HMUPI 188065.000     HMUSO 188065.000
HPCHI 127200.000
    HREFI 206661.000     HSCLX 127200.000
HTCLI 127200.000
    HVESO 334703.000     HWACHO 160305.000
HWBYPO 37763.6000
    HWCLRI 32469.1000    HWCLRO 32462.8000
HWCORO 60310.8000
    HWCTBO 76.9571000    HWEHXO 9714.27000
HWESCL 5.77484000
    HWESHL 674.460000    HWGAC 8.16541000
HWHCLO 180987.000
    HWHCUO 175784.000    HWHLRI 40872.1000
HWHLRO 40843.6000
    HWHXPO 55.5940000    HWIFDI 32462.8000
HWIPCI 49886.3000
    HWLHLO 42465.8000    HWMCPI 32257.0000
HWMCPO 32477.0000
    HWMHLL 42179.0000    HWMHLO 40827.6000
HWMHXI 42465.8000
    HWMHXO 5234.57000    HWMRPO 36.1514000
```

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HWPCHO 44.5846000
    HWREFO 1194.22000     HWSCLX 13376.8000
HWSHLX 16484.4000
    HWTCLO 6233.71000     HWTHLO 8153.35000
HWVESI 90958.5000
    HWVESO 34308.2000         I       8
IACH       2
    IDVANS       1         IHCL      24
IHCU      24
    ISCISC       7         JACF 3.0301E+08
JACH 3.0301E+08
     JACHO 3.0301E+08      JBYP 1.1661E+07
JBYPO 1.1661E+07
     JCLRI 0.             JCLRO 0.
JCORO 0.
     JCTBO-3.1387E+08     JEHXO-799926.000
JESHL 799926.000
      JHCL 5.5324E+08     JHCLO 5.5330E+08
JHCU 4.8490E+08
     JHCUO 4.8489E+08      JHLF 5.5324E+08
JHLRO 0.
      JHUF 4.8490E+08     JHXPO 1.1746E+06
JIFDI 0.
     JIPCI 0.             JLHLO 0.
JMCP 6.0000E+06
     JMCPI 0.             JMHLO 0.
JMHXO-3.1584E+08
     JMRPO 1.2377E+06     JPCHO 1.6182E+06
JPOI 3.1101E+08
     JREFC 1.5325E+07     JREFO 1.5325E+07
JSHLX 3.1584E+08
     JTCLO 0.            JTHDET 3.1357E+08
JTHLO 0.
     JVESI 0.             JWACC 0.
JWBYP 0.
     JWCLR-172745.000     JWCTB 0.
JWEPP-79515.3000
         JWESP 0.                JWHLC 0.
JWHLR-1.0650E+06
         JWHUC 0.                JWHXP 0.
JWIFD 0.
         JWIPR 0.                JWLHL-830245.000
JWMCL-190740.000
         JWMHL-597261.000        JWMHP-164595.000
JWMRP 0.
         JWOPR 0.                JWPCH 0.
JWPCL-130555.000
         JWREF 0.                JWSHP 0.
JWTCL 0.
         JWTHL 0.                KAACHI 0.14800000
KAACHO 0.06663000
        KABYPI 0.14800000        KABYPO 0.03622000
KACLRI 0.24966000
        KACLRO 0.24966000        KACORO 0.13326000
KACTBI 1.38000000
        KACTBO 100.000000        KAEEHX 500.000000
KAEHXO 1.06000000
        KAEMHX 8750.00000        KAESCL 100.000000
KAESHL 1.00000000
         KAGAC 0.24966000        KAHCLI 0.14800000
KAHCLO 0.05996700
        KAHCUI 0.14800000        KAHCUO 0.05996700
KAHLRI 0.24660000
        KAHLRO 0.24660000        KAHXPI 10.0000000
KAHXPO 10.0000000
        KAIFDI 0.24966000        KAIPCI 0.14800000
KALHLO 0.24966000
        KAMCLA 0.24966000        KAMCLI 0.24966000
KAMCPI 0.24966000
        KAMCPO 0.24966000        KAMHLL 0.24966000
KAMHLO 0.24660000
        KAMHXI 0.24966000        KAMHXO 2.50000000
KAMRPI 10.0000000
        KAMRPO 10.0000000        KAPCHI 10.0000000
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KAPCHO 10.0000000
     KAREFI 1.00000000      KAREFO 1.00000000
KARTRA(20) 1.0000E+10
     Z99997 0.                     0.
 0.
            0.                     0.
 0.
            0.                     0.
 0.
            0.              Z99998 0.
 1.0000E+10
            1.0000E+10             1.0000E+10
 1.0000E+10
            1.0000E+10             1.0000E+10
 1.0000E+10
            1.0000E+10             1.0000E+10
KASCLX 0.65670000
     KASHLX 1.10000000      KASICR 58.8600000
 9.81000000
            9.81000000             0.
 0.15000000
            1.00000000      Z99991 58.8600000
 9.81000000
            9.81000000      Z99992 0.
 0.15000000
            1.00000000      KASOCR 58.8600000
 9.81000000
            9.81000000             0.
 1.00000000
            10.0000000      Z99987 58.8600000
 9.81000000
            9.81000000      Z99988 0.
 1.00000000
            10.0000000      KATCLI 100.000000
KATCLO 1.38000000
     KATHLO 1.38000000      KAVESI 0.09285000
KAVESO 0.24660000
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     KBCCOR 4.2748E-04             0.00146622
 0.00131134
            0.00332481             7.7441E-04
 2.7879E-04
            1.5695E-04      KBCCNT 4.2748E-04
 0.00146622
            0.00131134             0.00332481
 7.7441E-04
            2.7879E-04             1.5695E-04
KBDCIL 0.
     KBDCOL 0.              KBECOR 0.00774000
KBECNT 0.00774000
     KBEPOI 0.00800000      KBFCOR 0.02140000
KBFCPG 0.02140000
     KBWCOR 0.16500000      KCACHI 0.16000000
KCACHO 1.00000000
     KCBYPI 0.16000000      KCBYPO 1.00000000
KCCANS 0.00100000
     KCCLRI 1.00000000      KCCLRO 1.00000000
KCCORO 1.00000000
     KCCTBI 1.00000000      KCCTBO 0.
KCEHXO 1.00000000
     KCESCL 1.00000000      KCESHL 1.00000000
KCFACC 0.
     KCFACF 0.              KCFBYP 0.
KCFCLR 0.
     KCFCOR 0.              KCFHCL 0.
KCFHCU 0.
     KCFACH 0.              KCFCTB 0.
KCFEPP 0.
     KCFESP 0.              KCFHLC 0.
KCFHLF 0.
     KCFHLR 0.              KCFHUC 0.
KCFHUF 0.
     KCFHXP 0.              KCFIFD 0.
KCFIPR 0.
     KCFLHL 0.              KCFMCL 0.
```

```
KCFMHL 0.
    KCFMHP 0.            KCFMRP 0.
KCFOPR 0.
    KCFPCH 0.            KCFPCL 0.
KCFREF 0.
    KCFSHP 0.            KCFTCL 0.
KCFTHL 0.
    KCHCLI 0.16000000    KCHCLO 1.00000000
KCHCUI 0.16000000
    KCHCUO 1.00000000    KCHEHX 1.0000E-04
KCHLRI 1.00000000
    KCHLRO 1.00000000    KCHMHX 1.0000E-04
KCHXPI 0.
    KCHXPO 0.            KCIFDI 0.30000000
KCIPCI 0.16000000
    KCLHLO 1.00000000    KCMCLI 1.00000000
KCMCPI 1.00000000
    KCMCPO 1.00000000    KCMHLO 1.00000000
KCMHXI 1.00000000
    KCMHXO 1.00000000    KCMRPI 0.
KCMRPO 0.
    KCPACF 620.000000    KCPCHI 0.
KCPCHO 0.
    KCPCOR 620.000000    KCPHCL 620.000000
KCPHCU 620.000000
    KCPACH 620.000000    KCPHLF 620.000000
KCPHUF 620.000000
    KCREFI 0.            KCREFO 0.
KCSCLX 1.00000000
    KCSHLX 1.00000000    KCTACC 0.01000000
KCTACF 1.00000000
    KCTBYP 0.01000000    KCTCLI 0.
KCTCLO 1.00000000
    KCTCLR 0.01000000    KCTCTB 0.01000000
KCTEPP 0.01000000
    KCTESP 0.01000000    KCTHLC 0.01000000
KCTHLF 1.00000000
    KCTHLO 1.00000000    KCTHLR 0.01000000
KCTHUC 0.01000000
    KCTHUF 1.00000000    KCTHXP 0.01000000
KCTIFD 0.01000000
    KCTIPR 0.01000000    KCTLHL 0.01000000
KCTMCL 0.01000000
    KCTMHL 0.01000000    KCTMHP 0.01000000
KCTMRP 0.01000000
    KCTOPR 0.01000000    KCTPCH 0.01000000
KCTPCL 0.01000000
    KCTREF 0.01000000    KCTSHP 0.01000000
KCTTCL 0.01000000
    KCTTHL 0.01000000    KCVACC 0.03370000
KCVCLR 2.51158000
    KCVCOR 0.03370000    KCVHCL 0.03370000
KCVHCU 0.03370000
    KCVBYP 0.03370000    KCVACH 0.03370000
KCVCTB 4500.00000
    KCVEPP 12.0000000    KCVESI 0.23000000
KCVESO 1.00000000
    KCVESP 12.0000000    KCVHLC 0.03370000
KCVHLR 3.75818000
    KCVHUC 0.03370000    KCVHXP 1200.00000
KCVIFD 0.37140000
    KCVIPR 0.48000000    KCVLHL 3.04336000
KCVMCL 4.70859000
    KCVMHL 3.76312000    KCVMHP 29.1000000
KCVMRP 500.000000
    KCVOPR 0.48000000    KCVPCH 300.000000
KCVPCL 3.46029000
    KCVREF 15.0000000    KCVSHP 29.1000000
KCVTCL 24.0000000
    KCVTHL 24.0000000    KDACHO 0.00254000
KDBCOR 0.26360000
    KDBCPG 0.26360000    KDBYPO 0.09500000
KDCCC 0.00228600
    KDCLRI 0.32550000    KDCLRO 0.32550000
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```
KDCORO 0.12000000
    KDCTBO 100.000000     KDEACC 0.00254000
KDEBYP 0.09500000
    KDECIL 0.32550000     KDECLR 0.32550000
KDECOL 0.56040000
    KDECOR 0.00254000     KDEACH 0.00254000
KDECTB 100.000000
    KDEEPP 0.05080000     KDEESP 0.05080000
KDEGAC 0.32550000
    KDEHCL 0.00228600     KDEHCU 0.00228600
KDEHLC 0.00228600
    KDEHLR 0.56040000     KDEHUC 0.00228600
KDEHXO 0.05080000
    KDEHXP 1.00000000     KDEIFD 0.19850000
KDEIPR 0.12000000
    KDELDS 0.32550000     KDELHL 0.32550000
KDEMCL 0.32550000
    KDEMCP 0.32550000     KDEMHL 0.56040000
KDEMHP 0.01600000
    KDEMRP 1.00000000     KDEMUS 0.32550000
KDEOPR 0.12000000
    KDEPCH 1.00000000     KDEPCL 0.32550000
KDEREF 0.15000000
    KDESCC 0.45720000     KDESCL 0.45720000
KDESHL 0.05080000
    KDESHP 0.01270000     KDETCL 0.76000000
KDETHL 0.76000000
    KDEVES 0.56040000      KDGAC 0.32550000
KDHACC 0.52700000
KDHCDH(16) 6.00000000     Z99981-1.24000000
 -1.24000000
         -1.32000000           -1.49000000
 -1.75000000
         -2.06000000           -2.52000000
 -2.99000000
    Z99982-10.0000000          0.
  1.00000000
                  2.00000000          3.00000000
    4.00000000
                  5.00000000          6.00000000
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    KDHCLR-13.5700000     KDHCTB 0.
KDHCUO 0.00228600
    KDHEHX 2792.00000     KDHEPP 0.
KDHESP 3.00000000
    KDHGAC 5.00000000     KDHHLC 0.52700000
KDHHLR 12.5000000
    KDHHUC 0.52700000     KDHHXP 0.
KDHIFD 0.
    KDHIPR 3.00000000     KDHLHL-1.83000000
KDHLRI 0.56040000
    KDHLRO 0.56040000     KDHMCL 0.
KDHMHL 0.
    KDHMHP 0.             KDHMHX 2391.00000
KDHMRP 0.
    KDHOPR 4.25300000     KDHPCH 0.
KDHPCL-4.88000000
    KDHREF 0.             KDHSHP 0.
KDHTCL-3.00000000
    KDHTHL 3.00000000     KDHXPO 1.00000000
KDIFDI 0.32550000
    KDIPCI 0.12000000     KDLHLO 0.32550000
KDMCLA 0.32550000
    KDMCPI 0.32550000     KDMCPO 0.32550000
KDMHLL 0.32550000
    KDMHLO 0.56040000     KDMHXI 0.32550000
KDMHXO 0.01600000
    KDMRPO 1.00000000     KDPCHO 1.00000000
KDRCOR 0.08640000
    KDRCPG 0.08640000     KDREFO 0.15000000
KDSCLX 0.45720000
    KDSHLX 0.01270000     KDTCLO 0.76000000
KDTHLO 0.76000000
    KDVESI 0.19850000     KDVESO 0.56040000
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KEACHO 0.
    KEBYPO 0.            KECLRI 4.5700E-05
KECLRO 4.5700E-05
    KECORO 0.            KECTBO 4.5700E-05
KEEHXO 4.5700E-05
    KEESCL 4.5700E-05    KEESHL 4.5700E-05
KEFPOI 3.2000E-11
     KEGAC 4.5700E-05    KEHCLO 0.
KEHCUO 0.
    KEHLRI 4.5700E-05    KEHLRO 4.5700E-05
KEHXPO 4.5700E-05
    KEIFDI 4.5700E-05    KEIPCI 0.
KELHLO 4.5700E-05
    KEMCPI 4.5700E-05    KEMCPO 4.5700E-05
KEMHLL 4.5700E-05
    KEMHLO 4.5700E-05    KEMHXI 4.5700E-05
KEMHXO 4.5700E-05
    KEMRPO 4.5700E-05    KEPCHO 4.5700E-05
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    KERBYP 0.            KERCIL 4.5700E-05
KERCLR 4.5700E-05
    KERCOL 4.5700E-05    KERCOR 0.
KERHCL 0.
    KERHCU 0.            KERACH 0.
KERCTB 4.5700E-05
    KEREFO 4.5700E-05    KEREPP 4.5700E-05
KERESP 4.5700E-05
    KERGAC 4.5700E-05    KERHLC 0.
KERHLR 4.5700E-05
    KERHUC 0.            KERHXP 4.5700E-05
KERIFD 4.5700E-05
    KERIPR 0.            KERLDS 4.5700E-05
KERLHL 4.5700E-05
    KERMCL 4.5700E-05    KERMCP 4.5700E-05
KERMHL 4.5700E-05
    KERMHP 4.5700E-05    KERMRP 4.5700E-05
KERMUS 4.5700E-05
    KEROPR 0.            KERPCH 4.5700E-05
KERPCL 4.5700E-05
    KERREF 4.5700E-05    KERSCC 4.5700E-05
KERSHP 4.5700E-05
    KERTCL 4.5700E-05    KERTHL 4.5700E-05
KERVES 1.5200E-06
    KESCLX 4.5700E-05    KESHLX 4.5700E-05
KETCLO 4.5700E-05
    KETHLO 4.5700E-05    KEVESI 4.5700E-05
KEVESO 1.5200E-06
       KEY       0       KFAACC 0.06663000
KFABYP 0.03622000
    KFACIL 0.24966000    KFACLR 0.24966000
KFACOL 0.24660000
    KFACOR 0.06663000    KFAACH 0.06663000
KFACTB 100.000000
    KFAEPP 1.06000000    KFAESP 1.00000000
KFAGAC 0.24966000
    KFAHCL 0.05996700    KFAHCU 0.05996700
KFAHLC 0.05996700
    KFAHLR 0.24660000    KFAHUC 0.05996700
KFAHXP 10.0000000
    KFAIFD 0.09285000    KFAIPR 0.14800000
KFALDS 0.24966000
    KFALHL 0.24966000    KFAMCL 0.24966000
KFAMCP 0.24966000
    KFAMHL 0.24660000    KFAMHP 2.50000000
KFAMRP 10.0000000
    KFAMUS 0.24966000    KFAOPR 0.13326000
KFAPCH 10.0000000
    KFAPCL 0.24966000    KFAREF 1.00000000
KFASCC 0.65670000
    KFASHP 1.10000000    KFATCL 1.38000000
KFATHL 1.38000000
    KFAVES 0.24660000    KFCCON 0.
KFDACF 3870.00000
    KFDCOR 3870.00000    KFDHCL 3870.00000
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KFDHCU 3870.00000
    KFDACH 3870.00000     KFDHLF 3870.00000
KFDHUF 3870.00000
    KFEDET 1.00000000     KFFISC 1.15000000
KFHCOR 0.52700000
    KDHHCL 0.52700000     KDHHCU 0.52700000
KDHBYP 0.52700000
    KDHACH 0.52700000     KFICON 1.05000000
KFLACC 0.52700000
    KFLBYP 0.99800000     KFLCLR 10.0600000
KFLCOR 0.52700000
    KFLHCL 0.52700000     KFLHCU 0.52700000
KFLACH 0.52700000
    KFLCTB 0.             KFLEPP 24.0000000
KFLESP 6.00000000
    KFLGAC 5.00000000     KFLHLC 0.52700000
KFLHLR 15.2400000
    KFLHUC 0.52700000     KFLHXP 0.
KFLIFD 4.00000000
    KFLIPR 3.00000000     KFLLDS 0.
KFLLHL 12.1900000
    KFLMCL 18.8600000     KFLMCP 0.
KFLMHL 15.2600000
    KFLMHP 40.0000000     KFLMRP 0.
KFLMUS 0.
    KFLOPR 3.00000000     KFLPCH 0.
KFLPCL 13.8600000
    KFLREF 0.             KFLSHP 12.2000000
KFLTCL 20.0000000
    KFLTHL 20.0000000     KFPPOI 1.5000E+10
KFRCOR 0.04400000
    KFRCPG 0.04400000     KFSCON 1.00000000
KFTACF 0.00127000
    KFTCOR 0.00127000     KFTHCL 0.00127000
KFTHCU 0.00127000
    KFTACH 0.00127000     KFTHLF 0.00127000
KFTHUF 0.00127000
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    KFVACF 0.03370000     KFVCOR 0.03370000
KFVHCL 0.03370000
    KFVHCU 0.03370000     KFVACH 0.03370000
KFVHLF 0.03370000
    KFVHUF 0.03370000     KFWISC 5.3638E-04
KGBCIL    F
    KGBCOL    F           KGCGAC 1.00000000
KGFGAC 0.07400000
    KGIPOI 0.05600000     KGPPOI 0.01130000
KGTCOR 5.0000E-04
    KGTCNT 5.0000E-04     KGXPOI 0.00300000
KHOGAC 168000.000
    KHACOR 0.90000000     KHCCCS 190857.000
KHMEHX 188065.000
    KHMMUS 188065.000     KHMMHX 188466.000
KHPCCS 148200.000
    KHSACF 1.00000000     KHSCCS 127200.000
KHSSCC 127200.000
    KHSHLF 1.00000000     KHSHUF 1.00000000
KHUCOR 1.07400000
    KHWACC 0.             KHWBYP 0.
KHWCLR 600.000000
    KHWCTB 0.             KHWEPP 350.000000
KHWESP 0.
    KHWHLC 0.             KHWHLR 900.000000
KHWHUC 0.
    KHWHXP 0.             KHWIFD 0.
KHWIPR 0.
    KHWLHL 500.000000     KHWMCL 350.000000
KHWMHL 500.000000
    KHWMHP 500.000000     KHWMRP 0.
KHWOPR 0.
    KHWPCH 0.             KHWPCL 350.000000
KHWREF 0.
    KHWSHP 0.             KHWTCL 0.
KHWTHL 0.
    KIIPOI 1.00000000     KIPPOI 1.00000000
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KISPOI 1.00000000
     KIXPOI 1.00000000     KJOCNT 3.1101E+08
KJOCOR 3.3000E+08
     KJOCPG 3.3000E+08     KJOMCP 6.0000E+06
KJNCNT 3.1101E+08
     KJNCOR 3.3000E+08     KJNCPG 3.3000E+08
KJPMCP(22) 2.00000000
Z99953(11) 0.            Z99954(11) 2.00000000
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     KKACOR 66.0000000     KKAHCL 66.0000000
KKAHCU 66.0000000
     KKAACH 66.0000000     KKAHLF 66.0000000
KKAHUF 66.0000000
     KKCACC 1.00000000     KKCBYP 1.00000000
KKCCIL 0.30000000
     KKCCLR 1.00000000     KKCCOL 1.00000000
KKCCOR 1.00000000
     KKCHCL 1.00000000     KKCHCU 1.00000000
KKCACH 1.00000000
     KKCCTB 0.             KKCEPP 1.00000000
KKCESP 1.00000000
     KKCGAC 1.00000000     KKCHLC 1.00000000
KKCHLR 1.00000000
     KKCHUC 1.00000000     KKCHXP 0.
KKCIFD 0.23000000
     KKCIPR 0.16000000     KKCLDS 1.00000000
KKCLHL 1.00000000
     KKCMCL 1.00000000     KKCMCP 1.00000000
KKCMCS 1.00000000
     KKCMHL 1.00000000     KKCMHP 1.00000000
KKCMRP 0.
     KKCMUS 1.00000000     KKCOPR 1.00000000
KKCPCH 0.
     KKCPCL 1.00000000     KKCREF 0.
KKCSCC 1.00000000
     KKCSHP 1.00000000     KKCTCL 1.00000000
KKCTHL 1.00000000
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     KKFACF 154.600000     KKFCON 1.00000000
KKFCOR 154.600000
     KKFHCL 154.600000     KKFHCU 154.600000
KKFACH 154.600000
     KKFGAC 0.01000000     KKFHLF 154.600000
KKFHUF 154.600000
     KKFMUS 0.01000000     KKIGAC 1000.00000
KKIMCP 1000.00000
     KKIMUS 1.00000000     KKISCC 1.00000000
KKLCON 5.0000E-06
     KKOACF 2.25000000     KKOCOR 2.25000000
KKOHCL 2.25000000
     KKOHCU 2.25000000     KKOACH 2.25000000
KKOHLF 2.25000000
     KKOHUF 2.25000000     KKPCIL 1000.00000
KKPCOL 1000.00000
     KKTCON 1.00000000     KKWCIL 1000.00000
KKWCOL 1000.00000
     KLACHO 0.52700000     KLACIL 10.0000000
KLACOL 10.0000000
     KLAGAC 10.0000000     KLAMCP 5.00000000
KLASCC 50.0000000
     KLBYPO 0.99800000     KLCCC 0.51700000
KLCCOR 0.01430000
            0.03050000           0.11100000
  0.29600000
            1.13000000           3.00000000
  1.1000E-04
     KLCCNT 0.01430000           0.03050000
  0.11100000
            0.29600000           1.13000000
  3.00000000
            1.1000E-04     KLCLRI 18.8600000
KLCLRO 10.0600000
     KLCORO 3.00000000     KLCTBO 0.
KLEHXO 24.0000000
     KLESHL 6.00000000     KLHCLO 0.52700000
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KLHCUO 0.52700000
    KLHLRO 15.2400000      KLHXPO 0.
KLIPCI 3.00000000
    KLIPOI 2.8750E-05      KLLHLO 12.1900000
KLMCPI 13.8600000
    KLMHLO 15.2600000      KLMHXI 0.
KLMHXO 40.0000000
    KLMRPO 0.              KLPCHO 0.
KLPPOI 3.5600E-06
    KLREFO 0.              KLSHLX 12.2000000
KLTCLO 20.0000000
    KLTHLO 20.0000000      KLVESI 4.00000000
KLXCON 0.
           0.                     1.00000000
  5.00000000
           5.00000000           -10.0000000
 -1.00000000
           0.                     1.00000000
  10.0000000
   Z99993 0.                      0.
  1.00000000
           5.00000000             5.00000000
Z99994-10.0000000
          -1.00000000             0.
  1.00000000
           10.0000000      KLXPOI 2.0920E-05
KNOCON 5.5555E+33
    KNOMCP 1.00000000      KNIANS 4.00000000
KNNACH 1.00000000
    KNNHCL 23.0000000      KNNHCU 23.0000000
KNPISC 0.10000000
    KNPMCP 0.10000000      KNSISC 0.10000000
KNSMCP 0.10000000
    KNUPOI 2.43000000      KOCCIL 0.60000000
KOCCOL 0.60000000
    KOFMUS     F           KOFSCC 1.00000000
KPOMCS 3.2931E+06
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    KPBCCS 150000.000     KPBSCC 150000.000
KPCCCS 3.1180E+06
    KPCCIL 350000.000     KPCCOL 290000.000
KPECCS 0.01000000
    KPFISC 0.80000000     KPLCCS 150000.000
KPLCON 150000.000
    KPLCOR 1.70000000     KPLMUS 100000.000
KPMCIL 1000.00000
    KPMCOL 1000.00000     KPMMCS 21000.0000
KPRMCP(18) 2.00000000
    Z99951 0.                    0.
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             13000.0000          50000.0000
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KSFHUF 7.6240E-04
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OFRCOR     F
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OSEISC      T
    OSEOSC      T           OSFISC     F
OSFOSC     F
    OSIISC     F            OSIOSC     F
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       PCCC 1.7308E+06        PCILC 350000.000
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      QHLF 1.0426E+07       QHUF 9.1366E+06
QIACF 2.1370E+07
     QIFFF 1.5274E+07      QIHLF 1.5436E+07
QIHUF 1.6720E+07
     QSACF 4.6494E+07      QSFFF 2.8895E+07
QSHLF 2.8642E+07
     QSHUF 3.1948E+07       RACH 0.
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     RACHO 1074.10000      RAREA 0.
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RCORO 1074.10000
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THCLO 131.141000

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Z99868    F

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    Z99880    F          Z99882-1.0000E+10
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Z99886    F
    Z99887 1.0000E+10    Z99888        0
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    Z99896    F          Z99897-10.5161000
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    Z99911    F          Z99912-6.9963E-05
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