AIROS
A DIGITAL SIMULATOR FOR
POWER REACTOR DYNAMICS

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ABSTRACT

AIROS solves the space independent reactor kinetics equations and provides for the determination of reactivity by solving in addition the discretized equations which represent the spatial heat and mass transfer model for several fuel channels. In addition, variation of the film coefficient with flow is accounted for along with the provision for flow decay and afterglow heating. Scrams can be initiated by delayed signals from instruments which sense any quantity calculated, e. g., power, inverse period, or temperature.

AIROS is built of small modules or subroutines so that future modifications or additions can be made as better physical models are available. An initial temperature calculation will be incorporated for use on an input option. This input generation routine is being written for optional use to compute the conduction and convection coefficients, for a $n \times m$ multichannel, nodal system with builtin tables of specific heat, density, conductivity, and viscosity for the common fuel, structure, and coolant materials. Similarly, other modifications can easily be made. Up to 100 feedback equations and 15 delayed neutron equations can be solved in addition to the prompt neutron equation.

The numerical method is that developed by E. R. Cohen; essentially a 5th-order method with automatic time-step variation to insure the required accuracy with the minimum expenditure of computer time. Special provisions are made for startup problems resulting in 60% reduction in running time over conventional codes.

Both printed and graphical output are provided at the user's option. Any 39 of the feedback variables can be printed and/or displayed. In addition, the grouping of feedbacks on each CRT frame is under the user's control.

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CONTENTS

	Page
I. Introduction	7
A. Need for Present Work	7
B. Justification for Digital Model	8
C. Previous Work (AIREK 3A)	12
D. Present Work	13
II. Physical Models	15
A. Neutron Behavior	15
B. Feedback Equations	17
C. Reactivity	19
D. Flow Equations	21
E. Afterglow Heating	22
III. Special Features	23
A. Initial Conditions on Neutron Levels	23
B. Preset Data	24
C. Interval Switching	25
D. Startup Problems	26
E. Problem Termination	27
F. Restart from Previous Case	28
IV. Future Extensions	29
A. Improvement of AIROS	29
B. Studies of Dynamical Parameters	30
V. Use of Code	32
A. Input Data	32
B. Discussion of Options	37
C. Operating Instructions	40
References	42

TABLES

	Page
1. Delayed Neutron Precursor Data	24
2. Coefficients for Equation 8	59

FIGURES

1. Sample Deck Setup	33
2. Sample Heat Transfer Model	56

APPENDICES

A. Main Symbols	43
B. Numerical Method	45
C. Interval Switching	53
D. Sample Heat Transfer Model	56
E. Sample Input Sheets	61
F. Printed Results	69
G. Graphical Results	103

I. INTRODUCTION

A major goal of the reactor kinetics project in the Atomics International Reactor Safety Program was development of a digital simulator for power reactor dynamics. This document is intended to present the need for such a code, justify the use of a digital rather than analog computer, and review previous codes of this type. Following this discussion, the physical models and numerical methods which are used will be presented, in addition to the special features and running instructions necessary for its proper use.

A. NEED FOR PRESENT WORK

In order to achieve economic nuclear power without compromising the need for safety, it is vitally important to be aware of potential problems in the design and operation of future reactor systems as well as to improve the understanding of present reactors. There is need for a tool capable of investigating the general area of reactor dynamics in order to develop a fundamental understanding and to seek out potential problems concerning the safety of reactor systems. With such a tool, theories can be formulated where none exist and, with present theories, tested or verified by experiments or application of previous measurements where feasible.

It is important to have such a tool, with realistic models of the dynamic behavior of reactor systems, in order to understand their basic safety. So the intent of this work is to develop a digital computer program as a tool which can lead to an understanding of the dynamic behavior of reactors; and to be able to use this tool for parametric safety studies, design studies, and hazard analysis.

Other attempts to develop digital simulators for power and SNAP reactors were not altogether successful, as pointed out in Reference 1. Various difficulties exist in each of the other simulators developed to date. AIREK 3² and SNAPKIN VI³ use the numerical integration scheme developed by E. R. Cohen,⁴ and represent the best attempts to date, although both are lacking in other respects. Both codes have excellent features — automatic interval switching, extensive graphical display of results, and generalized feedback equations. SNAPKIN VI comes close to what is needed for SNAP systems, but neither code is adequate for power reactor dynamics studies.

Two earlier codes were developed specifically for reactor dynamics, namely OSCAI-1⁵ and BOOMER.⁶ These codes simulate many of the physical phenomena of interest to power and SNAP reactors, respectively; and also provide graphical displays. Each, however, uses an Euler integration scheme. Both are slow, inaccurate, and suffer from other numerical and coding difficulties.

With these thoughts in mind, previous analog studies were reviewed and the people directly concerned with hazard studies were contacted to find out what was really wanted in the way of a power reactor dynamics simulator. The specifications which were arrived at are as follows: (1) heat transfer by conduction and convection in at least three channels with 3 through 5 axial nodes and 5 or more radial nodes; (2) equations for flow decay (tables and/or external loop simulation); (3) provisions for decay heat; (4) provisions for scrams; (5) simulation of control rod withdrawal and fall; (6) fuel melting; (7) channel boiling; (8) fast reliable numerical techniques; and (9) extensive graphical output. These specifications led to the development of AIREK 3A⁷ and finally to AIROS.

Before describing the work, a justification is necessary for the use of digital rather than analog simulation for this type of study.

B. JUSTIFICATION FOR DIGITAL SIMULATION

Dynamic simulation of the behavior of reactor systems for hazards studies has traditionally been performed on analog computers for reasons which were entirely justifiable up to a few years ago. Since that time, developments in digital computer speed, numerical methods, graphical display devices, and programming techniques far overcome the objections against digital simulation. Let us consider briefly the main objections against digital simulation and see how these have been overcome.

1. Cost of Programming and Checkout

Since every analog study is programmed from scratch, many engineers (unfamiliar with digital programming) assume that digital studies are also. Of course, this is not the case. Once a basic code such as AIREK 3 was available, only modifications were needed to handle the complications of conduction, convection, flow decay, scrams, etc. The code was modified — not programmed from scratch and at little cost. And, now that the first generation simulator is available, most studies can be performed with no recoding, no checkout, etc.

2. Time and Cost Required to Complete Study

Once the models are programmed on the analog, i. e., wiring diagram is complete, it is necessary to wire the patchboard, set up the pots and then begin the checkout of the wiring of the patchboards by seeing if the system is stable with no driving force, and if the solution to some special case can be obtained. During this period, one to two men are present; one from the analog lab and possibly the individual for whom the problem is being solved.

Periodically (three, four, or five times a day, or more?) it is necessary to recheck the setting of all pots.

At least one man is present during the actual runs, which typically cover a period of two weeks to a month. Often the problem specifier is also present and, because of the extended period required to obtain his answers, it is questionable as to how much useful work he can accomplish. Let us then, conservatively, use 1-1/2 men on the average. Thus we can take 4-1/2 man-weeks as typical of the cost of a hazards study on an analog computer, not counting the time to determine the basic parameters (lifetime, conduction coefficients, etc), which is the same as for digital simulation.

On the other hand, one man can fill out the data sheets in several hours, and no other expense is involved other than machine running time. The cases for a typical study require one to three minutes each and can be as complex as most analog studies. Taking 2 min a case on the average, allowing for 50 cases, the entire cost is $\rightarrow 2.5$ man-weeks, or 50% of the cost of the study on an analog computer. Furthermore, these 50 cases could be run overnight if desired — certainly in less than one week.

Although it is difficult to quote dollar savings by use of digital equipment (some argue that there are no direct savings), there are at least three other sources of savings: (1) less capital tied up in equipment (patchboards cost about \$1000); (2) availability of equipment to many users; and (3) the savings due to having an answer in days rather than weeks or months. Each of these is difficult to measure in dollars. Just how does one evaluate the benefit of having an answer sooner? It could mean the difference between getting a contract or not; or completing a job in time.

With these thoughts in mind, let us pursue more objective arguments in favor of digital studies.

3. Ease of Changing Parameters or Models

Many parameters can be changed quite easily on an analog simply by re-setting a pot. Certain ones, however, such as initial conditions can require major changes in pot settings due to scaling difficulties. In fact, most startup studies are done by using a digital code to follow the power and delayed neutrons to 0.1% power and then using the results as initial conditions for the analog study. In general, any change of model requires extensive rewiring and checkout.

On the other hand, digital codes are written in such a way as to require only changes in data from the previous case, and have no scaling problems. Furthermore, changes to the basic models are easily accomplished by changes in input data only; e. g., eliminating the protective system or adding more scram trip points.

4. Form of Output

Engineers argue correctly that graphical display is far more meaningful than digital printout. Examples in Appendix G show the type of graphical output from our present digital simulator. The graphs are titled and the scales are marked and labeled; further, by changing the input data, any combination of variables can be displayed on a given frame. Having seen the examples in Appendix G one can have little doubt as to the quality of digital displays.

5. Cost of a Few Cases

It costs no more per case to run 1 or 25 cases on a digital code, whereas, the same patchboard setup time and the same checkout time are required for 1 or 25 cases on an analog computer. Thus no one would rerun one doubtful case or a new critical case the day after the patchboards were torn apart, as the cost would be large. No such problem exists with a digital code.

6. Limitation on Equipment

Because of limitation on amplifiers, function generators, etc, the complexity of the model is restricted. Two channels with three axial nodes and three or four radial nodes each, six delayed groups, representation of flow decay and decay heat, and variable film coefficient will about fill a 200-amplifier computer (~36 differential equations). No such problem exists in our present simulator. It is set up to handle 15 delay groups and 100 other feedback

equations (116 differential equations), in addition to allowing for variable coefficients, flow decay, etc. These limits were chosen on the basis of practical problem size, not on machine restrictions; e. g., no difficulty is foreseen in doubling or tripling these limits. The advantages of more rigorous mathematical and physical representation of engineering problems are obvious.

7. Continual Improvement

Once a digital code is developed, it is amenable to continual improvement in speed, output, and complexity of models. Digital codes are written in modules (subroutines and functions), each performing a specific job; for example, the film coefficient may be calculated using the Dittus-Boelter equation in some function subprogram. The model is easily changed merely by replacing this one module.

Once the basic code is developed, it is possible to include such "frills" as an initial temperature calculation, automatic variation of any parameter (as initial power), or combinations of parameters.

More important, however, is the ability to include more basic physical calculations. For example, it would be possible to incorporate an existing code to compute the change of Doppler coefficient with spectrum as the transient proceeds. On the other hand, one could postulate a dynamic model for void formation, say, and use the code to determine the parameters, e. g., AIREK-KEWB.^{8, 9}

Of great importance is the fact that the improvement of a digital code could go on over months or years whereas, for practical reasons of scheduling and cost, extended studies are not feasible on an analog computer.

8. Repeatability and Accuracy

One additional advantage is that of repeatability. Because of problems of component drift and accidental change of pot setting, the results obtained by running a problem at two different times may not agree. Furthermore, because of sealing difficulty and 0.1 or 1.0% tolerance on components, loss of accuracy may occur, and may be difficult to detect.

These problems are avoided on a digital computer by numerical analysis and choice of method (double precision is available). Since digital computers are deterministic, once a program is checked out, one can be sure of obtaining

the same result each and every time a given problem is run. Accuracy on a digital computer is limited only by the approximations to the physical model.

Let us summarize the advantages of digital simulation for reactor dynamics studies (whether the intent of the study is design, hazard analysis, or model building). First, however, we will acknowledge the fact that for certain problems man-machine interaction is perhaps advantageous. The parameter study on a digital machine can accomplish the same objective, but can be more expensive in terms of time and dollars. First, once a sufficiently general digital program is available (as AIROS), many physical models can be simulated by changes to input data only with no reprogramming required. Second, every study uses the same (checked out) digital program, thus saving the cost and time delay of wiring diagrams, patchboard setup, checkout, etc. Third, studies can be run overnight, or over an essentially unlimited time interval. Fourth, more accurate representation of physical situations can be made. Fifth, flexibility and ease of program modification are increased. Sixth, report quality and CRT displays are improved.

Let us review AIREK 3 and AIREK 3A, upon which AIROS is based.

C. PREVIOUS WORK

In order to provide a useful tool for understanding the dynamic behavior of reactors, an extension of AIREK 3 was developed which incorporates the phenomenology of heat transfer, fluid flow, and decay heat.

For lack of a better name, the first simulator developed was called AIREK 3A⁷ because of the fact that the AIREK 3 code forms some 90%. AIREK 3 is a general space-independent reactor kinetics code allowing for 15 delayed neutron equations and 50 feedback equations. Many kinds of feedback can be represented by the formulation; however, the equation will not handle a distributed heat transfer model.

The equation describing the behavior of prompt neutrons is a nonlinear, variable coefficient, 1st-order differential equation while the remainder are linear, constant coefficient, 1st-order differential equations. The method used to solve these equations is that developed by E. R. Cohen⁴ — essentially a 5th-order correct method which we shall refer to as the Geneva-58 method. Since the equations are 1st-order, the problem is an initial value problem; i. e., given

conditions at time t , find the solution at a later time $t + h$ (where, hopefully, h is not too small).

Incorporated in AIREK 3 is an automatic interval switching technique such that the step-size, h , is changed (doubled or halved) through the calculation so as to bound the error. Intervals are recomputed automatically if the error exceeds the upper bound. The output is limited to digital printout and graphical display of the neutron level, reactivity, inverse period, 6 delayed-neutron groups (if wanted), and 4 feedbacks.

AIREK 3A differs significantly from its predecessor in only two respects, although other differences exist. Of most significance is the generalization of the feedback equations. A new form of the feedback equation allows for all the previous generality plus the representation of a nodal heat transfer model including both conduction and convection. One could follow one channel with 5 axial and 10 radial nodes, 3 channels each with 3 axial and 4 radial nodes, etc.

The second major change is that up to 14 of the feedbacks can be printed and/or displayed according to input options; furthermore, the feedbacks can be grouped on the CRT frames in an arbitrary fashion.

Other differences include the incorporation of models for flow decay, flow dependence of the film coefficient, decay heat production, and scrams based on power, temperature, and/or period with reactivity based on rod-drop through gravity.

The experience gained in developing and using AIREK 3 and AIREK 3A has led to the development of a far superior dynamic simulator, AIROS.

D. PRESENT WORK

One of the pitfalls in developing a general code of any type is that special calculations and subroutines somehow become included, usually because of a requirement to complete the code by a given date. Although AIREK 3A was intended to be general, several special features are included; e. g., only certain nodes can be used for scrams, special printing features, and the special form of the flow decay equations. The justification for these nongeneral features is, of course, the pressure of time. All was not lost, however, as much was learned and used in the new dynamics simulator, AIROS.

The foremost modification was more feedback equations; the present code allows for 100 with any 39 edited, i. e., printed and/or displayed. Little or no increase in running time per equation will result, and in fact we could allow several hundred; 100 is felt to be a practical upper limit.

The reactivity calculation has been generalized so that any feedback variable can be tested for reactivity scram, each with a unique delay time. Startup problems can be handled so that until sensible power generation, 0.1% full power, say, the feedback equations will not be integrated, since no change is expected; this feature reduces the running time of startup problems by 60 percent. CRT displays of neutron level, inverse period, delayed neutron precursors, and reactivity up to the time of sensible power can be provided (on an option), in addition to the normal displays. Flow variation can take several forms: (1) simple exponential as in AIREK 3A; (2) a table provided in the input data;* (3) defined by the external loop equations.* A special output routine can be extended so that specified linear combination of feedback variables can be edited. The interval switching procedure tests all feedback variables in addition to power.

AIROS is built of small modules or subroutines so that future modifications or additions can be made as better physical models are available. An initial temperature calculation will be incorporated for use on an input option. This input generation routine is being written for optional use to compute the conduction and convection coefficients, for a $n \times m$ multichannel, nodal system with builtin tables of specific heat, density, conductivity and viscosity for the common fuel, structure and coolant materials. Similarly, other modifications can easily be made.

*Not available in the present version.

II. PHYSICAL MODELS

AIROS solves the space-independent reactor kinetics equations and provides for the determination of reactivity by solving in addition the discretized equations which represent the spatial heat and mass transfer model for several fuel channels. In addition, variation of the film coefficient with flow is accounted for along with the provision for flow decay and afterglow heating. Scrams can be initiated by delayed signals from instruments which sense any quantity calculated, e. g. , power, inverse period, or temperature.

A. NEUTRON BEHAVIOR

The space-independent prompt and delayed precursor neutron equations are:⁴

$$\dot{N}(t) = \left[\frac{\rho(t) - \beta}{\ell} \right] N(t) + \sum_i \lambda_i C_i(t) + S_0 \quad \dots (1)$$

$$\dot{C}_i(t) = \frac{\beta f_i}{\ell} N(t) - \lambda_i C_i(t) \quad \dots (2)$$

where the symbols are defined in Appendix A, and the reactivity, $\rho(t)$, is a known function of time, power level, and the feedback variables.

It is assumed in these equations that the effective prompt lifetime, ℓ , the precursor fractions, f_i , and β are constant. In general, these parameters are affected by changes in temperature, spectrum, control rod position, and other variables of the system. Fortunately, for most applications the consequences of postulated accidents are not changed by accounting for these variations. Often the uncertainty in the parameters is greater than their variation during a transient.

Some cases do arise, however, where the variation in the parameters is significant and can lead to erroneous results if neglected. An example is the case of step reactivity insertion to a highly subcritical reactor resulting in a subcritical reactor.* Equations (1) and (2) predict the ratio of neutron level after the insertion to the level before insertion to be

*This example was pointed out by S. Birkin

$$\frac{\rho_{\text{before}}}{\rho_{\text{after}}} ;$$

whereas the correct result is

$$\frac{\delta k_{\text{before}}}{\delta k_{\text{after}}} .$$

Since $\rho = \delta k/k$, the neutron level is in error by a factor of $(k_{\text{after}}/k_{\text{before}})$. If ρ_{before} is $-\$10$ and ρ_{after} is $-\$0.5$, then assuming $\beta = 0.007$, the error is a factor of 1.07 corresponding to a 7% error in power.

Consequently, care must be exercised in the application of these models to any specific case. In general, Equations (1) and (2) are adequate for large homogeneous reactors where spectral changes and small local changes are not significant.

Equations (1) and (2) are transformed into the following:

$$\dot{N}(t) = \frac{\beta}{\ell} \left\{ [r(t) - 1] N(t) + \sum_i f_i W_i(t) + S \right\} \quad \dots (3)$$

$$\dot{W}_i(t) = \lambda_i [N(t) - W_i(t)] \quad \dots (4)$$

by the substitutions

$$r(t) = \frac{\rho(t)}{\beta} \quad \dots (5)$$

$$W_i(t) = \frac{\ell \lambda_i C_i(t)}{\beta f_i} \quad \dots (6)$$

$$S = \frac{\ell S_0}{\beta} \quad \dots (7)$$

so that $W_i(t)$ represents the ratio of delayed neutron precursors at time t to time zero, and $r(t)$ is the reactivity in dollars. Equations (3) and (4) are integrated by a numerical method, as discussed in Appendix B.

B. FEEDBACK EQUATIONS

Generalized feedback equations are used to provide flexibility in the models that represent multichannel heat transfer including conduction and convection, energy, pressure, and other phenomenon. (The term "feedback" arises because in general these quantities affect reactivity and hence, in the language of control people, these variables are feedbacks.) The equations used in AIROS are of the form:

$$\dot{F}_j(t) = P_j Q(t) + U_j N(0) + Y_j F_j(t) + \sum_i \alpha_{ij}(t) F_{k_{ij}}(t) \quad \dots (8)$$

with

$$Q(t) = q(t) + (1 - q(0)) N(t)$$

$$\alpha_{ij}(t) = \begin{cases} C_{k_{ij},j}; & k_{ij} > 0 \\ \omega C_{k_{ij},j}; & k_{ij} < 0 \end{cases}$$

and k_{ij} is the number of the i^{th} feedback "connected to" the j^{th} ($i = 1, 8$) and represents a transformation from a sparse indexing set, ℓ , $\ell = 1, \text{NF}$; j , $j = 1, \text{NF}$ to the condensed indexing set, i , $i = 1, 8$; j , $j = 1, \text{NF}$.

Thus if, for some j , $k_{1j} = 5$, $k_{2j} = 10$, $k_{3j} = 17$, then feedback variables 5, 10, and 17 are the first, second and third variables, respectively, "connected to" Node j . The transformation is used to save storage space in the computer, but limits the number of variables which can be "connected" to any other to eight.

The coefficients $\alpha_{ij}(t)$ are conduction and convection of the form $(UA)/(\rho C_p V)$ and $(\dot{\omega} C_p)/(\rho C_p V)$ respectively, for a nodal heat transfer calculation. Thus

the form of α_{ij} permits flow-dependent conduction coefficients, e. g., the film coefficient and convection terms. No provision is made at present for nucleate or bulk boiling, fuel element melting, or burnout. See reference 7 (AIREK 3B) for previous work in that direction.

Since $N(t)$ and $q(t)$ (consequently $Q(t)$) are usually expressed as fractions of full power, the coefficients U_j and P_j have units of ($^{\circ}\text{F}/\text{sec}$), whereas Y_j and α_{ij} are relaxation times with units (sec^{-1}).

1. Simple Feedback Equations

Many kinds of feedback can be represented by Equation (8). By setting $U_j = Y_j = \alpha_{ij} = q = 0$ for some j , Equation (8) becomes

$$\dot{F}_j(t) = P_j N(t) \quad \dots (9)$$

If P_j represents the initial reactor power in megawatts, the $F_j(t)$ is the energy produced to time t .

2. Heat Transfer

Multichannel heat transfer equations can be represented by Equation (8). Appendix C shows an oversimplified model consisting of one channel containing two radial nodes (fuel and coolant), each divided into three axial nodes. Representative coefficients for Equation (8) are obtained from the basic heat-balance equations and tabulated in Appendix D. One hundred feedback equations are sufficient to follow several channels representing the hot fuel element, the average fuel element, and one or more special test elements each having five radial and three axial nodes.

3. Instrumentation Response

It is pointed out in the next section that any feedback can initiate a scram. In a real reactor system, abnormal behavior such as high temperature, power or inverse period is sensed by a fission plate, thermocouple, or period meter, and in general by some instrument having its own response to the signal. This signal is finally relayed to a servomechanism which in turn initiates the scram.

It is convenient, then, to use an additional feedback equation to represent the response from each instrument which may initiate the scram signal. Let

$F_k(t)$ represent the response of some instrument. Then, from Equation (8), we see that setting

$$Y_k = -\frac{1}{\tau}, \alpha_{1k} = \frac{1}{\tau}, P_k = U_k = 0,$$

we have

$$\dot{F}_k(t) = \frac{1}{\tau} [F_j(t) - F_k(t)], \quad \dots (10)$$

which is the desired equation for the instrument response to one of the F_j 's. Response to the power can be found by setting $P_k = 1/\tau$, $Y_k = -1/\tau$, $\alpha_{ik} = U_k = 0$; $i = 1, 8$, viz,

$$\dot{F}_k(t) = \frac{1}{\tau} [Q(t) - F_k(t)] \quad \dots (11)$$

where τ is the instrument response time. Similarly other instrument response functions can be simulated.

C. REACTIVITY

The reactivity subroutine is quite flexible, in that any equation can be programmed and many special equations have been coded for special application. Examples are the simulation of the reactivity worth of the control drums for SNAP and bubble (void) models for AIREK-KEWB. The form chosen for the production version of AIROS is as follows.

1. Normal Reactivity

$$r(t) = r(0) + \gamma_1 t + \sum_j A_j [F_j(t) - F_j(0)]; t \leq (t_s + \tau_D) \quad \dots (12)$$

where

$r(0)$ = the initial reactivity given in the input or determined by the solution of the inhour equation for constant inverse period (see Section III. A. 2.) in dollars.

γ_1 = linear reactivity insertion rate (dollars/sec).

A_j = reactivity coefficient for the j^{th} feedback.

t_s = time at which the scram signal is sensed as discussed below.

τ_D = delay between the time the signal is sensed and rod motion starts and is found from τ_{j_s}

where

j_s = the number of the feedback causing the scram. (See Equation 13.)

Equation (12) represents reactivity from (1) step insertion at $t = 0$, (2) linear reactivity insertion which is assumed to terminate after a scram occurs and (3) reactivity feedback which is proportional to the deviation of the feedback variables from their initial conditions.

The time at which the scram occurs, t_s , is determined by comparing each of the feedback variables which can initiate a scram against a scram level FM_j specified in the input. Thus t_s is the earliest time at which the condition

$$F_j(t) \geq |FM_j| ; j = j_s \quad \dots (13)$$

is satisfied. The absolute value of FM_j is taken because the program determines those feedbacks, j , which can initiate a scram by the condition

$$FM_j < 0 \quad \dots (14)$$

2. Reactivity After a Scram

Reactivity after scram is assumed to be due to scram rods dropping from the full-out position, downward through the core under the influence of gravity. It is further assumed that the axial flux distribution is a sine; so that the importance (relative worth) is given by a sine squared. Thus the reactivity after scram is given by

$$r(t) = r(0) + \gamma_1 (t_s + \tau_D) + \sum_j A_j [F_j(t) - F_j(0)] + \gamma_2 \sin^2\left(\frac{\pi x}{2L}\right) \quad \dots (15)$$

where

$$t \geq t_s + \tau_D$$

γ_2 = maximum rod worth (dollars).

L = active core length (feet)

$x(t)$ = distance from top of core at time t as calculated for freefall, viz.,

$$x(t) = \begin{cases} 0 & ; t \leq t_s + \tau_D \\ \frac{1}{2} a [t - (t_s + \tau_D)]^2; 0 \leq x(t) \leq L, t > t_s + \tau_D & \dots (16) \\ L & ; t_s + \tau_D < t \rightarrow \infty \end{cases}$$

The constant a is the acceleration of gravity (ft/sec^2) as modified possibly by a friction factor. For input we define the constant γ_3 (see Section V. A.):

$$\gamma_3 = \left(\frac{1}{2} a \right) \left(\frac{\pi}{2L} \right) \dots (17)$$

D. FLOW EQUATIONS

At the present time, provisions for two flow conditions are available which allow for constant flow, flow decay from full power, and after a scram. External loop equations will be added in the near future. Provision will also be made for tabular data.

1. Flow Decay from Full Power

It is assumed that the reactor is operating at some power level at $t = 0$, and that an accident such as pump failure or pipe rupture occurs which causes the flow to decay from its normal value according to the following relation:

$$\dot{\omega}(t) = A \exp(Bt) + C; t \geq D \dots (18)$$

This option can also be used to simulate pump startup for increasing power levels, although no provision (other than end of problem) is made to terminate the increase. This option is selected if $D = 0$.

2. Flow Decay After Scram

In this case, the reactor operates according to Equations (3), (4), (8), and (15), and at constant flow up to the time of a scram, i. e.,

$$\dot{\omega}(t) = D ; t \leq (t_s + \tau_{\dot{\omega}}) \quad \dots (19)$$

where $\tau_{\dot{\omega}}$ is a delay time and according to

$$\dot{\omega}(t) = A \exp \left\{ B \left[t - (t_s + \tau_{\dot{\omega}}) \right] \right\} + C ; t > (t_s + \tau_{\dot{\omega}}) \quad \dots (20)$$

thereafter. For continuity, $D = A + C$.

E. AFTERGLOW HEATING

The formulation for afterglow heating is a 2-term exponential based on Reference 11.

$$q(t) = \begin{cases} q(0) & ; t \leq t_s \\ \delta_1 \exp \left[\delta_3 (t - t_s) \right] + \delta_2 \exp \left[\delta_4 (t - t_s) \right] & ; t > t_s \end{cases} \quad \dots (21)$$

One can simulate the afterglow heating for a startup after a previous scram ($q(0) \neq 0$), afterglow after a scram ($q(0) = 0$; $\delta_1, \delta_2 \neq 0$), or combinations. Improved formulations can be coded as data become available.

III. SPECIAL FEATURES

AIROS has several special features which can be used to great advantage. These features either reduce running time or make the program easier to use, i. e., require less input data.

A. INITIAL CONDITIONS ON NEUTRON LEVELS

Since the program solves a system of first-order differential equations, it is necessary to provide the initial conditions for the prompt and delayed precursor neutron levels, reactivity, flow and etc. To make input easy, the user can set certain of the initial conditions by a combination of three methods.

1. Builtin

At the beginning of the first run of a set of cases, the initial neutron and delayed precursor levels are set equal to one; i. e.,

$$N(0) = W_i(0) = 1 \quad ; \quad i = 1, 15 \quad , \quad \dots (22)$$

These values are used as the initial conditions for all cases until changed by one of the two methods which follow. Note that the initial reactivity, $r(0)$, flow, $\dot{\omega}(0)$, and feedback levels, $F_j(0)$ are not initialized by the program.

2. Specified by Input

The initial conditions for flow, decay heat, and feedback levels must be specified in the input data; and the initial neutron level must be specified if different from one. The initial reactivity and delayed precursor levels may be specified in the input data or determined by a third method which follows.

3. Inhour Equation

The third option for specifying the delayed neutron precursor levels and initial reactivity is to obtain them from the inhour equation which is solved for the case of constant period; i. e., it is assumed that the prompt and delayed neutron precursor levels are increasing exponentially with inverse period ω_0 . Then the delayed neutron precursor levels are given in terms of the initial prompt neutron level by:

$$W_i(0) = \frac{\lambda_i N(0)}{\lambda_i + \omega_0} ; \quad i = 1, NF \quad \dots (23)$$

and the initial reactivity by

$$\rho(0) = \omega_0 \left[\sum_i \frac{f_i}{\lambda_i + \omega_0} + \frac{\ell}{\beta} + S \right] . \quad \dots (24)$$

B. PRESET DATA

As a convenience, portions of the data are preset prior to the first case and are used in subsequent cases unless changed by input data. In addition to setting the neutron levels equal to one, the following values are preset.

1. Delayed Neutron Precursor Decay Constants and Fractions

The delayed neutron precursor data¹² are for thermal fissions in U²³⁵, and are as follows.

TABLE 1
DELAYED NEUTRON PRECURSOR DATA

Group	f_i	λ_i
1	0.033	0.0124
2	0.219	0.0305
3	0.196	0.111
4	0.395	0.301
5	0.115	1.130
6	0.042	3.000

The values in Table 1 will be used unless modified.

2. Maximum Values of Feedbacks

In order to preclude problem termination because of exceeding the maximum value of some feedback which is not used in the problem, all feedback maxima are set equal to 10^{35} i. e.,

$$FM_j = 10^{35} ; j = 1, 100 \quad \dots (25)$$

Those feedbacks which are used to terminate the problem or to initiate a scram must have maximum values provided in the input data.

C. INTERVAL SWITCHING

The interval size, h , is automatically adjusted by AIROS so that a given accuracy results. Since it is extremely difficult to perform an exact analysis of the truncation error or of the propagation of error, an approximate method was developed which has proven to be satisfactory in many test cases. This method is discussed in Appendix C and is implemented in the following way.

Let Q be the maximum relative truncation error as derived in Appendix C, and AL and AU be specified by the user. Then:

If $Q \leq AL$ the interval is doubled

If $AL < Q < AU$ the interval is unchanged and

If $AU \leq Q$ the interval is halved and the calculation is repeated for that interval. Thus a value h is known for the next step.

Further restrictions exist, in that h must satisfy the condition $HL \leq h \leq HU$, with HL and HU specified in the input data. HU will be the maximum value used for h throughout the calculation. In order to preclude wasted machine time, if the error test requires a step-size, h , which is less than the minimum, HL , the problem will be terminated, an edit will occur, and the program will proceed to the next case.

For engineering calculations of thermal reactors, the following values are suggested.

$$AL = 10^{-4}$$

$$AU = 10^{-3}$$

$$HL = 10^{-8}$$

$$HU = 3.0$$

Flow instability may impose further restriction on HU . These limits (AL and AU) will preclude flow instability. For startup and nonflow problems, 10^{-3} and 10^{-2} are adequate bounds.

D. STARTUP PROBLEMS

One of the classic accidents investigated in every hazards report is the startup accident. In this accident, a shim rod is withdrawn to achieve full power, and because of some malfunction continues to withdraw, causing the reactor to go highly supercritical. The initial power level (that of the source) is sufficiently small — 1 watt, say — so that negligible heat is generated during a large part of the transient. Consequently, no useful information is gained in solving Equations (8) for the temperatures, as they are constant; however, a large amount of computer time is wasted since we are solving 40 to 60 feedback equations.

Provision is made in AIROS to solve only Equations (3), (4), and (12) for the prompt neutron level, delayed-neutron precursor levels and reactivity, respectively, until such time that $N(t) \geq N_{\min}$ where $N_{\min}$ is provided as input data; thereafter Equation (8) is also solved. The user can bypass this option if desired by setting $N_{\min} = 0$, in which case the feedback equations will be solved at all time-points. Normally, however, $N_{\min}$ should be such that the feedback equations are solved when the prompt power exceeds 0.1% of full power.

A typical example of the computer time savings possible is the following problem from a sodium reactor hazards study.

The incident considered represents a conceivable rod withdrawal from shutdown for a control rod arrangement consisting of a single shim rod withdrawal from 0.45% δk shutdown. Operation at this level represents a startup condition with all 6 safety rods, and 1 shim rod withdrawn. The average reactivity insertion rate for a single shim-rod withdrawal at the nominal 0.30 ft/min rod speed is 0.00225 δk /sec. It was further postulated that afterglow power was at 2%, with reactor flow adjusted to 20% of rated capacity by manual adjustment of main loop pump speed to establish initial core component temperatures. The shutdown prompt power was taken to be eight orders of magnitude below full power. For this problem, 0.1% prompt power occurred at 360 sec, the peak power occurred at 380 sec, and the scram was initiated by a 50°F rise in the coolant outlet temperature of the average channel at 380 sec. By 400 sec, the prompt power was negligible and the afterglow power had dropped to less than 1% of full power; by 450 sec, all temperatures had dropped below their initial values. Thus the first 360 of 450 sec, or approximately 75% of the problem time

corresponding to 60% of the running time* was spent in the region where the prompt power was less than 0.1%. This problem required 7 min on an IBM 7094 on AIREK 3A, which did not incorporate the special treatment; and 2 min on AIROS.

E. PROBLEM TERMINATION

Normal termination of a problem occurs when one of the following three conditions is met.

- 1) $t \geq \text{TIMEM}$, the maximum problem time specified in the input.
- 2) $N(t) \geq N_{\text{max}}$, the maximum neutron level specified in the input.
- 3) $F_j(t) \geq \text{FM}_j$, the maximum value of one of the feedbacks.

Termination will also occur if:

- 4) The number of calculation points stored exceeds 200.
- 5) The time interval, h , is less than HL.
- 6) Insufficient 7094 time is requested on job card.
- 7) Insufficient line count is requested on job card.
- 8) Arithmetic subroutine is encountered (ESCORT) because of negative argument to the square root subroutine, argument to the exponential subroutine greater than 88, etc.
- 9) Incorrect format was used on input data card.
- 10) There are insufficient data cards, or last case in job has been completed (end of A2 message).

Item 4 above is a restriction on the amount of room available to store the calculated values. Items 5 and 8 will not arise unless the input data are scrambled or a physically nonrealistic problem is attempted. Items 6 through 10 will cause termination of the job.[†]

A complete data edit will be obtained according to the input specifications unless Item 8 arises, in which case the job is immediately terminated.

*Smaller time-step was used in the vicinity of the peak

†Set of cases to be run

Restart cards (see Section V) will be punched on an input option if termination is due to Items 1 through 3; and automatically (regardless of the option) if termination is due to items 4 through 7.

After the printed and graphical output and possibly punching of restart cards, the next case in the job will be processed if termination was due to one of Items 1 through 5; but occurrence of Items 6 through 9 terminates the job. Item 10 arises for one of two reasons:

- 1) Insufficient input cards, or
- 2) All cases have been processed.

F. RESTART FROM PREVIOUS CASE

A feature is provided in AIROS which permits restarting a case from cards punched by a previous case. These cards contain the information required to continue the problem, using the last computed values for the initial conditions. Punching of restart cards is automatic if difficulty is encountered in completing a case, but optional otherwise (see the previous remarks regarding problem termination). See Section V. B.

IV. FUTURE EXTENSIONS

The development of the AIROS code can be continued by using the code to perform parameter studies to find the importance of each parameter in determining the dynamical behavior of the system. With this understanding, the code can then be modified to account more rigorously for variations in parameters with temperature, spectrum, pressure, etc.

The next step in the development is twofold: (1) use the code to understand the dynamic behavior of reactors, and (2) improve the code by formulating physical models which will bring calculations into agreement with experiment. The results of this two-pronged approach will be a better understanding of reactor safety, the ability to predict behavior, and a tool which can be used by engineers in hazards and design studies.

A. IMPROVEMENT OF AIROS

The AIROS code can be modified by the use of improved mathematical representation of physical models (e. g., coolant flow), and incorporation of improved physical models (e. g., fuel melting). Preliminary studies have indicated that it is possible to obtain additional information regarding temperature profiles in fuel elements without the necessity of dividing the fuel into many radial nodes (which is costly). This will improve the accuracy of the calculation at little added cost. Experience with both analog and digital representation of the transport of coolant indicates that instabilities often arise. Thus a relation between the number of axial nodes and coolant velocity must be determined to assure stability of the numerical model. The dynamic simulator can be modified to include models for fuel melting, burnout, expansion, and the external heat transfer loop. These models must be checked out against reactors for which dynamic data are available to insure accuracy.

Four general types of improvement are possible, as follows.

1. Incorporation of Parameter Variation with Time

Due to change in temperature, spectrum, etc., this type of improvement was discussed in the previous section.

2. Improved Numerical Representation of Physical Models

Certain of the commonly used numerical approximations are subject to errors. For example, Mason and Winson¹³ discuss several numerical heat and mass transfer models and indicate their inherent errors.

3. Improved Programming Features

The utility of a computer code depends to a large extent on secondary features as well as on the validity of the mathematical and physical models. In addition, improving the integration equations in order to reduce machine running time will permit use of more sophisticated mathematical and physical models in comparable running time. Incorporation of a routine to generate the input data (material densities, specific heat, conductivity, etc), increased flexibility, and improved graphical display of output data all contribute to the usefulness of such a code.

4. Development and Programming of Physical Models

Extension of the simulator into the realm of coolant boiling and fuel melting is a necessity for a complete understanding of the consequences of postulated accidents to the reactor per se and to the public. The work with AIREK 3B indicates that such physical phenomena as coolant buoyancy effects, time dependency of fuel melting, and volumetric expansion are significant in determining the dynamic behavior of reactors during such catastrophies. Models for these effects must be reviewed and incorporated into the dynamic simulator. Calculations using the models can then be compared with experiment and discarded or improved.

Incorporation of the external loop equation is needed for representation of coolant delay times and for flow decay due to pipe rupture, loss of power, etc.

Incorporation of these improvements into AIROS will provide a tool capable of accurate prediction of reactor transient behavior, which can be used as the basis of design, control, and hazards studies.

B. STUDIES OF DYNAMICAL PARAMETERS

Every review of hazards studies cites lack of knowledge of the basic parameters which go into the study as the major uncertainty.^{14, 15} Questions relating to these parameters and their effect on reactor dynamics can be investigated and

resolved. Typical areas of investigation could include: the effect of uncertainties in lifetime, beta, heat transfer coefficients, etc, on the results of postulated accidents; the effect of burnup on these parameters and its effect on safety; the importance of variation of these parameters during a transient due to change of temperature, spectrum, volume, etc; and the best way to calculate these space independent parameters. The results of this study can provide insight into the importance of the errors, and help to set the reliability of future hazards studies. If, for example, the temperature variation of reactivity coefficients is significant in determining the result of a postulated accident, then the code should be so modified.

Studies of dynamical parameters contribute to reactor safety in several ways.

- 1) The results of such studies on specific reactor systems provide intimate knowledge of the effect and uncertainties of design parameters on postulated accidents, thus leading to an overall understanding of their relationship with safety. This understanding will permit more intelligent reactor design and ultimately relieve the present requirement for overdesign of safety features because of lack of knowledge.

- 2) These studies can indicate where future research emphasis should be directed, i. e., which parameters have little effect on the dynamical behavior or ultimately on the results of postulated accidents and which parameters are significant. If uncertainties exist in the method of calculating any of these or if only experiment will provide answer, then the way for future work is clear.

- 3) It will become obvious that the variation of certain of these parameters during a simulated transient must be taken specifically into account. At present it is the practice both in analog and digital dynamics studies to estimate average temperatures, pressures, spectra, etc, from which the parameters of the model (reactivity coefficients, conduction coefficient, lifetime, beta, etc) are calculated. (Only the film coefficient for heat transfer is allowed to vary in the typical hazard study.) In reality, all parameters used vary either directly because of temperature change or indirectly because the space-independent model dictates an average over the energy spectrum which in turn varies.

The result of such studies, then, can lead to improved knowledge of what is important and to the direction for future effort of improvement for AIROS.

V. USE OF CODE

A. INPUT DATA

1. General Information

There must be at least five cards of input data for any case (one each of the following types and in the following order).

a) One and only one title card containing up to 72 characters of alphanumeric information.

b) One or more cards of floating point data. Within this group, cards can be in any order; however, the final card must contain a "1" in Column 1.

c) One or more cards containing integer feedback output information. Within this group, cards can be in any order; however, the final card must contain a "1" in Column 1.

d) One or more cards of floating point feedback coefficients. Within this group, cards can be in any order; however, the final card must contain a "1" in Column 1.

e) One or more cards containing integer feedback connectors. Within this group, cards can be in any order; however, the final card must contain a "1" in Column 1. See Figure 1 for sample deck setup.

2. Detailed Description

a. Title Card - Columns 1 through 72

Up to 72 alphanumeric characters which will appear as the heading at the beginning of the case on the printout and the first 48 will appear as the title on the CRT.

b. Floating Point Data and Feedback Coefficients

Column 1 — left blank unless last card of floating point data (or feedback coefficients), in which case place a "1" in this column.

Column 4 through 6 — relative address of the first piece of data on card. All data following the first piece are stored in consecutively higher addresses; however, if any data field is left blank, no change is made to the data already stored from the previous case.

Figure 1. Sample Deck Setup

Columns 13 through 72 — floating-point data (as many as five numbers) according the format of the FORTRAN FIXED 10 DIGIT DECIMAL DATA sheets, in which case data should have decimal points and may have exponents. (See Appendix E.)

c. Integer Feedback Output Information and Feedback Connectors

Column 1 — left blank unless last card of integer feedback output information (or feedback connectors), in which case place a "1" in this column.

Columns 4 through 6 — relative address of the first piece of data on card. All data following the first piece are stored in consecutively higher addresses; however, if any data field is left blank, no change is made to the data already stored from the previous case.

Columns 13 through 72 — integer data (as many as five numbers) according to the format of the FORTRAN FIXED 10 DIGIT DECIMAL DATA sheets; data must be right-adjusted. (See Appendix E.)

3. Relative Addresses for Floating Point Data

<u>Address</u>	<u>Symbol</u>	<u>Explanation</u> *
1	ND	Number of delayed groups, $ND \leq 15$
2	NF	Number of feedbacks, $NF \leq 100$
3	B	β - delayed fraction (II. A)
4	ELL	ℓ - lifetime (II. A)
5	S	S - source (II. A)
6	ENO	N (0), initial neutron level (III. A)
7	RO	r (0), initial reactivity in dollars (III. A)
8	ϕMO	ω_0 , inverse period - 0 - no inhour calc. (III. A) $\neq 0$ - inhour calc.
9	HI	Initial calculational interval
10	HL	Minimum calculational interval (III. C)
11	HU	Maximum calculational interval (III. C)
12	RST	Restart option (V. B)
13	AL	Lower limit for Q test (III. C)
14	AU	Upper limit for Q test (III. C)
15	SCT	SC4020 output option (V. B)
16	TIMEM	Maximum problem time (III. E)
17	NMIN	N_{min} , startup option (III. D)
18	NMAX	N_{max} , maximum neutron level (III. E)
19	NPRINT	N_{print} , print frequency (V. B)
20	DNT	Delayed neutron output option (V. B)
21	QLO	q (0), initial afterglow heating level (II. E)
22-25†	DL(K)	δ_k , $K = 1, 4$ (II. E)
26	D	<div style="display: inline-block; vertical-align: middle; font-size: 4em; line-height: 1;">{</div> <div style="display: inline-block; vertical-align: middle;"> D D = 0: flow decay from full power D $\neq$ 0: flow decay after scram A flow constants (II. D) C B t: ω </div>
27	A	
28	C	
29	B	
30	TW	

*Reference sections are enclosed in parentheses.

†Hyphen (-) indicates "through".

<u>Address</u>	<u>Symbol</u>	<u>Explanation</u>
31-40		not used
41-43	G(K)	γ_k , $K = 1, 3$ (II. C)
44-50		not used
51-65	W(I)	$W_i(0)$, initial delayed neutron levels (III. A) I = 1, ND address = 51 + (I-1)
66-80	FR(I)	f_i , delayed neutron fractions (II. A) I = 1, ND address = 66 + (I-1)
81-95	EL(I)	λ_i , decay constants (II. A) I = 1, ND address = 81 + (I-1)
96-100		not used
101-200	P(J)	P_j , $J = 1, NF$ (II. B) address = 101 + (J-1)
201-300	U(J)	U_j , $J = 1, NF$ (II. B) address = 201 + (J-1)
301-400	Y(J)	Y_j , $J = 1, NF$ (II. B) address = 301 + (J-1)
401-500	F(J)	$F_j(0)$, initial feedback levels (III. A) J = 1, NF address = 401 + (J-1)
501-600	A(J)	A_j , reactivity feedback coefficients (II. C) J = 1, NF address = 501 + (J-1)
601-700	FM(J)	FM_j , $\begin{cases} >0 \text{ maximum allowed value of } F_j(t) & \text{(III. B)} \\ <0 \text{ scram level for } F_j(t) & \text{(II. C)} \end{cases}$ J = 1, NF address = 601 + (J-1)
701-800	DTAU(J)	τ_j , scram delay time associated with feedback j (II. C) J = 1, NF address = 701 + (J-1)

Note: The final card of this group must contain a "1" in Column 1.

4. Relative Addresses for Integer Feedback Output Information

<u>Address</u>	<u>Symbol</u>	<u>Explanation</u>
1-100	IPRINT (J)	<div style="display: flex; align-items: center;"> <div style="font-size: 4em; margin-right: 10px;">{</div> <div> <p>-1 print F_j ; do not plot (V. B)</p> <p>0 do not print or plot (V. B)</p> <p>M plot F_j on CRT frame M and print it (V. B)</p> </div> </div> <p>$J = 1, NF$ address = J No more than 39 F_j's can be printed and/or displayed.</p>

Note: The final card of this group must contain a "1" in Column 1.

5. Relative Addresses for Floating Point Feedback Coefficients

<u>Address</u>	<u>Symbol</u>	<u>Explanation</u>
1-800	C(J, I)	C_{ij} , heat transfer coefficients (II. B) $I = 1, 8; J = 1, 100$
.....		
1-100	C(J, 1)	$J = 1, NF; I = 1$ address = 1 + (J-1)
101-200	C(J, 2)	$J = 1, NF; I = 2$ address = 101 + (J-1)
201-300	C(J, 3)	$J = 1, NF; I = 3$ address = 201 + (J-1)
301-400	C(J, 4)	$J = 1, NF; I = 4$ address = 301 + (J-1)
401-500	C(J, 5)	$J = 1, NF; I = 5$ address = 401 + (J-1)
501-600	C(J, 6)	$J = 1, NF; I = 6$ address = 501 + (J-1)
601-700	C(J, 7)	$J = 1, NF; I = 7$ address = 601 + (J-1)
701-800	C(J, 8)	$J = 1, NF; I = 8$ address = 701 + (J-1)

Note: The final card of this group must contain a "1" in Column 1.

6. Relative Addresses for Integer Feedback Connectors

<u>Address</u>	<u>Symbol</u>	<u>Explanation</u>
1-800	KC (J, I)	k_{ij} , feedback connectors (II. B) $\begin{cases} >0 \text{ uses } C_{k_{ij}}, j \\ <0 \text{ uses } \dot{\omega} C_{k_{ij}}, j \end{cases}$
.....		
1-100	KC (J, 1)	J = 1, NF; I = 1 address = 1 + (J-1)
101-200	KC (J, 2)	J = 1, NF; I = 2 address = 101 + (J-1)
201-300	KC (J, 3)	J = 1, NF; I = 3 address = 201 + (J-1)
301-400	KC (J, 4)	J = 1, NF; I = 4 address = 301 + (J-1)
401-500	KC (J, 5)	J = 1, NF; I = 5 address = 401 + (J-1)
501-600	KC (J, 6)	J = 1, NF; I = 6 address = 501 + (J-1)
601-700	KC (J, 7)	J = 1, NF; I = 7 address = 601 + (J-1)
701-800	KC (J, 8)	J = 1, NF; I = 8 address = 701 + (J-1)

Note: There is a one-to-one correspondence between the addresses of C (J, I) and KC (J, I); i. e., for two indices K and L, the address of C (K, L) = address of KC (K, L).

The final card of this group must contain a "1" in Column 1.

B. DISCUSSION OF OPTIONS

1. Output

a. Print and/or graphical display option

IPRINT (J), (See V. A)

1) IPRINT (J) = -1, print the J^{th} feedback, but do not plot it.

- 2) IPRINT (J) = 0, do not print or plot the J^{th} feedback.
- 3) IPRINT (J) = M, print the J^{th} feedback and plot it on CRT frame M.

4) For example if,

```
IPRINT (1) = 0
IPRINT (2) = -1
IPRINT (3) = 1
IPRINT (4) = 2
IPRINT (5) = 0
IPRINT (6) = 1
```

then Feedbacks 1 and 5 will not be printed or plotted; Feedback 2 will be printed but not plotted; Feedbacks 3 and 6 will be printed and plotted on the first CRT frame; Feedback 4 will be printed and plotted on the second CRT frame.

b. Print Frequency Option - N_{print} (see V. A)

$N_{\text{print}} = K$, this says store every K^{th} calculation of the output variables for printing and/or plotting. For example if,

$N_{\text{print}} = 1$ every calculation point will be stored

$N_{\text{print}} = 5$ every 5th calculation point will be stored

Since the number of calculation points stored may not exceed 200, N_{print} can be used to increase the system time beyond 200 time-intervals; i. e., the total number of calculations may then = $200 \times N_{\text{print}}$, but the number that may be stored still is 200.

c. Delayed Neutron Output Option - DNT, (see Section V. A)

1) DNT = -1.0, print and plot the first N delayed neutron groups, where $N = \text{MIN}(\text{ND}, 7)$

2) DNT = 0.0, do not print or plot the delayed neutron groups.

3) DNT = 1.0, plot but do not print the first N delayed neutron groups, where $N = \text{MIN}(\text{ND}, 7)$

d. SC4020 Output Option - SCT (see Section V. A)

1) SCT = 1.0, print and plot, power, reactivity, inverse period and delayed neutrons (if requested), from $t = 0$ until the time when $N(t)$ reached

$N_{\min}$ (see Section III. D). Then print and plot power, reactivity, inverse period, and designated feedbacks and delayed neutrons (if requested) from that time until the end of the problem on separate CRT frames.

2) SCT = 2.0, print and plot power, reactivity, inverse period, and delayed neutrons (if requested) from $t = 0$ until the time when $N(t)$ reached $N_{\min}$ (see Section III. D). Then print and plot time, power, reactivity, inverse period, and designated feedbacks and delayed neutrons (if requested) from $t = 0$ until the end of the problem on separate frames.

3) SCT = 3.0, this option says print and plot power, reactivity, inverse period, designated feedbacks, and delayed neutrons (if requested) from $t = 0$ until the end of the problem on one set of CRT frames.

4) SCT = 4.0, this option says print and plot power, reactivity, inverse period, designated feedbacks, and delayed neutrons (if requested) from the time when $N(t)$ reached $N_{\min}$ (see Section III. D) until the end of the problem.

5) SCT = 5.0, print, do not plot power, reactivity, inverse period, designated feedbacks, and delayed neutrons (if requested) from the time when $N(t)$ reached $N_{\min}$ (see III. D) until the end of the problem.

Note: If the $N_{\min} = 0.0$ option is used (see Section III. D) 3 above should be used if plotting is desired, and 5 above should be used if plotting is not desired. In the printout, the column labelled POWER is the sum of prompt and afterglow power, i. e.,

$$\text{POWER} = Q(t) = q(t) + [1 - q(0)] N(t)$$

e. Restart Option - RST (see Section III. E)

1) RST = 1.0, punch restart cards only in the case of a non-normal termination.

2) RST = 2.0, punch restart cards.

3) RST = 3.0, this is a restart case which means punched input will be read in after the normal input (see Figure 1). Restart cards will be punched only in the case of a non-normal termination.*

4) RST = 4.0, this is a restart case which means punched input will be read in after the normal input (see Figure 1). Punch restart cards.*

*For restart cases ϕ_{MO} must be set to 0.0.

2. Multiple Cases

It is very easy to run multiple cases since each case can use the data of the previous case. A minimum of 5 cards must be included for each case (see Section V. A).

- a) Title Card — must be included
- b) Floating Point Data Cards - only changes to the previous case need be included. If there are no changes, this card should have a "1" in Column 1 and a "1" in Column 6; the remaining columns through 72 should be blank.
- c) Integer Feedback Output Information Cards — only changes to the previous case need be included. If there are no changes, this card should have a "1" in Column 1 and a "1" in Column 6; the remaining columns through 72 should be blank.
- d) Floating Point Feedback Coefficient Cards — only changes to the previous case need be included. If there are no changes, this card should have a "1" in Column 1 and a "1" in Column 6; the remaining columns through 72 should be blank.
- e) Integer Feedback Connector Cards — only changes to the previous case need be included. If there are no changes, this card should have a "1" in Column 1 and a "1" in Column 6; the remaining columns through 72 should be blank.
- f) Restart cards (if RST = 3.0 or 4.0) are to be inserted after the integer feedback connector cards.*

C. OPERATING INSTRUCTIONS

AIROS is written in the FORTRAN II language for the IBM 7090/7094 for the NAA FIB III monitor system, and requires an SC 4020 as the graphical display device. Submit a short form requesting K-9 x 9 CRT frames per case where $K = 3 + \text{number of feedback frames} + 1$ if the delayed neutrons CRT option is used. Check "special instructions attached" box, and on the special instructions sheet say "mount tape 12G on B1". Include the following two control cards.

*CHAIN (1, 7)

*DATA

and then your data.

*The first punched card is a copy of the title card so that the case may be identified; this card must be removed before inserting punched cards for restart.

The running time on an IBM 7094 is approximately given by 200 calculation points/second/equation where the number of equations = $1 + ND + NF$, including both printed and graphical output. Approximate running time is 1/2 to 1-1/2 minutes.

AIROS has been converted to FORTRAN IV for the IBM 7094. Operating instructions will be released at such time as IBSYS becomes the standard operating system at North American.

REFERENCES

1. W. B. Green, "A Study of Reactor Kinetics Codes at Atomics International and Their Applicability to SNAP Systems", NAA-SR-TDR-9328 (December 1963)
2. L. R. Blue and M. Hoffman, "AIREK 3 - A Generalized Program for the Numerical Solution of Space Independent Reactor Kinetics Equations", NAA-SR-MEMO-9197 (November 1963)
3. W. A. Rhoades, "The SNAPKIN VI Computer Program for SNAP Reactor Kinetics Calculations", NAA-SR-MEMO-7835 (October 1963)
4. E. R. Cohen, "Some Topics in Reactor Kinetics", Second Geneva Conference Proceedings, p 629 (September 1958)
5. O. D. Seawell, "OSCAI-1: Digital Multi-Channel Nuclear Reactor Transient Simulator Program", AI-MEMO-8296 (March 1963)
6. R. W. Winson, "BOOMER - A Digital Program for Evaluating the Thermal and Kinetics Response of SNAP 2/10A Reactor", NAA-SR-MEMO-8414 (July 1963)
7. R. A. Blaine and R. F. Berland, "Progress to Date Toward the Development of a Generalized Digital Simulator for Reactor Dynamics: AIREK 3A and 3B", NAA-SR-MEMO-9800 (May 1964)
8. L. R. Blue, M. Hoffman and M. Dunenfeld, "AIREK-KEWB", Atomics International AMTD-132 (November 1962)
9. R. A. Blaine, "A Note on the Numerical Solution used in AIREK to find the Void Volume and Pressure in KEWB", Atomics International AMTD-127 (April 1962)
10. R. A. Blaine, "30-THGC, A 30 Node Transient or Steady State Heat Generation Code", NAA-SR-MEMO-9791 (April 1964)
11. J. R. Stehn and E. F. Claury, "Fission Product Radioactivity and Heat Generation", 2nd U. N. Conference on Peaceful Uses of Atomic Energy, Geneva (September 1958)
12. ANL-5800, second edition (July 1963)
13. D. G. Mason and R. W. Winson, "A Reactor Transient Heat Transfer Model", NAA-SR-7938 (March 1964)
14. R. S. Hart and H. H. Cappel, "Principal Uncertainties in Sodium-Graphite Reactor Systems Hazard Evaluation", NAA-SR-TDR-5643 (1959)
15. W. P. Kunkel, "A Survey of the Assumptions and Areas of Uncertainty in OMR Hazards Evaluation", NAA-SR-TDR-6006 (1960)
16. M. Hoffman and W. A. Rhoades, "AICRT-3, A General Code for Display of Digital Data", NAA-SR-MEMO-9069 (October 1963)

(Questions regarding information in unavailable documents should be directed to their authors.)

APPENDIX A

MAIN SYMBOLS

Quantity	Definition
t	Time (sec)
$N(t)$	Prompt neutron level at time t
$\rho(t)$	Total reactivity ($\Delta k/k$) = $\Delta k/k$
β	Effective fraction of delayed neutrons
ℓ	Neutron lifetime (sec)
f_i	Fraction of delayed neutrons in group i
λ_i	Decay constant for delayed neutron precursor group i
$C_i(t)$	Delayed neutron precursor group i concentration at time t
S_0	Source term
F_j	Feedback variables
P_j, U_j, Y_j	Proportionality constants
$r(t)$	Total reactivity in dollars
$W_i(t)$	Normalized delayed neutron precursor group i concentration
S	Normalized source term
A_j	Feedback coefficients in the reactivity equation
γ_1	Time coefficient in the reactivity equation
$\omega(t)$	Inverse reactor period
k_{eff}	Effective multiplication constant
$\alpha_{ij}(t)$	Heat transfer coefficient between feedbacks i and j
$Q(t)$	Sum of neutron level and afterglow heating level (normalized)
ND	Number of delayed neutron precursor groups
NF	Number of feedback equations

Quantity	Definition
$q(t)$	Afterglow heat
$\dot{\omega}(t)$	Mass flow rate
t_s	Time at which a scram occurs
τ_D	Scram delay time

APPENDIX B

NUMERICAL METHOD

Of fundamental importance in reactor dynamics is the ability to follow the time behavior of a reactor including the various physical phenomena which affect the behavior. Although one can solve the space-independent equations (including delayed neutrons) analytically, it is in general not possible to do so if feedbacks are included; hence the necessity for a numerical method. As recently as 1957, the best* numerical method available was Runga-Kutta. This method is severely limited in the size of the time-step because of the existence of a solution of the form $\exp(-\beta t/l)$ where β/l is of order 10^{-2} - 10^{-6} . Thus thousands of calculations were required to follow reactor transients.

During FY 1958, E. R. Cohen developed a numerical procedure which was not so limited.⁴ This procedure is a generalization of Runga-Kutta accounting explicitly for the exponential nature of the solutions, and for the first time provided the industry with a fast reliable method for reactor kinetics calculations. As a result, the first AIREK code was developed. This code, used in one form or another for several years, was reprogrammed in 1962 (AIREK 3)² to take advantage of new programming and graphical display techniques.¹⁶

Special versions of AIREK were used in the KEWB program as tools to verify the physical models postulated to explain radiolytic gas formation, nucleate bubble production, and other feedback mechanisms.^{8, 9} These tools were invaluable in developing an understanding of the phenomenology of KEWB.

AIREK 3 became the standard engineering tool for space-independent reactor kinetics (in addition to analog computation) at Atomics International, throughout the country, and in other parts of the world. The equations solved by AIREK 3 are the usual space-independent equations.²

The code computes about 500 time-points per sec per differential equation on an IBM 7094. For example, a problem with six delayed neutron groups, one feedback equation, $l = 10^{-4}$, 90-cent step reactivity insertion required 66 time-steps (with a maximum step size of 0.2 sec) to follow the transient for 10 sec. The computer time was 1.5 sec for calculation, 1 sec for printed output, and

*Fastest method for a given accuracy.

4 sec for graphical output; the maximum error in the results was less than 0.1%. Thus AIREK 3 will follow rapid transients with a minimum of computer time. Unlike other codes, AIREK 3 also has the ability to take large (~3 sec or more) time-steps when following slow transients.

The numerical method used for the solution of Equations (3), (4), and (8) is described below.

Simplify Equations (1) and (2) of the text, by the following substitutions

$$r(t) = \frac{\rho(t)}{\beta}$$

$$W_i(t) = \frac{\ell \lambda_i C_i(t)}{\beta f_i}$$

$$S = \frac{\ell S_0}{\beta}$$

obtaining Equations (3) and (4) in the text:

$$\dot{N}(t) = \frac{\beta}{\ell} \left[(r(t) - 1) N(t) + \sum_i f_i W_i(t) + S \right]$$

$$W_i(t) = \lambda_i \left[N(t) - W_i(t) \right] \quad \dots (A1)$$

Rewriting Equations (8),

$$F_j(t) = P_j Q(t) + U_j N(0) + Y_j F_j(t) + \sum_i \alpha_{ij}(t) F_{k_{ij}}(t)$$

where $r(t)$ = some known function of t , $N(t)$, A_j and $F_j(t)$.

To facilitate numerical solution, Equation (A1) is further transformed as follows.

$$\dot{N}(t) = \alpha_N N(t) + R_N$$

$$\dot{W}_i = \alpha_{W_i} W_i(t) + R_{W_i}$$

$$F_j = \alpha_{F_j} F_j(t) + R_{F_j} \quad \dots (A2)$$

where

$$\alpha_N = \frac{\beta}{\ell} (r(t) - 1) ; \alpha_{W_i} = -\lambda_{ij} \alpha_{F_j} = Y_j$$

$$R_N = \frac{\beta}{\ell} \left\{ \left[r(t + \xi) - r(t) \right] N(t + \xi) + \sum f_i W_i(t + \xi) + S \right\}$$

$$R_{W_i} = \lambda_i N(t + \xi) ; R_{F_j} = P_j Q(t + \xi) + U_j N(0) + \sum_i \alpha_{ij}(t + \xi) F_{k_{ij}}(t + \xi)$$

and $0 \leq \xi \leq h$ over the time interval h . Now define the function $D_k(x)$ as follows.

For $x < 1$

$$D_3(x) = 2 \sum_{n=0}^{10} \frac{x^n}{(n+3)!}$$

$$D_2(x) = \frac{1}{2} \left[x D_3(x) + 1 \right]$$

$$D_1(x) = x D_2(x) + 1 \quad \dots (A3)$$

For $x \geq 1$

$$D_1(x) = \frac{e^x - 1}{x}$$

$$D_2(x) = \frac{D_1(x) - 1}{x}$$

$$D_3(x) = \frac{2 D_2(x) - 1}{x} \quad \dots (A4)$$

In order to show the numerical procedure used to go from time t to time $t + h$, the process will be written first for the single equation

$$\dot{N}(t) = \alpha N + R$$

(given initial conditions at time t), and then expanded for Equation (A2).

For the equation above, we have

$$N_0 = N(t) ; R_0 = R(N_0, t)$$

$$\delta_1 = \frac{1}{2} h D_1\left(\alpha \frac{h}{2}\right) \left[R_0 + \alpha N_0\right] \quad \dots (A4.0)$$

$$N_1 = N_0 + \delta_1 ; R_1 = R\left(N_1, t + \frac{h}{2}\right)$$

$$\delta_2 = \frac{1}{2} h D_2\left(\alpha \frac{h}{2}\right) \left[R_1 - R_0\right] \quad \dots (A4.1)$$

$$N_2 = N_1 + \delta_2 ; R_2 = R\left(N_2, t + \frac{h}{2}\right)$$

$$\delta_3 = h D_1(\alpha h) \left[R_0 + \alpha N_0\right] + 2 h D_2(\alpha h) \left[R_2 - R_0\right] \quad \dots (A4.2)$$

$$N_3 = N_0 + \delta_3 ; R_3 = R (N_3, t + h)$$

$$\delta_4 = h \left[2 D_3 (\alpha h) - D_2 (\alpha h) \right] \left[R_0 - 2 R_2 + R_3 \right] \quad \dots (A4.3)$$

$$N_4 = N_3 + \delta_4 ; R_4 = R (N_4, t + h)$$

$$\delta_5 = h \left[2 D_3 (\alpha h) - D_2 (\alpha h) \right] \left[R_4 - R_3 \right] \quad \dots (A4.4)$$

$$N (t + h) = N (t) + \delta_3 + \delta_4 + \delta_5 \quad \dots (A4.5)$$

Given $N (t)$, $W_i (t)$ and $F_j (t)$, the equations defining the functional values $N (t + h)$, $W_i (t + h)$ and $F_j (t + h)$ are as follows.

$$N_0 = N (t) ; W_{i0} = W_i (t) ; F_{j0} = F_j (t) ; Q_0 = Q (t)$$

$$R_{N0} = \frac{\beta}{\ell} \left[\sum_i f_i W_{i0} + S \right] ; R_{W_{i0}} = \lambda_i N_0$$

$$R_{F_{j0}} = P_j Q_0 + U_j N (0) + \sum_i \alpha_{ij} F_{k_{ij}0}$$

$$\delta_{N1} = \frac{1}{2} h D_1 \left(\alpha_N \frac{h}{2} \right) \left[R_{N0} + \alpha_N N_0 \right]$$

$$\delta_{W_{i1}} = \frac{1}{2} h D_1 \left(\alpha_{W_i} \frac{h}{2} \right) \left[R_{W_{i0}} + \alpha_{W_i} W_{i0} \right]$$

$$\delta_{F_{j1}} = \frac{1}{2} h D_1 \left(\alpha_{F_j} \frac{h}{2} \right) \left[R_{F_{j0}} + \alpha_{F_j} F_{j0} \right] \quad \dots (A5.0)$$

$$N_1 = N_0 + \delta_{N1} ; W_i 1 = W_i 0 + \delta_{w_i 1} ; F_j 1 = F_j 0 + \delta_{F_j 1} ; Q1 = Q \left(t + \frac{h}{2} \right)$$

$$R_{N1} = \frac{\beta}{\ell} \left\{ \left[r \left(t + \frac{h}{2} \right) - r(t) \right] N1 + \sum_i f_i W_i 1 + S \right\} ; R_{w_i 1} = \lambda_i N1$$

$$R_{F_j 1} = P_j Q1 + U_i N(0) + \sum_j \alpha_{ij} 1 F_{k_{ij} 1}$$

$$\delta_{N2} = \frac{1}{2} h D_2 \left(\alpha_N \frac{h}{2} \right) \left[R_{N1} - R_{N0} \right]$$

$$\delta_{w_i 2} = \frac{1}{2} h D_2 \left(\alpha_{w_i} \frac{h}{2} \right) \left[R_{w_i 1} - R_{w_i 0} \right]$$

$$\delta_{F_j 2} = \frac{1}{2} h D_2 \left(\alpha_{F_j} \frac{h}{2} \right) \left[R_{F_j 1} - R_{F_j 0} \right] \dots (A5.1)$$

$$N_2 = N_1 + \delta_{N2} ; W_i 2 = W_i 1 + \delta_{w_i 2} ; F_j 2 = F_j 1 + \delta_{F_j 2} ; Q_2 = Q \left(t + \frac{h}{2} \right)$$

$$R_{N2} = \frac{\beta}{\ell} \left\{ \left[r \left(t + \frac{h}{2} \right) - r(t) \right] N_2 + \sum_i f_i W_i 2 + S \right\} ; R_{w_i 2} = \lambda_i N_2$$

$$R_{F_i 2} = P_j Q_2 + U_j N(0) + \sum_i \alpha_{ij2} F_{k_{ij} 2}$$

$$\delta_{N3} = h D_1 \left(\alpha_N h \right) \left[R_{N0} + \alpha_N N_0 \right] + 2 h D_2 \left(\alpha_N h \right) \left[R_{N2} - R_{N0} \right]$$

$$\delta_{w_i 3} = h D_1 \left(\alpha_{w_i} h \right) \left[R_{w_i 0} + \alpha_{w_i} W_i 0 \right] + 2 h D_2 \left(\alpha_{w_i} h \right) \left[R_{w_i 2} - R_{w_i 0} \right]$$

$$\delta_{F_j 3} = h D_1 \left(\alpha_{F_j} h \right) \left[R_{F_j 0} + \alpha_{F_j} F_{j0} \right] + 2 h D_2 \left(\alpha_{F_j} h \right) \left[R_{F_j 2} - R_{F_j 0} \right] \dots (A5.2)$$

$$N_3 = N_0 + \delta_{N3} ; W_i^3 = W_i^0 + \delta_{w_i^3} ; F_j^3 = F_j^0 + \delta_{F_j^3} ; Q_3 = Q(t+h)$$

$$R_{N3} = \frac{\beta}{\ell} \left\{ \left[r(t+h) - r(t) \right] N_3 + \sum_i f_i W_i^3 + S \right\} ; R_{w_i^3} = \lambda_i N_3$$

$$R_{F_j^3} = P_j Q_3 + U_j N(0) + \sum_i \alpha_{\ddot{y}^3} F_{k_{\ddot{y}}^3}$$

$$\delta_{N4} = h \left[2 D_3 \left(\alpha_{N^h} \right) - D_2 \left(\alpha_{N^h} \right) \right] \left[R_{N0} - 2 R_{N2} + R_{N3} \right]$$

$$\delta_{w_i^4} = h \left[2 D_3 \left(\alpha_{w_i^h} \right) - D_2 \left(\alpha_{w_i^h} \right) \right] \left[R_{w_i^0} - 2 R_{w_i^2} + R_{w_i^3} \right]$$

$$\delta_{F_j^4} = h \left[2 D_3 \left(\alpha_{F_j^h} \right) - D_2 \left(\alpha_{F_j^h} \right) \right] \left[R_{F_j^0} - 2 R_{F_j^2} + R_{F_j^3} \right] \dots (A5.3)$$

$$N_4 = N_3 + \delta_{N4} ; W_i^4 = W_i^3 + \delta_{w_i^4} ; F_j^4 = F_j^3 + \delta_{F_j^4} ; Q_4 = Q(t+h)$$

$$R_{N4} = \frac{\beta}{\ell} \left\{ \left[r(t+h) - r(t) \right] N_4 + \sum_i f_i W_i^4 + S \right\} ; R_{w_i^4} = \lambda_i N_4$$

$$R_{F_j^4} = P_j Q_4 + U_j N(0) + \sum_i \alpha_{\ddot{y}^4} F_{k_{\ddot{y}}^4}$$

$$\delta_{N5} = h \left[2 D_3 \left(\alpha_{N^h} \right) - D_2 \left(\alpha_{N^h} \right) \right] \left[R_{N4} - R_{N3} \right]$$

$$\delta_{w_i^5} = h \left[2 D_3 \left(\alpha_{w_i^h} \right) - D_2 \left(\alpha_{w_i^h} \right) \right] \left[R_{w_i^4} - R_{w_i^3} \right]$$

$$\delta_{F_j^5} = h \left[2 D_3 \left(\alpha_{F_j^h} \right) - D_2 \left(\alpha_{F_j^h} \right) \right] \left[R_{F_j^4} - R_{F_j^3} \right] \dots (A5.4)$$

$$N(t+h) = N(t) + \delta_{N3} + \delta_{N4} + \delta_{N5}$$

$$W_i(t+h) = W_i(t) + \delta_{w_i3} + \delta_{w_i4} + \delta_{w_i5}$$

$$F_j(t+h) = F_j(t) + \delta_{F_j3} + \delta_{F_j4} + \delta_{F_j5} \quad \dots (A5.5)$$

Equation (A5.5) completes the numerical integration across the time-step h from t to $(t+h)$, thus yielding the values of all variables at $(t+h)$. Now the process may be repeated for the next time interval h with the value of the variables from above as initial conditions.

APPENDIX C

INTERVAL SWITCHING

An important feature in the AIREK and AIROS codes is the automatic interval switching facility; i. e., the time interval, h , is adjusted to satisfy some prescribed condition related to numerical accuracy. The condition which was used in AIREK 3 is lacking, in that only experimentation could determine the error bounds AL and AU as a function of the accuracy desired. Thus it is not clear how to apply this condition to the feedbacks, and there is no guarantee that the bounds giving desired accuracy for one problem would result in the same accuracy for another. Consequently, an attempt was made to relate the error bounds AL and AU to the truncation error on a given step. The procedure, used previously in AIREK 3A and 3B, can be described as follows.

A measure of the truncation error at time $t + h$ is given by E where

$$E_N = \left| \frac{[N^*(t+h) - N(t+h)]}{N(t+h)} \right| \quad \dots (C1)$$

where

t = time

h = present interval

h' = previous interval

$N(t+h)$ = the power as determined by the normal integration scheme based on $N(t)$

and

$N^*(t+h)$ = based on $N(t-h')$ and is a prediction of the value which would have been obtained had the interval been $(h+h')$.

Because of the strong stability inherent in the method, it is assumed that E is the error at time $(t+h)$. Although not highly refined, this technique gives physical meaning to the error bounds (AL and AU).

Calculation of $N^*(t+h)$ is of course the crux of the error test. Although several formulations were attempted, only the most successful is herein reported. The quantities $N(t-h')$, $N(t)$, and $N(t+h)$ are obtained by the numerical procedure described in equation (A4) and we will define $N^*(t+h)$ to be an estimate of the value of $N(t+h)$ based on $N(t-h')$ using an interval $(h'+h)$.

The numerical procedure defined by Equation (A4) can be thought of in the following way: find a function $f(t + \xi)$ expressed as a 2nd-order polynomial, which represents the deviation of $N(t)$ from exponential behavior over the interval $t, t + h$; i. e., we have the equation

$$\dot{N}(t) = \alpha N(t) + R \left[N(t), F_j(t), W_i(t), t \right] \quad \dots (C2)$$

which can be solved formerly by quadrature:

$$N(t + h) = N(t) e^{\alpha h} + \int_0^h R \left(N(t + \xi), F_j(t + \xi), W_i(t + \xi), t + \xi \right) e^{\alpha(h-\xi)} d\xi \quad \dots (C3)$$

Thus the numerical procedure described by Equation (A4) serves to determine the coefficients of such a polynomial by an iterative procedure, and as a result we have

$$f(t + \xi) \sim R \left[N(t + \xi), F_j(t + \xi), W_i(t + \xi), t + \xi \right] \quad , \quad \dots (C4)$$

where

$$f(t + \xi) = R_0 + \frac{\xi}{h} \left[4R_2 - 3R_0 - R_4 \right] + 2 \left(\frac{\xi}{h} \right)^2 \left[R_4 - 2R_2 + R_0 \right] \quad \dots (C5)$$

Substituting Equation (C5) into Equation (C3) gives us Equation (A4.5), which determines $N(t + h)$.

Thus, using Equation (C5) for $f(t + \xi)$, we can predict $N(t + h)$ based on $N(t - h')$ by extending the integration over two intervals h' and h :

$$\begin{aligned}
N^*(t+h) = & N(t-h') + (h+h') D_1 \left[\alpha' (h+h') \right] \left[R_0' + \alpha' N(t-h') \right] \\
& + \frac{(h+h')^2}{h'} D_2 \left[\alpha' (h+h') \right] \left[4 R_2' - 3 R_0' - R_4' \right] \\
& + 2 \frac{(h+h')^3}{h'^2} D_3 \left[\alpha' (h+h') \right] \left[R_0' - 2 R_2' + R_4' \right] \dots (C6)
\end{aligned}$$

One can derive a similar equation for $F_j^*(t+h)$ and define the relative error in the value of the feedback by

$$E_{F_j} = \left| \left[\frac{F_j^*(t+h) - F_j(t+h)}{F_j(t+h)} \right] \right| \dots (C7)$$

The interval size determined in AIROS is based on the following.

let

$$Q = \begin{cases} E_N & ; N(t) < N_{\min} \\ \text{Max} \left\{ E_N, E_{F_j} \right\}_j & ; N(t) \geq N_{\min} \end{cases} \dots (C8)$$

then

if $Q \leq AL$, the interval is doubled;
if $AL < Q < AU$, the interval is unchanged;
if $AU \leq Q$, the interval is halved; and
the calculation is repeated for that interval.

APPENDIX D

SAMPLE HEAT TRANSFER MODEL

Consider a simple nodal heat transfer model consisting of 2 radial nodes and 3 axial nodes, as shown in Figure 2.

Figure 2. Sample Heat Transfer Model

The equations for heat balance for this system can be written as

$$\begin{aligned}
 (\rho C_p V)_c \dot{T}_{j+3}(t) = & + (UA)_{fc} [T_j(t) - T_{j+3}(t)] \\
 & + (\dot{m} C_p)_c [\theta_j(t) - \theta_{j-1}(t)] ; j = 1, 3 \quad \dots (D1)
 \end{aligned}$$

$$(\rho C_p V)_f \dot{T}_j(t) = H_j N(t) + (UA)_{fc} [T_{j+3}(t) - T_j(t)] ; j = 1, 3 \quad \dots (D2)$$

where

$$T_{j+3}(t) = \frac{\theta_j(t) + \theta_{j-1}(t)}{2} ; j = 1, 3 \quad \dots (D3)$$

and

$$\theta_0 = \text{constant}$$

H_j = the volumetric heat generation rate in Btu/sec

$(UA)_{fc}$ = overall heat conduction coefficient (fuel, clad, film) in Btu/sec
between fuel and coolant, same for each node

ρ_j, Cp_j, V_j = density, specific heat and volume of node j

f = subscript for fuel

c = subscript for coolant

In this model we assume that the film coefficient, the overall heat transfer coefficient, and all material properties are constant.

We want to emphasize at this point that the model represented by Equations (D1) through (D3) is used here for illustrative purposes only; many other models will fit into the form represented by Equation (8).

Equations (D1) through (D3) are cast into the form of Equation (8) as follows. Dividing Equations (D1) and (D2) respectively by $(\rho Cp V)_c$ and $(\rho Cp V)_f$, we obtain:

$$\begin{aligned} \dot{T}_{j+3}(t) = & + \frac{(UA)_{fc}}{(\rho Cp V)_c} \left[T_j(t) - T_{j+3}(t) \right] \\ & + \frac{(\dot{\omega} Cp)_c}{(\rho Cp V)_c} \left[\theta_j(t) - \theta_{j-1}(t) \right] ; j = 1, 3 \end{aligned} \quad \dots (D4)$$

and

$$\dot{T}_j(t) = \frac{H_j}{(\rho Cp V)_f} N(t) + \frac{(UA)_{fc}}{(\rho Cp V)_f} \left[T_{j+3}(t) - T_j(t) \right] ; j = 1, 3 \quad \dots (D5)$$

Solving Equation (D3) for $\theta_j(t)$ gives us

$$\theta_j(t) = 2 T_j(t) - \theta_{j-1}(t) \quad \dots (D6)$$

Substituting (D6) into (D1) and rearranging terms, we finally have,

$$\begin{aligned} \dot{T}_4(t) = & \left[\frac{-UA_{fc}}{(\rho C_p V)_c} + 2 \frac{(\dot{\omega} C_p)_c}{(\rho C_p V)_c} \right] T_4(t) + \frac{(UA)_{fc}}{(\rho C_p V)_c} T_1(t) \\ & - 2 \frac{(\dot{\omega} C_p)_c}{(\rho C_p V)_c} \theta_0 \end{aligned} \quad \dots (D7)$$

$$\begin{aligned} \dot{T}_5(t) = & \left[- \frac{UA_{fc}}{(\rho C_p V)_c} + 2 \frac{(\dot{\omega} C_p)_c}{(\rho C_p V)_c} \right] T_5(t) + \frac{(UA)_{fc}}{(\rho C_p V)_c} T_2(t) \\ & - 4 \frac{(\dot{\omega} C_p)_c}{(\rho C_p V)_c} T_4(t) + 2 \frac{(\dot{\omega} C_p)_c}{(\rho C_p V)_c} \theta_0 \end{aligned} \quad \dots (D8)$$

$$\begin{aligned} \dot{T}_6(t) = & \left[- \frac{UA_{fc}}{(\rho C_p V)_c} + 2 \frac{(\dot{\omega} C_p)_c}{(\rho C_p V)_c} \right] T_6(t) + \frac{UA_{fc}}{(\rho C_p V)_c} T_3(t) \\ & - 4 \frac{(\dot{\omega} C_p)_c}{(\rho C_p V)_c} T_5(t) + \frac{4(\dot{\omega} C_p)_c}{(\rho C_p V)_c} T_4(t) - 2 \frac{(\dot{\omega} C_p)_c}{(\rho C_p V)_c} \theta_0 \end{aligned} \quad \dots (D9)$$

Identifying terms of Equations (D5) and (D7) through (D9) with Equation (8) and letting

$$\dot{T}_7(t) = 0 \quad \dots (D10)$$

with

$$T_7(0) = \theta_0 \quad ,$$

we obtain the following table.

TABLE 2
COEFFICIENTS FOR EQUATION 8

j	1-3	4	5	6	7
P_j	$\frac{H_j}{(\rho C_p V)_f}$	0	0	0	0
U_j	0	0	0	0	0
Y_j	$\frac{-UA_{fc}}{(\rho C_p V)_f}$	$\frac{-UA_{fc} + 2 \dot{\omega} C_p}{(\rho C_p V)_c}$	$\frac{-UA_{fc} + 2 \dot{\omega} C_p}{(\rho C_p V)_c}$	$\frac{-UA_{fc} + 2 \dot{\omega} C_p}{(\rho C_p V)_c}$	0
α_{1j}	$\frac{UA_{fc}}{(\rho C_p V)_f}$	$\frac{UA_{fc}}{(\rho C_p V)_c}$	$\frac{UA_{fc}}{(\rho C_p V)_c}$	$\frac{UA_{fc}}{(\rho C_p V)_c}$	0
α_{2j}	0	$-2 \left(\frac{\dot{\omega} C_p}{\rho C_p V} \right)_c$	$-4 \left(\frac{\dot{\omega} C_p}{\rho C_p V} \right)_c$	$-4 \left(\frac{\dot{\omega} C_p}{\rho C_p V} \right)_c$	0
α_{3j}	0	0	$+2 \left(\frac{\dot{\omega} C_p}{\rho C_p V} \right)_c$	$+4 \left(\frac{\dot{\omega} C_p}{\rho C_p V} \right)_c$	0
α_{4j}	0	0	0	$-2 \left(\frac{\dot{\omega} C_p}{\rho C_p V} \right)_c$	0
k_{1j}	j+3	1	2	3	0
k_{2j}	0	7	4	5	0
k_{3j}	0	0	7	4	0
k_{4j}	0	0	0	7	0
$T_j (0)$	$T_j (0)$	$T_4 (0)$	$T_5 (0)$	$T_6 (0)$	θ_0

In filling out the data sheets, the α_{ij} 's containing $\dot{\omega}$ as a factor are identified by a minus sign in front of k_{ij} . Consequently, Y_j , $j = 4, 6$ should be set equal to

$$-\frac{(UA)_{fc}}{(\rho CpV)_c}, \quad \alpha_{34} = \alpha_{45} = \alpha_{56} = \frac{2 Cp_c}{(\rho CpV)_c} \quad .$$

Drop the factor $\dot{\omega}$ from all terms, and set

$$k_{34} = -4, k_{45} = -5, k_{56} = -6, k_{24} = -7, k_{25} = -4, k_{35} = -7,$$

$$k_{26} = -5, k_{36} = -4, k_{46} = -7 \quad .$$

See Section V. A for more detail.

An input generation program is presently under preparation which can generate the α_{ij} , k_{ij} , P_j , U_j , etc, based on an N X M nodal net, given the material in each radial column and certain other data. This program will be available separately or optionally as a part of AIROS.

APPENDIX E
SAMPLE INPUT SHEETS

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER _____ DATE _____ PAGE 1 of 6 JOB NO. _____

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	A I R Ø S - F A S T S		Title
13	H I M R Ø D W I T H		
25	D R A W A L F R Ø M		
37	F U L L P Ø W E R		
49		73 80	
61		1 0	
1	1		Floating Point Data
13	6 . 0		ND
25	3 4 . 0		NF
37	7 . 0 - 0 3		B
49	5 . 0 - 0 4	73 80	ELL
61	0 . 0	2 0	S
1	6		
13	1 . 0		ENO
25	0 . 0		RO
37	0 . 0		ØMO
49	2 . 0 - 0 1	73 80	HI
61	1 . 0 - 0 5	3 0	HL
1	1 1		
13	2 . 0 - 0 1		HU
25	1 . 0		RST
37	1 . 0 - 0 2		AL
49	1 . 0 - 0 1	73 80	AU
61	3 . 0	4 0	SCT

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER _____ DATE _____ PAGE 2 of 6 JOB NO. _____

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	1 6		
13	3 0 . 0		TIMEM
25	0 . 0		NMIN
37	1 . 0 + 1 0		NMAX
49	1 . 0	73 80	NPRINT
61	0 . 0	5 0	DNT
1	2 1		
13	0 . 0 4 2		QL0
25	0 . 0 3 0 5		DL (1)
37	0 . 0 1 1 5		DL (2)
49	- 2 . 3 - 0 3	73 80	DL (3)
61	- 6 . 9 - 0 2	6 0	DL (4)
1	2 6		
13	1 . 0		D
25	0 . 9 4		A
37	0 . 0 6		C
49	- 0 . 4 2 5	73 80	B
61	0 . 0 7	7 0	TW
1	4 1		
13	1 . 3 5 - 0 2		G (1)
25	- 1 . 6 4 2 9 + 0 1		G (2)
37	4 . 2 2		G (3)
49		73 80	
61		8 0	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER _____ DATE _____ PAGE 3 of 6 JOB NO. _____

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	5 1		
13	1 . 0		W (1)
25	1 . 0		'
37	1 . 0		'
49	1 . 0	73 80	'
61	1 . 0	9 0	etc.
1	1 0 1		
13	1 0 9 . 5		P (1)
25	1 5 0 . 6		'
37	1 0 9 . 5		'
49		73 80	'
61		1 0 0	etc.
1	3 0 1		
13	- 3 . 5 8 7 - 0 1		Y (1)
25	- 3 . 5 8 7 - 0 1		'
37	- 3 . 5 8 7 - 0 1		'
49	- 6 . 2 7 4 - 0 1	73 80	'
61	- 6 . 2 7 4 - 0 1	3 0 0	etc.
1	4 0 1		
13	9 9 1 . 7		F (1)
25	1 2 8 2 . 5		'
37	1 3 7 9 . 2		'
49	8 1 3 . 5	73 80	'
61	1 0 3 7 . 5	4 0 0	etc.

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER _____ DATE _____ PAGE 4 of 6 JOB NO. _____

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	5 0 1		
13	- 2 . 7 5 7 - 0 4		A (1)
25	- 5 . 3 8 5 - 0 4		'
37	- 2 . 7 5 7 - 0 4		'
49	1 . 0 4 6 - 0 4	73 80	'
61	1 . 0 4 6 - 0 4	5 0 0	etc.
1	6 3 2		
13	- 1 . 2 5		FM (32)
25	- 1 2 0 0 . 0		'
37	- 1 2 5 0 . 0		'
49		73 80	'
61		6 0 0	etc.
1	1 7 3 2		Last card of floating point data
13	2 . 0 - 0 2		DTAU (32)
25	2 . 0 - 0 2		'
37	2 . 0 - 0 2		'
49		73 80	'
61		7 0 0	
1	1		Integer Feedback Output Information
13			IPRINT (1)
25	1		'
37	2		'
49		73 80	'
61		1 0 0 0	etc.

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER _____ DATE _____ PAGE 5 of 6 JOB NO. _____

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	1 3 0		Last card of Integer Feedback Output Information
13		3	IPRINT (30)
25			
37			
49		73 80	
61		1 1 0 0	
1	1		Floating Point Feedback Coefficients
13	- 6 . 3 3 - 0 2		C (1, 1)
25	- 6 . 3 3 - 0 2		C (2, 1)
37	- 6 . 3 3 - 0 2		'
49	- 2 . 0 0 5 6	73 80	'
61	- 2 . 0 0 5 6	2 0 0 0	etc.
1	1 5 2 5		Last card of Floating Point Feedback Coefficients
13	5 . 3 8 5		C (25, 6)
25	5 . 3 8 5		C (26, 6)
37	5 . 3 8 5		C (27, 6)
49		73 80	
61		2 5 0 0	
1	1		Integer Feedback Connectors
13		1	KC (1, 1)
25		2	KC (2, 1)
37		3	'
49		4	'
61		5	etc.

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. _____ PROGRAMMER _____ DATE _____ PAGE 6 of 6 JOB NO. _____

	NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	1 5 2 5		Last card of Integer Feedback Connectors
13	- 3 1		KC (25, 6)
25	- 2 8		KC (26, 6)
37	- 2 9		KC (27, 6)
49		73 80	
61		3 5 0 0	
1			
13			
25			
37			
49		73 80	
61			
1			
13			
25			
37			
49		73 80	
61			
1			
13			
25			
37			
49		73 80	
61

APPENDIX F
PRINTED RESULTS

AIR0S-FAST SHIM RCD WITHDRAWAL FROM FULL POWER

.0135\$/SEC.

CONTROL INFO DD(1) TC DD(50)

1	6.000000E 00	3.400000E 01	7.000000E-03	5.000000E-04	C.
6	1.000000E 00	0.	0.	2.000000E-01	1.000000E-05
11	2.000000E-01	1.000000E 00	10.000000E-03	1.000000E-01	3.000000E 00
16	3.000000E 01	0.	1.000000E 10	1.000000E 00	C.
21	4.200000E-02	3.050000E-02	1.150000E-02	-2.300000E-03	-6.900000E-02
26	1.000000E 00	9.400000E-01	6.000000E-02	-4.250000E-01	7.000000E-02
31	C.	0.	0.	0.	C.
36	C.	0.	0.	C.	C.
41	1.350000E-02	-1.642900E 01	4.220000E 00	0.	C.
46	C.	0.	0.	0.	C.

PRE-CLRSOR INFO DD(51) TC DD(95)

51	1.000000E 00	1.000000E 00	1.000000E 00	1.000000E 00	1.000000E 00	1.000000E 00
66	3.297000E-02	2.194000E-01	1.960000E-01	3.947000E-01	1.150000E-01	4.193000E-02
81	1.240000E-02	3.050000E-02	1.110000E-01	3.010000E-01	1.130000E 00	3.000000E 00

FEEDBACK INFO DD(101) TC DD(900)

101	1.095000E 02	1.506000E 02	1.095000E 02	0.	C.
	C.	2.950000E-01	4.050000E-01	2.950000E-01	C.
	C.	0.	6.260000E 02	8.580000E 02	6.260000E 02
	C.	0.	0.	0.	C.
	C.	3.640000E 02	5.000000E 02	3.640000E 02	C.
	C.	0.	0.	0.	C.
	C.	3.333000E 01	0.	0.	
201	C.	0.	0.	0.	0.
	C.	0.	0.	0.	C.
	C.	0.	0.	0.	C.
	C.	0.	0.	0.	C.
	C.	0.	0.	0.	C.
	C.	0.	0.	0.	C.
	C.	0.	0.	0.	C.
301	-3.587000E-01	-3.587000E-01	-3.587000E-01	-6.274000E-01	-6.274000E-01
	-6.274000E-01	-1.142000E-02	-1.142000E-02	-1.142000E-02	-2.845000E-01
	-2.845000E-01	-2.845000E-01	-8.340000E-01	-8.340000E-01	-8.340000E-01
	-7.100000E 00	-7.100000E 00	-7.100000E 00	-7.410000E-01	-7.410000E-01

NAA-SR-9943
70

-7.410000E-C1	-5.860000E-01	-5.860000E-01	-5.860000E-01	-9.520000E CC
-9.520000E CC	-9.520000E 00	-1.110000E 00	-1.110000E 00	-1.110000E CC
C.	-3.333000E 01	-1.000000E 00	-1.000000E 00	
4C1				
9.917000E C2	1.282500E 03	1.379200E 03	8.135000E C2	1.037500E C3
1.201000E C3	7.576000E 02	9.609000E 02	1.145100E 03	8.135000E C2
1.037500E C3	1.201000E 03	1.595800E 03	2.093000E 03	1.943100E 03
8.452000E C2	1.064200E 03	1.192500E 03	7.965000E 02	9.973000E 02
1.143800E C3	1.431200E 03	1.881300E 03	1.806800E 03	8.101000E C2
1.028100E C3	1.185700E 03	8.083000E 02	1.025600E 03	1.183900E C3
6.500000E C2	1.000000E 00	1.143000E 03	1.201000E 03	
5C1				
-2.757000E-C4	-5.385000E-04	-2.757000E-04	1.046000E-04	1.046000E-C4
3.540000E-C5	9.540000E-05	1.866000E-04	9.540000E-05	2.764000E-C4
2.764000E-C4	9.360000E-05	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
1.265000E-C4	0.	0.	0.	
6C1				
10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34
10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34
10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34
10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34
10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34
10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34
10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34
10.000000E 34	-1.250000E 00	-1.200000E 03	-1.250000E 03	
7C1				
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	2.000000E-02	2.000000E-02	2.000000E-02	
8C1				
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	

FEEDBACK PRINT AND CRT INFO IPRINT(1) TO IPRINT(100)

1								
	0	1	2	C		C		
	3	0	0	0		C		
	C	3	0	1		2		
	C	0	0	C		C		
	3	0	1	2		C		
	C	0	0	C		3		
	C	0	0	0				
FEEDBACK CONNECTORS AND COEFFICIENTS KC(1) TO KC(800) AND C(1) TO C(800)								
1	-1	4	-4	31	-31	0	0	0
	-6.33CCE-C2	1.7940E-01	3.1700E-02	1.7940E-01	3.1700E-02	C.	C.	0.
2	-2	5	-5	4	-4	0	C	0
	-6.33CCE-C2	1.7940E-01	3.1700E-02	1.7940E-01	3.1700E-02	C.	C.	0.
3	-3	6	-6	5	-5	0	0	0
	-6.33CCE-C2	1.7940E-01	3.1700E-02	1.7940E-01	3.1700E-02	C.	C.	0.
4	-4	31	-31	1	-1	7	C	0
	-2.0056E CC	-6.2740E-01	1.8280E 00	1.0050E 00	1.7740E-01	2.5000E-C1	C.	0.
5	-5	4	-4	2	-2	8	0	0
	-2.0056E CC	-6.2740E-01	1.8280E 00	1.0050E 00	1.7740E-01	2.5000E-C1	C.	0.
6	-6	5	-5	3	-3	9	C	0
	-2.0056E CC	-6.2740E-01	1.8280E 00	1.0050E 00	1.7740E-C1	2.5000E-C1	C.	0.
7	4	31	10	0	0	C	0	0
	1.94CCE-C3	5.7200E-03	3.7800E-03	0.	0.	C.	C.	0.
8	5	4	11	10	0	0	C	0
	1.94CCE-C3	1.9400E-03	3.7800E-03	3.7800E-03	0.	C.	C.	0.
9	6	5	12	11	0	0	0	0
	1.94CCE-C3	1.9400E-03	3.7800E-03	3.7800E-03	0.	C.	C.	0.
10	-10	7	31	-31	0	0	0	0
	-9.01CCE-C2	5.6900E-01	-2.8450E-01	9.0100E-02	0.	C.	C.	0.
11	-11	8	10	-10	0	0	0	0
	-9.01CCE-C2	5.6900E-01	-2.8450E-01	9.0100E-02	0.	C.	C.	0.
12	-12	9	11	-11	0	0	C	0
	-9.01CCE-C2	5.6900E-01	-2.8450E-01	9.0100E-02	0.	C.	C.	0.
13	16	0	0	0	0	0	0	0
	8.34CCE-C1	C.	0.	0.	0.	C.	C.	0.
14	17	0	0	0	0	0	0	0
	8.34CCE-C1	C.	0.	0.	0.	C.	C.	0.
15	18	0	0	0	0	0	0	0
	8.34CCE-C1	C.	0.	0.	0.	C.	C.	0.
16	-16	13	19	-19	31	-31	0	0
	-7.56CCE CC	2.0500E 00	2.5250E 00	3.7800E 00	2.5250E 00	3.7800E CC	C.	0.
17	-17	14	20	-20	19	-19	0	0
	-7.56CCE CC	2.0500E 00	2.5250E 00	3.7800E 00	2.5250E 00	3.7800E CC	C.	0.

18	-18	15	21	-21	20	-20	0	0
	-7.560CE CC	2.0500E 00	2.5250E 00	3.7800E 00	2.5250E 00	3.7800E CC	C.	0.
19	-19	16	-16	31	-31	0	C	0
	-4.204CE CC	1.4820E 00	2.2280E 00	-7.4100E-01	1.9760E 00	C.	C.	0.
20	-20	17	-17	19	-19	0	0	0
	-4.204CE CC	1.4820E 00	2.2280E 00	-7.4100E-01	1.9760E 00	C.	C.	0.
21	-21	18	-18	20	-20	0	C	0
	-4.204CE CC	1.4820E 00	2.2280E 00	-7.4100E-01	1.9760E 00	C.	C.	0.
22	25	0	0	0	0	0	0	0
	5.860CE-C1	C.	0.	0.	0.	C.	C.	0.
23	26	0	0	0	0	0	C	0
	5.860CE-C1	0.	0.	0.	0.	C.	0.	0.
24	27	0	0	0	0	0	0	0
	5.860CE-C1	0.	0.	0.	0.	C.	C.	0.
25	-25	22	28	-28	31	-31	C	0
	-1.077CE C1	2.340CE 00	3.5900E 00	5.3850E 00	3.5900E 00	5.3850E CC	C.	0.
26	-26	23	29	-29	28	-28	C	0
	-1.077CE C1	2.3400E 00	3.5900E 00	5.3850E 00	3.5900E CC	5.3850E CC	C.	0.
27	-27	24	30	-30	29	-29	C	0
	-1.077CE C1	2.340CE 00	3.5900E 00	5.3850E 00	3.5900E 00	5.3850E CC	C.	0.
28	-28	25	-25	31	-31	0	0	0
	-4.505CE CC	2.2200E 00	3.3300E 00	-1.1100E 00	1.1750E 00	C.	C.	0.
29	-29	26	-26	28	-28	0	C	0
	-4.505CE CC	2.2200E 00	3.3300E 00	-1.1100E 00	1.1750E 00	C.	C.	0.
30	-30	27	-27	29	-29	0	C	0
	-4.505CE CC	2.2200E 00	3.3300E 00	-1.1100E 00	1.1750E 00	C.	C.	0.
31	0	0	0	0	0	0	C	0
	C.	0.	0.	0.	0.	C.	C.	0.
32	0	0	0	0	0	0	0	0
	C.	C.	0.	0.	0.	C.	C.	0.
33	21	0	0	0	0	0	C	0
	1.000CE CC	C.	0.	0.	0.	C.	C.	0.
34	6	0	0	0	0	0	C	0
	1.000CE CC	0.	0.	0.	0.	C.	C.	0.

MAXIMUM TIME EXCEEDED

AIROS-FAST SHIM ROD WITHDRAWAL FROM FULL POWER

.0125%/SEC.

TIME	POWER	REACTIVITY	INV.PERIOD	F 2	F 3	F 6	F 12
C.	1C.0000E-01	0.	-2.0862E-07	1.2825E C3	1.3752E C3	1.201CE C3	1.2010E 03
2.CCCCE-C1	1.0017E 00	2.6979E-03	1.3049E-02	1.2826E 03	1.3752E 03	1.2011E C3	1.2010E 03
4.CCCCE-C1	1.0044E 00	5.3152E-03	1.4301E-02	1.2827E 03	1.3753E 03	1.2012E C3	1.2010E 03
6.CCCCE-C1	1.0072E 00	7.8563E-03	1.4781E-02	1.2829E 03	1.3755E 03	1.2013E C3	1.2010E 03
8.CCCCE-C1	1.0101E 00	1.0329E-02	1.5155E-02	1.2832E C3	1.3757E C3	1.2014E C3	1.2010E 03
10.CCCCE-C1	1.0130E 00	1.2738E-02	1.5479E-02	1.2835E 03	1.3759E 03	1.2016E C3	1.2010E 03
1.2CCCE CC	1.0160E 00	1.5088E-02	1.5764E-02	1.2839E 03	1.3803E 03	1.2018E C3	1.2010E 03
1.4CCCE CC	1.0191E 00	1.7382E-02	1.6018E-02	1.2844E C3	1.3806E 03	1.2020E C3	1.2010E 03
1.6CCCE CC	1.0223E 00	1.9621E-02	1.6244E-02	1.2850E C3	1.3810E 03	1.2022E C3	1.2010E 03
1.8CCCE CC	1.0255E 00	2.1807E-02	1.6448E-02	1.2856E C3	1.3815E 03	1.2025E C3	1.2010E 03
2.CCCCE CC	1.0287E 00	2.3942E-02	1.6630E-02	1.2862E C3	1.3821E 03	1.2028E C3	1.2010E 03
2.2CCCE CC	1.0320E 00	2.6026E-02	1.6795E-02	1.2870E C3	1.3826E 03	1.2031E C3	1.2010E 03
2.4CCCE CC	1.0353E 00	2.8062E-02	1.6942E-02	1.2878E C3	1.3833E 03	1.2035E C3	1.2010E 03
2.6CCCE CC	1.0387E 00	3.0049E-02	1.7077E-02	1.2886E C3	1.3840E 03	1.2039E C3	1.2010E 03
2.8CCCE CC	1.0421E 00	3.1990E-02	1.7199E-02	1.2895E 03	1.3847E 03	1.2044E C3	1.2010E 03
3.CCCCE CC	1.0456E 00	3.3886E-02	1.7308E-02	1.2905E C3	1.3855E 03	1.2049E C3	1.2010E 03
3.2CCCE CC	1.0490E 00	3.5737E-02	1.7408E-02	1.2915E C3	1.3863E 03	1.2054E C3	1.2010E 03
3.4CCCE CC	1.0525E 00	3.7545E-02	1.7499E-02	1.2925E 03	1.3872E 03	1.2060E C3	1.2010E 03
3.6CCCE CC	1.0561E 00	3.9311E-02	1.7581E-02	1.2936E C3	1.3881E 03	1.2066E C3	1.2010E 03
3.8CCCE CC	1.0596E 00	4.1035E-02	1.7656E-02	1.2948E C3	1.3891E 03	1.2073E C3	1.2010E 03
4.CCCCE CC	1.0632E 00	4.2720E-02	1.7724E-02	1.2960E 03	1.3902E C3	1.2080E C3	1.2011E 03
4.2CCCE CC	1.0668E 00	4.4366E-02	1.7786E-02	1.2973E 03	1.3912E 03	1.2087E C3	1.2011E 03
4.4CCCE CC	1.0705E 00	4.5974E-02	1.7842E-02	1.2986E C3	1.3924E 03	1.2094E C3	1.2011E 03
4.6CCCE CC	1.0742E 00	4.7545E-02	1.7894E-02	1.2999E C3	1.3935E 03	1.2102E C3	1.2011E 03
4.8CCCE CC	1.0778E 00	4.9080E-02	1.7940E-02	1.3013E 03	1.3947E 03	1.2111E C3	1.2011E 03
5.CCCCE CC	1.0816E 00	5.0581E-02	1.7983E-02	1.3027E C3	1.3960E 03	1.2119E C3	1.2011E 03
5.2CCCE CC	1.0853E 00	5.2048E-02	1.8021E-02	1.3042E C3	1.3973E 03	1.2128E C3	1.2011E 03
5.4CCCE CC	1.0890E 00	5.3482E-02	1.8056E-02	1.3057E C3	1.3987E 03	1.2137E C3	1.2011E 03
5.6CCCE CC	1.0928E 00	5.4884E-02	1.8088E-02	1.3072E C3	1.4000E 03	1.2147E C3	1.2011E 03
5.8CCCE CC	1.0966E 00	5.6256E-02	1.8116E-02	1.3088E 03	1.4015E 03	1.2157E C3	1.2012E 03
6.CCCCE CC	1.1004E 00	5.7598E-02	1.8142E-02	1.3104E 03	1.4029E 03	1.2167E C3	1.2012E 03
6.2CCCE CC	1.1043E 00	5.8910E-02	1.8165E-02	1.3121E C3	1.4044E C3	1.2177E C3	1.2012E 03
6.4CCCE CC	1.1081E 00	6.0194E-02	1.8187E-02	1.3137E C3	1.4060E 03	1.2188E C3	1.2012E 03
6.6CCCE CC	1.1120E 00	6.1451E-02	1.8205E-02	1.3154E 03	1.4076E 03	1.2199E C3	1.2012E 03
6.8CCCE CC	1.1159E 00	6.2681E-02	1.8222E-02	1.3172E 03	1.4092E 03	1.2210E C3	1.2012E 03

AIROS-FAST SHIP RCD WITHDRAWAL FROM FULL POWER

.0135\$/SEC.

TIME	POWER	REACTIVITY	INV.PERIOD	F 2	F 3	F 6	F 12
7.0000E 00	1.1198E 00	6.3886E-02	1.8237E-02	1.3190E 03	1.4108E 03	1.2221E C3	1.2013E 03
7.2000E 00	1.1237E 00	6.5065E-02	1.8251E-02	1.3208E 03	1.4125E 03	1.2233E C3	1.2013E 03
7.4000E 00	1.1276E 00	6.6220E-02	1.8263E-02	1.3226E 03	1.4143E 03	1.2245E C3	1.2013E 03
7.6000E 00	1.1316E 00	6.7352E-02	1.8273E-02	1.3244E 03	1.4160E 03	1.2257E C3	1.2013E 03
7.8000E 00	1.1356E 00	6.8461E-02	1.8282E-02	1.3263E 03	1.4178E 03	1.2269E C3	1.2013E 03
8.0000E 00	1.1396E 00	6.9547E-02	1.8290E-02	1.3282E 03	1.4196E 03	1.2282E C3	1.2014E 03
8.2000E 00	1.1436E 00	7.0612E-02	1.8296E-02	1.3302E 03	1.4215E 03	1.2295E C3	1.2014E 03
8.4000E 00	1.1476E 00	7.1656E-02	1.8303E-02	1.3321E 03	1.4234E 03	1.2308E C3	1.2014E 03
8.6000E 00	1.1516E 00	7.2679E-02	1.8307E-02	1.3341E 03	1.4253E 03	1.2321E C3	1.2014E 03
8.8000E 00	1.1557E 00	7.3683E-02	1.8311E-02	1.3361E 03	1.4272E 03	1.2335E C3	1.2015E 03
9.0000E 00	1.1598E 00	7.4668E-02	1.8314E-02	1.3381E 03	1.4292E 03	1.2348E C3	1.2015E 03
9.2000E 00	1.1638E 00	7.5633E-02	1.8316E-02	1.3402E 03	1.4312E 03	1.2362E C3	1.2015E 03
9.4000E 00	1.1679E 00	7.6581E-02	1.8317E-02	1.3422E 03	1.4332E 03	1.2376E C3	1.2016E 03
9.6000E 00	1.1721E 00	7.7511E-02	1.8317E-02	1.3443E 03	1.4353E 03	1.2390E C3	1.2016E 03
9.8000E 00	1.1762E 00	7.8424E-02	1.8317E-02	1.3464E 03	1.4374E 03	1.2405E C3	1.2016E 03
10.0000E 00	1.1803E 00	7.9320E-02	1.8317E-02	1.3486E 03	1.4395E 03	1.2419E C3	1.2017E 03
1.0200E 01	1.1845E 00	8.0200E-02	1.8315E-02	1.3507E 03	1.4416E 03	1.2434E C3	1.2017E 03
1.0400E 01	1.1832E 00	6.9117E-02	-8.8988E-02	1.3528E 03	1.4437E 03	1.2449E C3	1.2017E 03
1.0500E 01	1.0708E 00	-2.2431E-01	-2.7870E 00	1.3533E 03	1.4444E 03	1.2463E C3	1.2018E 03
1.0550E 01	8.6716E-01	-7.2317E-01	-6.2876E 00	1.3524E 03	1.4439E 03	1.2473E C3	1.2018E 03
1.0575E 01	7.2899E-01	-1.1231E 00	-8.3690E 00	1.3513E 03	1.4431E 03	1.2479E C3	1.2019E 03
1.0600E 01	5.8589E-01	-1.6487E 00	-1.0232E 01	1.3497E 03	1.4420E 03	1.2484E C3	1.2019E 03
1.0625E 01	4.5620E-01	-2.3173E 00	-1.1390E 01	1.3475E 03	1.4406E 03	1.2490E C3	1.2019E 03
1.0650E 01	3.5227E-01	-3.1426E 00	-1.1523E 01	1.3450E 03	1.4388E 03	1.2496E C3	1.2020E 03
1.0675E 01	2.7633E-01	-4.1325E 00	-1.0791E 01	1.3422E 03	1.4368E 03	1.2501E C3	1.2020E 03
1.0700E 01	2.2323E-01	-5.2865E 00	-9.7013E 00	1.3392E 03	1.4347E 03	1.2507E C3	1.2020E 03
1.0725E 01	1.8605E-01	-6.5935E 00	-8.6282E 00	1.3360E 03	1.4325E 03	1.2512E C3	1.2021E 03
1.0750E 01	1.5945E-01	-8.0287E 00	-7.6522E 00	1.3328E 03	1.4303E 03	1.2517E C3	1.2021E 03
1.0775E 01	1.4003E-01	-9.5520E 00	-6.7335E 00	1.3295E 03	1.4280E 03	1.2522E C3	1.2022E 03
1.0800E 01	1.2570E-01	-1.1106E 01	-5.8308E 00	1.3263E 03	1.4257E 03	1.2527E C3	1.2022E 03
1.0825E 01	1.1509E-01	-1.2616E 01	-4.9175E 00	1.3230E 03	1.4234E 03	1.2531E C3	1.2023E 03
1.0850E 01	1.0732E-01	-1.3993E 01	-3.9732E 00	1.3197E 03	1.4211E 03	1.2535E C3	1.2023E 03
1.0875E 01	1.0181E-01	-1.5135E 01	-2.9789E 00	1.3164E 03	1.4188E 03	1.2539E C3	1.2024E 03
1.0900E 01	9.8198E-02	-1.5936E 01	-1.9141E 00	1.3132E 03	1.4166E 03	1.2543E C3	1.2025E 03
1.0925E 01	9.6303E-02	-1.6294E 01	-7.5494E-01	1.3100E 03	1.4143E 03	1.2546E C3	1.2025E 03

AIROS-FAST SHIM RCD WITHDRAWAL FROM FULL POWER

.0135\$/SEC.

TIME	POWER	REACTIVITY	INV.PERIOD	F 2	F 3	F 6	F 12
1.095CE 01	9.5738E-02	-1.6302E 01	-2.8583E-01	1.3068E 03	1.4121E 03	1.2550E C3	1.2026E 03
1.100CE 01	9.4921E-02	-1.6296E 01	-2.8378E-01	1.3006E 03	1.4078E 03	1.2556E C3	1.2027E 03
1.110CE 01	9.3389E-02	-1.6284E 01	-2.6593E-01	1.2885E 03	1.3954E 03	1.2565E C3	1.2030E 03
1.120CE 01	9.1980E-02	-1.6273E 01	-2.5099E-01	1.2770E 03	1.3914E 03	1.2573E C3	1.2033E 03
1.130CE 01	9.0674E-02	-1.6263E 01	-2.3826E-01	1.2661E 03	1.3838E 03	1.2579E C3	1.2036E 03
1.140CE 01	8.9455E-02	-1.6252E 01	-2.2731E-01	1.2555E 03	1.3765E 03	1.2584E C3	1.2040E 03
1.150CE 01	8.8311E-02	-1.6243E 01	-2.1781E-01	1.2455E 03	1.3696E 03	1.2587E C3	1.2043E 03
1.160CE 01	8.7232E-02	-1.6233E 01	-2.0949E-01	1.2359E 03	1.3629E 03	1.2590E C3	1.2047E 03
1.170CE 01	8.6210E-02	-1.6224E 01	-2.0213E-01	1.2266E 03	1.3565E 03	1.2591E C3	1.2051E 03
1.180CE 01	8.5239E-02	-1.6216E 01	-1.9558E-01	1.2178E 03	1.3504E 03	1.2593E C3	1.2055E 03
1.190CE 01	8.4313E-02	-1.6207E 01	-1.8970E-01	1.2093E 03	1.3446E 03	1.2594E C3	1.2059E 03
1.200CE 01	8.3428E-02	-1.6199E 01	-1.8438E-01	1.2012E C3	1.3390E 03	1.2594E C3	1.2063E 03
1.210CE 01	8.2579E-02	-1.6192E 01	-1.7953E-01	1.1934E 03	1.3336E 03	1.2595E C3	1.2067E 03
1.220CE 01	8.1764E-02	-1.6184E 01	-1.7509E-01	1.1859E 03	1.3284E 03	1.2595E C3	1.2071E 03
1.230CE 01	8.0980E-02	-1.6177E 01	-1.7100E-01	1.1788E 03	1.3235E 03	1.2596E C3	1.2075E 03
1.240CE 01	8.0224E-02	-1.6170E 01	-1.6720E-01	1.1719E 03	1.3188E 03	1.2596E C3	1.2079E 03
1.250CE 01	7.9494E-02	-1.6164E 01	-1.6368E-01	1.1653E 03	1.3142E 03	1.2596E C3	1.2083E 03
1.260CE 01	7.8789E-02	-1.6158E 01	-1.6039E-01	1.1589E 03	1.3098E 03	1.2596E C3	1.2087E 03
1.270CE 01	7.8106E-02	-1.6151E 01	-1.5730E-01	1.1529E 03	1.3056E 03	1.2597E C3	1.2090E 03
1.280CE 01	7.7444E-02	-1.6146E 01	-1.5440E-01	1.1470E 03	1.3016E 03	1.2597E C3	1.2094E 03
1.290CE 01	7.6803E-02	-1.6140E 01	-1.5166E-01	1.1414E 03	1.2977E 03	1.2597E C3	1.2098E 03
1.300CE 01	7.6180E-02	-1.6135E 01	-1.4907E-01	1.1360E 03	1.2940E 03	1.2597E C3	1.2102E 03
1.310CE 01	7.5575E-02	-1.6129E 01	-1.4662E-01	1.1308E 03	1.2904E 03	1.2598E C3	1.2105E 03
1.320CE 01	7.4987E-02	-1.6124E 01	-1.4427E-01	1.1259E 03	1.2870E 03	1.2598E C3	1.2109E 03
1.330CE 01	7.4414E-02	-1.6119E 01	-1.4205E-01	1.1211E 03	1.2836E 03	1.2598E C3	1.2112E 03
1.340CE 01	7.3857E-02	-1.6115E 01	-1.3991E-01	1.1165E 03	1.2805E 03	1.2598E C3	1.2115E 03
1.350CE 01	7.3313E-02	-1.6110E 01	-1.3788E-01	1.1121E 03	1.2774E 03	1.2599E C3	1.2119E 03
1.360CE 01	7.2784E-02	-1.6106E 01	-1.3592E-01	1.1078E 03	1.2745E 03	1.2599E C3	1.2122E 03
1.370CE 01	7.2267E-02	-1.6102E 01	-1.3403E-01	1.1038E 03	1.2717E 03	1.2599E C3	1.2125E 03
1.390CE 01	7.1270E-02	-1.6094E 01	-1.3054E-01	1.0961E 03	1.2663E 03	1.2600E C3	1.2131E 03
1.410CE 01	7.0319E-02	-1.6086E 01	-1.2723E-01	1.0890E 03	1.2614E 03	1.2600E C3	1.2136E 03
1.430CE 01	6.9410E-02	-1.6080E 01	-1.2410E-01	1.0824E 03	1.2568E 03	1.2600E C3	1.2142E 03
1.450CE 01	6.8540E-02	-1.6073E 01	-1.2116E-01	1.0764E 03	1.2526E 03	1.2600E C3	1.2146E 03
1.470CE 01	6.7706E-02	-1.6067E 01	-1.1835E-01	1.0708E 03	1.2487E 03	1.2600E C3	1.2151E 03
1.490CE 01	6.6905E-02	-1.6062E 01	-1.1568E-01	1.0656E 03	1.2451E 03	1.2600E C3	1.2155E 03

AIR05-FAST SHIP RCD WITHDRAWAL FROM FULL POWER

.01356/SEC.

TIME	POWER	REACTIVITY	INV.PERIOD	F 2	F 3	F 6	F 12
1.51CCE 01	6.6137E-02	-1.6057E 01	-1.1313E-01	1.0608E 03	1.2417E 03	1.2599E C3	1.2159E 03
1.53CCE 01	6.5397E-02	-1.6052E 01	-1.1068E-01	1.0563E 03	1.2386E 03	1.2599E C3	1.2163E 03
1.55CCE 01	6.4686E-02	-1.6047E 01	-1.0832E-01	1.0522E 03	1.2357E 03	1.2598E C3	1.2166E 03
1.57CCE 01	6.4001E-02	-1.6043E 01	-1.0604E-01	1.0484E 03	1.2330E 03	1.2597E C3	1.2169E 03
1.59CCE 01	6.3340E-02	-1.6040E 01	-1.0384E-01	1.0448E 03	1.2304E 03	1.2595E C3	1.2172E 03
1.61CCE 01	6.2703E-02	-1.6036E 01	-1.0171E-01	1.0415E 03	1.2281E 03	1.2594E C3	1.2175E 03
1.63CCE 01	6.2088E-02	-1.6033E 01	-9.9646E-02	1.0384E 03	1.2259E 03	1.2592E C3	1.2178E 03
1.65CCE 01	6.1494E-02	-1.6030E 01	-9.7648E-02	1.0356E 03	1.2238E 03	1.2590E C3	1.2180E 03
1.67CCE 01	6.0920E-02	-1.6027E 01	-9.5707E-02	1.0330E 03	1.2219E 03	1.2588E C3	1.2182E 03
1.69CCE 01	6.0365E-02	-1.6024E 01	-9.3815E-02	1.0305E C3	1.2201E 03	1.2586E C3	1.2184E 03
1.71CCE 01	5.9828E-02	-1.6022E 01	-9.1980E-02	1.0282E 03	1.2184E 03	1.2584E C3	1.2186E 03
1.73CCE 01	5.9309E-02	-1.6019E 01	-9.0206E-02	1.0260E 03	1.2168E 03	1.2582E C3	1.2188E 03
1.75CCE 01	5.8805E-02	-1.6017E 01	-8.8469E-02	1.0240E 03	1.2153E 03	1.2579E C3	1.2190E 03
1.77CCE 01	5.8317E-02	-1.6015E 01	-8.6788E-02	1.0221E C3	1.2139E 03	1.2577E C3	1.2192E 03
1.79CCE 01	5.7844E-02	-1.6013E 01	-8.5151E-02	1.0204E 03	1.2125E 03	1.2574E C3	1.2194E 03
1.81CCE 01	5.7385E-02	-1.6011E 01	-8.3566E-02	1.0187E 03	1.2113E 03	1.2571E C3	1.2195E 03
1.83CCE 01	5.6940E-02	-1.6010E 01	-8.2019E-02	1.0172E 03	1.2101E 03	1.2568E C3	1.2197E 03
1.85CCE 01	5.6508E-02	-1.6008E 01	-8.0518E-02	1.0157E 03	1.2089E 03	1.2565E C3	1.2198E 03
1.87CCE 01	5.6088E-02	-1.6007E 01	-7.9065E-02	1.0143E 03	1.2078E 03	1.2563E C3	1.2200E 03
1.89CCE 01	5.5679E-02	-1.6005E 01	-7.7647E-02	1.0130E 03	1.2068E 03	1.2559E C3	1.2202E 03
1.91CCE 01	5.5282E-02	-1.6004E 01	-7.6275E-02	1.0118E 03	1.2058E 03	1.2556E C3	1.2203E 03
1.93CCE 01	5.4896E-02	-1.6003E 01	-7.4939E-02	1.0106E 03	1.2048E 03	1.2553E C3	1.2205E 03
1.95CCE 01	5.4520E-02	-1.6002E 01	-7.3643E-02	1.0095E 03	1.2039E 03	1.2550E C3	1.2206E 03
1.97CCE 01	5.4155E-02	-1.6001E 01	-7.2388E-02	1.0085E 03	1.2030E 03	1.2547E C3	1.2208E 03
1.99CCE 01	5.3798E-02	-1.6000E 01	-7.1171E-02	1.0075E 03	1.2022E 03	1.2544E C3	1.2209E 03
2.01CCE 01	5.3451E-02	-1.5999E 01	-6.9983E-02	1.0065E C3	1.2014E 03	1.2540E C3	1.2211E 03
2.03CCE 01	5.3112E-02	-1.5998E 01	-6.8844E-02	1.0056E 03	1.2006E 03	1.2537E C3	1.2212E 03
2.05CCE 01	5.2782E-02	-1.5997E 01	-6.7717E-02	1.0047E 03	1.1998E 03	1.2534E C3	1.2214E 03
2.07CCE 01	5.2460E-02	-1.5996E 01	-6.6655E-02	1.0039E 03	1.1991E 03	1.2531E C3	1.2215E 03
2.09CCE 01	5.2145E-02	-1.5995E 01	-6.5603E-02	1.0030E 03	1.1984E 03	1.2527E C3	1.2217E 03
2.11CCE 01	5.1838E-02	-1.5994E 01	-6.4591E-02	1.0023E 03	1.1977E 03	1.2524E C3	1.2219E 03
2.13CCE 01	5.1538E-02	-1.5994E 01	-6.3614E-02	1.0015E 03	1.1970E 03	1.2520E C3	1.2220E 03
2.15CCE 01	5.1245E-02	-1.5993E 01	-6.2654E-02	1.0008E 03	1.1963E 03	1.2517E C3	1.2222E 03
2.17CCE 01	5.0959E-02	-1.5992E 01	-6.1732E-02	1.0001E 03	1.1957E 03	1.2514E C3	1.2223E 03
2.19CCE 01	5.0679E-02	-1.5992E 01	-6.0843E-02	9.9937E 02	1.1951E 03	1.2510E C3	1.2225E 03

AIROS-FAST SHIM ROD WITHDRAWAL FROM FULL POWER

.0135\$/SEC.

TIME	POWER	REACTIVITY	INV.PERIOD	F 2	F 3	F 6	F 12
2.210CE 01	5.0405E-02	-1.5991E 01	-5.9985E-02	9.9871E 02	1.1944E 03	1.2507E 03	1.2227E 03
2.230CE 01	5.0137E-02	-1.5990E 01	-5.9135E-02	9.9806E 02	1.1938E 03	1.2503E 03	1.2228E 03
2.250CE 01	4.9874E-02	-1.5990E 01	-5.8332E-02	9.9743E 02	1.1933E 03	1.2500E 03	1.2230E 03
2.270CE 01	4.9617E-02	-1.5989E 01	-5.7540E-02	9.9681E 02	1.1927E 03	1.2496E 03	1.2232E 03
2.290CE 01	4.9365E-02	-1.5989E 01	-5.6779E-02	9.9620E 02	1.1921E 03	1.2493E 03	1.2234E 03
2.310CE 01	4.9118E-02	-1.5988E 01	-5.6036E-02	9.9561E 02	1.1916E 03	1.2490E 03	1.2235E 03
2.330CE 01	4.8877E-02	-1.5988E 01	-5.5322E-02	9.9504E 02	1.1910E 03	1.2486E 03	1.2237E 03
2.350CE 01	4.8640E-02	-1.5987E 01	-5.4626E-02	9.9447E 02	1.1905E 03	1.2483E 03	1.2239E 03
2.370CE 01	4.8407E-02	-1.5987E 01	-5.3960E-02	9.9391E 02	1.1899E 03	1.2479E 03	1.2240E 03
2.390CE 01	4.8179E-02	-1.5986E 01	-5.3302E-02	9.9336E 02	1.1894E 03	1.2476E 03	1.2242E 03
2.410CE 01	4.7955E-02	-1.5986E 01	-5.2677E-02	9.9282E 02	1.1889E 03	1.2472E 03	1.2244E 03
2.430CE 01	4.7735E-02	-1.5985E 01	-5.2063E-02	9.9229E 02	1.1884E 03	1.2469E 03	1.2246E 03
2.450CE 01	4.7520E-02	-1.5985E 01	-5.1473E-02	9.9177E 02	1.1879E 03	1.2466E 03	1.2247E 03
2.470CE 01	4.7308E-02	-1.5985E 01	-5.0885E-02	9.9125E 02	1.1874E 03	1.2462E 03	1.2249E 03
2.490CE 01	4.7100E-02	-1.5984E 01	-5.0335E-02	9.9074E 02	1.1869E 03	1.2459E 03	1.2251E 03
2.510CE 01	4.6895E-02	-1.5984E 01	-4.9792E-02	9.9024E 02	1.1864E 03	1.2455E 03	1.2252E 03
2.530CE 01	4.6694E-02	-1.5983E 01	-4.9265E-02	9.8974E 02	1.1859E 03	1.2452E 03	1.2254E 03
2.550CE 01	4.6497E-02	-1.5983E 01	-4.8753E-02	9.8925E 02	1.1854E 03	1.2449E 03	1.2256E 03
2.570CE 01	4.6303E-02	-1.5983E 01	-4.8260E-02	9.8876E 02	1.1849E 03	1.2445E 03	1.2257E 03
2.590CE 01	4.6112E-02	-1.5982E 01	-4.7785E-02	9.8828E 02	1.1845E 03	1.2442E 03	1.2259E 03
2.610CE 01	4.5924E-02	-1.5982E 01	-4.7318E-02	9.8780E 02	1.1840E 03	1.2439E 03	1.2261E 03
2.630CE 01	4.5739E-02	-1.5981E 01	-4.6867E-02	9.8733E 02	1.1835E 03	1.2435E 03	1.2262E 03
2.650CE 01	4.5557E-02	-1.5981E 01	-4.6425E-02	9.8686E 02	1.1831E 03	1.2432E 03	1.2264E 03
2.670CE 01	4.5378E-02	-1.5981E 01	-4.6000E-02	9.8640E 02	1.1826E 03	1.2429E 03	1.2265E 03
2.690CE 01	4.5202E-02	-1.5980E 01	-4.5585E-02	9.8594E 02	1.1822E 03	1.2425E 03	1.2267E 03
2.710CE 01	4.5028E-02	-1.5980E 01	-4.5189E-02	9.8548E 02	1.1817E 03	1.2422E 03	1.2268E 03
2.730CE 01	4.4857E-02	-1.5980E 01	-4.4790E-02	9.8503E 02	1.1813E 03	1.2419E 03	1.2270E 03
2.750CE 01	4.4689E-02	-1.5979E 01	-4.4409E-02	9.8458E 02	1.1808E 03	1.2416E 03	1.2271E 03
2.770CE 01	4.4523E-02	-1.5979E 01	-4.4046E-02	9.8413E 02	1.1804E 03	1.2412E 03	1.2273E 03
2.790CE 01	4.4360E-02	-1.5978E 01	-4.3681E-02	9.8368E 02	1.1800E 03	1.2409E 03	1.2274E 03
2.810CE 01	4.4199E-02	-1.5978E 01	-4.3333E-02	9.8324E 02	1.1795E 03	1.2406E 03	1.2275E 03
2.830CE 01	4.4040E-02	-1.5978E 01	-4.2992E-02	9.8280E 02	1.1791E 03	1.2403E 03	1.2277E 03
2.850CE 01	4.3883E-02	-1.5977E 01	-4.2659E-02	9.8237E 02	1.1787E 03	1.2400E 03	1.2278E 03
2.870CE 01	4.3729E-02	-1.5977E 01	-4.2332E-02	9.8194E 02	1.1782E 03	1.2396E 03	1.2279E 03
2.890CE 01	4.3577E-02	-1.5977E 01	-4.2023E-02	9.8151E 02	1.1778E 03	1.2393E 03	1.2281E 03

NAA-SR-9943
79

AIROS-FAST SHIP RCD WITHDRAWAL FROM FULL POWER

.0135\$/SEC.

TIME	POWER	REACTIVITY	INV. PERIOD	F 2	F 3	F 6	F 12
2.910CE C1	4.3427E-02	-1.5976E 01	-4.1717E-02	9.8108E 02	1.1774E 03	1.239CE C3	1.2282E 03
2.930CE C1	4.3279E-02	-1.5976E 01	-4.1414E-02	9.8065E 02	1.1770E 03	1.2387E C3	1.2283E 03
2.950CE C1	4.3133E-02	-1.5976E 01	-4.1130E-02	9.8023E 02	1.1766E 03	1.2384E C3	1.2284E 03
2.970CE C1	4.2989E-02	-1.5975E 01	-4.0843E-02	9.7981E 02	1.1762E 03	1.2381E C3	1.2286E 03
2.990CE C1	4.2847E-02	-1.5975E 01	-4.0560E-02	9.7939E 02	1.1757E 03	1.2378E C3	1.2287E 03
3.010CE C1	4.2706E-02	-1.5975E 01	-4.0292E-02	9.7898E 02	1.1753E 03	1.2375E C3	1.2288E 03

AIR05-FAST SHIM RED WITHDRAWAL FROM FULL POWER

.0135\$/SEC.

TIME	F 14	F 15	F 21	F 23	F 24	F 30	F 12
C.	2.0930E 03	1.9431E 03	1.1438E 03	1.8813E 03	1.8068E 03	1.1839E C3	
2.0000E-01	2.0931E 03	1.9432E 03	1.1438E 03	1.8814E 03	1.8069E 03	1.1839E C3	
4.0000E-01	2.0936E 03	1.9435E 03	1.1438E 03	1.8817E 03	1.8071E 03	1.1839E C3	
6.0000E-01	2.0944E 03	1.9442E 03	1.1439E 03	1.8822E 03	1.8075E 03	1.1839E C3	
8.0000E-01	2.0956E 03	1.9451E 03	1.1440E 03	1.8829E 03	1.8080E 03	1.1840E C3	
10.0000E-01	2.0971E 03	1.9462E 03	1.1441E 03	1.8839E 03	1.8087E 03	1.1841E C3	
1.2000E 00	2.0989E 03	1.9475E 03	1.1444E 03	1.8851E 03	1.8096E 03	1.1843E C3	
1.4000E 00	2.1010E 03	1.9491E 03	1.1448E 03	1.8864E 03	1.8106E 03	1.1846E C3	
1.6000E 00	2.1033E 03	1.9508E 03	1.1452E 03	1.8879E 03	1.8117E 03	1.1849E C3	
1.8000E 00	2.1059E 03	1.9528E 03	1.1457E 03	1.8897E 03	1.8130E 03	1.1853E C3	
2.0000E 00	2.1087E 03	1.9549E 03	1.1463E 03	1.8915E 03	1.8144E 03	1.1858E C3	
2.2000E 00	2.1116E 03	1.9572E 03	1.1470E 03	1.8936E 03	1.8160E 03	1.1864E C3	
2.4000E 00	2.1148E 03	1.9597E 03	1.1478E 03	1.8958E 03	1.8177E 03	1.1870E C3	
2.6000E 00	2.1182E 03	1.9623E 03	1.1487E 03	1.8981E 03	1.8195E 03	1.1878E C3	
2.8000E 00	2.1217E 03	1.9651E 03	1.1496E 03	1.9005E 03	1.8214E 03	1.1885E C3	
3.0000E 00	2.1253E 03	1.9680E 03	1.1506E 03	1.9031E 03	1.8235E 03	1.1894E C3	
3.2000E 00	2.1291E 03	1.9710E 03	1.1517E 03	1.9059E 03	1.8256E 03	1.1903E C3	
3.4000E 00	2.1331E 03	1.9742E 03	1.1528E 03	1.9087E 03	1.8279E 03	1.1913E C3	
3.6000E 00	2.1371E 03	1.9775E 03	1.1540E 03	1.9117E 03	1.8303E 03	1.1923E C3	
3.8000E 00	2.1413E 03	1.9809E 03	1.1552E 03	1.9147E 03	1.8328E 03	1.1934E C3	
4.0000E 00	2.1455E 03	1.9844E 03	1.1565E 03	1.9179E 03	1.8354E 03	1.1945E C3	
4.2000E 00	2.1499E 03	1.9880E 03	1.1578E 03	1.9211E 03	1.8380E 03	1.1957E C3	
4.4000E 00	2.1544E 03	1.9918E 03	1.1592E 03	1.9245E 03	1.8408E 03	1.1970E C3	
4.6000E 00	2.1589E 03	1.9956E 03	1.1606E 03	1.9279E 03	1.8437E 03	1.1982E C3	
4.8000E 00	2.1636E 03	1.9994E 03	1.1620E 03	1.9314E 03	1.8466E 03	1.1996E C3	
5.0000E 00	2.1683E 03	2.0034E 03	1.1635E 03	1.9350E 03	1.8497E 03	1.2009E C3	
5.2000E 00	2.1730E 03	2.0074E 03	1.1650E 03	1.9387E 03	1.8528E 03	1.2023E C3	
5.4000E 00	2.1779E 03	2.0116E 03	1.1665E 03	1.9424E 03	1.8559E 03	1.2038E C3	
5.6000E 00	2.1828E 03	2.0157E 03	1.1681E 03	1.9462E 03	1.8592E 03	1.2053E C3	
5.8000E 00	2.1877E 03	2.0200E 03	1.1697E 03	1.9501E 03	1.8625E 03	1.2068E C3	
6.0000E 00	2.1928E 03	2.0243E 03	1.1713E 03	1.9540E 03	1.8659E 03	1.2084E C3	
6.2000E 00	2.1978E 03	2.0287E 03	1.1730E 03	1.9580E 03	1.8694E 03	1.2099E C3	
6.4000E 00	2.2030E 03	2.0331E 03	1.1746E 03	1.9621E 03	1.8729E 03	1.2116E C3	
6.6000E 00	2.2081E 03	2.0375E 03	1.1763E 03	1.9662E 03	1.8765E 03	1.2132E C3	
6.8000E 00	2.2134E 03	2.0421E 03	1.1780E 03	1.9703E 03	1.8801E 03	1.2149E C3	

AIR09-FAST SHIP ROD WITHDRAWAL FROM FULL POWER

.0135%/SEC.

TIME	F 14	F 15	F 21	F 23	F 24	F 30	F 12
7.0000E 00	2.2186E 03	2.0466E 03	1.1797E 03	1.9745E 03	1.8838E 03	1.2166E 03	
7.2000E 00	2.2239E 03	2.0512E 03	1.1815E 03	1.9788E 03	1.8876E 03	1.2183E 03	
7.4000E 00	2.2293E 03	2.0559E 03	1.1833E 03	1.9831E 03	1.8914E 03	1.2200E 03	
7.6000E 00	2.2346E 03	2.0606E 03	1.1850E 03	1.9874E 03	1.8952E 03	1.2218E 03	
7.8000E 00	2.2401E 03	2.0653E 03	1.1868E 03	1.9918E 03	1.8991E 03	1.2236E 03	
8.0000E 00	2.2455E 03	2.0701E 03	1.1886E 03	1.9962E 03	1.9030E 03	1.2254E 03	
8.2000E 00	2.2510E 03	2.0749E 03	1.1904E 03	2.0007E 03	1.9070E 03	1.2273E 03	
8.4000E 00	2.2565E 03	2.0797E 03	1.1923E 03	2.0051E 03	1.9110E 03	1.2291E 03	
8.6000E 00	2.2621E 03	2.0846E 03	1.1941E 03	2.0097E 03	1.9151E 03	1.2310E 03	
8.8000E 00	2.2676E 03	2.0895E 03	1.1960E 03	2.0142E 03	1.9192E 03	1.2329E 03	
9.0000E 00	2.2733E 03	2.0945E 03	1.1979E 03	2.0188E 03	1.9233E 03	1.2348E 03	
9.2000E 00	2.2789E 03	2.0994E 03	1.1997E 03	2.0235E 03	1.9275E 03	1.2367E 03	
9.4000E 00	2.2846E 03	2.1044E 03	1.2016E 03	2.0281E 03	1.9317E 03	1.2387E 03	
9.6000E 00	2.2903E 03	2.1095E 03	1.2035E 03	2.0328E 03	1.9360E 03	1.2406E 03	
9.8000E 00	2.2960E 03	2.1145E 03	1.2055E 03	2.0375E 03	1.9403E 03	1.2426E 03	
10.0000E 00	2.3017E 03	2.1196E 03	1.2074E 03	2.0423E 03	1.9446E 03	1.2446E 03	
1.0200E 01	2.3075E 03	2.1247E 03	1.2093E 03	2.0471E 03	1.9489E 03	1.2466E 03	
1.0400E 01	2.3132E 03	2.1297E 03	1.2113E 03	2.0518E 03	1.9532E 03	1.2486E 03	
1.0500E 01	2.3125E 03	2.1297E 03	1.2129E 03	2.0521E 03	1.9539E 03	1.2503E 03	
1.0550E 01	2.3052E 03	2.1246E 03	1.2142E 03	2.0482E 03	1.9513E 03	1.2516E 03	
1.0575E 01	2.2980E 03	2.1194E 03	1.2149E 03	2.0441E 03	1.9484E 03	1.2523E 03	
1.0600E 01	2.2878E 03	2.1122E 03	1.2157E 03	2.0383E 03	1.9443E 03	1.2531E 03	
1.0625E 01	2.2750E 03	2.1029E 03	1.2165E 03	2.0308E 03	1.9350E 03	1.2539E 03	
1.0650E 01	2.2600E 03	2.0921E 03	1.2173E 03	2.0221E 03	1.9327E 03	1.2548E 03	
1.0675E 01	2.2433E 03	2.0800E 03	1.2181E 03	2.0123E 03	1.9258E 03	1.2557E 03	
1.0700E 01	2.2257E 03	2.0673E 03	1.2189E 03	2.0020E 03	1.9184E 03	1.2566E 03	
1.0725E 01	2.2074E 03	2.0541E 03	1.2197E 03	1.9912E 03	1.9106E 03	1.2574E 03	
1.0750E 01	2.1888E 03	2.0407E 03	1.2204E 03	1.9802E 03	1.9027E 03	1.2583E 03	
1.0775E 01	2.1702E 03	2.0272E 03	1.2211E 03	1.9690E 03	1.8948E 03	1.2591E 03	
1.0800E 01	2.1515E 03	2.0137E 03	1.2217E 03	1.9578E 03	1.8868E 03	1.2599E 03	
1.0825E 01	2.1329E 03	2.0003E 03	1.2223E 03	1.9467E 03	1.8788E 03	1.2606E 03	
1.0850E 01	2.1145E 03	1.9870E 03	1.2228E 03	1.9355E 03	1.8708E 03	1.2614E 03	
1.0875E 01	2.0963E 03	1.9739E 03	1.2232E 03	1.9245E 03	1.8629E 03	1.2621E 03	
1.0900E 01	2.0783E 03	1.9610E 03	1.2235E 03	1.9135E 03	1.8551E 03	1.2627E 03	
1.0925E 01	2.0607E 03	1.9482E 03	1.2238E 03	1.9027E 03	1.8473E 03	1.2633E 03	

AIR0S-FAST SHIM RED WITHDRAWAL FROM FULL POWER

.0125\$/SEC.

TIME	F 14	F 15	F 21	F 23	F 24	F 30	F 12
1.095CE C1	2.0433E 03	1.9357E 03	1.2240E 03	1.8920E 03	1.8357E 03	1.2639E C3	
1.100CE C1	2.0095E 03	1.9113E 03	1.2243E 03	1.8710E 03	1.8247E 03	1.2650E C3	
1.110CE C1	1.9453E 03	1.8652E 03	1.2240E 03	1.8307E 03	1.7960E 03	1.2667E C3	
1.120CE C1	1.8856E 03	1.8222E 03	1.2228E 03	1.7925E 03	1.7689E 03	1.2680E C3	
1.130CE C1	1.8298E 03	1.7820E 03	1.2208E 03	1.7563E 03	1.7431E 03	1.2688E C3	
1.140CE C1	1.7777E 03	1.7445E 03	1.2182E 03	1.7218E 03	1.7187E 03	1.2692E C3	
1.150CE C1	1.7290E 03	1.7093E 03	1.2151E 03	1.6891E 03	1.6955E 03	1.2693E C3	
1.160CE C1	1.6834E 03	1.6763E 03	1.2116E 03	1.6580E 03	1.6735E 03	1.2691E C3	
1.170CE C1	1.6407E 03	1.6454E 03	1.2077E 03	1.6284E 03	1.6525E 03	1.2686E C3	
1.180CE C1	1.6007E 03	1.6162E 03	1.2037E 03	1.6003E 03	1.6325E 03	1.2680E C3	
1.190CE C1	1.5632E 03	1.5888E 03	1.1994E 03	1.5735E 03	1.6135E 03	1.2672E C3	
1.200CE C1	1.5280E 03	1.5629E 03	1.1951E 03	1.5480E 03	1.5954E 03	1.2663E C3	
1.210CE C1	1.4949E 03	1.5385E 03	1.1907E 03	1.5237E 03	1.5782E 03	1.2652E C3	
1.220CE C1	1.4638E 03	1.5154E 03	1.1863E 03	1.5005E 03	1.5617E 03	1.2642E C3	
1.230CE C1	1.4345E 03	1.4936E 03	1.1819E 03	1.4785E 03	1.5460E 03	1.2630E C3	
1.240CE C1	1.4070E 03	1.4730E 03	1.1776E 03	1.4574E 03	1.5310E 03	1.2618E C3	
1.250CE C1	1.3811E 03	1.4534E 03	1.1733E 03	1.4374E 03	1.5167E 03	1.2606E C3	
1.260CE C1	1.3567E 03	1.4349E 03	1.1691E 03	1.4183E 03	1.5030E 03	1.2594E C3	
1.270CE C1	1.3338E 03	1.4173E 03	1.1650E 03	1.4000E 03	1.4899E 03	1.2582E C3	
1.280CE C1	1.3121E 03	1.4006E 03	1.1610E 03	1.3826E 03	1.4774E 03	1.2570E C3	
1.290CE C1	1.2917E 03	1.3848E 03	1.1571E 03	1.3660E 03	1.4655E 03	1.2558E C3	
1.300CE C1	1.2724E 03	1.3697E 03	1.1534E 03	1.3501E 03	1.4540E 03	1.2547E C3	
1.310CE C1	1.2542E 03	1.3554E 03	1.1497E 03	1.3350E 03	1.4431E 03	1.2535E C3	
1.320CE C1	1.2370E 03	1.3418E 03	1.1462E 03	1.3205E 03	1.4326E 03	1.2524E C3	
1.330CE C1	1.2207E 03	1.3288E 03	1.1428E 03	1.3067E 03	1.4225E 03	1.2513E C3	
1.340CE C1	1.2054E 03	1.3165E 03	1.1395E 03	1.2935E 03	1.4129E 03	1.2502E C3	
1.350CE C1	1.1909E 03	1.3048E 03	1.1363E 03	1.2809E 03	1.4037E 03	1.2492E C3	
1.360CE C1	1.1772E 03	1.2936E 03	1.1333E 03	1.2688E 03	1.3949E 03	1.2482E C3	
1.370CE C1	1.1642E 03	1.2829E 03	1.1303E 03	1.2573E 03	1.3864E 03	1.2472E C3	
1.390CE C1	1.1402E 03	1.2630E 03	1.1248E 03	1.2357E 03	1.3706E 03	1.2454E C3	
1.410CE C1	1.1187E 03	1.2450E 03	1.1197E 03	1.2160E 03	1.3559E 03	1.2436E C3	
1.430CE C1	1.0995E 03	1.2285E 03	1.1150E 03	1.1979E 03	1.3425E 03	1.2421E C3	
1.450CE C1	1.0821E 03	1.2134E 03	1.1107E 03	1.1813E 03	1.3301E 03	1.2406E C3	
1.470CE C1	1.0665E 03	1.1997E 03	1.1067E 03	1.1661E 03	1.3187E 03	1.2392E C3	
1.490CE C1	1.0524E 03	1.1871E 03	1.1031E 03	1.1521E 03	1.3082E 03	1.2380E C3	

AIR05-FAST SHIP RCD WITHDRAWAL FROM FULL POWER

.0135%/SEC.

TIME	F 14	F 15	F 21	F 23	F 24	F 30	F 12
1.510CE C1	1.0396E 03	1.1757E 03	1.0998E 03	1.1393E 03	1.2985E 03	1.2368E C3	
1.530CE C1	1.0281E 03	1.1651E 03	1.0967E 03	1.1275E 03	1.2895E 03	1.2357E C3	
1.550CE C1	1.0177E 03	1.1555E 03	1.0939E 03	1.1167E 03	1.2812E 03	1.2347E C3	
1.570CE C1	1.0083E 03	1.1467E 03	1.0913E 03	1.1067E 03	1.2735E 03	1.2338E C3	
1.590CE C1	9.9980E 02	1.1386E 03	1.0890E 03	1.0975E 03	1.2664E 03	1.2329E C3	
1.610CE C1	9.9207E 02	1.1311E 03	1.0868E 03	1.0890E 03	1.2599E 03	1.2321E C3	
1.630CE C1	9.8506E 02	1.1243E 03	1.0848E 03	1.0812E 03	1.2528E 03	1.2313E C3	
1.650CE C1	9.7869E 02	1.1180E 03	1.0830E 03	1.0740E 03	1.2481E 03	1.2306E C3	
1.670CE C1	9.7290E 02	1.1123E 03	1.0813E 03	1.0674E 03	1.2429E 03	1.2299E C3	
1.690CE C1	9.6765E 02	1.1069E 03	1.0797E 03	1.0612E 03	1.2380E 03	1.2292E C3	
1.710CE C1	9.6286E 02	1.1021E 03	1.0783E 03	1.0555E 03	1.2335E 03	1.2286E C3	
1.730CE C1	9.5851E 02	1.0976E 03	1.0769E 03	1.0502E 03	1.2293E 03	1.2280E C3	
1.750CE C1	9.5455E 02	1.0934E 03	1.0757E 03	1.0453E 03	1.2254E 03	1.2274E C3	
1.770CE C1	9.5094E 02	1.0896E 03	1.0745E 03	1.0408E 03	1.2217E 03	1.2268E C3	
1.790CE C1	9.4766E 02	1.0860E 03	1.0734E 03	1.0365E 03	1.2183E 03	1.2262E C3	
1.810CE C1	9.4466E 02	1.0828E 03	1.0724E 03	1.0326E 03	1.2151E 03	1.2257E C3	
1.830CE C1	9.4193E 02	1.0798E 03	1.0715E 03	1.0289E 03	1.2121E 03	1.2251E C3	
1.850CE C1	9.3943E 02	1.0770E 03	1.0706E 03	1.0255E 03	1.2093E 03	1.2246E C3	
1.870CE C1	9.3715E 02	1.0744E 03	1.0698E 03	1.0224E 03	1.2067E 03	1.2240E C3	
1.890CE C1	9.3508E 02	1.0720E 03	1.0690E 03	1.0194E 03	1.2042E 03	1.2235E C3	
1.910CE C1	9.3317E 02	1.0698E 03	1.0682E 03	1.0166E 03	1.2019E 03	1.2229E C3	
1.930CE C1	9.3144E 02	1.0678E 03	1.0675E 03	1.0140E 03	1.1997E 03	1.2224E C3	
1.950CE C1	9.2985E 02	1.0659E 03	1.0669E 03	1.0115E 03	1.1976E 03	1.2218E C3	
1.970CE C1	9.2839E 02	1.0641E 03	1.0662E 03	1.0092E 03	1.1956E 03	1.2213E C3	
1.990CE C1	9.2706E 02	1.0625E 03	1.0656E 03	1.0071E 03	1.1938E 03	1.2207E C3	
2.010CE C1	9.2583E 02	1.0609E 03	1.0650E 03	1.0050E 03	1.1920E 03	1.2202E C3	
2.030CE C1	9.2471E 02	1.0595E 03	1.0645E 03	1.0031E 03	1.1903E 03	1.2196E C3	
2.050CE C1	9.2368E 02	1.0582E 03	1.0640E 03	1.0012E 03	1.1887E 03	1.2191E C3	
2.070CE C1	9.2273E 02	1.0569E 03	1.0634E 03	9.9948E 02	1.1871E 03	1.2185E C3	
2.090CE C1	9.2185E 02	1.0557E 03	1.0629E 03	9.9782E 02	1.1857E 03	1.2179E C3	
2.110CE C1	9.2104E 02	1.0546E 03	1.0624E 03	9.9624E 02	1.1842E 03	1.2173E C3	
2.130CE C1	9.2029E 02	1.0536E 03	1.0620E 03	9.9473E 02	1.1829E 03	1.2167E C3	
2.150CE C1	9.1960E 02	1.0526E 03	1.0615E 03	9.9328E 02	1.1815E 03	1.2162E C3	
2.170CE C1	9.1896E 02	1.0517E 03	1.0611E 03	9.9190E 02	1.1803E 03	1.2155E C3	
2.190CE C1	9.1836E 02	1.0508E 03	1.0606E 03	9.9057E 02	1.1790E 03	1.2149E C3	

AIROS-FAST SHIM RED WITHDRAWAL FROM FULL POWER

.0135\$/SEC.

TIME	F 14	F 15	F 21	F 23	F 24	F 30	F 12
2.210CE C1	9.1780E 02	1.0500E 03	1.0602E 03	9.8929E 02	1.1778E 03	1.2143E C3	
2.230CE 01	9.1727E 02	1.0492E 03	1.0598E 03	9.8805E 02	1.1766E 03	1.2137E C3	
2.250CE 01	9.1678E 02	1.0485E 03	1.0594E 03	9.8685E 02	1.1755E 03	1.2131E C3	
2.270CE 01	9.1632E 02	1.0478E 03	1.0590E 03	9.8569E 02	1.1744E 03	1.2124E C3	
2.290CE 01	9.1588E 02	1.0471E 03	1.0586E 03	9.8457E 02	1.1733E 03	1.2118E C3	
2.310CE 01	9.1547E 02	1.0465E 03	1.0582E 03	9.8347E 02	1.1722E 03	1.2111E C3	
2.330CE 01	9.1507E 02	1.0458E 03	1.0578E 03	9.8241E 02	1.1712E 03	1.2104E C3	
2.350CE 01	9.1469E 02	1.0452E 03	1.0574E 03	9.8137E 02	1.1701E 03	1.2098E C3	
2.370CE 01	9.1433E 02	1.0447E 03	1.0570E 03	9.8035E 02	1.1691E 03	1.2091E C3	
2.390CE 01	9.1398E 02	1.0441E 03	1.0566E 03	9.7936E 02	1.1681E 03	1.2084E C3	
2.410CE 01	9.1364E 02	1.0436E 03	1.0563E 03	9.7838E 02	1.1671E 03	1.2077E C3	
2.430CE 01	9.1332E 02	1.0430E 03	1.0559E 03	9.7742E 02	1.1662E 03	1.2070E C3	
2.450CE 01	9.1300E 02	1.0425E 03	1.0555E 03	9.7647E 02	1.1652E 03	1.2063E C3	
2.470CE 01	9.1269E 02	1.0420E 03	1.0551E 03	9.7555E 02	1.1642E 03	1.2056E C3	
2.490CE 01	9.1238E 02	1.0415E 03	1.0548E 03	9.7463E 02	1.1633E 03	1.2048E C3	
2.510CE 01	9.1208E 02	1.0410E 03	1.0544E 03	9.7372E 02	1.1623E 03	1.2041E C3	
2.530CE 01	9.1178E 02	1.0406E 03	1.0540E 03	9.7283E 02	1.1614E 03	1.2034E C3	
2.550CE 01	9.1148E 02	1.0401E 03	1.0537E 03	9.7194E 02	1.1604E 03	1.2026E C3	
2.570CE 01	9.1119E 02	1.0397E 03	1.0533E 03	9.7107E 02	1.1595E 03	1.2019E C3	
2.590CE 01	9.1090E 02	1.0392E 03	1.0529E 03	9.7020E 02	1.1586E 03	1.2011E C3	
2.610CE 01	9.1061E 02	1.0388E 03	1.0526E 03	9.6934E 02	1.1576E 03	1.2003E C3	
2.630CE 01	9.1032E 02	1.0383E 03	1.0522E 03	9.6848E 02	1.1567E 03	1.1996E C3	
2.650CE 01	9.1002E 02	1.0379E 03	1.0518E 03	9.6764E 02	1.1558E 03	1.1988E C3	
2.670CE 01	9.0973E 02	1.0375E 03	1.0515E 03	9.6679E 02	1.1548E 03	1.1980E C3	
2.690CE 01	9.0943E 02	1.0370E 03	1.0511E 03	9.6595E 02	1.1539E 03	1.1972E C3	
2.710CE 01	9.0914E 02	1.0366E 03	1.0507E 03	9.6512E 02	1.1530E 03	1.1964E C3	
2.730CE 01	9.0884E 02	1.0362E 03	1.0504E 03	9.6429E 02	1.1521E 03	1.1956E C3	
2.750CE 01	9.0854E 02	1.0357E 03	1.0500E 03	9.6346E 02	1.1511E 03	1.1948E C3	
2.770CE 01	9.0823E 02	1.0353E 03	1.0496E 03	9.6264E 02	1.1502E 03	1.1940E C3	
2.790CE 01	9.0793E 02	1.0349E 03	1.0493E 03	9.6182E 02	1.1493E 03	1.1931E C3	
2.810CE 01	9.0761E 02	1.0345E 03	1.0489E 03	9.6100E 02	1.1483E 03	1.1923E C3	
2.830CE 01	9.0730E 02	1.0340E 03	1.0485E 03	9.6018E 02	1.1474E 03	1.1915E C3	
2.850CE 01	9.0698E 02	1.0336E 03	1.0481E 03	9.5937E 02	1.1465E 03	1.1906E C3	
2.870CE 01	9.0666E 02	1.0332E 03	1.0478E 03	9.5856E 02	1.1455E 03	1.1898E C3	
2.890CE 01	9.0634E 02	1.0328E 03	1.0474E 03	9.5775E 02	1.1446E 03	1.1889E C3	

AIR05-FAST SHIP RCD WITHDRAWAL FROM FULL POWER

.0125\$/SEC.

TIME	F 14	F 15	F 21	F 23	F 24	F 30	F 12
2.910CE C1	9.0601E 02	1.0323E 03	1.0470E 03	9.5694E 02	1.1437E 03	1.1881E C3	
2.930CE C1	9.0568E 02	1.0319E 03	1.0466E 03	9.5613E C2	1.1427E 03	1.1872E C3	
2.950CE C1	9.0534E 02	1.0315E 03	1.0462E 03	9.5533E 02	1.1418E 03	1.1863E C3	
2.970CE C1	9.0500E 02	1.0310E 03	1.0458E 03	9.5453E 02	1.1408E 03	1.1854E C3	
2.990CE C1	9.0466E 02	1.0306E 03	1.0454E 03	9.5372E 02	1.1399E C3	1.1846E C3	
3.010CE 01	9.0431E 02	1.0302E 03	1.0450E 03	9.5292E C2	1.1389E 03	1.1837E C3	

AIRDS-FLOW DECAY FROM FULL POWER

CONTROL INFO DD(1) TO DD(50)

1	6.000000E 00	3.400000E 01	7.000000E-03	5.000000E-C4	0.
6	1.000000E 00	0.	0.	2.000000E-C1	1.000000E-05
11	2.000000E-01	1.000000E 00	10.000000E-03	1.000000E-C1	3.000000E 00
16	1.000000E 01	0.	1.000000E 10	1.000000E 00	0.
21	4.200000E-02	3.050000E-02	1.150000E-02	-2.300000E-03	-6.900000E-02
26	0.	9.400000E-01	6.000000E-02	-4.250000E-C1	0.
31	0.	0.	0.	0.	0.
36	0.	0.	0.	0.	0.
41	0.	-1.642900E 01	4.220000E 00	0.	0.
46	0.	0.	0.	0.	0.

PRE-CURSOR INFO DD(51) TO DD(95)

51	1.000000E 00	1.000000E 00	1.000000E 00	1.000000E 00	1.000000E 00
66	3.297000E-C2	2.194000E-01	1.960000E-01	3.947000E-01	1.150000E-C1
81	1.240000E-C2	3.050000E-02	1.110000E-01	3.010000E-01	1.130000E 00

FEEDBACK INFO DD(101) TO DD(900)

101	1.095000E C2	1.506000E 02	1.095000E 02	0.	0.
	0.	2.950000E-01	4.050000E-01	2.950000E-01	0.
	0.	0.	6.260000E 02	8.580000E 02	6.260000E C2
	0.	0.	0.	0.	0.
	0.	3.640000E 02	5.000000E 02	3.640000E 02	0.
	0.	0.	0.	0.	0.
	0.	3.333000E 01	0.	0.	0.
201	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.
301	-3.587000E-C1	-3.587000E-01	-3.587000E-01	-6.274000E-01	-6.274000E-C1
	-6.274000E-C1	-1.142000E-02	-1.142000E-02	-1.142000E-C2	-2.845000E-C1
	-2.845000E-C1	-2.845000E-01	-8.340000E-01	-8.340000E-01	-8.340000E-C1
	-7.100000E 00	-7.100000E 00	-7.100000E 00	-7.410000E-01	-7.410000E-C1

87

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FEEDBACK PRINT AND CRT INFO IPRINT(1) TO IPRINT(100)
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1								
	C	1	2	C	C			
	3	0	0	C	C			
	C	3	0	1	2			
	C	0	0	C	C			
	3	0	1	2	C			
	0	0	0	C	3			
	C	0	0	0				
FEEDBACK CONNECTORS AND COEFFICIENTS KC(1) TO KC(800) AND C(1) TO C(800)								
1	-1	4	-4	31	-31	C	C	0
	-6.330CE-C2	1.7940E-01	3.1700E-02	1.7940E-01	3.1700E-02	C.	C.	C.
2	-2	5	-5	4	-4	C	C	0
	-6.330CE-C2	1.7940E-01	3.1700E-02	1.7940E-01	3.1700E-02	C.	C.	C.
3	-3	6	-6	5	-5	C	C	0
	-6.330CE-C2	1.7940E-01	3.1700E-02	1.7940E-01	3.1700E-02	C.	C.	C.
4	-4	31	-31	1	-1	7	C	0
	-2.0056E CC	-6.2740E-01	1.8280E 00	1.0050E 00	1.7740E-01	2.500CE-C1	C.	C.
5	-5	4	-4	2	-2	8	C	0
	-2.0056E CC	-6.2740E-01	1.8280E 00	1.0050E 00	1.7740E-01	2.500CE-C1	C.	C.
6	-6	5	-5	3	-3	9	C	0
	-2.0056E CC	-6.2740E-01	1.8280E 00	1.0050E 00	1.7740E-01	2.500CE-C1	C.	C.
7	4	31	10	0	0	C	C	0
	1.940CE-C3	5.7200E-03	3.7800E-03	0.	0.	C.	C.	C.
8	5	4	11	10	0	C	C	0
	1.940CE-C3	1.9400E-03	3.7800E-03	3.7800E-03	0.	C.	C.	C.
9	6	5	12	11	0	C	C	0
	1.940CE-C3	1.9400E-03	3.7800E-03	3.7800E-03	0.	C.	C.	C.
10	-10	7	31	-31	0	C	C	0
	-9.010CE-C2	5.6900E-01	-2.8450E-01	9.0100E-02	0.	C.	C.	C.
11	-11	8	10	-10	0	C	C	0
	-9.010CE-C2	5.6900E-01	-2.8450E-01	9.0100E-02	0.	C.	C.	C.
12	-12	9	11	-11	0	C	C	0
	-9.010CE-C2	5.6900E-01	-2.8450E-01	9.0100E-02	0.	C.	C.	C.
13	16	0	0	0	0	C	C	0
	8.340CE-C1	C.	0.	0.	0.	C.	C.	C.
14	17	0	0	0	0	C	C	0
	8.340CE-C1	C.	0.	0.	0.	C.	C.	C.
15	18	0	0	0	0	C	C	0
	8.340CE-C1	C.	0.	0.	0.	C.	C.	C.
16	-16	13	19	-19	31	-31	C	0
	-7.560CE CC	2.0500E 00	2.5250E 00	3.7800E 00	2.5250E 00	3.780CE CC	C.	C.
17	-17	14	20	-20	19	-19	C	0
	-7.560CE CC	2.0500E 00	2.5250E 00	3.7800E 00	2.5250E 00	3.780CE CC	C.	C.

18	-18	15	21	-21	20	-20	0	0
	-7.560CE CC	2.0500E 00	2.5250E 00	3.7800E 00	2.5250E 00	3.7800E CC	C.	0.
19	-19	16	-16	31	-31	0	0	0
	-4.204CE CC	1.4820E 00	2.2280E 00	-7.4100E-01	1.9760E 00	C.	C.	C.
20	-20	17	-17	19	-19	0	C	0
	-4.204CE CC	1.4820E 00	2.2280E 00	-7.4100E-01	1.9760E 00	C.	C.	0.
21	-21	18	-18	20	-20	0	0	0
	-4.204CE CC	1.4820E 00	2.2280E 00	-7.4100E-01	1.9760E 00	C.	C.	0.
22	25	0	0	0	0	0	0	0
	5.860CE-C1	0.	0.	0.	0.	C.	C.	0.
23	26	0	0	0	0	0	0	0
	5.860CE-C1	0.	0.	0.	0.	C.	C.	0.
24	27	0	0	0	0	0	C	0
	5.860CE-C1	0.	0.	0.	0.	C.	C.	0.
25	-25	22	28	-28	31	-31	0	0
	-1.077CE C1	2.3400E 00	3.5900E 00	5.3850E 00	3.5900E 00	5.3850E CC	C.	0.
26	-26	23	29	-29	28	-28	C	0
	-1.077CE C1	2.3400E 00	3.5900E 00	5.3850E 00	3.5900E 00	5.3850E CC	C.	0.
27	-27	24	30	-30	29	-29	0	0
	-1.077CE C1	2.3400E 00	3.5900E 00	5.3850E 00	3.5900E 00	5.3850E CC	C.	0.
28	-28	25	-25	31	-31	C	0	0
	-4.505CE CC	2.2200E 00	3.3300E 00	-1.1100E 00	1.1750E 00	C.	C.	0.
29	-29	26	-26	28	-28	0	0	0
	-4.505CE CC	2.2200E 00	3.3300E 00	-1.1100E 00	1.1750E 00	C.	C.	0.
30	-30	27	-27	29	-29	C	0	0
	-4.505CE CC	2.2200E 00	3.3300E 00	-1.1100E 00	1.1750E 00	C.	C.	0.
31	0	0	0	0	0	0	0	0
	C.	C.	0.	0.	0.	C.	C.	0.
32	0	0	0	0	0	C	C	0
	C.	0.	0.	0.	0.	C.	C.	0.
33	21	0	0	0	C	C	C	0
	1.000CE CC	0.	0.	0.	0.	C.	C.	0.
34	6	0	0	0	0	C	C	0
	1.000CE CC	0.	0.	0.	0.	C.	C.	0.

MAXIMUM TIME EXCEEDED

AIROS-FLOW DECAY FROM FULL POWER

TIME	POWER	REACTIVITY	INV.PERIOD	F 2	F 3	F 6	F 12
C.	1C.0000E-01	0.	-2.0862E-07	1.2825E C3	1.3752E C3	1.201CE C3	1.2010E 03
2.CCCCE-C1	1.0002E 00	4.0211E-04	2.4280E-03	1.2828E C3	1.3754E C3	1.203CE C3	1.2011E 03
4.CCCCE-C1	1.0009E 00	1.1326E-03	3.8141E-03	1.2837E C3	1.38C2E C3	1.2083E C3	1.2014E 03
6.CCCCE-C1	1.0016E 00	1.7790E-03	3.4419E-03	1.2853E C3	1.3817E C3	1.2158E C3	1.2018E 03
8.CCCCE-C1	9.4941E-01	-1.4527E-01	-1.2639E 00	1.2875E C3	1.3838E C3	1.225CE C3	1.2024E 03
8.5CCCE-C1	8.4626E-01	-4.6060E-01	-3.8171E 00	1.2875E C3	1.3839E C3	1.2275E C3	1.2026E 03
9.CCCCE-C1	6.4848E-01	-1.1118E 00	-7.6215E 00	1.2864E C3	1.3824E C3	1.230CE C3	1.2027E 03
9.25CCCE-C1	5.3139E-01	-1.6110E 00	-9.4738E 00	1.2853E C3	1.3827E C3	1.2312E C3	1.2028E 03
9.5CCCE-C1	4.2137E-01	-2.2501E 00	-1.0752E 01	1.2838E C3	1.3817E C3	1.2324E C3	1.2029E 03
9.75CCCE-C1	3.2995E-01	-3.0436E 00	-1.1118E 01	1.2820E C3	1.38C4E C3	1.2336E C3	1.2030E 03
10.CCCCE-C1	2.6101E-01	-4.0006E 00	-1.0624E 01	1.2798E C3	1.3750E C3	1.2347E C3	1.2031E 03
1.C25CE CC	2.1173E-01	-5.1228E 00	-9.6842E 00	1.2775E C3	1.3774E C3	1.2358E C3	1.2032E 03
1.C5CCCE CC	1.7683E-01	-6.4012E 00	-8.6783E 00	1.2751E C3	1.3758E C3	1.2369E C3	1.2032E 03
1.C75CE CC	1.5175E-01	-7.8140E 00	-7.7335E 00	1.2726E C3	1.3741E C3	1.238CE C3	1.2033E 03
1.10CCCE CC	1.3339E-01	-9.3242E 00	-6.8353E 00	1.2700E C3	1.3723E C3	1.2389E C3	1.2034E 03
1.125CE CC	1.1981E-01	-1.0878E 01	-5.9500E 00	1.2675E C3	1.37C6E C3	1.2399E C3	1.2035E 03
1.15CCCE CC	1.0972E-01	-1.2404E 01	-5.0534E 00	1.2649E C3	1.3688E C3	1.24C8E C3	1.2036E 03
1.175CE CC	1.0230E-01	-1.3816E 01	-4.1265E 00	1.2623E C3	1.3671E C3	1.2417E C3	1.2037E 03
1.20CCCE CC	9.6983E-02	-1.5014E 01	-3.1514E 00	1.2597E C3	1.3654E C3	1.2425E C3	1.2038E 03
1.225CE CC	9.3419E-02	-1.5892E 01	-2.1092E 00	1.2572E C3	1.3636E C3	1.2434E C3	1.2039E 03
1.25CCCE CC	9.1421E-02	-1.6347E 01	-9.7733E-01	1.2547E C3	1.3619E C3	1.2441E C3	1.2040E 03
1.275CE CC	9.0774E-02	-1.6388E 01	-2.4725E-01	1.2522E C3	1.36C3E C3	1.2449E C3	1.2041E 03
1.325CE CC	9.0063E-02	-1.6383E 01	-2.7178E-01	1.2473E C3	1.3570E C3	1.2462E C3	1.2042E 03
1.375CE CC	8.9376E-02	-1.6378E 01	-2.6302E-01	1.2425E C3	1.3538E C3	1.2475E C3	1.2044E 03
1.425CE CC	8.8718E-02	-1.6373E 01	-2.5499E-01	1.2379E C3	1.35C7E C3	1.2487E C3	1.2046E 03
1.475CE CC	8.8085E-02	-1.6368E 01	-2.4761E-01	1.2333E C3	1.3477E C3	1.2497E C3	1.2048E 03
1.525CE CC	8.7477E-02	-1.6364E 01	-2.4081E-01	1.2289E C3	1.3448E C3	1.25C7E C3	1.2050E 03
1.575CE CC	8.6890E-02	-1.6359E 01	-2.3453E-01	1.2246E C3	1.3419E C3	1.2516E C3	1.2052E 03
1.625CE CC	8.6324E-02	-1.6355E 01	-2.2872E-01	1.2204E C3	1.3352E C3	1.2524E C3	1.2054E 03
1.675CE CC	8.5777E-02	-1.6351E 01	-2.2333E-01	1.2162E C3	1.3365E C3	1.2531E C3	1.2056E 03
1.725CE CC	8.5246E-02	-1.6347E 01	-2.1833E-01	1.2122E C3	1.3338E C3	1.2538E C3	1.2058E 03
1.775CE CC	8.4732E-02	-1.6343E 01	-2.1366E-01	1.2082E C3	1.3313E C3	1.2544E C3	1.2060E 03
1.825CE CC	8.4233E-02	-1.6339E 01	-2.0930E-01	1.2044E C3	1.3288E C3	1.255CE C3	1.2062E 03
1.875CE CC	8.3747E-02	-1.6335E 01	-2.0522E-01	1.2006E C3	1.3263E C3	1.2555E C3	1.2064E 03
1.925CE CC	8.3275E-02	-1.6332E 01	-2.0140E-01	1.1970E C3	1.3239E C3	1.256CE C3	1.2066E 03

AIROS-FLOW DECAY FROM FULL POWER

TIME	POWER	REACTIVITY	INV.PERIOD	F 2	F 3	F 6	F 12
1.975CE CC	8.2815E-02	-1.6328E 01	-1.9780E-01	1.1934E C3	1.3216E C3	1.2565E C3	1.2068E C3
2.025CE CC	8.2367E-02	-1.6324E 01	-1.9440E-01	1.1898E C3	1.3193E C3	1.2569E C3	1.2070E C3
2.075CE CC	8.1929E-02	-1.6321E 01	-1.9121E-01	1.1864E C3	1.3171E C3	1.2572E C3	1.2072E C3
2.125CE CC	8.1502E-02	-1.6317E 01	-1.8818E-01	1.1830E C3	1.3149E C3	1.2576E C3	1.2074E C3
2.225CE CC	8.0676E-02	-1.6311E 01	-1.8262E-01	1.1765E C3	1.3107E C3	1.2582E C3	1.2077E C3
2.425CE CC	7.9126E-02	-1.6298E 01	-1.7285E-01	1.1642E C3	1.3029E C3	1.2591E C3	1.2085E C3
2.625CE CC	7.7693E-02	-1.6287E 01	-1.6476E-01	1.1529E C3	1.2956E C3	1.2598E C3	1.2092E C3
2.825CE CC	7.6359E-02	-1.6276E 01	-1.5779E-01	1.1425E C3	1.2890E C3	1.2603E C3	1.2099E C3
3.025CE CC	7.5111E-02	-1.6267E 01	-1.5170E-01	1.1329E C3	1.2829E C3	1.2606E C3	1.2106E C3
3.225CE CC	7.3936E-02	-1.6258E 01	-1.4630E-01	1.1240E C3	1.2773E C3	1.2609E C3	1.2112E C3
3.425CE CC	7.2827E-02	-1.6249E 01	-1.4146E-01	1.1158E C3	1.2721E C3	1.2611E C3	1.2118E C3
3.625CE CC	7.1777E-02	-1.6241E 01	-1.3706E-01	1.1083E C3	1.2673E C3	1.2612E C3	1.2124E C3
3.825CE CC	7.0780E-02	-1.6234E 01	-1.3304E-01	1.1013E C3	1.2629E C3	1.2613E C3	1.2129E C3
4.025CE CC	6.9831E-02	-1.6227E 01	-1.2933E-01	1.0948E C3	1.2588E C3	1.2614E C3	1.2134E C3
4.225CE CC	6.8926E-02	-1.6221E 01	-1.2590E-01	1.0888E C3	1.2549E C3	1.2614E C3	1.2139E C3
4.425CE CC	6.8061E-02	-1.6215E 01	-1.2268E-01	1.0832E C3	1.2514E C3	1.2614E C3	1.2143E C3
4.625CE CC	6.7233E-02	-1.6210E 01	-1.1965E-01	1.0781E C3	1.2481E C3	1.2613E C3	1.2147E C3
4.825CE CC	6.6440E-02	-1.6205E 01	-1.1680E-01	1.0733E C3	1.2450E C3	1.2613E C3	1.2151E C3
5.025CE CC	6.5679E-02	-1.6200E 01	-1.1408E-01	1.0689E C3	1.2422E C3	1.2612E C3	1.2154E C3
5.225CE CC	6.4948E-02	-1.6196E 01	-1.1149E-01	1.0647E C3	1.2395E C3	1.2611E C3	1.2158E C3
5.425CE CC	6.4244E-02	-1.6192E 01	-1.0902E-01	1.0609E C3	1.2370E C3	1.2609E C3	1.2161E C3
5.625CE CC	6.3567E-02	-1.6188E 01	-1.0664E-01	1.0573E C3	1.2347E C3	1.2608E C3	1.2164E C3
5.825CE CC	6.2915E-02	-1.6185E 01	-1.0436E-01	1.0540E C3	1.2325E C3	1.2606E C3	1.2166E C3
6.025CE CC	6.2286E-02	-1.6181E 01	-1.0215E-01	1.0509E C3	1.2305E C3	1.2604E C3	1.2169E C3
6.225CE CC	6.1680E-02	-1.6178E 01	-1.0003E-01	1.0480E C3	1.2286E C3	1.2602E C3	1.2171E C3
6.425CE CC	6.1094E-02	-1.6175E 01	-9.7968E-02	1.0453E C3	1.2268E C3	1.2600E C3	1.2173E C3
6.625CE CC	6.0528E-02	-1.6173E 01	-9.5976E-02	1.0428E C3	1.2251E C3	1.2598E C3	1.2175E C3
6.825CE CC	5.9981E-02	-1.6170E 01	-9.4045E-02	1.0404E C3	1.2235E C3	1.2596E C3	1.2177E C3
7.025CE CC	5.9451E-02	-1.6168E 01	-9.2174E-02	1.0382E C3	1.2220E C3	1.2593E C3	1.2179E C3
7.225CE CC	5.8939E-02	-1.6166E 01	-9.0363E-02	1.0361E C3	1.2206E C3	1.2591E C3	1.2181E C3
7.425CE CC	5.8443E-02	-1.6164E 01	-8.8595E-02	1.0341E C3	1.2192E C3	1.2588E C3	1.2182E C3
7.625CE CC	5.7962E-02	-1.6162E 01	-8.6883E-02	1.0323E C3	1.2179E C3	1.2586E C3	1.2184E C3
7.825CE CC	5.7496E-02	-1.6160E 01	-8.5228E-02	1.0305E C3	1.2167E C3	1.2583E C3	1.2186E C3
8.025CE CC	5.7043E-02	-1.6158E 01	-8.3616E-02	1.0288E C3	1.2155E C3	1.2580E C3	1.2187E C3
8.225CE CC	5.6605E-02	-1.6157E 01	-8.2055E-02	1.0273E C3	1.2144E C3	1.2577E C3	1.2189E C3

AIROS-FLOW DECAY FROM FULL POWER

TIME		POWER	REACTIVITY	INV.PERIOD	F 2	F 3	F 6	F 12
8.425CE	CC	5.6178E-02	-1.6155E 01	-8.0532E-02	1.0258E 03	1.2133E 03	1.2574E 03	1.2190E 03
8.625CE	CC	5.5764E-02	-1.6154E 01	-7.9062E-02	1.0244E 03	1.2123E 03	1.2571E 03	1.2192E 03
8.825CE	CC	5.5362E-02	-1.6152E 01	-7.7631E-02	1.0231E 03	1.2113E 03	1.2568E 03	1.2194E 03
9.025CE	CC	5.4971E-02	-1.6151E 01	-7.6241E-02	1.0218E 03	1.2104E 03	1.2565E 03	1.2195E 03
9.225CE	CC	5.4590E-02	-1.6150E 01	-7.4888E-02	1.0206E 03	1.2095E 03	1.2562E 03	1.2197E 03
9.425CE	CC	5.4219E-02	-1.6149E 01	-7.3579E-02	1.0194E 03	1.2086E 03	1.2559E 03	1.2198E 03
9.625CE	CC	5.3859E-02	-1.6147E 01	-7.2316E-02	1.0183E 03	1.2077E 03	1.2556E 03	1.2200E 03
9.825CE	CC	5.3507E-02	-1.6146E 01	-7.1077E-02	1.0172E 03	1.2069E 03	1.2553E 03	1.2201E 03
1.0025E	01	5.3165E-02	-1.6145E 01	-6.9888E-02	1.0162E 03	1.2061E 03	1.2549E 03	1.2203E 03

AIRCS-FLOW DECAY FROM FULL POWER

TIME	F 14	F 15	F 21	F 23	F 24	F 30	F 12
C.	2.0930E 03	1.9431E 03	1.1438E 03	1.8813E 03	1.8068E 03	1.1839E 03	
2.000CE-C1	2.0934E 03	1.9434E 03	1.1460E 03	1.8815E 03	1.8070E 03	1.1862E 03	
4.000CE-C1	2.0951E 03	1.9448E 03	1.1530E 03	1.8826E 03	1.8079E 03	1.1933E 03	
6.000CE-C1	2.0987E 03	1.9480E 03	1.1644E 03	1.8850E 03	1.8100E 03	1.2046E 03	
8.000CE-C1	2.1025E 03	1.9519E 03	1.1794E 03	1.8877E 03	1.8129E 03	1.2193E 03	
8.500CE-C1	2.1002E 03	1.9506E 03	1.1836E 03	1.8865E 03	1.8123E 03	1.2232E 03	
9.000CE-C1	2.0917E 03	1.9448E 03	1.1879E 03	1.8816E 03	1.8091E 03	1.2273E 03	
9.250CE-C1	2.0842E 03	1.9395E 03	1.1900E 03	1.8773E 03	1.8061E 03	1.2295E 03	
9.500CE-C1	2.0744E 03	1.9327E 03	1.1922E 03	1.8716E 03	1.8021E 03	1.2316E 03	
9.750CE-C1	2.0627E 03	1.9244E 03	1.1944E 03	1.8647E 03	1.7973E 03	1.2337E 03	
10.000CE-C1	2.0496E 03	1.9151E 03	1.1966E 03	1.8570E 03	1.7919E 03	1.2358E 03	
1.025CE 00	2.0355E 03	1.9051E 03	1.1987E 03	1.8487E 03	1.7861E 03	1.2379E 03	
1.050CE 00	2.0209E 03	1.8947E 03	1.2007E 03	1.8400E 03	1.7800E 03	1.2399E 03	
1.075CE 00	2.0059E 03	1.8840E 03	1.2027E 03	1.8311E 03	1.7737E 03	1.2419E 03	
1.100CE 00	1.9907E 03	1.8733E 03	1.2047E 03	1.8220E 03	1.7674E 03	1.2439E 03	
1.125CE 00	1.9755E 03	1.8625E 03	1.2065E 03	1.8129E 03	1.7610E 03	1.2458E 03	
1.150CE 00	1.9604E 03	1.8518E 03	1.2083E 03	1.8038E 03	1.7546E 03	1.2476E 03	
1.175CE 00	1.9454E 03	1.8412E 03	1.2100E 03	1.7947E 03	1.7482E 03	1.2494E 03	
1.200CE 00	1.9306E 03	1.8307E 03	1.2117E 03	1.7857E 03	1.7419E 03	1.2512E 03	
1.225CE 00	1.9159E 03	1.8204E 03	1.2132E 03	1.7768E 03	1.7357E 03	1.2529E 03	
1.250CE 00	1.9015E 03	1.8102E 03	1.2147E 03	1.7679E 03	1.7295E 03	1.2545E 03	
1.275CE 00	1.8873E 03	1.8003E 03	1.2160E 03	1.7592E 03	1.7235E 03	1.2561E 03	
1.325CE 00	1.8598E 03	1.7809E 03	1.2186E 03	1.7421E 03	1.7116E 03	1.2591E 03	
1.375CE 00	1.8332E 03	1.7623E 03	1.2208E 03	1.7255E 03	1.7002E 03	1.2619E 03	
1.425CE 00	1.8076E 03	1.7444E 03	1.2227E 03	1.7093E 03	1.6890E 03	1.2645E 03	
1.475CE 00	1.7828E 03	1.7272E 03	1.2243E 03	1.6936E 03	1.6782E 03	1.2669E 03	
1.525CE 00	1.7590E 03	1.7106E 03	1.2257E 03	1.6783E 03	1.6678E 03	1.2691E 03	
1.575CE 00	1.7359E 03	1.6946E 03	1.2269E 03	1.6634E 03	1.6576E 03	1.2711E 03	
1.625CE 00	1.7137E 03	1.6792E 03	1.2278E 03	1.6489E 03	1.6478E 03	1.2730E 03	
1.675CE 00	1.6922E 03	1.6643E 03	1.2284E 03	1.6348E 03	1.6382E 03	1.2747E 03	
1.725CE 00	1.6714E 03	1.6500E 03	1.2289E 03	1.6211E 03	1.6289E 03	1.2763E 03	
1.775CE 00	1.6513E 03	1.6361E 03	1.2292E 03	1.6077E 03	1.6198E 03	1.2777E 03	
1.825CE 00	1.6319E 03	1.6227E 03	1.2294E 03	1.5946E 03	1.6111E 03	1.2790E 03	
1.875CE 00	1.6131E 03	1.6098E 03	1.2293E 03	1.5819E 03	1.6025E 03	1.2802E 03	
1.925CE 00	1.5949E 03	1.5973E 03	1.2292E 03	1.5695E 03	1.5942E 03	1.2813E 03	

AIR05-FLOW DECAY FROM FULL POWER

TIME	F 14	F 15	F 21	F 23	F 24	F 30	F 12
1.975CE CC	1.5773E 03	1.5852E 03	1.2289E 03	1.5575E 03	1.5861E 03	1.2822E 03	
2.025CE CC	1.5602E 03	1.5735E 03	1.2284E 03	1.5457E 03	1.5783E 03	1.2831E 03	
2.075CE CC	1.5437E 03	1.5621E 03	1.2279E 03	1.5342E 03	1.5706E 03	1.2839E 03	
2.125CE CC	1.5277E 03	1.5511E 03	1.2273E 03	1.5230E 03	1.5631E 03	1.2846E 03	
2.225CE CC	1.4972E 03	1.5301E 03	1.2257E 03	1.5014E 03	1.5488E 03	1.2857E 03	
2.425CE CC	1.4416E 03	1.4917E 03	1.2218E 03	1.4613E 03	1.5222E 03	1.2872E 03	
2.625CE CC	1.3923E 03	1.4576E 03	1.2172E 03	1.4249E 03	1.4982E 03	1.2878E 03	
2.825CE CC	1.3486E 03	1.4270E 03	1.2121E 03	1.3918E 03	1.4764E 03	1.2879E 03	
3.025CE CC	1.3096E 03	1.3995E 03	1.2069E 03	1.3616E 03	1.4565E 03	1.2876E 03	
3.225CE CC	1.2748E 03	1.3746E 03	1.2016E 03	1.3341E 03	1.4384E 03	1.2870E 03	
3.425CE CC	1.2436E 03	1.3521E 03	1.1965E 03	1.3089E 03	1.4218E 03	1.2863E 03	
3.625CE CC	1.2157E 03	1.3317E 03	1.1915E 03	1.2859E 03	1.4066E 03	1.2854E 03	
3.825CE CC	1.1906E 03	1.3131E 03	1.1867E 03	1.2649E 03	1.3927E 03	1.2845E 03	
4.025CE CC	1.1681E 03	1.2961E 03	1.1822E 03	1.2456E 03	1.3799E 03	1.2835E 03	
4.225CE CC	1.1478E 03	1.2806E 03	1.1779E 03	1.2280E 03	1.3681E 03	1.2825E 03	
4.425CE CC	1.1294E 03	1.2664E 03	1.1739E 03	1.2117E 03	1.3572E 03	1.2816E 03	
4.625CE CC	1.1128E 03	1.2533E 03	1.1701E 03	1.1968E 03	1.3472E 03	1.2807E 03	
4.825CE CC	1.0978E 03	1.2414E 03	1.1666E 03	1.1831E 03	1.3379E 03	1.2798E 03	
5.025CE CC	1.0842E 03	1.2303E 03	1.1633E 03	1.1705E 03	1.3294E 03	1.2789E 03	
5.225CE CC	1.0719E 03	1.2202E 03	1.1602E 03	1.1589E 03	1.3215E 03	1.2781E 03	
5.425CE CC	1.0606E 03	1.2108E 03	1.1574E 03	1.1481E 03	1.3142E 03	1.2773E 03	
5.625CE CC	1.0504E 03	1.2022E 03	1.1547E 03	1.1382E 03	1.3074E 03	1.2766E 03	
5.825CE CC	1.0411E 03	1.1943E 03	1.1522E 03	1.1291E 03	1.3011E 03	1.2759E 03	
6.025CE CC	1.0326E 03	1.1869E 03	1.1499E 03	1.1206E 03	1.2952E 03	1.2752E 03	
6.225CE CC	1.0249E 03	1.1801E 03	1.1477E 03	1.1128E 03	1.2898E 03	1.2745E 03	
6.425CE CC	1.0178E 03	1.1738E 03	1.1457E 03	1.1056E 03	1.2847E 03	1.2739E 03	
6.625CE CC	1.0114E 03	1.1679E 03	1.1438E 03	1.0989E 03	1.2800E 03	1.2733E 03	
6.825CE CC	1.0055E 03	1.1625E 03	1.1420E 03	1.0926E 03	1.2756E 03	1.2727E 03	
7.025CE CC	1.0000E 03	1.1574E 03	1.1403E 03	1.0868E 03	1.2715E 03	1.2721E 03	
7.225CE CC	9.9505E 02	1.1527E 03	1.1387E 03	1.0814E 03	1.2676E 03	1.2715E 03	
7.425CE CC	9.9048E 02	1.1484E 03	1.1372E 03	1.0764E 03	1.2640E 03	1.2710E 03	
7.625CE CC	9.8627E 02	1.1443E 03	1.1357E 03	1.0717E 03	1.2607E 03	1.2704E 03	
7.825CE CC	9.8240E 02	1.1405E 03	1.1344E 03	1.0673E 03	1.2575E 03	1.2699E 03	
8.025CE CC	9.7884E 02	1.1370E 03	1.1331E 03	1.0633E 03	1.2545E 03	1.2693E 03	
8.225CE CC	9.7555E 02	1.1337E 03	1.1318E 03	1.0594E 03	1.2517E 03	1.2688E 03	

AIROS-FLOW DECAY FROM FULL POWER

TIME		F 14	F 15	F 21	F 23	F 24	F 30	F 12
8.425CE	CC	9.7252E 02	1.1306E 03	1.1306E 03	1.0558E 03	1.2491E 03	1.2682E 03	
8.625CE	CC	9.6971E 02	1.1277E 03	1.1295E 03	1.0524E 03	1.2465E 03	1.2676E 03	
8.825CE	CC	9.6711E 02	1.1250E 03	1.1284E 03	1.0493E 03	1.2442E 03	1.2671E 03	
9.025CE	CC	9.6470E 02	1.1224E 03	1.1273E 03	1.0463E 03	1.2419E 03	1.2665E 03	
9.225CE	CC	9.6247E 02	1.1200E 03	1.1263E 03	1.0435E 03	1.2398E 03	1.2660E 03	
9.425CE	CC	9.6039E 02	1.1178E 03	1.1253E 03	1.0408E 03	1.2377E 03	1.2654E 03	
9.625CE	CC	9.5845E 02	1.1156E 03	1.1243E 03	1.0382E 03	1.2358E 03	1.2648E 03	
9.825CE	CC	9.5664E 02	1.1136E 03	1.1233E 03	1.0358E 03	1.2339E 03	1.2642E 03	
1.0025E	C1	9.5495E 02	1.1117E 03	1.1224E 03	1.0336E 03	1.2322E 03	1.2636E 03	

RUN TIME - COMPUTE PHASE - 24.0 SECONDS
 - PRINT PHASE - 3.0 SECONDS
 - GRAPH PHASE - 6.0 SECONDS
 - TOTAL CODE - 33.0 SECONDS

TOTAL NUMBER OF POINTS CALCULATED - 79

AIROS-STARTUP FROM COLD SHUTDOWN, REC WITHDRAWAL

.0022\$/SEC.

CONTROL INFO DD(1) TC DD(50)

1	6.00000E 00	3.400000E 01	7.000000E-03	5.000000E-04	5.424000E-09
6	8.475000E-09	-6.400000E-01	0.	2.000000E-01	1.000000E-05
11	2.000000E-01	1.000000E 00	10.000000E-03	1.000000E-01	4.000000E 00
16	4.500000E 02	8.475000E-04	1.000000E 10	5.000000E 00	0.
21	2.000000E-02	1.450000E-02	5.500000E-03	-2.300000E-03	-6.900000E-02
26	2.000000E-01	1.400000E-01	6.000000E-02	-4.250000E-01	1.070000E 00
31	0.	0.	0.	0.	0.
36	0.	0.	0.	0.	0.
41	3.200000E-03	-1.642900E 01	4.220000E 00	0.	0.
46	0.	0.	0.	0.	0.

PRE-CURSOR INFO DD(51) TC DD(95)

51	8.475000E-09	8.475000E-09	8.475000E-09	8.475000E-09	8.475000E-09
66	3.297000E-02	2.194000E-01	1.960000E-01	3.947000E-01	1.150000E-01
81	1.240000E-02	3.050000E-02	1.110000E-01	3.010000E-01	1.130000E 00

FEEDBACK INFO DD(101) TC DD(900)

101	1.095000E 02	1.095000E 02	0.	0.
	0.	4.050000E-01	2.950000E-01	0.
	0.	6.260000E 02	8.580000E 02	6.260000E 02
	0.	0.	0.	0.
	3.640000E 02	5.000000E 02	3.640000E 02	0.
	0.	0.	0.	0.
	3.333000E 01	0.	0.	0.
201	0.	0.	0.	0.
	0.	0.	0.	0.
	0.	0.	0.	0.
	0.	0.	0.	0.
	0.	0.	0.	0.
	0.	0.	0.	0.
	0.	0.	0.	0.
301	-3.587000E-01	-3.587000E-01	-6.274000E-01	-6.274000E-01
	-6.274000E-01	-1.142000E-02	-1.142000E-02	-2.845000E-01
	-2.845000E-01	-8.340000E-01	-8.340000E-01	-8.340000E-01
	-7.100000E 00	-7.100000E 00	-7.410000E-01	-7.410000E-01

-7.410000E-C1	-5.860000E-01	-5.860000E-01	-5.860000E-01	-9.520000E CC
-9.520000E C0	-9.520000E 00	-1.110000E 00	-1.110000E 00	-1.110000E C0
C.	-3.333000E 01	-1.000000E 00	-1.000000E 00	
4C1				
6.641000E C2	6.857000E 02	7.029000E 02	6.664000E 02	6.888000E C2
7.052000E C2	6.587000E 02	6.783000E 02	6.975000E 02	6.664000E C2
6.888000E C2	7.052000E 02	6.770000E 02	7.012000E 02	7.117000E C2
6.620000E C2	6.811000E 02	6.967000E 02	6.646000E 02	6.847000E C2
6.993000E C2	6.734000E 02	6.983000E 02	7.112000E C2	6.610000E C2
6.812000E C2	6.982000E 02	6.659000E 02	6.878000E 02	7.037000E C2
6.500000E C2	2.000000E-02	6.993000E 02	7.052000E 02	
5C1				
-2.757000E-C4	-5.385000E-04	-2.757000E-04	1.046000E-C4	1.046000E-C4
3.540000E-C5	9.540000E-05	1.866000E-04	9.540000E-05	2.764000E-C4
2.764000E-C4	9.360000E-05	0.	0.	C.
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	C.
1.265000E-C4	0.	0.	0.	
6C1				
10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34
10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34
10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34
10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34
10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34
10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34	10.000000E 34
10.000000E 34	-1.250000E 00	-1.200000E 03	-7.552000E 02	
7C1				
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	C.
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	C.
C.	1.020000E 00	1.020000E 00	1.020000E CC	
8C1				
C.	0.	0.	0.	C.
C.	0.	0.	0.	0.
C.	0.	0.	0.	C.
C.	0.	0.	0.	0.
C.	0.	0.	0.	0.
C.	0.	0.	0.	C.
C.	0.	0.	0.	

FEEDBACK PRINT AND CRT INFO IPRINT(1) TO IPRINT(100)

C	1	2	0	C
3	0	0	0	C
C	3	0	1	2
C	0	0	0	C
3	0	1	2	C
C	0	0	0	3
C	0	0	C	

FEEDBACK CONNECTORS AND COEFFICIENTS KC(1) TO KC(800) AND C(1) TO C(800)

1	-1	4	-4	31	-31	0	0	0
	-6.33CCE-C2	1.7940E-01	3.1700E-02	1.7940E-01	3.1700E-02	C.	C.	0.
2	-2	5	-5	4	-4	0	0	0
	-6.33CCE-C2	1.7940E-01	3.1700E-02	1.7940E-01	3.1700E-02	C.	C.	0.
3	-3	6	-6	5	-5	0	C	0
	-6.33CCE-C2	1.7940E-01	3.1700E-02	1.7940E-01	3.1700E-02	C.	C.	0.
4	-4	31	-31	1	-1	7	C	0
	-2.0056E CC	-6.2740E-01	1.8280E 00	1.0050E 00	1.7740E-01	2.5000E-C1	C.	0.
5	-5	4	-4	2	-2	8	C	0
	-2.0056E CC	-6.2740E-01	1.8280E 00	1.0050E 00	1.7740E-01	2.5000E-C1	C.	0.
6	-6	5	-5	3	-3	9	C	0
	-2.0056E CC	-6.2740E-01	1.8280E 00	1.0050E 00	1.7740E-01	2.5000E-C1	C.	0.
7	4	31	10	0	0	0	C	0
	1.9400E-C3	5.7200E-03	3.7800E-03	0.	0.	C.	0.	0.
8	5	4	11	10	0	0	0	0
	1.9400E-C3	1.9400E-03	3.7800E-03	3.7800E-03	0.	C.	C.	0.
9	6	5	12	11	0	0	C	0
	1.9400E-C3	1.9400E-03	3.7800E-03	3.7800E-03	0.	C.	0.	0.
10	-10	7	31	-31	0	0	C	0
	-9.0100E-C2	5.6900E-01	-2.8450E-01	9.0100E-02	0.	C.	C.	0.
11	-11	8	10	-10	0	0	C	0
	-9.0100E-C2	5.6900E-01	-2.8450E-01	9.0100E-02	0.	C.	0.	0.
12	-12	9	11	-11	0	0	0	0
	-9.0100E-C2	5.6900E-01	-2.8450E-01	9.0100E-02	0.	C.	C.	0.
13	16	0	0	0	0	0	C	0
	8.3400E-C1	0.	0.	0.	0.	C.	C.	0.
14	17	0	0	0	0	0	0	0
	8.3400E-C1	0.	0.	0.	0.	C.	C.	0.
15	18	0	0	0	0	0	C	0
	8.3400E-C1	0.	0.	0.	0.	C.	0.	0.
16	-16	13	19	-19	31	-31	C	0
	-7.5600E CC	2.0500E 00	2.5250E 00	3.7800E 00	2.5250E 00	3.7800E CC	0.	0.
17	-17	14	20	-20	19	-19	C	0
	-7.5600E CC	2.0500E 00	2.5250E 00	3.7800E 00	2.5250E 00	3.7800E CC	0.	0.

18	-18	15	21	-21	20	-20	0	0
	-7.560CE CC	2.0500E 00	2.5250E 00	3.7800E 00	2.5250E 00	3.7800E CC	C.	C.
19	-19	16	-16	31	-31	0	C	0
	-4.204CE CC	1.4820E 00	2.2280E 00	-7.4100E-01	1.9760E 00	C.	C.	0.
20	-20	17	-17	19	-19	0	0	0
	-4.2040E CC	1.4820E 00	2.2280E 00	-7.4100E-01	1.9760E 00	C.	0.	0.
21	-21	18	-18	20	-20	C	0	0
	-4.204CE CC	1.4820E 00	2.2280E 00	-7.4100E-01	1.9760E CC	C.	C.	0.
22	25	0	0	0	C	C	0	0
	5.8600E-C1	0.	0.	0.	0.	C.	C.	0.
23	26	0	0	0	0	C	0	0
	5.860CE-C1	0.	0.	0.	0.	C.	C.	0.
24	27	0	0	0	0	0	0	0
	5.860CE-C1	0.	0.	0.	0.	C.	C.	0.
25	-25	22	28	-28	31	-31	C	0
	-1.077CE C1	2.3400E 00	3.5900E 00	5.3850E 00	3.5900E CC	5.385CE CC	C.	0.
26	-26	23	29	-29	28	-28	0	0
	-1.077CE C1	2.3400E 00	3.5900E 00	5.3850E 00	3.5900E 00	5.385CE CC	C.	0.
27	-27	24	30	-30	29	-29	C	0
	-1.077CE C1	2.3400E 00	3.5900E 00	5.3850E 00	3.5900E CC	5.385CE CC	C.	0.
28	-28	25	-25	31	-31	C	0	0
	-4.505CE CC	2.2200E 00	3.3300E 00	-1.1100E 00	1.1750E 00	C.	C.	0.
29	-29	26	-26	28	-28	C	C	0
	-4.505CE CC	2.2200E 00	3.3300E 00	-1.1100E 00	1.1750E 00	C.	C.	0.
30	-30	27	-27	29	-29	0	C	0
	-4.505CE CC	2.2200E 00	3.3300E 00	-1.1100E 00	1.1750E 00	C.	C.	0.
31	0	0	0	0	0	C	C	0
	C.	0.	0.	0.	0.	C.	C.	0.
32	0	0	0	0	C	0	0	0
	C.	0.	0.	0.	0.	C.	C.	0.
33	21	0	0	0	0	0	C	0
	1.000CE CC	0.	0.	0.	0.	C.	C.	0.
34	6	0	0	0	0	0	0	0
	1.000CE CC	0.	0.	0.	0.	C.	C.	0.

PROBLEM TERMINATED MINIMUM INTERVAL ENCOUNTERED

AIRGS-STARTUP FROM COLD SHUTDOWN, REC WITHDRAWAL

.0032%/SEC.

TIME	POWER	REACTIVITY	INV. PERIOD	F 2	F 3	F 6	F 12
C.	2.0000E-02	-6.4000E-01	-9.1700E-08	6.8570E 02	7.0290E 02	7.0520E 02	7.0520E 02
3.570CE 02	2.0891E-02	5.0232E-01	1.7371E-01	6.8578E 02	7.0297E 02	7.0524E 02	7.0520E 02
3.580CE 02	2.1060E-02	5.0536E-01	1.7630E-01	6.8599E 02	7.0314E 02	7.0536E 02	7.0519E 02
3.590CE 02	2.1265E-02	5.0840E-01	1.7894E-01	6.8620E 02	7.0333E 02	7.0549E 02	7.0520E 02
3.600CE 02	2.1514E-02	5.1144E-01	1.8160E-01	6.8643E 02	7.0352E 02	7.0564E 02	7.0521E 02
3.610CE 02	2.1817E-02	5.1447E-01	1.8428E-01	6.8667E 02	7.0374E 02	7.0579E 02	7.0522E 02
3.620CE 02	2.2185E-02	5.1748E-01	1.8698E-01	6.8693E 02	7.0397E 02	7.0596E 02	7.0523E 02
3.630CE 02	2.2636E-02	5.2047E-01	1.8969E-01	6.8723E 02	7.0423E 02	7.0616E 02	7.0525E 02
3.640CE 02	2.3188E-02	5.2343E-01	1.9239E-01	6.8756E 02	7.0453E 02	7.0637E 02	7.0526E 02
3.650CE 02	2.3866E-02	5.2635E-01	1.9507E-01	6.8794E 02	7.0487E 02	7.0661E 02	7.0528E 02
3.660CE 02	2.4701E-02	5.2923E-01	1.9772E-01	6.8838E 02	7.0527E 02	7.0689E 02	7.0530E 02
3.670CE 02	2.5731E-02	5.3204E-01	2.0032E-01	6.8889E 02	7.0573E 02	7.0721E 02	7.0532E 02
3.680CE 02	2.7005E-02	5.3478E-01	2.0284E-01	6.8951E 02	7.0628E 02	7.0759E 02	7.0535E 02
3.690CE 02	2.8582E-02	5.3743E-01	2.0525E-01	6.9024E 02	7.0693E 02	7.0804E 02	7.0537E 02
3.700CE 02	3.0540E-02	5.3995E-01	2.0752E-01	6.9114E 02	7.0771E 02	7.0857E 02	7.0540E 02
3.710CE 02	3.2973E-02	5.4232E-01	2.0958E-01	6.9222E 02	7.0866E 02	7.0922E 02	7.0543E 02
3.720CE 02	3.5997E-02	5.4451E-01	2.1138E-01	6.9355E 02	7.0982E 02	7.1000E 02	7.0547E 02
3.730CE 02	3.9760E-02	5.4645E-01	2.1284E-01	6.9517E 02	7.1123E 02	7.1095E 02	7.0550E 02
3.740CE 02	4.4438E-02	5.4811E-01	2.1387E-01	6.9718E 02	7.1297E 02	7.1211E 02	7.0555E 02
3.750CE 02	5.0246E-02	5.4939E-01	2.1434E-01	6.9966E 02	7.1511E 02	7.1353E 02	7.0559E 02
3.760CE 02	5.7439E-02	5.5022E-01	2.1411E-01	7.0273E 02	7.1774E 02	7.1528E 02	7.0565E 02
3.770CE 02	6.6315E-02	5.5048E-01	2.1303E-01	7.0652E 02	7.2099E 02	7.1744E 02	7.0571E 02
3.780CE 02	7.7204E-02	5.5006E-01	2.1091E-01	7.1120E 02	7.2500E 02	7.2010E 02	7.0578E 02
3.790CE 02	9.0462E-02	5.4879E-01	2.0754E-01	7.1697E 02	7.2994E 02	7.2337E 02	7.0586E 02
3.800CE 02	1.0644E-01	5.4651E-01	2.0274E-01	7.2403E 02	7.3599E 02	7.2740E 02	7.0595E 02
3.810CE 02	1.2546E-01	5.4305E-01	1.9631E-01	7.3264E 02	7.4338E 02	7.3232E 02	7.0606E 02
3.820CE 02	1.4772E-01	5.3819E-01	1.8814E-01	7.4305E 02	7.5232E 02	7.3831E 02	7.0619E 02
3.830CE 02	1.7330E-01	5.3177E-01	1.7817E-01	7.5549E 02	7.6304E 02	7.4554E 02	7.0634E 02
3.840CE 02	2.0202E-01	5.2363E-01	1.6647E-01	7.7019E 02	7.7577E 02	7.5418E 02	7.0653E 02
3.850CE 02	2.3346E-01	5.1365E-01	1.5327E-01	7.8731E 02	7.9068E 02	7.6439E 02	7.0674E 02
3.860CE 02	2.6690E-01	5.0179E-01	1.3892E-01	8.0692E 02	8.0787E 02	7.7630E 02	7.0700E 02

AIROS-STARTUP FROM COLD SHUTDOWN, REC WITHDRAWAL

.0032\$/SEC.

TIME	F 14	F 15	F 21	F 23	F 24	F 30	F 12
C.	7.0120E 02	7.1170E 02	6.9930E 02	6.9830E 02	7.1120E 02	7.0370E 02	
3.570CE 02	7.0157E 02	7.1189E 02	6.9932E 02	6.9844E 02	7.1129E 02	7.0356E 02	
3.580CE 02	7.0223E 02	7.1226E 02	6.9942E 02	6.9874E 02	7.1156E 02	7.0366E 02	
3.590CE 02	7.0277E 02	7.1261E 02	6.9960E 02	6.9904E 02	7.1183E 02	7.0382E 02	
3.600CE 02	7.0330E 02	7.1302E 02	6.9987E 02	6.9938E 02	7.1213E 02	7.0403E 02	
3.610CE 02	7.0387E 02	7.1351E 02	7.0019E 02	6.9977E 02	7.1248E 02	7.0428E 02	
3.620CE 02	7.0451E 02	7.1409E 02	7.0059E 02	7.0023E 02	7.1291E 02	7.0458E 02	
3.630CE 02	7.0525E 02	7.1478E 02	7.0105E 02	7.0077E 02	7.1341E 02	7.0494E 02	
3.640CE 02	7.0611E 02	7.1559E 02	7.0159E 02	7.0142E 02	7.1401E 02	7.0537E 02	
3.650CE 02	7.0713E 02	7.1656E 02	7.0222E 02	7.0220E 02	7.1474E 02	7.0589E 02	
3.660CE 02	7.0836E 02	7.1772E 02	7.0296E 02	7.0314E 02	7.1562E 02	7.0650E 02	
3.670CE 02	7.0985E 02	7.1912E 02	7.0384E 02	7.0428E 02	7.1668E 02	7.0724E 02	
3.680CE 02	7.1167E 02	7.2082E 02	7.0490E 02	7.0567E 02	7.1798E 02	7.0814E 02	
3.690CE 02	7.1390E 02	7.2289E 02	7.0618E 02	7.0738E 02	7.1956E 02	7.0923E 02	
3.700CE 02	7.1664E 02	7.2542E 02	7.0774E 02	7.0947E 02	7.2150E 02	7.1056E 02	
3.710CE 02	7.2003E 02	7.2854E 02	7.0964E 02	7.1206E 02	7.2388E 02	7.1218E 02	
3.720CE 02	7.2422E 02	7.3239E 02	7.1198E 02	7.1525E 02	7.2681E 02	7.1418E 02	
3.730CE 02	7.2942E 02	7.3714E 02	7.1486E 02	7.1921E 02	7.3044E 02	7.1663E 02	
3.740CE 02	7.3588E 02	7.4303E 02	7.1842E 02	7.2412E 02	7.3493E 02	7.1967E 02	
3.750CE 02	7.4390E 02	7.5034E 02	7.2283E 02	7.3021E 02	7.4049E 02	7.2342E 02	
3.760CE 02	7.5385E 02	7.5940E 02	7.2830E 02	7.3777E 02	7.4738E 02	7.2806E 02	
3.770CE 02	7.6618E 02	7.7062E 02	7.3508E 02	7.4713E 02	7.5591E 02	7.3382E 02	
3.780CE 02	7.8141E 02	7.8449E 02	7.4348E 02	7.5870E 02	7.6646E 02	7.4095E 02	
3.790CE 02	8.0015E 02	8.0158E 02	7.5387E 02	7.7295E 02	7.7947E 02	7.4976E 02	
3.800CE 02	8.2306E 02	8.2252E 02	7.6668E 02	7.9040E 02	7.9543E 02	7.6063E 02	
3.810CE 02	8.5085E 02	8.4801E 02	7.8239E 02	8.1162E 02	8.1489E 02	7.7398E 02	
3.820CE 02	8.8422E 02	8.7877E 02	8.0156E 02	8.3720E 02	8.3845E 02	7.9028E 02	
3.830CE 02	9.2377E 02	9.1547E 02	8.2475E 02	8.6765E 02	8.6668E 02	8.1005E 02	
3.840CE 02	9.6995E 02	9.5868E 02	8.5251E 02	9.0342E 02	9.0010E 02	8.3379E 02	
3.850CE 02	1.0229E 03	1.0088E 03	8.9534E 02	9.4475E 02	9.3912E 02	8.6197E 02	
3.860CE 02	1.0825E 03	1.0659E 03	9.2362E 02	9.9166E 02	9.8356E 02	8.9501E 02	

RUN TIME - COMPUTE PHASE	-	78.0	SECONDS
-PRINT PHASE	-	1.0	SECONDS
- GRAPH PHASE	-	6.0	SECONDS
- TOTAL CODE	-	85.0	SECONDS

TOTAL NUMBER OF POINTS CALCULATED - 1936

APPENDIX G
GRAPHICAL RESULTS

NAA-SR-9943
104

AIROS-FAST SHIM ROD WITHDRAWAL FROM FULL POWER

7742-06
002 000

AIROS-FAST SHIM ROD WITHDRAWAL FROM FULL POWER

7742-06
003 000

AIROS-FAST SHIM ROD WITHDRAWAL FROM FULL POWER

7742-06
004 000

AIROS-FAST SHIM ROD WITHDRAWAL FROM FULL POWER

7742-06
005 000

AIROS-FAST SHIM ROD WITHDRAWAL FROM FULL POWER

7742-06
006 000

AIROS-FLOW DECAY FROM FULL POWER

7742-08
008 000

AIROS-FLOW DECAY FROM FULL POWER

7742-06
009 000

AIROS-FLOW DECAY FROM FULL POWER

7742-06
010 000

AIROS-FLOW DECAY FROM FULL POWER

7742-06
011 000

AIROS-FLOW DECAY FROM FULL POWER

7742-06
012 000

AIROS-STARTUP FROM COLD SHUTDOWN, ROD WITHDRAWAL

7742-16
008 000

AIROS-STARTUP FROM COLD SHUTDOWN, ROD WITHDRAWAL

7742-16
009 000

AIROS-STARTUP FROM COLD SHUTDOWN, ROD WITHDRAWAL

7742-16
010 000

AIROS-STARTUP FROM COLD SHUTDOWN. ROD WITHDRAWAL

7742-16
011 000

AIROS-STARTUP FROM COLD SHUTDOWN, ROD WITHDRAWAL

7742-16
012 000