ornl

RECEIVED
FEB 29 1996
OSTI

ORNL/TM-13042

**OAK RIDGE
NATIONAL
LABORATORY**

MARTIN MARIETTA

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

Jose March-Leuba

August 1995

Advanced Neutron Source

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401, FTS 626-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ORNL/TM-13042

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

Jose March-Leuba

Date published: August 1995

Prepared by
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
LOCKHEED MARTIN ENERGY SYSTEMS
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

Table *Page*

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

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

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.

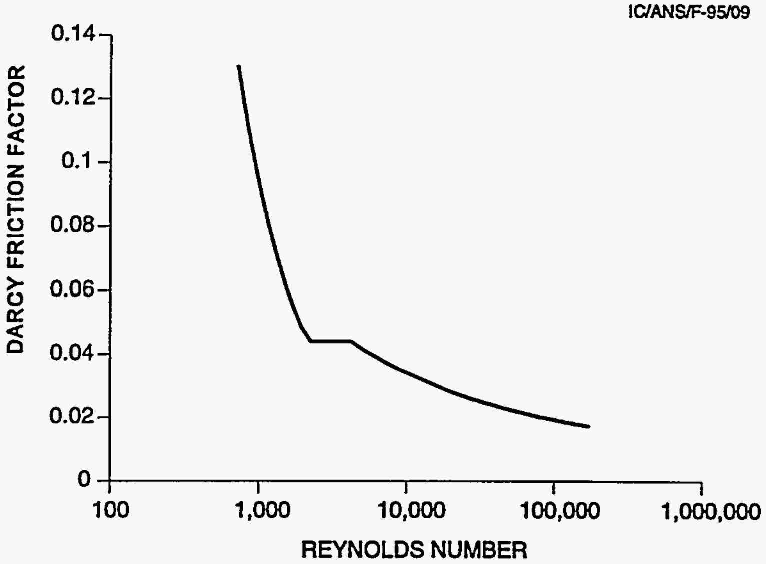

Fig. 1. Friction factor calculated by the Advanced Neutron Source Dynamic Model after scram and transition to natural circulation.

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.

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

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

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

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:

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

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

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

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

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

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:

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

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

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

```
      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     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
      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             ! 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
        SF0 = SF
        SF  = 1./(3.48 - 1.7372*ALOG(C1 + C2/SF))
        SFERR     = ABS((SF - SF0)/SF0)
        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 4/6/94 (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 nxeitg = .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,mirhcu,xirhcu,msrhcu,xsrhcu
prepar mcrhcl,xcrhcl,mirhcl,xirhcl,msrhcl,xsrhcl
prepar tveso,thiro
prepar tmcpl,tmcpo,tclrl,tvesl
prepar fcnfx,jcpg,fdhfx,jrefc
prepar wmuso,wgac,widsl,wcilc,wcolc
prepar wsclx,tsclx,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 oselsc = .f., oseosc = .f.
end

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

proced norcon
! Rods will not move
  set kvslcr =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 khwlhl = 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 khwlhl = 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 'va'=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 lossicr = 1.e10
 end

 proced noipoi
  s klipoi = 0.  ! No initial Iodine
  s kbxpoi = 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 DTFCON = 0.01     ! Power (flux) control sampling time
  set DTPCON = 0.5      ! Pressure control sampling time
  set DTTCON = 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, 1.036, 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, 1.036, 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,
.162066E+01,...
   .157873E+01, .144616E+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,
.966873E+00

! Lower core BOC  M1
  s kplcor = 1.46936
  s knnhcl = 35
  s kpshcl =...
   .198589E+01, .199658E+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.

  t3                                              ! t3 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 kkccil = 1.09624          !For RELAP benchmark only.  WRONG #!!!
  s kkcifd = 0.               !For RELAP benchmark only.  WRONG #!!!
  s kbwcor = 0.1664636
  s kgfgac = 0.025
  s kcfihl = 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 kcfifd = 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 = 0.02           ! 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, tvesi, tveso, twhlf, zqwhcl(23)
  prepar        pipcl, zipopr, nmcp, uacho
  prepar        wmcpo, wshx, 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, tvesi, tveso, twhlf, zqwhcl(23)
  print t, pipcl, zipopr, nmcp, uacho
  print t, wmcpo, wshx, 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., 0.8, 0.8
  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, pipcl, 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, pipcl, 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 kwlccs = 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, whlro, widsl, wmuso, wgac
  prepar jcpg, fcnfx, fdhfx
  prepar qhuf, qchuf, qshuf, ztwhcu(5), zqwhcu(5)
  prepar qhlf, qchlf, qshlf, ztwhcl(5), zqwhcl(5)
  prepar ziplpr, zipopr, pgac

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

```
  s cint = 0.0002
  start

  print t, wcolc, wvesl, whlro, 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, zipl|x, 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 38.3 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 :
1 / 9

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



===================================================
======================
 ----------- 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 :
2 / 9

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



==================================================
======================
 ---------- 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 :
3 / 9

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



===================================================
======================
 ---------- 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 :
4 / 9

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


===================================================
======================
 ---------- 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
---------------------------
 ---

 --- Current Simulation Time : 0.00000E+00 PAGE :
5 / 9

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



====================================================
======================
 ---------- 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
```

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

 --- Current Simulation Time : 0.00000E+00 PAGE :
6 / 9

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


=====================================================
======================
 ---------- 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
```

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

 --- Current Simulation Time : 0.00000E+00 PAGE :
7 / 9

**************************************************
*********************


**************************************************
*********************
 ---------- 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
```

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

 --- Current Simulation Time : 0.00000E+00 PAGE :
8 / 9

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



====================================================
======================
 ---------- 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
```

```
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
```

```
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
```

```
    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
```

```
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
KDHCLO 0.00228600
    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
```

```
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
KERACC 0.
    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
```

```
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
```

```
     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
```

```
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
KKAACF 66.0000000
     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

     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
```

```
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
```

```
    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.
  3300.00000
           13000.0000            50000.0000
  110000.000
           200000.000            310000.000
  310000.000
    Z99952-1.00000000            0.
  0.10000000
           0.20000000            0.40000000
  0.60000000
           0.80000000            1.00000000
  2.00000000
KPSACH(50) 1.00000000     KPSCON 1.7011E+06
KPSHCL(50) 1.00000000
KPSHCU(50) 1.00000000     KPSISC 1.3584E+06
KPTMCP 1.50000000
    KPUCOR 1.49000000 KPWMCP(22) 2.40000000
Z99955(11) 0.
Z99956(11) 2.40000000     KROCNT 0.
KRACOR 7.40000000
    KRBCOR 9.10000000     KRFCOR-0.00125000
KRRREF 29.0000000
    KRSISC 0.20000000     KSAACC 0.
KSAACF 2.5400E-04
    KSABYP 0.             KSACLR 30.8643000
KSACOR 2.5400E-04
    KSAHCL 2.5400E-04     KSAHCU 2.5400E-04
```

```
KSAACH 2.5400E-04
    KSACTB 0.              KSAEPP 26.5000000
KSAESP 0.
    KSAHLC 0.              KSAHLF 2.5400E-04
KSAHLR 26.8250000
    KSAHUC 0.              KSAHUF 2.5400E-04
KSAHXP 0.
    KSAIFD 7.48413000      KSAIPR 0.
KSALHL 37.3991000
    KSAMCL 57.8628000      KSAMHL 26.8602000
KSAMHP 40.0000000
    KSAMRP 0.              KSAOPR 0.
KSAPCH 0.
    KSAPCL 42.5227000      KSAREF 0.
KSASHP 0.
    KSATCL 0.              KSATHL 0.
KSFACF 7.6240E-04
    KSFCOR 7.6240E-04      KSFHCL 7.6240E-04
KSFHCU 7.6240E-04
    KSFACH 7.6240E-04      KSFHLF 7.6240E-04
KSFHUF 7.6240E-04
    KSOACF 2.5000E-05      KSOCOR 2.5000E-05
KSOACH 2.5000E-05
    KSOHCL 1.5000E-05      KSOHCU 1.5000E-05
KSOHLF 1.5000E-05
    KSOHUF 1.5000E-05      KSSISC-1.0000E+10
KSSPOI 4.0800E-24
    KSXPOI 2.7200E-22      KTCMCP 2.00000000
KTDDET 0.25000000
    KTDISC 0.03000000      KTDOSC 0.12000000
KTFDET 0.02500000
    KTLCIL 0.25000000      KTLCOL 0.25000000
KTLCON 1.00000000
    KTLMUS 5.00000000      KTNCON 600.000000
KTPDET 0.03000000
    KTSCON 45.0000000      KTSEHX 0.
KTSISC 55.0000000
```

```
    KTSMHX 0.              KTTDET 2.00000000
KTWDET 0.25000000
    KUCACH 1.30500000      KUCCOR 1.30500000
KUCHCL 1.21508000
    KUCHCU 1.21508000      KUFCOR 0.03795000
KUFHCL 0.03795000
    KUFHCU 0.03795000      KUFACH 0.03795000
KUGACH 1.55400000
    KUGCOR 1.55400000      KUGHCL 1.44693000
KUGHCU 1.44693000
    KUWEHX 8.7000E-05      KUWMHX 2.6000E-04
KVAGAC 21.0000000
    KVFICR 0.03000000      KVFOCR 0.
KVSICR 0.01500000
    KVSOCR 1.0000E+10      KWCCCS 2144.00000
KWOMCP 2144.00000
    KWCCOR 2144.00000      KWCCON 2144.00000
KWECCS 104.000000
    KWFISC 0.08000000      KWLCCS 14.6000000
KWLMUS 14.6000000
    KWLLDS 14.6000000      KWLCON 14.6000000
KWNCON 0.
KWRICR(28) 1.00000000 Z99989(14)-15.2100000
Z99990(14) 1.00000000
KWROCR(20) 1.00000000      Z99985 0.
 0.
              -0.25000000          -2.02000000
 -3.11000000
              -4.00000000          -4.60000000
 -6.58000000
              -8.53000000          -8.53000000
Z99986-1.00000000
              -0.80000000          -0.60000000
 -0.50000000
              -0.40000000          -0.30000000
 -0.25000000
              -0.12500000            0.
```

```
    1.00000000
      KWSCCS 2800.00000      KWSISC 171.520000
  KWXCON 1.20000000
      KXOICR-0.15000000      KXOOCR-0.80000000
  KXMICR 0.60000000
      KXMOCR 0.              KXNICR-0.60000000
  KXNOCR-0.80000000
      KXSICR 0.01700000      KXSOCR 1.0000E+10
  KZOGAC 5.00000000
        LCNT-2.7054E-07        LGAC 4.63000000
  MCRACH 3.81319000
      MCRCOR 1.99977000      MCRHCL 1.99977000
  MCRHCU 2.25843000
      MIRACH 2.46468000      MIRCOR 1.33148000
  MIRHCL 1.33148000
      MIRHCU 1.46455000       MLDSI 0.
  MMUSO 0.
      MPRACH 4.85824000      MPRCOR 1.50195000
  MPRHCL 1.50195000
      MPRHCU 1.73936000      MPRMCP 7.26493000
  MSRACH 6.27408000
      MSRCOR 3.17389000      MSRHCL 3.17389000
  MSRHCU 3.48308000
      MUACHO 3.9498E-04      MUBYPO 6.2862E-04
  MUCLRI 7.2425E-04
      MUCLRO 7.2451E-04      MUCORO 3.9498E-04
  MUCTBO 9.8605E-04
      MUEHXO 7.3303E-04      MUESCL 8.7855E-04
  MUESHL 8.4429E-04
       MUGAC 7.9493E-04      MUHCLO 2.5096E-04
  MUHCUO 2.7469E-04
      MUHLRI 4.2217E-04      MUHLRO 4.2280E-04
  MUHXPO 8.7855E-04
      MUIFDI 7.2451E-04      MUIPCI 7.2402E-04
  MULHLO 4.2366E-04
      MUMCPI 7.3323E-04      MUMCPO 7.2396E-04
  MUMHLL 4.2366E-04

      MUMHLO 4.2316E-04      MUMHXI 4.2366E-04
  MUMHXO 7.3117E-04
      MUMRPO 8.7855E-04      MUPCHO 8.7855E-04
  MUREFO 4.9822E-04
      MUSCLX 9.8605E-04      MUSHLX 5.8445E-04
  MUTCLO 9.8605E-04
      MUTHLO 5.8445E-04      MUVESI 7.2451E-04
  MUVESO 4.2217E-04
      MXNERR 100000            NACF 3.00000000
  NERROR      0
        NHLF 2.00000000        NHUF 3.00000000
  NLL 2.2421E-44
        NMCP 1.00000000      NPHMCP 7.26493000
  NSPCON 1.00000000
      ODCCON    F            OFFGAC    F
  OFICON    F
      OFIICR    F            OFIOCR    F
  OFRCOR    F
      OMSKER    F            OPRINT     T
  OSCISC    F
      OSCMCP 5.5555E+33      OSCPPS      9
  OSEISC    T
      OSEOSC     T           OSFISC    F
  OSFOSC    F
      OSIISC    F            OSIOSC    F
  PACHI 3.1991E+06
       PACHO 1.7083E+06       PBYPI 3.1991E+06
  PBYPO 3.1469E+06
        PCCC 1.7308E+06       PCILC 350000.000
  PCLRI 3.2675E+06
       PCLRO 3.4001E+06       PCOLC 290000.000
  PCORO 1.8104E+06
       PCTBI 150000.000       PCTBO 150051.000
  PEHXO 1.6502E+06
       PESCL 150000.000       PESHL 117542.000
  PGAC 1.5864E+06
       PHCLI 3.1991E+06       PHCLO 1.7077E+06
```

```
PHCUI 3.1991E+06
     PHCUO 1.6608E+06      PHLRI 1.8416E+06
PHLRO 1.6983E+06
     PHXPI 150000.000      PHXPO 150000.000
PIFDI 3.4001E+06
     PIPCI 3.1991E+06      PLDSI 1.6906E+06
PLHLO 1.6906E+06
     PMCLI 3.2931E+06      PMCPI 1.6516E+06
PMCPO 3.2931E+06
     PMHLA 1.6906E+06      PMHLL 1.6906E+06
PMHLO 1.6871E+06
     PMHXI 1.6906E+06      PMHXO 1.6704E+06
PMRPI 150000.000
     PMRPO 150000.000      PMUPI 100000.000
PMUSO 1.6906E+06
     PPCHI 150000.000      PPCHO 150000.000
PRACHO 2.60095000
    PRBYPO 4.28197000     PRCLRI 4.99365000
PRCLRO 4.99561000
    PRCORO 2.60095000     PRCTBO 6.97953000
PREFI 1.0000E+06
     PREFO 1000000.00     PREHXO 5.05941000
PRESCL 6.15881000
    PRESHL 5.89861000      PRGAC 5.52519000
PRHCLO 1.64830000
    PRHCUO 1.79702000     PRHLRI 2.79044000
PRHLRO 2.79490000
    PRHXPO 6.15881000     PRIFDI 4.99561000
PRIPCI 4.99193000
    PRLHLO 2.80089000      PRMCP 227334.000
PRMCPI 5.06093000
    PRMCPO 4.99149000     PRMHLL 2.80089000
PRMHLO 2.79741000
    PRMHXI 2.80089000     PRMHXO 5.04548000
PRMRPO 6.15881000
    PRPCHO 6.15881000     PRREFO 3.33062000
PRSCLX 6.97953000
```

```
    PRSHLX 3.95688000     PRTCLO 6.97953000
PRTHLO 3.95688000
    PRVESI 4.99561000     PRVESO 2.79044000
PSACHO 55645.0000
    PSBYPO 12579.6000     PSCISC      6
PSCLRI 8332.30000
    PSCLRO 8323.77000      PSCLX 262089.000
PSCORO 55645.0000
    PSCTBO 3682.75000     PSEHXO 8053.77000
PSESCL 4930.89000
    PSESHL 5473.49000      PSGAC 6434.33000
PSHCLO 270704.000
    PSHCUO 196327.000     PSHLRI 44496.8000
PSHLRO 44273.9000
     PSHLX 181766.000     PSHXPO 4930.89000
PSIFDI 8323.77000
    PSIPCI 8339.75000     PSLHLO 43976.6000
PSMCPI 8047.46000
    PSMCPO 8341.69000     PSMHLL 43976.6000
PSMHLO 44149.3000
    PSMHXI 43976.6000     PSMHXO 8111.53000
PSMRPO 4930.89000
    PSPCHO 4930.89000     PSREFO 25867.8000
PSSCLX 3682.75000
    PSSHLX 15679.3000     PSTCLO 3682.75000
PSTHLO 15679.3000
    PSVESI 8323.77000     PSVESO 44496.8000
PTCLI 232037.000
     PTCLO 262089.000      PTHLO 149999.000
PTMCP     13
     PVESI 3.1180E+06      PVESO 1.8416E+06
PWACF 201030.000
     PWFFF 689249.000      PWHLF 1.2327E+06
PWHUF 847871.000
      QACF 5.7094E+06      QCACF 3.3257E+07
QCFFF 2.6034E+07
     QCHLF 2.6277E+07      QCHUF 2.7756E+07
```

```
QFFF 5.9333E+06
     QHACF 8.8725E+06       QHHLF 2.0456E+07
QHHUF 1.5554E+07
      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.
RACHI 1098.47000
     RACHO 1074.10000       RAREA 0.
RBYP 0.
     RBYPI 1098.47000       RBYPO 1094.48000
RCLRI 1098.48000
     RCLRO 1098.49000        RCOR 0.
RCORO 1074.10000
     RCROD 0.               RCTBI 1092.09000
RCTBO 1104.88000
    REACHO 172775.000     REBYPO 1.4760E+06
RECLRI 3.8594E+06
    RECLRO 3.8580E+06     RECORO 4.0813E+06
RECTBO 2.8394E+06
    REEHXO 140173.000     REESCL 541.218000
REESHL 6257.58000
     REGAC 1.0000E-04     REHCLO 235035.000
REHCUO 214141.000
    REHLRI 1.1541E+07     REHLRO 1.1523E+07
REHXO 1098.79000
    REHXPO 11522.2000     REIFDI 3.8580E+06
REIPCI 2.4009E+06
    RELHLO 6.5977E+06     REMCPI 3.8123E+06
REMCPO 3.8611E+06
    REMHLL 6.5528E+06     REMHLO 1.1513E+07
REMHXI 6.5977E+06
    REMHXO 18766.4000     REMRPO 6691.42000
REPCHO 8749.79000
```

```
    REREFO 60214.4000      RESCL 1102.80000
RESCLX 1.9768E+06
     RESHL 1102.01000     RESHLX 55311.9000
RESPOI-0.58127600
    RETCLO 1.5637E+06     RETHLO 2.6384E+06
REVESI 6.3262E+06
    REVESO 1.1541E+07     REXPOI-2.98575000
RGAC 1100.71000
    RHACHO-1.7118E-04     RHBYPO-1.1623E-04
RHCLI 1098.47000
     RHCLO 1036.40000     RHCLRI-9.6851E-05
RHCLRO-9.6798E-05
    RHCORO-1.7118E-04     RHCTBO-3.7841E-05
RHCUI 187933.000
     RHCUO 1045.93000     RHEHXO-9.5065E-05
RHESCL-6.3995E-05
    RHESHL-7.1650E-05      RHGAC-8.2256E-05
RHHCLO-2.2835E-04
    RHHCUO-2.1608E-04     RHHLRI-1.6344E-04
RHHLRO-1.6326E-04
    RHHXPO-6.3995E-05     RHIFDI-9.6798E-05
RHIPCI-9.6898E-05
    RHLHLO-1.6303E-04      RHLRI 1077.89000
RHLRO 1077.97000
    RHMCPI-9.5023E-05     RHMCPO-9.6910E-05
RHMHLL-1.6303E-04
    RHMHLO-1.6316E-04     RHMHXI-1.6303E-04
RHMHXO-9.5443E-05
    RHMRPO-6.3995E-05     RHPCHO-6.3995E-05
RHREFO-1.4430E-04
    RHSCLX-3.7841E-05     RHSHLX-1.2535E-04
RHTCLO-3.7841E-05
    RHTHLO-1.2535E-04     RHVESI-9.6798E-05
RHVESO-1.6344E-04
     RHXPI 1100.00000      RHXPO 1102.80000
RICR 0.
     RIFDI 1098.49000      RIPCI 1098.47000
```

```
RLHLO 1078.08000
     RMCLI 1098.47000      RMCPI 1098.79000
RMCPO 1098.47000
     RMHLL 1078.08000      RMHLO 1078.02000
RMHXI 1078.08000
     RMHXO 1098.72000      RMRPI 1100.00000
RMRPO 1102.80000
      ROCR 0.              RPCHI 1100.00000
RPCHO 1102.80000
     RREFC 0.              RREFI 1100.00000
RREFO 1085.92000
    RSCISC      3          RSCLX 1104.88000
RSHLX 1092.09000
     RSPOI-0.58127600      RTCLI 1104.88000
RTCLO 1104.88000
     RTHLO 1092.09000      RVESI 1098.49000
RVESO 1077.89000
     RXESM-3.56703000      RXPOI-2.98575000
SSCISC      8
     TOANS 0.              TACHI 44.4794000
TACHO 85.6446000
     TBYPO 52.4385000      TCACF 214.000000
TCCC 131.141000
     TCFFF 234.715000      TCHLF 312.079000
TCHUF 280.782000
     TCLRI 44.4626000      TCLRO 44.4434000
TCORO 85.6446000
    TCSDET 29.9297000      TCTBO 29.9297000
TDAY 0.
    TDHCDH 1.0000E+10      TEHXO 43.8247000
TESCL 34.9428000
     TESHL 36.7836000       TFFF 225.170000
TGAC 39.6870000
     TGGAC 39.6870000     THCACF 284.127000
THCHLF 426.651000
    THCHUF 365.747000      THCLI 44.4794000
THCLO 131.141000
```

```
     THCUI 44.4794000      THCUO 120.837000
THLRI 80.1483000
     THLRO 80.0271000      THOUR 0.
THSDET 56.8998000
    THWACF 140.472000     THWHLF 200.415000
THWHUF 187.396000
     THXPO 34.9428000      TIFDI 44.4434000
TIPCI 44.4794000
     TLHLO 79.8647000      TMCPI 43.8101000
TMCPO 44.4838000
     TMHLL 79.8647000      TMHLO 79.9592000
TMHXI 79.8647000
     TMHXO 43.9586000       TMIN 0.
TMRPO 34.9428000
     TPCHO 34.9428000      TREFO 67.5966000
TSACHO 204.636000
    TSBYPO 236.395000     TSCISC      5
TSCLRI 238.518000
    TSCLRO 240.786000      TSCLX 29.9297000
TSCORO 207.452000
    TSCTBO 112.703000     TSEHXO 202.974000
TSESCL 112.693000
    TSESHL 105.558000      TSGAC 201.100000
TSHCLO 204.618000
    TSHCUO 203.282000     TSHLRI 208.289000
TSHLRO 204.352000
     TSHLX 56.8998000     TSHXPO 112.693000
TSIFDI 240.786000
    TSIPCI 237.321000     TSLHLO 204.136000
TSMCPI 203.015000
    TSMCPO 238.960000     TSMHLL 204.136000
TSMHLO 204.035000
    TSMHXI 204.136000     TSMHXO 203.558000
TSMRPO 112.693000
    TSPCHO 112.693000     TSREFO 180.355000
TSSCLX 130.201000
    TSSHLX 118.528000     TSTCLO 130.201000
```

```
TSTHLO 112.693000
     TSTOP 0.             TSVESI 235.878000
TSVESO 208.289000
     TTCLO 29.9297000      TTHLO 56.8998000
TVESI 44.4434000
     TVESO 80.1483000      TWACC 0.
TWACF 121.576000
     TWBYP 0.              TWCLR 34.9428000
TWCTB 0.
     TWEPP 34.9428000      TWESP 0.
TWFFF 165.013000
     TWHLC 0.              TWHLF 189.580000
TWHLR 34.9428000
     TWHUC 0.              TWHUF 173.423000
TWHXP 0.
     TWIFD 35.0189000      TWIPR 0.
TWLHL 34.9428000
     TWMCL 34.9428000      TWMHL 34.9428000
TWMHP 34.9428000
     TWMRP 0.              TWOPR 85.6446000
TWPCH 0.
     TWPCL 34.9428000      TWREF 0.
TWSHP 0.
     TWTCL 0.              TWTHL 0.
UACHO 25.0137000
     UBYPO 8.92343000       UCCC 24.8959000
UCLRI 7.81752000
     UCLRO 7.81745000      UCORO 12.5068000
UCTBO 0.02534010
     UEHXO 1.84080000      UESCL 9.4305E-04
UESHL 0.09437340
      UGAC 0.              UHCLO 24.8959000
UHCUO 24.6021000
     UHLRI 8.06563000      UHLRO 8.06502000
UHXPO 0.00917924
     UIFDI 7.81745000      UIPCI 13.1872000
ULHLO 7.96536000
```

```
     UMCPI 7.81555000      UMCPO 7.81784000
UMHLL 7.91112000
     UMHLO 8.06468000      UMHXI 7.96536000
UMHXO 0.78053300
     UMRPO 0.00533074      UPCHO 0.00697055
UREFO 0.18417500
     USCLX 3.85871000      USHLX 2.33080000
UTCLO 1.83624000
     UTHLO 1.85789000      UVESI 21.0200000
UVESO 8.06563000
     VCICR 0.              VCOCR 0.
VGGAC 1.55400000
    VIRCON 0.              WACHI 1790.16000
WACHO 1790.16000
     WBYPI 353.744000      WBYPO 353.744000
WCILC 0.
     WCLRI 2143.93000      WCLRO 2143.93000
WCOLC 0.
     WCORO 1790.16000      WCTBI 2799.77000
WCTBO 2799.77000
     WEHXO 2144.00000      WESCL 104.000000
WESHL 104.000000
     WHCLI 1547.26000      WHCLO 1547.28000
WHCUI 1543.07000
     WHCUO 1543.07000      WHLRI 2143.90000
WHLRO 2143.90000
     WHXPI 101.284000      WHXPO 101.229000
WIFDI 2143.93000
     WIPCI 2143.90000     WLDCON 14.6000000
WLDSI 14.6000000
     WLHLO 2143.90000      WMCLI 2143.93000
WMCPO 2144.00000
     WMHLA 2143.90000      WMHLL 2129.30000
WMHLO 2143.90000
     WMHXI 2143.90000      WMHXO 2143.97000
WMRPI 58.7873000
     WMRPO 58.7875000      WMUSO 14.6000000
```

```
WPCHI 76.8711000
     WPCHO 76.8714000      WREFI 200.000000
WREFO 200.000000
    WSCISC      4          WSCLX 2799.77000
WSDET 2799.77000
     WSHLX 2800.00000      WTCLI 2799.77000
WTCLO 2799.77000
     WVESI 2143.93000      WVESO 2143.90000
XCRACH 98.1025000
    XCRHCL 43.7258000     XCRHCU 68.8227000
XIRACH 98.1025000
    XIRHCL 47.9086000     XIRHCU 68.8227000
XPRACH 98.1025000
    XPRHCL 47.9086000     XPRHCU 68.8227000
XSRACH 98.1025000
    XSRHCL 47.9086000     XSRHCU 68.8227000
z99829-5.76493000
    z99830       0        z99831      12
z99832    F
    z99833    F           z99834      15
z99835 1.00000000
    z99836      17        z99837 1.00000000
z99846      10
    z99847-1.24000000     z99848-2.2000E+08
z99849       0
    z99850      11        z99851    F
z99852    F
    z99854      12        z99855 0.
z99856-0.80000000
    z99857       0        z99858      10
z99859    F
    z99860    F           z99861       5
z99862 58.8600000
    z99863      21        z99864 0.98000000
z99865-0.75000000
    z99866       0        z99867       9
z99868    F
    z99869    F           z99870       5
z99871 58.8600000
    z99874       8        z99875 1.00000000
z99876-1.0000E+10
    z99877       0        z99878       8
z99879    F
    z99880    F           z99882-1.0000E+10
z99883       0
    z99884       7        z99885    F
z99886    F
    z99887 1.0000E+10     z99888       0
z99889       6
    z99890    F           z99891    F
z99892-339605.000
    z99893       0        z99894       5
z99895    F
    z99896    F           z99897-10.5161000
z99898       0
    z99899       4        z99900    F
z99901    F
    z99902-1972.48000     z99903       0
z99904       3
    z99905    F           z99906    F
z99907-0.20000000
    z99908       0        z99909       2
z99910    F
    z99911    F           z99912-6.9963E-05
z99913       0
    z99914       1        z99915    F
z99916    F
    z99917      12        z99918 0.
z99919      12
    z99920 0.             z99921      12
z99922 0.
    z99923      21        z99924 0.98000000
z99925      21
    z99926 0.98000000     z99979      10
```

```
Z99980-1.24000000
     Z99995     12          Z99996 0.
ZAEEHX 500.000000
     ZAEMHX 8750.00000      ZAUACF 2.5306E+06
ZAUHLF 3.3488E+06
     ZAUHUF 3.3177E+06      ZB2ACC 0.45020300
ZB2BYP 0.24473000
     ZB2CLR 1.00000000      ZB2COR 0.54038900
ZB2CTB 0.01380000
     ZB2EPP 0.42400000      ZB2ESP 0.01000000
ZB2HLC 0.40518200
     ZB2HLR 1.00000000      ZB2HUC 0.40518200
ZB2HXP 1.00000000
     ZB2IFD 0.37190600      ZB2IPR 0.62736500
ZB2LHL 0.98774300
     ZB2MCL 1.00000000      ZB2MHL 1.00000000
ZB2MHP 0.09986400
     ZB2MRP 1.00000000      ZB2OPR 0.50000000
ZB2PCH 1.00000000
     ZB2PCL 0.23552800      ZB2REF 1.00000000
ZB2SHP 0.59700000
     ZB2TCL 0.01380000      ZB2THL 0.79710100
ZBDCIL 0.
     ZBDCOL 0.              ZBTCNT 0.00774000
ZCVCIL 0.
     ZCVCOL 0.              ZDECPG 0.05754400
ZDHACC 150.256000
     ZDHBYP 14.2309000      ZDHCLR-0.50672300
ZDHCTB-1.2745E-06
     ZDHEPP 23.7187000      ZDHESP 0.00466240
ZDHHLC 2699.44000
     ZDHHLR-0.46265300      ZDHHUC 238.107000
ZDHHXP-0.71966300
     ZDHIFD 0.              ZDHIPR-608.837000
ZDHLHL-0.43457300
     ZDHMCL-0.40749600      ZDHMHL-0.25996300
ZDHMHP 25.1418000

     ZDHMRP 0.00579261      ZDHOPR 0.
ZDHPCH 0.01194720
     ZDHPCL-0.00150202      ZDHREF-1.5506E-05
ZDHSHP 61.9591000
     ZDHTCL 0.              ZDHTHL 0.
ZDJEHX 7.6076E-05
     ZDJMHX 3.2418E-05      ZDLCON-0.01537870
ZDNCON-8.6018E-04
     ZDPCON 1.5480E+06      ZDRCNT 1.00000000
ZDTCON 0.48389100
     ZDWCCS-0.24569400      ZEIPOI 1.8931E+22
ZEPPOI 3.0850E+22
     ZESPOI 5.7700E+21      ZEXPOI 4.4457E+20
ZFAACF 53.0709000
     ZFAHLF 53.0709000      ZFAHUF 53.0709000
ZFEGAC 0.
     ZFEMUS 0.00681001      ZFEPOI 4.6652E+18
ZFPOI 4.6652E+18
     ZFRCNT 0.              ZFSCON 1.00000000
ZH0ANS 187933.000
     ZH0MCP 2798.51000      ZHFACF 159027.000
ZHFHLF 178291.000
     ZHFHUF 173687.000      ZHLACF 1980.77000
ZHLHLF 2212.85000
     ZHLHUF 2216.67000      ZHPEHX 10101.1000
ZHPMCP 0.99990000
     ZHPMHX 6802.45000      ZHSEHX 207.757000
ZHSMHX 10493.1000
     ZHTACF 159027.000      ZHTHLF 178291.000
ZHTHUF 173687.000
     ZIACOR 1074.10000      ZIBCOR 1094.48000
ZIICIL 3.4001E+06
     ZIICOL 1.8414E+06      ZIJSCC-3.1390E+08
ZIPACC 2.9267E+06
     ZIPBYP 3.1580E+06      ZIPCLR 3.2675E+06
ZIPCTB 150051.000
     ZIPEPP 1.6688E+06      ZIPESP 149995.000
```

```
ZIPGAC 1.6904E+06
     ZIPHLC 2.9253E+06      ZIPHLR 1.8416E+06
ZIPHUC 2.8828E+06
     ZIPHXP 150000.000      ZIPIFD 3.1879E+06
ZIPIPR 3.2574E+06
     ZIPLHL 1.6879E+06      ZIPMCL 3.2931E+06
ZIPMHL 1.6983E+06
     ZIPMHP 1.6968E+06      ZIPMRP 150000.000
ZIPOPR 1.8763E+06
     ZIPPCH 150000.000      ZIPPCL 1.6178E+06
ZIPREF 1000000.00
     ZIPSHP 266012.000      ZIPTCL 230175.000
ZIPTHL 182725.000
     ZIRREF 1085.92000      ZITGAC 39.6870000
ZITLDS 0.
     ZITMUS 0.              ZIWCIL 2144.00000
ZIWCOL 2144.00000
     ZJDACF 0.              ZJDCPG 1.8990E+07
ZJDHLF 0.
     ZJDHUF 0.              ZJFACF 3.0301E+08
ZJFHLF 5.5324E+08
     ZJFHUF 4.8490E+08      ZJNCPG 3.1101E+08
ZJPMCP 1.00000000
     ZJWACF 3.0301E+08      ZJWHLF 5.5330E+08
ZJWHUF 4.8489E+08
     ZKCACC 0.04398380      ZKCACF 1.6192E-05
ZKCBYP 0.06042160
     ZKCCLR 0.              ZKCCOR 0.21124200
ZKCCTB 0.97259000
     ZKCEPP 0.28800000      ZKCESP 0.49500000
ZKCHLC 0.04758540
     ZKCHLF 1.1748E-05      ZKCHLR 0.
ZKCHUC 0.04758540
     ZKCHUF 1.1748E-05      ZKCHXP 0.
ZKCIFD 0.09421410
     ZKCIPR 0.03193710      ZKCLHL 1.5023E-04
ZKCMCL 0.
```

```
     ZKCMHL 0.              ZKCMHP 0.81024500
ZKCMRP 0.
     ZKCOPR 0.25000000      ZKCPCH 0.
ZKCPCL 0.38223600
     ZKCREF 0.              ZKCSHP 0.16240900
ZKCTCL 0.
     ZKCTHL 0.04116780      ZKFACF 1.4683E-05
ZKFHLF 1.0239E-05
     ZKFHUF 1.0239E-05      ZKGACC 5.16987000
ZKGBYP 5.16987000
     ZKGCLR-133.122000      ZKGCTB 0.
ZKGEPP 0.
     ZKGESP 29.4300000      ZKGHLC 5.16987000
ZKGHLR 122.625000
     ZKGHUC 5.16987000      ZKGHXP 0.
ZKGIFD 0.
     ZKGIPR 29.4300000      ZKGLHL-17.9523000
ZKGMCL 0.
     ZKGMHL 0.              ZKGMHP 0.
ZKGMRP 0.
     ZKGOPR 41.7219000      ZKGPCH 0.
ZKGPCL-47.8728000
     ZKGREF 0.              ZKGSHP 0.
ZKGTCL-29.4300000
     ZKGTHL 29.4300000       ZLACH 0.98102500
ZLAGAC 20.0272000
      ZLHCL 0.98102500       ZLHCU 0.98102500
ZNOMCP 1.00000000
     ZNPCCS 2.00000000      ZNWEHX 35.0000000
ZNWMHX 6.00000000
     ZOCCIL 0.60000000      ZOCCOL 0.60000000
ZPOANS 3.1180E+06
     ZPOGAC 1.5864E+06      ZPOMCP 1.6418E+06
ZPACF 1.7083E+06
ZPCACH(50) 5.5555E+33 ZPCHCL(50) 5.5555E+33
ZPCHCU(50) 5.5555E+33
     ZPDACC 336023.000      ZPDBYP 43575.6000
```

```
ZPDCLR 33565.8000
    ZPDCTB 0.35473300      ZPDEPP 1861.63000
ZPDESP 4.90742000
    ZPDHLC 321186.000      ZPDHLR 35058.0000
ZPDHUC 316531.000
    ZPDHXP 0.04646020      ZPDIFD 242678.000
ZPDIPR 95514.0000
    ZPDLHL 34200.4000      ZPDMCL 33566.1000
ZPDMHL 35056.5000
    ZPDMHP 334.688000      ZPDMRP 0.01566900
ZPDOPR 84005.9000
    ZPDPCH 0.02679180      ZPDPCL 33558.7000
ZPDREF 18.4175000
    ZPDSHP 2966.48000      ZPDTCL 1862.70000
ZPDTHL 1884.81000
    ZPFACC 1.2129E+06      ZPFBYP 5396.20000
ZPFCLR 13638.4000
    ZPFCTB 0.              ZPFEPP 18623.0000
ZPFESP 20.9974000
    ZPFGAC 0.              ZPFHLC 1.2123E+06
ZPFHLR 11169.7000
    ZPFHUC 1.2166E+06      ZPFHXP 0.
ZPFIFD 69832.9000
    ZPFIPR 26018.8000      ZPFLHL 16654.1000
ZPFMCL 25568.6000
    ZPFMHL 11184.0000      ZPFMHP 26378.7000
ZPFMRP 0.
    ZPFOPR 21074.1000      ZPFPCH 0.
ZPFPCL 18791.9000
    ZPFREF 0.              ZPFSHP 84246.8000
ZPFTCL 602.010000
    ZPFTHL 585.577000      ZPGACC 5552.95000
ZPGBYP 5658.33000
    ZPGCLR-146233.000      ZPGCTB 0.
ZPGEPP 0.
    ZPGESP 32432.0000      ZPGGAC 103984.000
ZPGHLC 5358.07000

    ZPGHLR 132186.000      ZPGHUC 5407.32000
ZPGHXP 0.
    ZPGIFD 0.              ZPGIPR 32328.1000
ZPGLHL-19354.0000
    ZPGMCL 0.              ZPGMHL 0.
ZPGMHP 0.
    ZPGMRP 0.              ZPGOPR 44813.5000
ZPGPCH 0.
    ZPGPCL-52602.3000      ZPGREF 0.
ZPGSHP 0.
    ZPGTCL-32516.6000      ZPGTHL 32140.3000
ZPHLF 1.7077E+06
     ZPHUF 1.6608E+06      ZPIACC 0.
ZPIBYP 0.
    ZPICLR 0.              ZPICTB 0.
ZPIEPP 0.
    ZPIESP 0.              ZPIHLC 0.
ZPIHLR 0.
    ZPIHUC 0.              ZPIHXP 0.
ZPIIFD 0.
    ZPIIPR 0.              ZPILHL 0.
ZPIMCL 0.
    ZPIMHL 0.              ZPIMHP 0.
ZPIMRP 0.
    ZPIOPR 0.              ZPIPCH 0.
ZPIPCL 0.
    ZPIREF 0.              ZPISHP 0.
ZPITCL 0.
    ZPITHL 0.              ZPLCIL 5.5555E+33
ZPLCOL 5.5555E+33
    ZPPSCC 81985.7000      ZPRMCS 3.2931E+06
ZPSACH(50) 5.5555E+33
ZPSHCL(50) 5.5555E+33 ZPSHCU(50) 5.5555E+33
ZPTMCP 1.00000000
ZQCACH(50) 5.5555E+33 ZQCHCL(50) 5.5555E+33
ZQCHCU(50) 5.5555E+33
ZQSACH(50) 5.5555E+33 ZQSHCL(50) 5.5555E+33
```

```
ZQSHCU(50) 5.5555E+33
ZQWACH(50) 5.5555E+33 ZQWHCL(50) 5.5555E+33
ZQWHCU(50) 5.5555E+33
    ZR0CNT-3.56703000     ZR0ICR 0.98000000
ZR0OCR 0.
    ZRACOR 0.             ZRBCOR 0.
ZRCACF 80859.8000
    ZRCHLF 80859.8000     ZRCHUF 80859.8000
ZRFCOR 0.
    ZRMPOI-3.56703000      ZSCNT 0.
ZSMACH 1.00000000
    ZSMHCL 1.70348000     ZSMHCU 1.48739000
ZT0ACF 121.629000
    ZT0HLF 189.045000     ZT0HUF 173.482000
ZTACC 85.6446000
     ZTBYP 52.4385000 ZTCACH(50) 5.5555E+33
ZTCEHX 8.88197000
ZTCHCL(50) 5.5555E+33 ZTCHCU(50) 5.5555E+33
ZTCLR 44.4433000
    ZTCMHX 14.0289000      ZTCTB 29.9297000
ZTDCDH 0.
     ZTEPP 43.8247000      ZTESP 36.7836000
ZTFCOR 205.381000
    ZTHEHX 7.17500000      ZTHLC 131.141000
ZTHLR 80.0268000
    ZTHMHX 22.9649000      ZTHUC 120.837000
ZTHXP 34.9428000
     ZTIFD 44.4434000      ZTIPR 44.4794000
ZTLHL 79.8645000
     ZTMCL 44.4626000     ZTMEHX 7.99815000
ZTMHL 79.9591000
     ZTMHP 43.9584000     ZTMMHX 18.1314000
ZTMRP 34.9428000
     ZTOPR 85.6446000      ZTPCH 34.9428000
ZTPCL 43.8101000
     ZTREF 67.5966000      ZTSHP 56.8998000
ZTSISC 1.0000E+10

    ZTSMCP 5.5555E+33      ZTTCL 29.9297000
ZTTHL 56.8998000
ZTWACH(50) 5.5555E+33 ZTWHCL(50) 5.5555E+33
ZTWHCU(50) 5.5555E+33
ZTXACH(50) 5.5555E+33 ZTXHCL(50) 5.5555E+33
ZTXHCU(50) 5.5555E+33
    ZUEEHX 100014.000     ZUEMHX 1.7420E+07
ZW0ANS 2144.00000
    ZWCCON 2144.00000     ZWLCOR 0.86414400
ZWPMCP 1.00000000
    ZWUCOR 0.84857100     ZZSEED   55555555
ZZWEHX 104.000000
    ZZWMHX 2800.00000     ZZZISC 0.
```

Internal Distribution

1.	R. B. Battle	12.	C. D. West
2.	J. E. Cleaves	13.	J. D. White
3.	D. N. Fry	14.	G. L. Yoder
4.	R. M. Harrington	15–16.	Central Research Library
5–7.	J. A. March-Leuba	17.	Document Reference Section
8.	D. W. McDonald	18.	ORNL Patent Section
9.	G. R. McNutt	19–20.	Laboratory Records Department
10.	D. L. Moses	21.	Laboratory Records Department, RC
11.	D. L. Selby	22–31.	Y-12 Technical Library

External Distribution

32. U.S. Department of Energy, Oak Ridge Operations, FEDC, MS-8218, P.O. Box 2009, Oak Ridge, TN 37831-8218

33-34. Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831