UNCLASSIFIED

MASTER

CLASSIFICATION LEVEL

(S, C, OR U)

ATOMICS INTERNATIONAL

A Division of North American Aviation, Inc.

NAA-SR-MEMO 9800

This document contains 80 pages

This is copy _____ of _____ series _____

Do not remove
this sheet

CLASSIFICATION TYPE

(RD OR DI)

*NAA-SR-MEMOs are working papers and may be expanded,
modified, or withdrawn at any time,
and are intended for internal use only.*

This report may not be published without the approval of the Patent Branch, AEC.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

UNCLASSIFIED

CLASSIFICATION LEVEL

(S, C, OR U)

DISCLAIMER

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

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

April, 1964

NAA-SR-MEMO-9800

NAA PROGRAM DESCRIPTION

Progress To Date Toward the Development
of a Generalized Digital Simulator for
Reactor Dynamics: AIREK 3A and 3B

by

R. A. Blaine

R. F. Berland

Mathematics and Computer Applications

ATOMICS INTERNATIONAL

a division of North American Aviation, Inc.

ACKNOWLEDGMENT

The authors want to acknowledge the contributions of R. Audette who offered many valuable suggestions, formulated several of the equations and aided in the check-out of AIREK 3A. We are also grateful to L. R. Blue and M. Hoffman for allowing us to build upon AIREK 3.

The work was performed under G.O. 7549, Reactor Safety; S.A. 4589, Reactor Kinetics.

ABSTRACT

Modifications to AIREK to provide additional generality for dynamic simulation of a reactor using a numerical method developed by E. R. Cohen.

AIREK 3A - includes equations for flow decay from full power and after a scram, scrams based on delayed instrumentation signals, after glow heating, control rod fall under gravity and generalized printed and graphical output. Any feedbacks can be grouped on a CRT frame and/or printed. Provision for heat transfer by conduction and convection with flow dependent film coefficient.

AIREK 3B - modification of AIREK 3A to provide crude models for fuel melting, nucleate and bulk boiling, vaporization of coolant and burnout.

TABLE OF CONTENTS

	page
I. INTRODUCTION	1
II. JUSTIFICATION FOR A DIGITAL SIMULATOR	2
III. AIREK 3A	5
A. Special Features	5
B. Input Instructions	9
C. Running Instructions	14
IV. AIREK 3B	15
A. Special Features	16
B. Input Instructions	18
C. Running Instructions	23
V. WHAT WAS LEARNED	23
VI. REFERENCES	25
APPENDIX A - Interval Switching	26
APPENDIX B - Sample Problem for AIREK 3A	29
APPENDIX C - Sample Problem for AIREK 3B	52

I. INTRODUCTION

A major goal of the reactor kinetics project (7549-4589) for fiscal year 1964 was the development of a digital simulator for power reactor dynamics. This document is intended to serve two purposes: (1) as a progress report and (2) as a user's manual for the two codes developed to date.

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. Cohen⁴ 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 other codes were developed specifically for reactor dynamics, the are OSCAI-1⁵ and BOOMER⁶. These codes simulate many of the physical phenomena of interest to power and SNAP reactors, respectively, and also provide graphical displays; however each 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 3-5 axial nodes and five 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; (9) Extensive graphical output. Although not all these specifications are met in the codes described herein, several useful studies have been performed and we are along way towards having a useful generalized dynamic simulator for power reactors. Before

describing the work I would like to justify once and for all the use of digital rather than analog simulation for this type of study.

II. 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.

A. 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 as AIREK 3 was available, only modifications were needed to handle the complications of conduction, convection, flow decay, scrams, and et cetera. The code was modified - not programmed from scratch at little cost. And, now that the first generation simulator is available most studies can be performed with no re-coding, no checkout, et cetera.

B. 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. During this period two to three men are involved.

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

Two men (usually) are present during the actual runs which typically cover a period of two weeks to a month. Thus we can take six man-weeks as typical of the cost of a hazards study on an analog computer (~ \$3000 at \$500 per week) 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 (\$36, say) and no other expense is involved other than machine running time. Now the cases for a typical SGR study required 1 to 3 minutes each and were as complex as most analog studies. Taking 2 minutes a case on the average, allowing for 50 cases and figuring at North American Aviation, Incorporated's exorbitant rate (\$735 per hour), the entire machine cost was somewhat less than \$1200 or 40% 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.

Digital simulation clearly has both the time and cost advantage over analog simulation.

C. Ease of Changing Parameters

Many parameters can be changed quite easily on an analog simply by resetting a pot. Certain ones, however, such as initial conditions can require major changes in pot settings due to scaling difficulties. In fact, most start-up 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.

On the other hand, digital codes at Atomics International 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.

D. Form of Output

Engineers argue correctly that graphical display is far more meaningful than digital print-out. Examples in Appendices B and C 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 occur on a given frame. Clearly, digital displays are now superior to analog displays.

Now that we have disposed of the classic arguments against the use of digital simulation, let us look at the advantages.

E. Cost of a Few Cases

It costs no more per case to run 1 case or 25 on a digital code. Whereas, the same patchboard set-up time and the same checkout time is required for 1 or 20 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.

F. Limitation on Equipment

Because of limitation on amplifiers, function generators, et cetera, 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 50 other feedback equations (166 differential equations) in addition to allowing for variable coefficients, flow decay, et cetera. 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 (as we have done in the simulator presently under development).

G. 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 sub-program. 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 combination of parameters.

More important, however, is the ability to include more basic physical calculations. For example, it would be possible to incorporate an already 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 and use the code to determine the parameters e.g., AIREK-KEWB^{7,8}.

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.

Now that the reader is sufficiently aware of the arguments in favor of the digital approach over the analog approach, let us describe the digital simulators developed to date.

III. AIREK 3A

We will refer to the first simulator we attempted as AIREK 3A for two reasons: (1) lack of a better name, and (2) the code represents modifications to AIREK 3 but is basically as programmed. I want to give credit to the authors of AIREK 3 for programming in such a way as to make modification and extension a straight forward task.

A. Special Features

We will not describe the numerical methods in any detail since they are adequately described elsewhere^{2,4} but will emphasize the new features of the code using the formulation of AIREK 3.

Neutron Equations

The prompt and delayed neutron equations are unchanged and can be written as

$$\dot{n}(t) = \frac{\beta}{\Lambda} [(k(t)-1)n(t) + \sum f_i W_i(t) + S^*] \quad (1)$$

$$\dot{W}_i(t) = \lambda_i [n(t) - W_i(t)] \quad (2)$$

where the symbols have the same meaning as in the AIREK 3 document.

Feedback Equations

The form of the feedback equation is generalized to allow for heat transfer by conduction and convection as follows:

$$\dot{F}_j(t) = P_j Q(t) + U_j n(t) + Y_j F_j(t) + \sum_{i=1}^6 \alpha_{ij}(t) F_{k_{ij}}(t) \quad (3)$$

where k_{ij} defines how the nodes are connected, e.g., if

$$\begin{array}{ll} k_{1j} = 5 & \text{then nodes 5, 10 and} \\ k_{2j} = 10 & \text{17 are connected to } j. \\ k_{3j} = 17 \end{array}$$

$$Q(t) = n(t) + g(t)$$

and $g(t)$ is the after glow heat.

The coefficients $\alpha_{ij}(t)$ are of the form

$$\alpha_{ij}(t) = \begin{cases} C_{ij} \\ w(t) C_{ij} \end{cases} \quad (4)$$

where C_{ij} is constant and is usually of the form $(UA)_{ij}/(pcv)_j$,
 $w(t)$ is the mass flow rate at time t .

The form of $\alpha_{ij}(t)$ provides for flow dependent film coefficients.

The 50 feedback equations are sufficient to follow a hot and an average channel each having five axial and five radial nodes, three channels with three axial and five radial nodes or any other combinations.

It is still possible to do problem with other kinds of feedbacks, e.g., by setting $U_j = Y_j = \alpha_{ij} = g(t) = 0$ for some j , the equation becomes

$$\dot{F}_j(t) = P_j n(t)$$

i.e., the feedback is proportional to the energy.

Reactivity Equations

The reactivity equations are changed from AIREK 3 to provide for delayed scrams based on instrumentation response to various feedbacks.

The reactivity due to the scram is based on an assumed importance weighting of the form $\sin^2\left(\frac{\pi x}{2L}\right)$.

where x is measured from the rod full out position and is given by an equation of the form $x = \frac{1}{2}a(t - t_s - t_D)^2$ which represents fall due to gravity. (Friction can be accounted for by adjusting the constant a .)

$$\rho(t) = \begin{cases} \rho(0) + \gamma_1 t + \sum_i A_i [F_i(t) - F_i(0)] & ; t \leq t_s + t_D \\ \rho(0) + \gamma_1 t + \sum_i A_i [F_i(t) - F_i(0)] + \gamma_2 \sin^2\left(\frac{\pi x}{2L}\right) & x \leq L \\ \rho(0) + \gamma_1 t + \sum_i A_i [F_i(t) - F_i(0)] + \gamma_2 & t \rightarrow \infty \end{cases} \quad (5)$$

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

t_D = time delay (γ_2 in input)

t_s is the time at which any of the following conditions occur:

$$F_{32}(t) \geq \gamma_4$$

$$F_{33}(t) \geq \gamma_5$$

$$F_{34}(t) \geq \gamma_6$$

(6)

where feedbacks 32-34 are used for instrumentation delays for example

$$\dot{F}_k(t) = -\frac{1}{\tau} [F_k(t) - 1] \quad k = 32, 33, 34$$

$$\left(\gamma_k = -\frac{1}{\tau}\right) \quad \alpha_{jk} = \frac{1}{\tau}, \quad F_k(0) = 1$$

NAA-SR-MEMO-9800

$$\text{or } \dot{F}_K(t) = \frac{1}{\tau} [n(t) - F_K(t)]$$

$$(P_K = \frac{1}{\tau}, \gamma_K = -\frac{1}{\tau}, \alpha_{jK} = \omega_K = 0)$$

or any other from which can be developed from equation (3).

Note that nodes 32, 33 and 34 are reserved for scram signals.

Flow Equations

Two situations are provided on an input option.

a) Flow Decay from Full Power

It is assumed that the reactor is operating at full power at $t = 0$ and that the flow decays because of pump failure, pipe rupture, etc.,

$$w(t) = A e^{Bt} + C \quad (6)$$

b) Decay after Scram

$$w(t) = D \quad ; \quad t < (t_s + \gamma_w) \quad (7)$$

$$w(t) = A \exp[B(t - t_s - \gamma_w)] + C; t \geq (t_s + \gamma_w) \quad (8)$$

where γ_w is the delay time and $D = A + C$

Afterglow Heating

The equation for afterglow heating is the standard two term exponential.

$$g(t) = g(0) \quad ; \quad t \leq t_s \quad (9)$$

$$g(t) = S_1 e^{S_3(t-t_s)} + S_2 e^{S_4(t-t_s)} \quad ; \quad t > t_s \quad (10)$$

Thus one can account for the afterglow heating in start-up after a previous scram ($g(0) \neq 0$), afterglow heating after a scram, or combinations of the terms.

Output

A major modification was made to the output routines (printed and graphical) of AIREK 3 as a first step toward truly general output. These routines were modified such that the user inputs information which determines

- a) which feedbacks are printed,
- b) which feedbacks are displayed,
- c) how the feedbacks are to be grouped on each frame, and
- d) frequency of printout, where every N^{th} time step is printed according to the value of N print (equations (1), (2), (5)).

Also an option to print the delayed neutron levels is available.

A sample problem appears in Appendix B.

B. Input Instructions

General Information

There must be at least three 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 information.
Within this group cards can be in any order, however, the final card must contain a "1" in column 1.

Detailed Description

- a) Title Card - columns 1-72

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

- Column 1 - left blank unless last card of floating point data, in which case place a "1" in this column.
- Columns 4-6 - relative address of first piece of data on card. All data following the first piece is 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 13-72 - floating point data (as many as five numbers) according to 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 B.

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, $NF \leq 50$
3	B	β - delayed fraction
4	ELL	ℓ - lifetime
5	S	S^* - source
6	ENO	$n(t=0)$ initial neutron level
7	RO	$\rho(t=0)$ initial reactivity in dollars
8	ØMO	$w(t=0)$ 0 - no inhour calculation 1 - inhour calculation
9	HI	initial calculational interval
10	HL	minimum calculational interval
11	HU	maximum calculational interval
12	HMN	maximum number of calculation intervals
13	AL	lower limit for Q test
14	AU	upper limit for Q test
15	SCT	non-zero if SC4020 output desired
16-30	FR(I)	f_i , delayed neutron fraction, I = 1, ND address = 16 + (I-1)
31-45	EL(I)	λ_i , decay constants, I = 1, ND address = 31 + (I-1)
46-60	W(I)	$w(t=0)$ initial delayed neutron levels, I = 1, ND address = 46 + (I-1)
61-110	P(J)	β_j^* , J = 1, NF address = 61 + (J-1)
111-160	U(J)	β_j^* , J = 1, NF address = 111 + (J-1)
161-210	Y(J)	γ_j^* , J = 1, NF address = 161 + (J-1)

*see equation (3)

<u>Address</u>	<u>Symbol</u>	<u>Explanation</u>
211-260	F(J)	$F_j(t=0)$ initial feedback levels, J = 1, NF address = 211 + (J-1)
261-310	A(J)	A_j , reactivity feedback coefficients J = 1, NF address = 261 + (J-1)
311-360	FM(J)	maximum allowed value of feedback, $F_j(t)$ address = 311 + (J-1)
361	PM	maximum neutron level allowed
362	TIMEM	maximum time allowed
363-372	G(K)	γ_K , K = 1, 7 (see equations (5) and (6)) address = 363 + (K-1)
373	DNT	non-zero if delayed neutrons are to be printed
374	NT	maximum number of F_i 's connected to any $F_j \leq 6$
375	NPRINT	Nprint, print frequency
376-379	E(K)	ε_K , K = 1, 4 address = 376 + (K-1)
380		not used
381	A	A } see discussion on B } flow equations C }
382	B	
383	C	
384	D	D { D if flow decay after scram 0 { 0 if flow decay from full power
385-388	E(K)	ε_K , K = 5, 8 address = 385 + (K-5)
389		not used
390	TW	τ_w flow delay time
391-395	DL(K)	δ_K see section on afterglow heating, K = 1, 4 address = 391 + (K-1)
400-699	C(J,I)	C_{ij} heat transfer coefficients (see equations (3) and (4))

<u>Address</u>	<u>Symbol</u>	<u>Explanation</u>
400-449		$J = 1, NF; I = 1$
450-499		$J = 1, NF; I = 2$
500-549		$J = 1, NF; I = 3$
550-599		$J = 1, NF; I = 4$
600-649		$J = 1, NF; I = 5$
650-799		$J = 1, NF; I = 6$
		$Address = 400 + (J-1) + 50(I-1)$

c) Integer Data

Column 1 -

left blank unless last card of integer data in which case place a "1" in this column.

Columns 4-6 -

relative address of the first piece of data on card. All data following the first piece is 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 13-72 -

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 B.

Relative Addresses for Integer Data

<u>Address</u>	<u>Symbol</u>	<u>Explanation</u>
1-300	KC(J,I)	$K_{ij} \begin{cases} + \text{ uses } C_{ij} \\ - \text{ uses } w(t)C_{ij} \end{cases}$ <p>(see equations (3) and (4))</p>
1-50		J = 1, NF; I = 1
51-100		J = 1, NF; I = 2
101-150		J = 1, NF; I = 3
151-200		J = 1, NF; I = 4
201-250		J = 1, NF; I = 5
251-300		J = 1, NF; I = 6
301-350	IPRINT(J)	<p>address = J + 50(I-1)</p> $\begin{cases} -1 & \text{print } \bar{F}_j; \text{ do not plot} \\ 0 & \text{do not print or plot} \\ M & \text{plot } \bar{F}_j \text{ on frame M and print it} \end{cases}$ <p>J = 1, NF</p> <p>address = 301 + (J-1)</p> <p>No more than 14 $\bar{F}_j$'s can be printed and/or displayed.</p>

C. Running Instructions

AIREK 3A is filed at Department 792 as deck number 3W831.

Submit a short form requesting approximately ten 9x9 frames per case.

Running time on an IBM 7094 is approximately given by

200 calculation points/second/equation

where the number of equations = 1 + ND + NF

IV. AIREK 3B

In order to provide conditions typical of catastrophic excursions in a SGR for the fission product retention project (Safety Project) AIREK 3A was modified to incorporate crude models of fuel melting, nucleate boiling, vaporization of coolant and burnout. The modifications were made for a specific heat transfer model providing both an average channel (for reactivity feedback) and a hot channel (which represented the twelve central elements in this study). Each channel was represented by one fuel and one coolant radial node but three axial nodes as shown below.

Let us write the equations for heat balance in the hot channel.

$$(\rho C_p V)_c \dot{T}_{c(i+6)} = - (UH)_{fc i} [T_{fi}(t) - T_{c(i+6)}(t)] + \sum_{i'=1,3}^{SCFAD} [\theta_{i'}(t) - \theta_{i-1}(t)] \quad (11)$$

$$(\rho C_p V)_f \dot{T}_{fi} = Q_i + (UH)_{fc i} [T_{fi}(t) - T_{c(i+6)}(t)] ; \quad i = 1, 3 \quad (12)$$

$$\text{where } \theta_i(t) = \frac{T_{c(i+6)} - T_{c(i+7)}}{2} \quad i = 1, 2 \quad (13)$$

and $\theta_3(t) = \text{constant.}$

$$\text{LET } q_i(t) = -(UA)_{fci} [T_{fi}(t) - T_{c(i+1)}(t)] \quad (14)$$

so that $q_i(t)$ represents the heat flux out of the i^{th} fuel node.

$$Q_i(t) = P_i \cdot n(t) \quad \text{BTU/SEC, the volumetric heat generation rate}$$

$$P_i = \text{const}$$

$$n(t) = \text{neutron level}$$

$$(UA)_{fci} = \text{overall heat conduction coefficient (fuel, clad, film) between fuel and coolant, same for each node.}$$

$$\rho, C_P, V = \text{density, specific heat and volume}$$

$$v = \text{coolant velocity}$$

$$f = \text{subscript for fuel}$$

$$c = \text{subscript for coolant}$$

Note that $\{\alpha_{ij}\}$ defined in equation (4) is here given by

$$\alpha_{ij} = \begin{cases} \frac{(UA)_{fci}}{(PC_P V)_f} & i = 1, 3 \\ -\frac{(UA)_{fci}}{(PC_P V)_c} & i' = 1, 3 \end{cases} \quad (15)$$

Similar equations are obtained for the average channel by letting $i = 4, 6$.

A. Special Features

The modifications consist of the following models:

1. Burn-out

If the heat flux $q_i(t)$, exceeds burn-out (input) in any axial node of the hot channel, the fuel is assumed to part instantaneously and falls according to gravity (friction can be accounted for) with a reactivity contribution varying as the importance of the distance to which the fuel has fallen, i.e.,

$$\text{if } q_i(t) \geq q_{BO} \quad i = 1, 6 \quad (16)$$

than

$$R_f(t) = R_F \sin^2 [a(t-t_{B0})^2], \left\{ \begin{array}{l} t \geq t_{B0} \\ a(t-t_{B0})^2 < \frac{\pi}{2} \end{array} \right\} \quad (17)$$

$$= R_F$$

where $a = (\frac{1}{2} g f) (\frac{\pi}{2D})$

and $g = 32.2 \text{ FT/SEC}^2$, f = friction factor ≤ 1 , D = distance of fall

Burn-out in the average channel terminates the calculation.

2. Nucleate Boiling

If the temperature in any coolant node (j) of the hot or average channel exceeds 1570°F , the overall heat transfer coefficient between fuel and coolant, $(UA)_{fcj}$, is instantaneously replaced in that node by one in which the film coefficient reflects nucleate boiling conditions.

$$\text{i.e., } (UA)_{fcj} \rightarrow (UA)_{fc}' \quad (18)$$

These coefficients are input data.

3. Bulk Boiling

If the temperature in any coolant node of the hot or average channel reaches the boiling point of sodium (1618°F), the temperature is held constant until sufficient heat has passed into the coolant to vaporize $\times$ % of the node, i.e., until a time τ_v determined by

$$\int_{t_B}^{t_B + \tau_v} q_c(t) dt = Q_{VL} \quad (19)$$

where t_B is the time at which the node boils, $q_c(t)$ is the heat flux.

Q_{VL} is defined by $Q_{VL} = \frac{\times}{100} Q_L$, i.e., the heat necessary to vaporize $\times$ % of the node.

Q_L is the latent heat of vaporization. At that time ($t = t_B + \tau_V$) the channel is assumed voided, a positive reactivity step is inserted and the fuel rod parts. At such time later that 100% of the node has vaporized heat transfer is by radiation but is not followed.

The time at which complete vaporization occurs is defined by

$$\int_{t_B}^{t_B + \tau_{100}} g_i(t) dt = Q_L \quad (20)$$

Vaporization of any node in the average channel terminates the problem.

B. Input Instructions

1. General Information

There must be at least three cards of input data for any case (one each of the following types and 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 information. Within this group, cards can be in any order; however, the final card must contain a "1" in column 1.

2. Detailed Description

a) Title Card

Columns 1-72 - up to 72 alphanumeric characters which will appear as the heading at the beginning of the case on the print out, and the first 48 will appear as the title on the CRT.

b) Floating Point Data

Column 1 - left blank unless last card of floating

- point data, in which case place a "1" in this column.
- Columns 4-6 - relative address of first piece of data on card. All data following the first piece is 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 13-72- floating point data (as many as five numbers) according to 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 C.

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, $NF \leq 50$
3	B	β - delayed fraction
4	ELL	ℓ - lifetime
5	S	S* source
6	ENO	$n(t=0)$ initial neutron level
7	RO	$\rho(t=0)$ initial reactivity in dollars
8	$\emptyset MO$	$\omega(t=0) \begin{cases} 0 & \text{- no inhour calculation} \\ 1 & \text{- inhour calculation} \end{cases}$
9	HI	Initial calculational interval
10	HL	Minimum calculational interval
11	HU	Maximum calculational interval
12	HMN	Maximum number of calculation intervals
13	AL	Lower limit for Q test
14	AU	Upper limit for Q test
15	SCT	Non-zero if SC 4020 output desired
16-30	FR(I)	f_i , delayed neutron fraction, $I = 1, ND$ Address = $16 + (I - 1)$

<u>Address</u>	<u>Symbol</u>	<u>Explanation</u>
31-45	EL(I)	λ_i , decay constants, $I = 1, ND$ Address = $31 + (I - 1)$
46-60	W(I)	$W(t = 0)$, initial delayed neutron levels, $I = 1, ND$ Address = $46 + (I - 1)$
61-110	P(J)	P_j^* , $J = 1, NF$ Address = $61 + (J - 1)$
111-160	U(J)	U_j^* , $J = 1, NF$ Address = $111 + (J - 1)$
161-210	Y(J)	Y_j^* , $J = 1, NF$ Address = $161 + (J - 1)$
211-260	F(J)	$F_j(t = 0)$ initial feedback levels, $J = 1, NF$ Address = $211 + (J - 1)$
261-310	A(J)	A_j , reactivity feedback coefficients $J = 1, NF$ Address = $261 + (J - 1)$
311-360	FM(J)	Maximum allowed value of feedback Address = $311 + (J - 1)$
361	PM	Maximum neutron level allowed
362	TIMEM	Maximum time allowed
363	G(1)	σ , linear rod withdrawal rate
364-365		Not used for input
366	G(4)	Maximum reactivity allowed due to rod withdrawal
367-372		Not used
373	DNT	Non zero if delayed neutrons are to be printed
374	NT	Must be 6.0 for this model
375	NPRINT	Nprint, print frequency
376-384		Not used
385		$(- UA / (PCPV)_f) **$
386		$(- UA / (PCPV)_c)$

*See Equation (3)

**See Equation (11)

NAA-SR-MEMO-9800

<u>Address</u>	<u>Symbol</u>	<u>Explanation</u>
387	UA	UA
388	$(- UA' / (\rho C_P V)_f)$	
389	$(- UA' / (\rho C_P V)_c)$	
390	UA'	
391		Temperature at which nucleate boiling coefficients are to be inserted
392		Boiling point of sodium
393	Q_{VL}	, see equation (19)
394	Q_L	, latent heat of vaporization of coolant
395	q_{BD}	, burnout heat flux
396		Positive reactivity step insertion for channel voiding
397	R_F	} See Equation (17)
398	α	
399-505		Not used for input for this model
506-511		$(-2Z)$, See below
512-555		Not used
556-557		$(4Z)$
558		$(2Z)$
559-560		$(4Z)$
561		$(2Z)$
562-605		Not used
606		$(-4Z)$
607		$(-2Z)$
608		Not used
609		$(-4Z)$
610		$(-2Z)$
611-655		Not used
656		$(2Z)$
659		$(2Z)$

Where $Z = (\dot{W} C_P) / (\rho C_P V)_c$; these coefficients arise from substituting equation 13 into equation 12 and collating terms.

c. Integer Data

Column 1 -

left blank unless last card of integer data in which case place a "1" in this column.

Columns 4-6 -

relative address of the first piece of data on card. All data following the first piece is 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 13-72 -

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 C.

Relative Addresses for Integer Data

<u>Address</u>	<u>Symbol</u>	<u>Explanation</u>
1-300	KC(J,I)	$K_{ij} \begin{cases} + \text{ uses } C_{ij} \\ - \text{ uses } W(t)C_{ij} \end{cases}$ <p>See Equations (3) and (4)</p>
1-50		$J = 1, NF; I = 1$
51-100		$J = 1, NF; I = 2$
101-150		$J = 1, NF; I = 3$
151-200		$J = 1, NF; I = 4$
201-250		$J = 1, NF; I = 5$
251-300		$J = 1, NF; I = 6$
		Address = $J + 50 (I - 1)$
301-350	IPRINT(J)	$\begin{cases} -1 & \text{print } F_j; \text{ do not plot} \\ 0 & \text{do not print or plot} \\ M & \text{plot } F_j \text{ on frame M and print it} \end{cases}$ <p>$J = 1, NF$</p> <p>Address = $301 + (J - 1)$</p> <p>No more than 14 F_j's can be printed and/or displayed</p>

C. Running Instructions

AIREK 3B is filed at Department 792 as deck number 3W831.

Submit a short form requesting approximately ten 9 x 9 frames per case.

Running time on an IBM 7094 is approximately given by

200 calculation points/second/equation

where the number of equation = $1 + ND + NK$

V. WHAT WAS LEARNED

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 demand 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 (32, 33 and 34) are used for SCRAMS, special printing and the form of the flow decay equations. The justification for these non-general features is of course the pressure of time.

All was not lost however, as much was learned and much can be used directly in the next general dynamics simulator, which will probably be checked out by the time this report is released. This section, then, will serve as the specifications.

Foremost is the need for more feedback equations; the plans at present call for 100 with any 50 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, but 100 is felt to be a practical upper limit.

The reactivity calculation will be generalized so that any feedback variable can be tested for reactivity scram each with a unique delay time.

Start-up problems will be handled such that until sensible power generation 0.1% full power say, the feedback equations will not be integrated; since no change is expected this feature will reduce the running time of start-up problem by 75%. CRT displays of neutron level, inverse period delayed neutrons and reactivity up to the time of sensible power will be provided (on an option) in addition to the normal displays.

NAA-SR-MEMO-9800

Flow variation can take several forms. (1) Simple exponential as in AIREK 3A; (2) a table provided in the input data; and (3) defined by the external loop equations.

The special output routine will be extended so that specified linear combinations of feedback variables can be edited.

The interval switching procedure will test all feedback variables in addition to power.

The next simulator will be 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.

An input generation routine will be written for optional use to compute the conduction and convection coefficients, C_{ij} , for $n \times m$ nodal systems with built-in tables of specific heat, density, conductivity and viscosity for the common fuel, structure and coolant materials.

REFERENCES

- ¹W. B. Green, "A Study of Reactor Kinetics Codes at Atomics International and their Applicability to SNAP Systems", NAA-SR-TDR-9328 (December, 1963).
- ²L. 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).
- ³W. A. Rhoades, "The SNAPKIN VI Computer Program for SNAP Reactor Kinetics Calculations", NAA-SR-MEMO-7835 (October, 1963).
- ⁴E. R. Cohen, "Some Topics in Reactor Kinetics", Second Geneva Conference Proceedings, p. 629 (September, 1958).
- ⁵O. D. Seawell, "OSCAI-1: Digital Multi-Channel Nuclear Reactor Transient Simulator Program", AI-MEMO-8296 (March, 1963).
- ⁶R. W. Winson, "BOOMER - A Digital Program for Evaluating the Thermal and Kinetics Response of SNAP 2/10A Reactor", NAA-SR-MEMO-8414 (July, 1963).
- ⁷L. R. Blue, M. Hoffman and M. Dunenfeld, "AIREK-KEWB", Atomics International AMTD-132 (November, 1962).
- ⁸R. 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).

INTERVAL SWITCHING

An important feature in the AIREK 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, not clear how to apply this condition to all feedback 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 can be described as follows:

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

E where

$$E(t+h) = \left[n^*(t+h) - n(t+h) \right] / n(t+h) \quad (A1)$$

where t = time

h = present interval

h' = previous interval

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

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

If $E < AL$ the interval is doubled

If $AU > E > AL$ the interval is unchanged

If $E > AU$ the interval is halved

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).

Deviation on $n^*(t+h)$

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 (6) reference 2 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 (6) can be thought of in the following way: find a function $f(t+\xi)$ expressed as a second order polynomial which represents the deviation of $n(t)$ from exponential behavior over the interval $t, t+h$, i.e., we have the equation

$$\dot{n}(t) = \lambda n(t) + R(n(t), F_j(t), W_i(t), t) \quad (A2)$$

which can be solved formerly by quadrature:

$$n(t+h) = n(t)e^{\lambda h} + \int_0^h R[n(t+\xi), F_j(t+\xi), W_i(t+\xi), t+\xi] e^{\lambda(h-\xi)} d\xi \quad (A3)$$

The numerical procedure described by equation (6) serves to determine the coefficients of such a polynomial by an iterative procedure and as a result we have

$$f(t+\xi) \sim R[n(t+\xi), F_j(t+\xi), W_i(t+\xi), t+\xi] \quad (A4)$$

$$\text{where } f(t+\xi) = R_0 + \left(\frac{\xi}{h}\right) [4R_2 - 3R_0 - F_4] + \left(\frac{\xi}{h}\right)^2 [2R_4 - 4R_2 + 2R_0] \quad (A5)$$

and the notation is that of reference 2.

Substituting equation (A5) into equation (A3) gives us equation 6.5 of the reference which determines $n(t+h)$.

Thus using equation (A5) 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 :

$$\begin{aligned}
 n^*(t+h) = & n(t-h') + (h+h') D_1[x'(t+h')] [R_0' + x'(t-h')] \\
 & + \frac{(h+h')^2}{h'} D_2[x'(t+h')] [4R_0' - 3R_2' - R_4'] \\
 & + \frac{(h+h')^3}{h'^2} D_3[x'(t+h')] [R_0' - 3R_2' + R_4']
 \end{aligned}
 \tag{A6}$$

where the notation is again that of reference 2 and the primes indicate the values are evaluated at time $(t-h')$.

Using this formulation, one can specify the relative error bounds and be assured that the truncation error is somewhat less than the smaller.

For engineering calculations the following error bounds are suggested:

$$AL = 0.01$$

$$AU = 0.10$$

i.e., the error will be somewhat less than 1%.

Consideration other than truncation error may place an upper limit on h , e.g., flow instability.

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. AIK3A PROGRAMMER RA BAINE DATE 4/8/64 PAGE 1 of 2 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1 SRE III - L		Title Card
13 SS OF FLW		
25 FRM FULL P		
37 WER (0.06)		
49	73 80	
61	1.0	
1 1		Floating Data
13 6.		LD
25 34.		NF
37 7. -03		B
49 .0005	73 80	L
61	2.0	S
1 6		
13 1.		nlo)
25		R(c)
37		W(0)
49 .2	73 80	hi
61 1. -0.6	3.0	HL
1 1 674		Last Card
13 5.385		
25 5.385		
37 5.385		
49	73 80	
61	1.0.0	

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. A1263A PROGRAMMER RA 3615 DATE 7/8/68 PAGE 2 of 2 JOB NO. _____

NUMBER		IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	1		Integer Data
13			K11 K0(J,I) array
25			K12
37			K13
49			K14
61			K15
1	51		
13			
25			
37			
49			
61			
1	301		IPRINT Array
13			
25			
37			
49			
61			
1	330		
13			
25			
37			
49			
61			

APPENDIX B NAA-SR-MEMO-9800 page 30

SRE III - LOSS OF FLOW FROM FULL POWER (0.06)

CONTROL INFO DD(1) TO DD(15)

1	8.000000E 00	3.400000E 01	7.000000E-03	5.000000E-04	0.
6	1.000000E 00	0.	0.	2.000000E-01	10.000000E-07
11	2.000000E-01	5.000000E 02	10.000000E-03	1.000000E-01	1.000000E 00

PRE-CURSOR INFO DD(16) TO DD(60)

16	3.297000E-02	2.194000E-01	1.960000E-01	3.947000E-01	1.150000E-01	4.193000E-02
31	1.240000E-02	3.050000E-02	1.110000E-01	3.010000E-01	1.130000E 00	3.000000E 00
46	1.000000E 00	1.000000E 00	1.000000E 00	1.000000E 00	1.000000E 00	1.000000E 00

FEEDBACK INFO DD(61) TO DD(360)

61	1.051000E 02	1.446000E 02	1.051000E 02	0.	0.
0.	0.	2.830000E-01	3.890000E-01	2.830000E-01	0.
0.	0.	0.	6.010000E 02	8.237000E 02	6.010000E 02
0.	0.	0.	0.	0.	0.
0.	3.494000E 02	4.800000E 02	3.494000E 02	0.	0.
0.	0.	0.	0.	0.	0.
0.	3.333000E 01	0.	0.	0.	0.
111	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.
0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.
161	-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	-2.845000E-01	-8.340000E-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	-7.410000E-01
-7.410000E-01	-5.860000E-01	-5.860000E-01	-5.860000E-01	-9.520000E 00	-9.520000E 00
-9.520000E 00	-9.520000E 00	-1.110000E 00	-1.110000E 00	-1.110000E 00	-1.110000E 00
0.	-3.333000E 01	-4.000000E 00	-4.000000E 00	-4.000000E 00	-4.000000E 00
211	9.917000E 02	1.282500E 03	1.379200E 03	8.135000E 02	1.037500E 03
1.201000E 03	7.576000E 02	9.609000E 02	1.145100E 03	8.135000E 02	8.135000E 02

11

1.037500E 03	1.201000E 03	1.595800E 03	2.093000E 03	1.943100E 03
8.452000E 02	1.064200E 03	1.192500E 03	7.965000E 02	9.973000E 02
1.143800E 03	1.431200E 03	1.881300E 03	1.806800E 03	8.101000E 02
1.028100E 03	1.185700E 03	8.083000E 02	1.025600E 03	1.183900E 03
6.500000E 02	1.000000E 00	1.143800E 03	1.183900E 03	

261

-2.757000E-04	-5.385000E-04	-2.757000E-04	1.046000E-04	1.046000E-04
3.540000E-05	9.540000E-05	1.866000E-04	9.540000E-05	2.764000E-04
2.764000E-04	9.360000E-05	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
1.265000E-04	0.	0.	0.	0.

311

1.000000E 04	1.000000E 04	1.000000E 04	1.000000E 04	1.000000E 04
1.000000E 04	1.000000E 04	1.000000E 04	1.000000E 04	1.000000E 04
1.000000E 04	1.000000E 04	1.000000E 04	1.000000E 04	1.000000E 04
1.000000E 04	1.000000E 04	1.000000E 04	1.000000E 04	1.000000E 04
1.000000E 04	1.000000E 04	1.000000E 04	1.000000E 04	1.000000E 04
1.000000E 04	1.000000E 04	1.000000E 04	1.000000E 04	1.000000E 04
1.000000E 04	10.000000E 14	1.000000E 04	1.000000E 04	1.000000E 04

OTHER NON-ZERO INFO IN DATA BLOCK DD(361) - DD(699)

DD(361)=	1.000000E 10
DD(362)=	1.000000E 01
DD(364)=	-1.642900E 01
DD(365)=	4.220000E 00
DD(366)=	1.250000E 00
DD(367)=	2.000000E 03
DD(368)=	1.214000E 03
DD(369)=	1.100000E-01
DD(374)=	6.000000E 00
DD(375)=	1.000000E 00
DD(376)=	6.600000E-02
DD(377)=	9.340000E-01
DD(378)=	5.400000E-02
DD(379)=	9.460000E-01
DD(381)=	9.400000E-01
DD(382)=	-4.250000E-01
DD(383)=	6.000000E-02
DD(385)=	3.340000E 01
DD(386)=	5.640000E 01
DD(387)=	2.800000E 00

DD(388)=	3.930000E 01
DD(391)=	3.050000E-02
DD(392)=	1.150000E-02
DD(393)=	-2.300000E-03
DD(394)=	-6.900000E-02
DD(395)=	4.200000E-02
DD(400)=	-6.330000E-02
DD(401)=	-6.330000E-02
DD(402)=	-6.330000E-02
DD(403)=	-2.005600E 00
DD(404)=	-2.005600E 00
DD(405)=	-2.005600E 00
DD(406)=	1.940000E-03
DD(407)=	1.940000E-03
DD(408)=	1.940000E-03
DD(409)=	-9.010000E-02
DD(410)=	-9.010000E-02
DD(411)=	-9.010000E-02
DD(412)=	8.340000E-01
DD(413)=	8.340000E-01
DD(414)=	8.340000E-01
DD(415)=	-7.560000E 00
DD(416)=	-7.560000E 00
DD(417)=	-7.560000E 00
DD(418)=	-4.204000E 00
DD(419)=	-4.204000E 00
DD(420)=	-4.204000E 00
DD(421)=	5.860000E-01
DD(422)=	5.860000E-01
DD(423)=	5.860000E-01
DD(424)=	-1.077000E 01
DD(425)=	-1.077000E 01
DD(426)=	-1.077000E 01
DD(427)=	-4.505000E 00
DD(428)=	-4.505000E 00
DD(429)=	-4.505000E 00
DD(432)=	4.000000E 00
DD(433)=	4.000000E 00
DD(450)=	1.794000E-01
DD(451)=	1.794000E-01
DD(452)=	1.794000E-01
DD(453)=	-6.274000E-01
DD(454)=	-6.274000E-01

DD(455)=	-6.274000E-01
DD(456)=	5.720000E-03
DD(457)=	1.940000E-03
DD(458)=	1.940000E-03
DD(459)=	5.690000E-01
DD(460)=	5.690000E-01
DD(461)=	5.690000E-01
DD(465)=	2.050000E 00
DD(466)=	2.050000E 00
DD(467)=	2.050000E 00
DD(468)=	1.482000E 00
DD(469)=	1.482000E 00
DD(470)=	1.482000E 00
DD(474)=	2.340000E 00
DD(475)=	2.340000E 00
DD(476)=	2.340000E 00
DD(477)=	2.220000E 00
DD(478)=	2.220000E 00
DD(479)=	2.220000E 00
DD(500)=	3.170000E-02
DD(501)=	3.170000E-02
DD(502)=	3.170000E-02
DD(503)=	1.828000E 00
DD(504)=	1.828000E 00
DD(505)=	1.828000E 00
DD(506)=	3.780000E-03
DD(507)=	3.780000E-03
DD(508)=	3.780000E-03
DD(509)=	-2.845000E-01
DD(510)=	-2.845000E-01
DD(511)=	-2.845000E-01
DD(515)=	2.525000E 00
DD(516)=	2.525000E 00
DD(517)=	2.525000E 00
DD(518)=	2.228000E 00
DD(519)=	2.228000E 00
DD(520)=	2.228000E 00
DD(524)=	3.590000E 00
DD(525)=	3.590000E 00
DD(526)=	3.590000E 00
DD(527)=	3.330000E 00
DD(528)=	3.330000E 00
DD(529)=	3.330000E 00

DD(550)=	1.794000E-01
DD(551)=	1.794000E-01
DD(552)=	1.794000E-01
DD(553)=	1.005000E 00
DD(554)=	1.005000E 00
DD(555)=	1.005000E 00
DD(557)=	3.780000E-03
DD(558)=	3.780000E-03
DD(559)=	9.010000E-02
DD(560)=	9.010000E-02
DD(561)=	9.010000E-02
DD(565)=	3.780000E 00
DD(566)=	3.780000E 00
DD(567)=	3.780000E 00
DD(568)=	-7.410000E-01
DD(569)=	-7.410000E-01
DD(570)=	-7.410000E-01
DD(574)=	5.385000E 00
DD(575)=	5.385000E 00
DD(576)=	5.385000E 00
DD(577)=	-1.110000E 00
DD(578)=	-1.110000E 00
DD(579)=	-1.110000E 00
DD(600)=	3.170000E-02
DD(601)=	3.170000E-02
DD(602)=	3.170000E-02
DD(603)=	1.774000E-01
DD(604)=	1.774000E-01
DD(605)=	1.774000E-01
DD(615)=	2.525000E 00
DD(616)=	2.525000E 00
DD(617)=	2.525000E 00
DD(618)=	1.976000E 00
DD(619)=	1.976000E 00
DD(620)=	1.976000E 00
DD(624)=	3.590000E 00
DD(625)=	3.590000E 00
DD(626)=	3.590000E 00
DD(627)=	1.175000E 00
DD(628)=	1.175000E 00
DD(629)=	1.175000E 00
DD(653)=	2.500000E-01
DD(654)=	2.500000E-01

DD(655)=	2.500000E-01
DD(665)=	3.780000E 00
DD(666)=	3.780000E 00
DD(667)=	3.780000E 00
DD(674)=	5.385000E 00
DD(675)=	5.385000E 00
DD(676)=	5.385000E 00

MAXIMUM TIME EXCEEDED

SRE III - LOSS OF FLOW FROM FULL POWER (0.06)

TIME	POWER	REACTIVITY	INV.PERIOD	F 2	F 3	F 6	F 8
0.	1.0420E 00	0.	-2.0862E-07	1.2825E 03	1.3792E 03	1.2010E 03	9.6090E 02
2.0000E-01	1.0422E 00	3.9329E-04	2.3863E-03	1.2828E 03	1.3794E 03	1.2030E 03	9.6090E 02
4.0000E-01	1.0429E 00	1.1160E-03	3.7716E-03	1.2837E 03	1.3802E 03	1.2083E 03	9.6091E 02
6.0000E-01	1.0436E 00	1.7554E-03	3.4008E-03	1.2854E 03	1.3817E 03	1.2158E 03	9.6093E 02
8.0000E-01	1.0442E 00	2.0892E-03	1.9224E-03	1.2878E 03	1.3840E 03	1.2250E 03	9.6095E 02
10.0000E-01	1.0444E 00	2.0053E-03	-2.0666E-04	1.2911E 03	1.3871E 03	1.2353E 03	9.6098E 02
1.2000E 00	1.0366E 00	-1.7700E-02	-1.6870E-01	1.2950E 03	1.3910E 03	1.2464E 03	9.6102E 02
1.2500E 00	1.0098E 00	-1.1075E-01	-1.0861E 00	1.2960E 03	1.3921E 03	1.2493E 03	9.6103E 02
1.3000E 00	9.1545E-01	-3.7670E-01	-3.2707E 00	1.2967E 03	1.3928E 03	1.2522E 03	9.6104E 02
1.3500E 00	7.2345E-01	-9.4891E-01	-6.8600E 00	1.2963E 03	1.3929E 03	1.2551E 03	9.6105E 02
1.4000E 00	4.8240E-01	-1.9785E 00	-1.0365E 01	1.2944E 03	1.3919E 03	1.2579E 03	9.6105E 02
1.4500E 00	2.9654E-01	-3.5999E 00	-1.0880E 01	1.2911E 03	1.3898E 03	1.2606E 03	9.6105E 02
1.5000E 00	1.9571E-01	-5.8745E 00	-8.9810E 00	1.2868E 03	1.3871E 03	1.2631E 03	9.6105E 02
1.5500E 00	1.4428E-01	-8.7141E 00	-7.0508E 00	1.2822E 03	1.3841E 03	1.2654E 03	9.6105E 02
1.6000E 00	1.1648E-01	-1.1805E 01	-5.2518E 00	1.2774E 03	1.3810E 03	1.2676E 03	9.6105E 02
1.6500E 00	1.0137E-01	-1.4570E 01	-3.4246E 00	1.2726E 03	1.3779E 03	1.2696E 03	9.6104E 02
1.7000E 00	9.4245E-02	-1.6225E 01	-1.3979E 00	1.2679E 03	1.3749E 03	1.2714E 03	9.6104E 02
1.7500E 00	9.2687E-02	-1.6390E 01	-1.4395E-01	1.2633E 03	1.3720E 03	1.2730E 03	9.6104E 02
1.8000E 00	9.1976E-02	-1.6385E 01	-2.6952E-01	1.2588E 03	1.3691E 03	1.2746E 03	9.6104E 02
1.8500E 00	9.1269E-02	-1.6380E 01	-2.6099E-01	1.2544E 03	1.3664E 03	1.2760E 03	9.6104E 02
1.9500E 00	8.9939E-02	-1.6372E 01	-2.4585E-01	1.2460E 03	1.3611E 03	1.2784E 03	9.6104E 02
2.1500E 00	8.7557E-02	-1.6355E 01	-2.2156E-01	1.2303E 03	1.3513E 03	1.2821E 03	9.6104E 02
2.3500E 00	8.5462E-02	-1.6341E 01	-2.0407E-01	1.2160E 03	1.3426E 03	1.2847E 03	9.6104E 02
2.5500E 00	8.3582E-02	-1.6327E 01	-1.9044E-01	1.2030E 03	1.3347E 03	1.2865E 03	9.6105E 02
2.7500E 00	8.1873E-02	-1.6315E 01	-1.7947E-01	1.1910E 03	1.3274E 03	1.2876E 03	9.6106E 02
2.9500E 00	8.0302E-02	-1.6304E 01	-1.7038E-01	1.1799E 03	1.3208E 03	1.2884E 03	9.6108E 02
3.1500E 00	7.8847E-02	-1.6294E 01	-1.6267E-01	1.1697E 03	1.3147E 03	1.2889E 03	9.6109E 02
3.3500E 00	7.7490E-02	-1.6284E 01	-1.5599E-01	1.1603E 03	1.3091E 03	1.2891E 03	9.6111E 02
3.5500E 00	7.6218E-02	-1.6275E 01	-1.5012E-01	1.1517E 03	1.3039E 03	1.2892E 03	9.6113E 02
3.7500E 00	7.5020E-02	-1.6267E 01	-1.4489E-01	1.1436E 03	1.2991E 03	1.2891E 03	9.6115E 02
3.9500E 00	7.3889E-02	-1.6259E 01	-1.4018E-01	1.1361E 03	1.2946E 03	1.2890E 03	9.6117E 02
4.1500E 00	7.2817E-02	-1.6252E 01	-1.3591E-01	1.1292E 03	1.2905E 03	1.2888E 03	9.6120E 02
4.3500E 00	7.1799E-02	-1.6246E 01	-1.3198E-01	1.1228E 03	1.2866E 03	1.2886E 03	9.6122E 02
4.5500E 00	7.0830E-02	-1.6240E 01	-1.2834E-01	1.1168E 03	1.2830E 03	1.2883E 03	9.6125E 02
4.7500E 00	6.9904E-02	-1.6234E 01	-1.2496E-01	1.1112E 03	1.2796E 03	1.2879E 03	9.6128E 02

SRE III - LOSS OF FLOW FROM FULL POWER (0.06)

TIME	POWER	REACTIVITY	INV.PERIOD	F 2	F 3	F 6	F 8
4.9500E 00	6.9020E-02	-1.6229E 01	-1.2180E-01	1.1060E 03	1.2764E 03	1.2876E 03	9.6131E 02
5.1500E 00	6.8174E-02	-1.6224E 01	-1.1881E-01	1.1012E 03	1.2734E 03	1.2872E 03	9.6134E 02
5.3500E 00	6.7363E-02	-1.6219E 01	-1.1600E-01	1.0967E 03	1.2706E 03	1.2868E 03	9.6137E 02
5.5500E 00	6.6585E-02	-1.6215E 01	-1.1331E-01	1.0924E 03	1.2679E 03	1.2864E 03	9.6140E 02
5.7500E 00	6.5837E-02	-1.6210E 01	-1.1075E-01	1.0885E 03	1.2654E 03	1.2859E 03	9.6143E 02
5.9500E 00	6.5118E-02	-1.6207E 01	-1.0830E-01	1.0848E 03	1.2631E 03	1.2855E 03	9.6146E 02
6.1500E 00	6.4425E-02	-1.6203E 01	-1.0595E-01	1.0813E 03	1.2608E 03	1.2850E 03	9.6150E 02
6.3500E 00	6.3758E-02	-1.6200E 01	-1.0368E-01	1.0780E 03	1.2587E 03	1.2846E 03	9.6153E 02
6.5500E 00	6.3115E-02	-1.6197E 01	-1.0149E-01	1.0749E 03	1.2567E 03	1.2841E 03	9.6157E 02
6.7500E 00	6.2495E-02	-1.6194E 01	-9.9382E-02	1.0720E 03	1.2548E 03	1.2836E 03	9.6160E 02
6.9500E 00	6.1896E-02	-1.6191E 01	-9.7336E-02	1.0693E 03	1.2529E 03	1.2831E 03	9.6164E 02
7.1500E 00	6.1317E-02	-1.6188E 01	-9.5363E-02	1.0667E 03	1.2512E 03	1.2826E 03	9.6167E 02
7.3500E 00	6.0758E-02	-1.6186E 01	-9.3442E-02	1.0642E 03	1.2495E 03	1.2821E 03	9.6171E 02
7.5500E 00	6.0216E-02	-1.6183E 01	-9.1588E-02	1.0619E 03	1.2479E 03	1.2816E 03	9.6175E 02
7.7500E 00	5.9693E-02	-1.6181E 01	-8.9783E-02	1.0597E 03	1.2464E 03	1.2811E 03	9.6178E 02
7.9500E 00	5.9185E-02	-1.6179E 01	-8.8033E-02	1.0576E 03	1.2449E 03	1.2806E 03	9.6182E 02
8.1500E 00	5.8694E-02	-1.6177E 01	-8.6339E-02	1.0556E 03	1.2434E 03	1.2800E 03	9.6185E 02
8.3500E 00	5.8217E-02	-1.6175E 01	-8.4688E-02	1.0537E 03	1.2421E 03	1.2795E 03	9.6189E 02
8.5500E 00	5.7755E-02	-1.6174E 01	-8.3084E-02	1.0519E 03	1.2407E 03	1.2790E 03	9.6193E 02
8.7500E 00	5.7306E-02	-1.6172E 01	-8.1532E-02	1.0501E 03	1.2394E 03	1.2785E 03	9.6196E 02
8.9500E 00	5.6871E-02	-1.6170E 01	-8.0021E-02	1.0484E 03	1.2382E 03	1.2780E 03	9.6200E 02
9.1500E 00	5.6447E-02	-1.6169E 01	-7.8563E-02	1.0468E 03	1.2370E 03	1.2774E 03	9.6203E 02
9.3500E 00	5.6036E-02	-1.6167E 01	-7.7141E-02	1.0453E 03	1.2358E 03	1.2769E 03	9.6207E 02
9.5500E 00	5.5636E-02	-1.6166E 01	-7.5761E-02	1.0438E 03	1.2347E 03	1.2764E 03	9.6210E 02
9.7500E 00	5.5247E-02	-1.6165E 01	-7.4426E-02	1.0423E 03	1.2335E 03	1.2758E 03	9.6214E 02
9.9500E 00	5.4869E-02	-1.6163E 01	-7.3132E-02	1.0409E 03	1.2325E 03	1.2753E 03	9.6217E 02
1.0150E 01	5.4500E-02	-1.6162E 01	-7.1874E-02	1.0396E 03	1.2314E 03	1.2748E 03	9.6221E 02

SRE III - LOSS OF FLOW FROM FULL POWER (0.06)

TIME	F 9	F 12	F 14	F 15	F 21	F 23	F 24
0.	1.1451E 03	1.2010E 03	2.0958E 03	1.9431E 03	1.1438E 03	1.9206E 03	1.8068E 03
2.0000E-01	1.1451E 03	1.2011E 03	2.0962E 03	1.9434E 03	1.1460E 03	1.9209E 03	1.8070E 03
4.0000E-01	1.1451E 03	1.2014E 03	2.0980E 03	1.9449E 03	1.1530E 03	1.9220E 03	1.8079E 03
6.0000E-01	1.1451E 03	1.2018E 03	2.1016E 03	1.9481E 03	1.1644E 03	1.9244E 03	1.8101E 03
8.0000E-01	1.1452E 03	1.2024E 03	2.1072E 03	1.9533E 03	1.1794E 03	1.9281E 03	1.8136E 03
10.0000E-01	1.1452E 03	1.2031E 03	2.1147E 03	1.9605E 03	1.1974E 03	1.9332E 03	1.8187E 03
1.2000E 00	1.1452E 03	1.2038E 03	2.1237E 03	1.9697E 03	1.2178E 03	1.9395E 03	1.8253E 03
1.2500E 00	1.1452E 03	1.2040E 03	2.1256E 03	1.9718E 03	1.2231E 03	1.9409E 03	1.8269E 03
1.3000E 00	1.1453E 03	1.2042E 03	2.1253E 03	1.9724E 03	1.2286E 03	1.9411E 03	1.8277E 03
1.3500E 00	1.1453E 03	1.2044E 03	2.1194E 03	1.9690E 03	1.2341E 03	1.9379E 03	1.8260E 03
1.4000E 00	1.1453E 03	1.2045E 03	2.1048E 03	1.9593E 03	1.2397E 03	1.9297E 03	1.8208E 03
1.4500E 00	1.1453E 03	1.2047E 03	2.0821E 03	1.9437E 03	1.2453E 03	1.9166E 03	1.8120E 03
1.5000E 00	1.1453E 03	1.2049E 03	2.0547E 03	1.9247E 03	1.2507E 03	1.9006E 03	1.8011E 03
1.5500E 00	1.1453E 03	1.2051E 03	2.0255E 03	1.9045E 03	1.2558E 03	1.8834E 03	1.7894E 03
1.6000E 00	1.1453E 03	1.2053E 03	1.9960E 03	1.8841E 03	1.2606E 03	1.8659E 03	1.7775E 03
1.6500E 00	1.1453E 03	1.2055E 03	1.9669E 03	1.8639E 03	1.2651E 03	1.8484E 03	1.7657E 03
1.7000E 00	1.1453E 03	1.2057E 03	1.9384E 03	1.8443E 03	1.2692E 03	1.8312E 03	1.7541E 03
1.7500E 00	1.1453E 03	1.2059E 03	1.9109E 03	1.8255E 03	1.2729E 03	1.8145E 03	1.7428E 03
1.8000E 00	1.1453E 03	1.2061E 03	1.8844E 03	1.8074E 03	1.2763E 03	1.7982E 03	1.7320E 03
1.8500E 00	1.1453E 03	1.2063E 03	1.8588E 03	1.7900E 03	1.2794E 03	1.7824E 03	1.7214E 03
1.9500E 00	1.1453E 03	1.2067E 03	1.8104E 03	1.7572E 03	1.2847E 03	1.7520E 03	1.7014E 03
2.1500E 00	1.1454E 03	1.2075E 03	1.7233E 03	1.6987E 03	1.2919E 03	1.6961E 03	1.6649E 03
2.3500E 00	1.1454E 03	1.2083E 03	1.6472E 03	1.6482E 03	1.2956E 03	1.6458E 03	1.6325E 03
2.5500E 00	1.1454E 03	1.2090E 03	1.5805E 03	1.6042E 03	1.2967E 03	1.6005E 03	1.6038E 03
2.7500E 00	1.1455E 03	1.2098E 03	1.5216E 03	1.5655E 03	1.2958E 03	1.5595E 03	1.5780E 03
2.9500E 00	1.1455E 03	1.2105E 03	1.4696E 03	1.5313E 03	1.2935E 03	1.5223E 03	1.5549E 03
3.1500E 00	1.1455E 03	1.2111E 03	1.4233E 03	1.5008E 03	1.2904E 03	1.4885E 03	1.5340E 03
3.3500E 00	1.1456E 03	1.2118E 03	1.3821E 03	1.4735E 03	1.2866E 03	1.4578E 03	1.5150E 03
3.5500E 00	1.1456E 03	1.2124E 03	1.3453E 03	1.4488E 03	1.2824E 03	1.4297E 03	1.4978E 03
3.7500E 00	1.1457E 03	1.2129E 03	1.3123E 03	1.4266E 03	1.2781E 03	1.4040E 03	1.4821E 03
3.9500E 00	1.1457E 03	1.2134E 03	1.2826E 03	1.4063E 03	1.2737E 03	1.3805E 03	1.4677E 03
4.1500E 00	1.1458E 03	1.2139E 03	1.2559E 03	1.3879E 03	1.2694E 03	1.3590E 03	1.4545E 03
4.3500E 00	1.1458E 03	1.2144E 03	1.2318E 03	1.3710E 03	1.2651E 03	1.3393E 03	1.4424E 03
4.5500E 00	1.1459E 03	1.2148E 03	1.2100E 03	1.3555E 03	1.2609E 03	1.3211E 03	1.4312E 03
4.7500E 00	1.1459E 03	1.2152E 03	1.1903E 03	1.3413E 03	1.2570E 03	1.3044E 03	1.4209E 03

SRE III - LOSS OF FLOW FROM FULL POWER (0.06)

TIME	F 9	F 12	F 14	F 15	F 21	F 23	F 24
4.9500E 00	1.1460E 03	1.2156E 03	1.1724E 03	1.3282E 03	1.2531E 03	1.2891E 03	1.4114E 03
5.1500E 00	1.1460E 03	1.2160E 03	1.1561E 03	1.3161E 03	1.2495E 03	1.2749E 03	1.4026E 03
5.3500E 00	1.1461E 03	1.2163E 03	1.1413E 03	1.3049E 03	1.2460E 03	1.2618E 03	1.3945E 03
5.5500E 00	1.1461E 03	1.2166E 03	1.1278E 03	1.2945E 03	1.2428E 03	1.2497E 03	1.3869E 03
5.7500E 00	1.1462E 03	1.2169E 03	1.1155E 03	1.2849E 03	1.2396E 03	1.2386E 03	1.3799E 03
5.9500E 00	1.1462E 03	1.2172E 03	1.1042E 03	1.2760E 03	1.2367E 03	1.2282E 03	1.3733E 03
6.1500E 00	1.1463E 03	1.2174E 03	1.0939E 03	1.2677E 03	1.2339E 03	1.2186E 03	1.3672E 03
6.3500E 00	1.1463E 03	1.2177E 03	1.0844E 03	1.2600E 03	1.2312E 03	1.2097E 03	1.3615E 03
6.5500E 00	1.1464E 03	1.2179E 03	1.0757E 03	1.2528E 03	1.2287E 03	1.2014E 03	1.3562E 03
6.7500E 00	1.1464E 03	1.2181E 03	1.0677E 03	1.2460E 03	1.2262E 03	1.1937E 03	1.3512E 03
6.9500E 00	1.1465E 03	1.2183E 03	1.0604E 03	1.2398E 03	1.2239E 03	1.1865E 03	1.3465E 03
7.1500E 00	1.1465E 03	1.2185E 03	1.0536E 03	1.2339E 03	1.2217E 03	1.1798E 03	1.3422E 03
7.3500E 00	1.1466E 03	1.2187E 03	1.0473E 03	1.2284E 03	1.2196E 03	1.1736E 03	1.3380E 03
7.5500E 00	1.1466E 03	1.2189E 03	1.0415E 03	1.2232E 03	1.2176E 03	1.1677E 03	1.3341E 03
7.7500E 00	1.1467E 03	1.2191E 03	1.0361E 03	1.2183E 03	1.2156E 03	1.1622E 03	1.3305E 03
7.9500E 00	1.1467E 03	1.2193E 03	1.0311E 03	1.2137E 03	1.2137E 03	1.1571E 03	1.3270E 03
8.1500E 00	1.1468E 03	1.2195E 03	1.0265E 03	1.2094E 03	1.2119E 03	1.1522E 03	1.3237E 03
8.3500E 00	1.1468E 03	1.2196E 03	1.0222E 03	1.2054E 03	1.2101E 03	1.1477E 03	1.3206E 03
8.5500E 00	1.1469E 03	1.2198E 03	1.0181E 03	1.2015E 03	1.2084E 03	1.1434E 03	1.3177E 03
8.7500E 00	1.1469E 03	1.2200E 03	1.0144E 03	1.1979E 03	1.2067E 03	1.1393E 03	1.3148E 03
8.9500E 00	1.1470E 03	1.2201E 03	1.0109E 03	1.1944E 03	1.2051E 03	1.1355E 03	1.3122E 03
9.1500E 00	1.1470E 03	1.2203E 03	1.0076E 03	1.1911E 03	1.2034E 03	1.1318E 03	1.3096E 03
9.3500E 00	1.1471E 03	1.2205E 03	1.0045E 03	1.1880E 03	1.2019E 03	1.1283E 03	1.3071E 03
9.5500E 00	1.1471E 03	1.2206E 03	1.0016E 03	1.1850E 03	1.2003E 03	1.1251E 03	1.3048E 03
9.7500E 00	1.1472E 03	1.2208E 03	9.9885E 02	1.1822E 03	1.1988E 03	1.1219E 03	1.3025E 03
9.9500E 00	1.1472E 03	1.2210E 03	9.9626E 02	1.1795E 03	1.1973E 03	1.1189E 03	1.3003E 03
1.0150E 01	1.1473E 03	1.2212E 03	9.9382E 02	1.1769E 03	1.1958E 03	1.1161E 03	1.2982E 03

SRE III - LOSS OF FLOW FROM FULL POWER (0.06)

TIME	F 30	F 31	F 32	F 15	F 21	F 23	F 24
0.	1.1839E 03	1.2754E 03	1.2756E 03				
2.0000E-01	1.1862E 03	1.2796E 03	1.2792E 03				
4.0000E-01	1.1933E 03	1.2889E 03	1.2877E 03				
6.0000E-01	1.2046E 03	1.3020E 03	1.2999E 03				
8.0000E-01	1.2193E 03	1.3183E 03	1.3152E 03				
10.0000E-01	1.2367E 03	1.3371E 03	1.3329E 03				
1.2000E 00	1.2564E 03	1.3579E 03	1.3524E 03				
1.2500E 00	1.2614E 03	1.3635E 03	1.3579E 03				
1.3000E 00	1.2666E 03	1.3689E 03	1.3631E 03				
1.3500E 00	1.2719E 03	1.3739E 03	1.3680E 03				
1.4000E 00	1.2773E 03	1.3779E 03	1.3724E 03				
1.4500E 00	1.2825E 03	1.3807E 03	1.3761E 03				
1.5000E 00	1.2877E 03	1.3825E 03	1.3792E 03				
1.5500E 00	1.2927E 03	1.3835E 03	1.3819E 03				
1.6000E 00	1.2974E 03	1.3838E 03	1.3842E 03				
1.6500E 00	1.3019E 03	1.3837E 03	1.3861E 03				
1.7000E 00	1.3062E 03	1.3832E 03	1.3879E 03				
1.7500E 00	1.3102E 03	1.3824E 03	1.3893E 03				
1.8000E 00	1.3139E 03	1.3813E 03	1.3906E 03				
1.8500E 00	1.3174E 03	1.3801E 03	1.3917E 03				
1.9500E 00	1.3238E 03	1.3772E 03	1.3934E 03				
2.1500E 00	1.3342E 03	1.3697E 03	1.3950E 03				
2.3500E 00	1.3419E 03	1.3607E 03	1.3950E 03				
2.5500E 00	1.3475E 03	1.3509E 03	1.3937E 03				
2.7500E 00	1.3515E 03	1.3405E 03	1.3915E 03				
2.9500E 00	1.3542E 03	1.3301E 03	1.3887E 03				
3.1500E 00	1.3560E 03	1.3198E 03	1.3854E 03				
3.3500E 00	1.3570E 03	1.3097E 03	1.3820E 03				
3.5500E 00	1.3575E 03	1.3000E 03	1.3785E 03				
3.7500E 00	1.3577E 03	1.2907E 03	1.3749E 03				
3.9500E 00	1.3575E 03	1.2819E 03	1.3713E 03				
4.1500E 00	1.3571E 03	1.2735E 03	1.3679E 03				
4.3500E 00	1.3566E 03	1.2656E 03	1.3645E 03				
4.5500E 00	1.3560E 03	1.2582E 03	1.3612E 03				
4.7500E 00	1.3553E 03	1.2512E 03	1.3581E 03				

SRE III - LOSS OF FLOW FROM FULL POWER (0.06)

TIME	F 30	F 31	F 32	F 15	F 21	F 23	F 24
4.9500E 00	1.3546E 03	1.2447E 03	1.3551E 03				
5.1500E 00	1.3539E 03	1.2385E 03	1.3523E 03				
5.3500E 00	1.3531E 03	1.2327E 03	1.3495E 03				
5.5500E 00	1.3524E 03	1.2273E 03	1.3469E 03				
5.7500E 00	1.3516E 03	1.2222E 03	1.3444E 03				
5.9500E 00	1.3508E 03	1.2174E 03	1.3420E 03				
6.1500E 00	1.3501E 03	1.2129E 03	1.3397E 03				
6.3500E 00	1.3494E 03	1.2087E 03	1.3375E 03				
6.5500E 00	1.3486E 03	1.2047E 03	1.3355E 03				
6.7500E 00	1.3479E 03	1.2010E 03	1.3334E 03				
6.9500E 00	1.3472E 03	1.1975E 03	1.3315E 03				
7.1500E 00	1.3465E 03	1.1941E 03	1.3297E 03				
7.3500E 00	1.3458E 03	1.1910E 03	1.3279E 03				
7.5500E 00	1.3450E 03	1.1880E 03	1.3261E 03				
7.7500E 00	1.3443E 03	1.1851E 03	1.3245E 03				
7.9500E 00	1.3436E 03	1.1824E 03	1.3228E 03				
8.1500E 00	1.3429E 03	1.1799E 03	1.3213E 03				
8.3500E 00	1.3422E 03	1.1774E 03	1.3197E 03				
8.5500E 00	1.3414E 03	1.1751E 03	1.3182E 03				
8.7500E 00	1.3407E 03	1.1728E 03	1.3167E 03				
8.9500E 00	1.3400E 03	1.1707E 03	1.3153E 03				
9.1500E 00	1.3392E 03	1.1686E 03	1.3139E 03				
9.3500E 00	1.3385E 03	1.1666E 03	1.3125E 03				
9.5500E 00	1.3377E 03	1.1647E 03	1.3111E 03				
9.7500E 00	1.3369E 03	1.1628E 03	1.3097E 03				
9.9500E 00	1.3361E 03	1.1610E 03	1.3084E 03				
1.0150E 01	1.3353E 03	1.1593E 03	1.3070E 03				

RUN TIME - COMPUTE PHASE - 16.0 SECONDS
- PRINT PHASE - 2.0 SECONDS
- GRAPH PHASE - 10.0 SECONDS
- TOTAL CODE - 28.0 SECONDS

TOTAL NUMBER OF POINTS CALCULATED - 62

SRE III - LOSS OF FLOW FROM FULL POWER (0.06)

SRE III - LOSS OF FLOW FROM FULL POWER (0.06)

7545-34
036 000

SRE III - LOSS OF FLOW FROM FULL POWER (0.06)

7545-34
038 000

SRE III - LOSS OF FLOW FROM FULL POWER (0.06)

SRE III - LOSS OF FLOW FROM FULL POWER (0.06)

7949-34 L
040 000

SRE III - LOSS OF FLOW FROM FULL POWER (0.06)

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. AIREK 3B PROGRAMMER RA BLAINE DATE 4/8/64 PAGE 1 of 2 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1 13 25 37 49 61 1 13 25 37 49 61	AIREK 3B - HNP F-#1/SEC.	Title Card
1 13 25 37 49 61	1 6. 1.9 E+1 7. E-3 5. E-4 0.	Floating Data ND NF B S
1 13 25 37 49 61	6 1. 0. 0. 0.05 1. -0.5	M(0) R(0) W(0) hi HL
1 13 25 37 49 61	1 656 3.483 3.483 10.0	Last Card 2Z 2Z

SAMPLE PROBLEM - AIREK 3B
NAA-SR-MEMO-9800
APPENDIX C
page 52

FORTRAN FIXED 10 DIGIT DECIMAL DATA

DECK NO. AIPEK 38 PROGRAMMER RA BLAINE DATE 4/8/64 PAGE 2 of 2 JOB NO. _____

NUMBER	IDENTIFICATION	DESCRIPTION DO NOT KEY PUNCH
1	1	Integer Data
13		K ₁₁ K C (J, I) array
25		K ₁₂
37		K ₁₃
49		K ₁₄
61	200	K ₁₅
1	51	
13		
25		
37		
49		
61	210	
1	301	IPRINT Array
13		
25		
37		
49		
61	300	
1	306	
13		
25		
37		
49		
61	310	

NAA-SR-MEMO-9800

APPENDIX C

page 53

CONTROL INFO CD(1) TO CD(15)

1	6.000000E 00	1.900000E 01	7.000000E-03	5.000000E-04	C.
6	1.000000E 00	C.	0.	5.000000E-02	1.000000E-05
11	1.000000E-01	8.000000E 02	10.000000E-03	1.000000E-01	C.

PRE-CURSOR INFO CD(16) TO CD(60)

16	3.297000E-02	2.194000E-01	1.960000E-01	3.947000E-01	1.150000E-01	4.193000E-02
31	1.240000E-02	3.050000E-02	1.110000E-01	3.010000E-01	1.130000E 00	3.000000E 00
46	1.000000E 00	1.000000E 00	1.000000E 00	1.000000E 00	1.000000E 00	1.000000E 00

FEEDBACK INFO CD(61) TO CD(360)

61	5.543000E 01	7.557000E 01	5.543000E 01	4.620000E 01	6.299000E 01
	4.620000E 01	C.	0.	0.	C.
	C.	0.	0.	0.	C.
	C.	0.	0.	0.	
111	C.	C.	0.	0.	C.
	C.	C.	0.	0.	C.
	C.	0.	0.	0.	C.
	C.	0.	0.	0.	
161	C.	0.	0.	0.	C.
	C.	0.	0.	0.	C.
	C.	C.	0.	0.	C.
	C.	C.	0.	0.	
211	1.229500E 03	1.241200E 03	1.002500E 03	1.126300E 03	1.136100E 03
	9.371500E 02	8.850000E 02	7.715100E 02	6.580200E 02	8.392100E 02
	7.446200E 02	6.500200E 02	0.	0.	C.
	C.	0.	0.	6.100000E 02	
261	C.	C.	0.	-5.478000E-04	-1.019000E-03
	5.478000E-04	0.	0.	0.	2.073000E-04
	3.856000E-04	2.073000E-04	0.	0.	C.
	C.	C.	0.	0.	
311	1.000000E 10	1.000000E 10	1.000000E 10	1.000000E 10	1.000000E 10
	1.000000E 10	1.000000E 10	1.000000E 10	1.000000E 10	1.000000E 10
	1.000000E 10	1.000000E 10	1.000000E 10	1.000000E 10	1.000000E 10

1.000000E 10 1.000000E 10 1.000000E 10 1.000000E 10

OTHER NON-ZERO INFO IN DATA BLOCK DD(361) - DD(699)

DD(361)= 1.000000E C3
DD(362)= 3.000000E C1
DD(363)= 1.000000E C0
DD(364)= -2.500000E C0
DD(365)= 2.370200E C0
DD(366)= 1.000000E C1
DD(374)= 6.000000E C0
DD(375)= 1.000000E C0
DD(385)= -1.609000E-C1
DD(386)= -4.855000E-C1
DD(387)= 1.861000E-C1
DD(388)= -1.993000E-C1
DD(389)= -6.014000E-C1
DD(390)= 2.305000E-C1
DD(391)= 1.570000E C3
DD(392)= 1.618000E C3
DD(393)= 1.866600E C3
DD(394)= 2.073300E C3
DD(395)= 5.907000E C2
DD(396)= 1.430000E-C1
DD(397)= -5.000000E C0
DD(398)= 1.185100E C0
DD(400)= -1.993000E-C1
DD(401)= -1.993000E-C1
DD(402)= -1.609000E-C1
DD(403)= -1.993000E-C1
DD(404)= -1.993000E-C1
DD(405)= -1.609000E-C1
DD(408)= -4.855000E-C1
DD(410)= -6.014000E-C1
DD(411)= -4.855000E-C1
DD(412)= 2.305000E-C1
DD(413)= 2.305000E-C1
DD(415)= 2.305000E-C1
DD(416)= 2.305000E-C1
DD(450)= 1.993000E-C1
DD(451)= 1.993000E-C1
DD(452)= 1.609000E-C1
DD(453)= 1.993000E-C1
DD(454)= 1.993000E-C1
DD(455)= 1.609000E-C1

APPENDIX C

NAA-SR-MEMO-9800
page 55

CC(458)=	4.855000E-C1
CC(460)=	6.014000E-C1
CC(461)=	4.855000E-C1
CC(462)=	-2.305000E-C1
CC(463)=	-2.305000E-C1
CC(465)=	-2.305000E-C1
CC(466)=	-2.305000E-C1
CC(506)=	-3.483000E C0
CC(507)=	-3.483000E CC
CC(508)=	-3.483000E CC
CC(509)=	-3.483000E CC
CC(510)=	-3.483000E CC
CC(511)=	-3.483000E CC
CC(556)=	6.966000E CC
CC(557)=	6.966000E CC
CC(558)=	3.483000E CC
CC(559)=	6.966000E CC
CC(560)=	6.966000E CC
CC(561)=	3.483000E CC
CC(606)=	-6.966000E CC
CC(607)=	-3.483000E CC
CC(609)=	-6.966000E CC
CC(610)=	-3.483000E CC
CC(656)=	3.483000E CC
CC(659)=	3.483000E CC

CONDITION OCCURRING	CHANNEL	NODE	TIME
NUC BOILING COEF	HOT	7	3.55C00
COOLANT BOILED	HOT	7	3.65C00
NUC BOILING COEF	AVE	10	4.05C00
COOLANT BOILED	AVE	10	4.25C00
NUC BOILING COEF	HOT	8	4.95C00
BURNOUT HEAT FLUX AND FUEL FALLS	HOT	2	4.95C00
COOLANT BOILED	HOT	8	5.05C00
COOLANT VAPORIZED	HOT	8	8.25C00
NUC BOILING COEF	AVE	11	8.35C00
BURNOUT HEAT FLUX	AVE	5	8.35C00

END OF STUDY

MAXIMUM VALUE OF SOME FEEDBACK EXCEEDED

APPENDIX C

NAA-SR-MEMO-9800
page 57

TIME	F 12	F 13	F 14	F 1	F 2	F 3	F 4
0.	1.0000E C0	C.	-2.0862E-C7	1.2295E C3	1.2412E C3	1.0025E C3	1.1263E C3
5.0000E-C2	1.0142E CC	4.9971E-02	5.0544E-C1	1.2295E C3	1.2412E C3	1.0025E C3	1.1263E C3
1.5000E-C1	1.0932E CC	1.4941E-C1	9.2320E-01	1.2298E C3	1.2416E C3	1.0028E C3	1.1265E C3
2.5000E-C1	1.2112E CC	2.4773E-C1	1.1132E 00	1.2306E C3	1.2427E C3	1.0036E C3	1.1272E C3
3.5000E-C1	1.3641E CC	3.4459E-C1	1.2654E 00	1.2322E C3	1.2448E C3	1.0052E C3	1.1285E C3
4.5000E-C1	1.5601E CC	4.3958E-01	1.4219E 00	1.2346E C3	1.2482E C3	1.0076E C3	1.1306E C3
5.5000E-C1	1.8136E CC	5.3221E-C1	1.5938E 00	1.2383E C3	1.2532E C3	1.0113E C3	1.1336E C3
6.5000E-C1	2.1469E CC	6.2177E-C1	1.7841E 00	1.2435E C3	1.2603E C3	1.0165E C3	1.1380E C3
7.5000E-C1	2.5925E CC	7.0727E-01	1.9916E 00	1.2508E C3	1.2702E C3	1.0238E C3	1.1441E C3
8.5000E-C1	3.1984E CC	7.8731E-C1	2.2099E 00	1.2609E C3	1.2839E C3	1.0338E C3	1.1524E C3
9.5000E-C1	4.0330E CC	8.5985E-C1	2.4245E 00	1.2747E C3	1.3028E C3	1.0476E C3	1.1640E C3
1.0500E CC	5.1894E CC	9.2203E-01	2.6083E 00	1.2938E C3	1.3288E C3	1.0667E C3	1.1799E C3
1.1500E CC	6.7787E CC	9.6986E-01	2.7168E 00	1.3201E C3	1.3646E C3	1.0929E C3	1.2018E C3
1.2500E CC	8.8953E CC	9.9828E-01	2.6874E 00	1.3563E C3	1.4139E C3	1.1290E C3	1.2320E C3
1.3500E CC	1.1524E C1	1.0018E CC	2.4490E 00	1.4051E C3	1.4803E C3	1.1776E C3	1.2727E C3
1.4500E CC	1.4393E C1	9.7656E-C1	1.9526E 00	1.4686E C3	1.5667E C3	1.2408E C3	1.3256E C3
1.5500E CC	1.6895E C1	9.2379E-01	1.2224E 00	1.5463E C3	1.6725E C3	1.3182E C3	1.3904E C3
1.6500E CC	1.8313E C1	8.5253E-01	3.9283E-01	1.6341E C3	1.7919E C3	1.4055E C3	1.4636E C3
1.7500E CC	1.8337E C1	7.7769E-C1	-3.2569E-01	1.7248E C3	1.9151E C3	1.4955E C3	1.5392E C3
1.8500E CC	1.7318E C1	7.1340E-C1	-7.5814E-01	1.8114E C3	2.0325E C3	1.5811E C3	1.6113E C3
1.9500E CC	1.5927E C1	6.6658E-C1	-8.6164E-01	1.8901E C3	2.1391E C3	1.6586E C3	1.6769E C3
2.0500E CC	1.4691E C1	6.3852E-01	-7.2271E-01	1.9607E C3	2.2342E C3	1.7276E C3	1.7358E C3
2.1500E CC	1.3830E C1	6.2395E-01	-4.7655E-01	2.0250E C3	2.3204E C3	1.7899E C3	1.7893E C3
2.2500E CC	1.3354E C1	6.1827E-01	-2.3042E-01	2.0851E C3	2.4007E C3	1.8476E C3	1.8394E C3
2.3500E CC	1.3183E C1	6.1717E-01	-3.7946E-02	2.1431E C3	2.4777E C3	1.9029E C3	1.8878E C3
2.4500E CC	1.3224E C1	6.1755E-01	8.8395E-02	2.2005E C3	2.5535E C3	1.9570E C3	1.9357E C3
2.5500E CC	1.3393E C1	6.1749E-01	1.5660E-01	2.2582E C3	2.6293E C3	2.0111E C3	1.9838E C3
2.6500E CC	1.3626E C1	6.1596E-01	1.8130E-01	2.3167E C3	2.7058E C3	2.0655E C3	2.0325E C3
2.7500E CC	1.3875E C1	6.1260E-01	1.7728E-01	2.3762E C3	2.7833E C3	2.1205E C3	2.0821E C3
2.8500E CC	1.4111E C1	6.0753E-01	1.5718E-01	2.4367E C3	2.8618E C3	2.1761E C3	2.1325E C3
2.9500E CC	1.4316E C1	6.0109E-01	1.3073E-01	2.4980E C3	2.9410E C3	2.2321E C3	2.1836E C3
3.0500E CC	1.4485E C1	5.9375E-01	1.0466E-01	2.5599E C3	3.0206E C3	2.2883E C3	2.2352E C3
3.1500E CC	1.4621E C1	5.8594E-01	8.2937E-02	2.6222E C3	3.1006E C3	2.3446E C3	2.2871E C3
3.2500E CC	1.4731E C1	5.7806E-01	6.7190E-02	2.6847E C3	3.1805E C3	2.4008E C3	2.3392E C3
3.3500E CC	1.4822E C1	5.7035E-01	5.7403E-02	2.7473E C3	3.2602E C3	2.4568E C3	2.3914E C3

TIME	F 12	F 13	F 14	F 1	F 2	F 3	F 4
3.45COE CC	1.49C4E C1	5.6259E-C1	5.2569E-C2	2.8095E C3	3.3396E C3	2.5124E C3	2.4436E C3
3.55COF CC	1.4981E C1	5.56C4E-01	5.1254E-C2	2.8726E C3	3.4187E C3	2.5677E C3	2.4558E C3
3.65COE CC	1.5059F C1	5.4951E-C1	5.2202E-02	2.9304E C3	3.4975E C3	2.6226E C3	2.5480E C3
3.75COE CC	1.5139E C1	5.4338E-C1	5.4178E-C2	2.9874E C3	3.576CE C3	2.6772E C3	2.6CC1E C3
3.85COE CC	1.5223E C1	5.3759E-01	5.6434E-02	3.0437E C3	3.6541E C3	2.7315E C3	2.6522E C3
3.95COE CC	1.5311E C1	5.3210E-01	5.85C2E-C2	3.0993E C3	3.732CE C3	2.7856E C3	2.7044E C3
4.05COE CC	1.5403E C1	5.2686E-01	6.0159E-02	3.1544E C3	3.8C57E C3	2.8393E C3	2.7566E C3
4.15COF CC	1.5539E C1	5.2639E-01	1.0733E-C1	3.2089E C3	3.8873E C3	2.8929E C3	2.8045E C3
4.25COE CC	1.5718E C1	5.2449E-01	1.1625E-C1	3.2633E C3	3.9652E C3	2.9466E C3	2.8529E C3
4.35COE CC	1.5726E C1	5.0861E-C1	1.0762E-C3	3.3171E C3	4.0430E C3	3.00C1E C3	2.9CC5E C3
4.45COE CC	1.5731E C1	5.0162E-01	7.2161F-C3	3.3695E C3	4.1198E C3	3.0529E C3	2.9471E C3
4.55COE CC	1.5753E C1	4.96C4E-01	2.1602E-C2	3.4217E C3	4.1959E C3	3.105CE C3	2.9929E C3
4.65COF CC	1.58C0E C1	4.9159E-01	3.77C4E-C2	3.4727E C3	4.2713E C3	3.1566E C3	3.0379E C3
4.75COE CC	1.5872E C1	4.8757E-01	5.2064E-02	3.523CE C3	4.3463E C3	3.2078E C3	3.0823E C3
4.85COE CC	1.5964E C1	4.8489E-01	6.3286E-C2	3.5727E C3	4.4211E C3	3.2587E C3	3.1262E C3
4.95COF CC	1.6073E C1	4.8215F-01	7.1199E-02	3.6221E C3	4.4957E C3	3.3095E C3	3.1697E C3
5.0CCOE CC	1.7480E C1	6.0492E-01	1.2558E C0	3.6486E C3	4.53C3E C3	3.3368E C3	3.1930E C3
5.05COE CC	1.8177E C1	5.4940F-01	2.8615E-01	3.6778E C3	4.5687E C3	3.3669E C3	3.2185E C3
5.15COE CC	1.6831F C1	3.5236E-C1	-1.81C8E C0	3.7348E C3	4.6435E C3	3.4259E C3	3.2683E C3
5.25COF CC	1.2840E C1	7.1118F-02	-3.4460E C0	3.7749E C3	4.6955E C3	3.4683E C3	3.3040E C3
5.35COE CC	8.7364E C0	-2.7992E-C1	-4.0510E C0	3.791CE C3	4.7147E C3	3.4868E C3	3.3196E C3
5.45COE CC	5.8642F C0	-7.1C25F-01	-3.8137E C0	3.7875E C3	4.7074E C3	3.4859E C3	3.3189E C3
5.55COF CC	4.0915F C0	-1.2348E C0	-3.3752E C0	3.7716E C3	4.682CE C3	3.4724E C3	3.3077E C3
5.65COE CC	3.1891E C0	-1.46C8E C0	8.7265E-C2	3.7484E C3	4.6489E C3	3.4516E C3	3.29C5E C3
5.70COE CC	3.2152E C0	-1.3894E C0	2.1111E-01	3.7361E C3	4.63C9E C3	3.44C5E C3	3.2812E C3
5.75COF CC	3.2533F C0	-1.3186E C0	2.5602E-01	3.724CE C3	4.6132E C3	3.4295E C3	3.2722E C3
5.85COE CC	3.3479E C0	-1.1792E C0	3.1511E-01	3.7C06E C3	4.5788E C3	3.4081E C3	3.2546E C3
5.95COF CC	3.4646E C0	-1.0425E C0	3.70C0E-01	3.6782E C3	4.5458E C3	3.3877E C3	3.2379E C3
6.05COE CC	3.6C50E C0	-9.0846E-01	4.2492E-01	3.6569E C3	4.5145E C3	3.3683E C3	3.2221E C3
6.15COE CC	3.7720E C0	-7.7713E-01	4.8073E-01	3.6369F C3	4.4849E C3	3.35CCE C3	3.2073E C3
6.25COF CC	3.9691F C0	-6.4863E-01	5.3799F-01	3.6183E C3	4.4573E C3	3.3329E C3	3.1937E C3
6.35COE CC	4.2CC9E C0	-5.2316E-01	5.9711E-01	3.6012E C3	4.4318E C3	3.3173E C3	3.1812E C3
6.45COE CC	4.4731E C0	-4.01CCE-01	6.5829F-01	3.5859E C3	4.4087E C3	3.3033E C3	3.17C2E C3
6.55COF CC	4.7928E C0	-2.8251E-01	7.2150E-01	3.5725E C3	4.3883E C3	3.291CE C3	3.1608E C3
6.65COE CC	5.1683E C0	-1.6815E-C1	7.8634F-01	3.5612E C3	4.37C8E C3	3.28C9E C3	3.1531E C3

TIME	F 12	F 13	F 14	F 1	F 2	F 3	F 4
6.7500E CC	5.6099E CO	-5.8492E-02	8.5192E-01	3.5524E C3	4.3568E C3	3.2731E C3	3.1474E C3
6.8500E CC	6.1291E CO	4.5775E-02	9.1664E-01	3.5464E C3	4.3466E C3	3.2681E C3	3.1441E C3
6.9500E CC	6.7392E CO	1.4383E-01	9.7799E-01	3.5436E C3	4.3409E C3	3.2663E C3	3.1433E C3
7.0500E CC	7.4532E CC	2.3472E-01	1.0323E 00	3.5445E C3	4.3402E C3	3.2681E C3	3.1457E C3
7.1500E CC	8.2834E CC	3.1736E-01	1.0743E 00	3.5497E C3	4.3453E C3	3.2741E C3	3.1515E C3
7.2500E CC	9.2369E CO	3.9057E-01	1.0978E CO	3.5596E C3	4.3569E C3	3.2849E C3	3.1613E C3
7.3500E CC	1.0312E C1	4.5316E-01	1.0954E 00	3.5749E C3	4.3760E C3	3.3011E C3	3.1755E C3
7.4500E CC	1.1491E C1	5.0407E-01	1.0598E CO	3.5961E C3	4.4031E C3	3.3233E C3	3.1946E C3
7.5500E CC	1.2735E C1	5.4257E-01	9.8599E-01	3.6235E C3	4.4388E C3	3.3518E C3	3.2189E C3
7.6500E CC	1.3983E C1	5.6851E-01	8.7358E-01	3.6573E C3	4.4831E C3	3.3868E C3	3.2484E C3
7.7500E CC	1.5155E C1	5.8252E-01	7.2881E-01	3.6971E C3	4.5357E C3	3.4280E C3	3.2830E C3
7.8500E CC	1.6171E C1	5.8615E-01	5.6530E-01	3.7421E C3	4.5955E C3	3.4747E C3	3.3219E C3
7.9500E CC	1.6973E C1	5.8167E-01	4.0164E-01	3.7913E C3	4.6609E C3	3.5257E C3	3.3641E C3
8.0500E CC	1.7538E C1	5.7178E-01	2.5664E-01	3.8432E C3	4.7301E C3	3.5796E C3	3.4087E C3
8.1500E CC	1.7888E C1	5.5906E-01	1.4390E-01	3.8966E C3	4.8013E C3	3.6354E C3	3.4545E C3
8.2500E CC	1.8073E C1	5.4563E-01	6.8556E-02	3.9504E C3	4.8731E C3	3.6917E C3	3.5005E C3
8.3500E CC	1.8156E C1	5.3289E-01	2.7509E-02	4.0038E C3	4.9445E C3	3.7480E C3	3.5463E C3

TIME	F 5	F 6	F 7	F 8	F 9	F 10	F 11
0.	1.1361E C3	9.3715E 02	8.8500E 02	7.7151E C2	6.5802E C2	8.3921E C2	7.4462E C2
5.0000E-C2	1.1361E C3	9.3716E 02	8.8500E 02	7.7151E C2	6.5802E C2	8.3921E C2	7.4462E 02
1.5000E-C1	1.1364E C3	9.3739E 02	8.8501E 02	7.7152E 02	6.5802E C2	8.3921E C2	7.4462E C2
2.5000E-C1	1.1374E C3	9.3807E 02	8.8504E 02	7.7156E 02	6.5805E C2	8.3924E C2	7.4466E C2
3.5000E-C1	1.1391E C3	9.3936E 02	8.8512E 02	7.7168E C2	6.5811E C2	8.3931E C2	7.4476E C2
4.5000E-C1	1.1419E C3	9.4143E 02	8.8531E 02	7.7192E C2	6.5824E C2	8.3947E C2	7.4496E 02
5.5000E-C1	1.1461E C3	9.4449E 02	8.8567E 02	7.7235E C2	6.5844E C2	8.3976E C2	7.4532E C2
6.5000E-C1	1.1520E C3	9.4884E 02	8.8625E C2	7.7303E C2	6.5876E C2	8.4025E 02	7.4589E 02
7.5000E-C1	1.1603E C3	9.5450E 02	8.8716E 02	7.7406E C2	6.5923E C2	8.4100E C2	7.4674E C2
8.5000E-C1	1.1717E C3	9.6325E 02	8.8852E C2	7.7555E C2	6.5989E C2	8.4214E C2	7.4799E C2
9.5000E-C1	1.1874E C3	9.7476E 02	8.9050E 02	7.7766E C2	6.6081E 02	8.4379E C2	7.4974E C2
1.0500E C0	1.2091E C3	9.9062E 02	8.9331E 02	7.8061E 02	6.6209E C2	8.4614E C2	7.5221E 02
1.1500E C0	1.2350E C3	1.0125E 03	8.9728E 02	7.8472E C2	6.6386E C2	8.4944E C2	7.5563E C2
1.2500E C0	1.2800E C3	1.0425E 03	9.0280E 02	7.9040E C2	6.6630E C2	8.5404E C2	7.6037E C2
1.3500E C0	1.3354E C3	1.0831E 03	9.1045E 02	7.9823E C2	6.6964E C2	8.6042E C2	7.6689E C2
1.4500E C0	1.4074E C3	1.1358E 03	9.2092E C2	8.0884E C2	6.7415E C2	8.6914E C2	7.7573E C2
1.5500E C0	1.4956E C3	1.2003E C3	9.3493E 02	8.2287E C2	6.8003E C2	8.8082E C2	7.8743E 02
1.6500E C0	1.5951E C3	1.2730E 03	9.5311E 02	8.4068E C2	6.8732E C2	8.9598E C2	8.0227E 02
1.7500E C0	1.6978E C3	1.3480E C3	9.7575E C2	8.6213E C2	6.9580E C2	9.1484E C2	8.2015E C2
1.8500E C0	1.7957E C3	1.4194E C3	1.0027E 03	8.8652E C2	7.0503E C2	9.3730E C2	8.4048E 02
1.9500E C0	1.8845E C3	1.4840E C3	1.0334E 03	9.1281E C2	7.1450E C2	9.6287E C2	8.6240E C2
2.0500E C0	1.9638E C3	1.5415E 03	1.0670E 03	9.3992E C2	7.2380E C2	9.9088E C2	8.8499E C2
2.1500E C0	2.0357E C3	1.5934E 03	1.1026E 03	9.6697E C2	7.3266E C2	1.0206E C3	9.0754E C2
2.2500E C0	2.1026E C3	1.6416E 03	1.1396E C3	9.9342E C2	7.4101E C2	1.0514E C3	9.2958E C2
2.3500E C0	2.1668E C3	1.6876E C3	1.1770E C3	1.0190E C3	7.4888E C2	1.0826E C3	9.5090E 02
2.4500E C0	2.2300E C3	1.7327E 03	1.2146E 03	1.0436E C3	7.5635E C2	1.1139E C3	9.7145E 02
2.5500E C0	2.2932E C3	1.7778E C3	1.2518E C3	1.0675E C3	7.6355E C2	1.1449E C3	9.9130E 02
2.6500E C0	2.3569E C3	1.8231E 03	1.2886E C3	1.0906E C3	7.7056E C2	1.1756E C3	1.0106E 03
2.7500E C0	2.4215E C3	1.8650E 03	1.3248E 03	1.1133E C3	7.7746E C2	1.2058E C3	1.0295E 03
2.8500E C0	2.4869E C3	1.9153E C3	1.3606E 03	1.1356E C3	7.8432E C2	1.2356E C3	1.0481E 03
2.9500E C0	2.5529E C3	1.9620E 03	1.3959E 03	1.1577E C3	7.9117E C2	1.2650E C3	1.0665E C3
3.0500E C0	2.6193E C3	2.0089E 03	1.4308E 03	1.1797E C3	7.9803E C2	1.2941E C3	1.0848E C3
3.1500E C0	2.6859E C3	2.0558E 03	1.4654E 03	1.2016E C3	8.0490E C2	1.3230E C3	1.1031E 03
3.2500E C0	2.7525E C3	2.1026E 03	1.4999E 03	1.2235E C3	8.1177E C2	1.3517E C3	1.1213E C3
3.3500E C0	2.8190E C3	2.1493E 03	1.5342E 03	1.2454E C3	8.1864E C2	1.3803E C3	1.1396E 03

TIME	F 5	F 6	F 7	F 8	F 9	F 10	F 11
3.45COE CO	2.8852E C3	2.1956E 03	1.5684E 03	1.2672E C3	8.2549E 02	1.4088E C3	1.1578E 03
3.55COE CO	2.9511E C3	2.2417E 03	1.6025E 03	1.2890E C3	8.3232E 02	1.4373E C3	1.1759E 03
3.65COE CC	3.0168E C3	2.2875E 03	1.6180E 03	1.3107E 03	8.3912E 02	1.4657E C3	1.1941E 03
3.75COE CC	3.0822E C3	2.3330E 03	1.6180E 03	1.3324E C3	8.4589E 02	1.4940E C3	1.2121E 03
3.85COE CO	3.1474E C3	2.3783E 03	1.6180E 03	1.3540E C3	8.5263E 02	1.5222E C3	1.2301E 03
3.95COE CO	3.2123E C3	2.4233E 03	1.6180E 03	1.3755E C3	8.5932E 02	1.5505E C3	1.2481E 03
4.05COE CC	3.2771E C3	2.4681E 03	1.6180E 03	1.3969E C3	8.6598E 02	1.5786E C3	1.2659E 03
4.15COE CO	3.3417E C3	2.5128E 03	1.6180E 03	1.4183E C3	8.7261E 02	1.6179E C3	1.2837E 03
4.25COE CO	3.4067E C3	2.5576E 03	1.6180E 03	1.4395E C3	8.7922E 02	1.6180E C3	1.3014E 03
4.35COE CC	3.4715E C3	2.6022E 03	1.6180E 03	1.4607E C3	8.8582E 02	1.6180E C3	1.3191E 03
4.45COE CC	3.5355E C3	2.6461E 03	1.6180E 03	1.4819E C3	8.9238E 02	1.6180E C3	1.3367E 03
4.55COF CC	3.5989E C3	2.6896E 03	1.6180E 03	1.5029E 03	8.9890E 02	1.6180E C3	1.3543E 03
4.65COE CO	3.6618E C3	2.7326E 03	1.6180E 03	1.5238E C3	9.0535E 02	1.6180E C3	1.3717E 03
4.75COE CC	3.7243E C3	2.7752E 03	1.6180E 03	1.5446E C3	9.1175E 02	1.6180E C3	1.3890E 03
4.85COE CO	3.7866E C3	2.8177E 03	1.6180E 03	1.5652E C3	9.1810E 02	1.6180E C3	1.4062E 03
4.95COE CO	3.8489E C3	2.8600E 03	1.6180E 03	1.5857E C3	9.2441E 02	1.6180E C3	1.4233E 03
5.00COE CO	3.8822E C3	2.8828E 03	1.6180E 03	1.6112E C3	9.2756E 02	1.6180E C3	1.4318E 03
5.05COE CO	3.9188E C3	2.9079E 03	1.6180E 03	1.6180E C3	9.3079E 02	1.6180E C3	1.4404E 03
5.15COE CO	3.9905E C3	2.9570E 03	1.6180E 03	1.6180E C3	9.3749E 02	1.6180E C3	1.4580E 03
5.25COF CO	4.0434E C3	2.9923E 03	1.6180E 03	1.6180E C3	9.4406E 02	1.6180E C3	1.4756E 03
5.35COE CC	4.0694E C3	3.0078E 03	1.6180E 03	1.6180E C3	9.4967E 02	1.6180E C3	1.4919E 03
5.45COE CC	4.0732E C3	3.0070E 03	1.6180E 03	1.6180E C3	9.5374E 02	1.6180E C3	1.5057E 03
5.55COF CC	4.0630E C3	2.9958E 03	1.6180E 03	1.6180E C3	9.5615E 02	1.6180E C3	1.5163E 03
5.65COE CO	4.0444E C3	2.9784E 03	1.6180E 03	1.6180E C3	9.5705E 02	1.6180E C3	1.5236E 03
5.70COE CO	4.0342E C3	2.9691E 03	1.6180E 03	1.6180E C3	9.5703E 02	1.6180E C3	1.5261E 03
5.75COF CC	4.0243E C3	2.9600E 03	1.6180E 03	1.6180E C3	9.5677E 02	1.6180E C3	1.5278E 03
5.85COF CO	4.0051E C3	2.9422E 03	1.6180E 03	1.6180E C3	9.5571E 02	1.6180E C3	1.5295E 03
5.95COE CO	3.9868E C3	2.9252E 03	1.6180E 03	1.6180E C3	9.5416E 02	1.6180E C3	1.5293E 03
6.05COE CO	3.9697E C3	2.9090E 03	1.6180E 03	1.6180E C3	9.5232E 02	1.6180E C3	1.5276E 03
6.15COE CO	3.9537E C3	2.8937E 03	1.6180E 03	1.6180E C3	9.5033E 02	1.6180E C3	1.5249E 03
6.25COF CC	3.9391E C3	2.8795E 03	1.6180E 03	1.6180E C3	9.4828E 02	1.6180E C3	1.5214E 03
6.35COE CO	3.9260E C3	2.8665E 03	1.6180E 03	1.6180E C3	9.4625E 02	1.6180E C3	1.5176E 03
6.45COF CO	3.9146E C3	2.8548E 03	1.6180E 03	1.6180E C3	9.4429E 02	1.6180E C3	1.5136E 03
6.55COE CO	3.9051E C3	2.8446E 03	1.6180E 03	1.6180E C3	9.4245E 02	1.6180E C3	1.5095E 03
6.65COF CO	3.8980E C3	2.8362E 03	1.6180E 03	1.6180E C3	9.4076E 02	1.6180E C3	1.5057E 03

TIME	F 5	F 6	F 7	F 8	F 9	F 10	F 11
6.7500E CC	3.8934E C3	2.8297E C3	1.6180E 03	1.6180E C3	9.3927E C2	1.6180E C3	1.5020E C3
6.8500E CC	3.8918E C3	2.8255E C3	1.6180E C3	1.6180E C3	9.3802E C2	1.6180E C3	1.4988E C3
6.9500E CC	3.8938E C3	2.8240E C3	1.6180E C3	1.6180E C3	9.3704E C2	1.6180E C3	1.4962E C3
7.0500F CC	3.8998E C3	2.8255E C3	1.6180F C3	1.6180E C3	9.3638E C2	1.6180E C3	1.4941E C3
7.1500E CC	3.9105E C3	2.8305E C3	1.6180E C3	1.6180E C3	9.3610E C2	1.6180E C3	1.4929E C3
7.2500E CC	3.9266E C3	2.8395E C3	1.6180E C3	1.6180E C3	9.3625E C2	1.6180E C3	1.4926E C3
7.3500E CC	3.9488E C3	2.8530E C3	1.6180E C3	1.6180E C3	9.3690E C2	1.6180E C3	1.4933E C3
7.4500F CC	3.9777E C3	2.8715E C3	1.6180E C3	1.6180E C3	9.3811E C2	1.6180E C3	1.4953E C3
7.5500E CC	4.0138E C3	2.8953E C3	1.6180E C3	1.6180E C3	9.3995E C2	1.6180E C3	1.4987E C3
7.6500E CC	4.0572E C3	2.9245E C3	1.6180E C3	1.6180E C3	9.4247E C2	1.6180E C3	1.5036E C3
7.7500E CC	4.1076E C3	2.9588E C3	1.6180E C3	1.6180E C3	9.4570E C2	1.6180E C3	1.5102E C3
7.8500E CC	4.1642E C3	2.9977E C3	1.6180E C3	1.6180E C3	9.4964E C2	1.6180E C3	1.5186E C3
7.9500E CC	4.2257E C3	3.0402E C3	1.6180E C3	1.6180E C3	9.5426E C2	1.6180E C3	1.5286E C3
8.0500E CC	4.2907E C3	3.0852E C3	1.6180E C3	1.6180E C3	9.5948E C2	1.6180E C3	1.5403E C3
8.1500E CC	4.3577E C3	3.1316E C3	1.6180E C3	1.6180E C3	9.6519E C2	1.6180E C3	1.5534E C3
8.2500F CC	4.4255E C3	3.1786E C3	1.6180E C3	1.6180E C3	9.7128E C2	1.6180E C3	1.5678E C3
8.3500E CC	4.4932E C3	3.2255E C3	1.6180E C3	1.6180E C3	9.7764E C2	1.6180E C3	1.5831E C3

TIME	F 12	F 13	F 14	F 8	F 9	F 10	F 11
0.	6.50C2E C2	8.74C9F C1	5.3427E C1				
5.00C0E-C2	6.50C2E C2	8.7413E C1	5.3429E C1				
1.50C0E-C1	6.50C3E C2	8.7481F C1	5.3471E C1				
2.50C0E-C1	6.50C5E C2	8.7681E C1	5.3594E C1				
3.50C0E-C1	6.5010E C2	8.8052E C1	5.3821E C1				
4.50C0E-C1	6.5020E C2	8.8635E C1	5.4177E C1				
5.50C0F-C1	6.5038E C2	8.9488E C1	5.4692E C1				
6.50C0E-C1	6.5064E C2	9.0685E C1	5.5412E C1				
7.50C0E-C1	6.51C3E C2	9.2340E C1	5.6400E C1				
8.50C0E-C1	6.5158E C2	9.4610F C1	5.7747F C1				
9.50C0F-C1	6.5235E C2	9.7725E C1	5.9587E C1				
1.05C0E CC	6.5341E C2	1.02C1E C2	6.2111E C1				
1.15C0F CC	6.5489E C2	1.0792E C2	6.5582E C1				
1.25C0E CC	6.5692F C2	1.1603E C2	7.0334E C1				
1.35C0E CC	6.5971F C2	1.2693E C2	7.6716E C1				
1.45C0F CC	6.6347E C2	1.41C4F C2	8.4940E C1				
1.55C0E CC	6.6837F C2	1.5812E C2	9.4829E C1				
1.65C0F CC	6.7444F C2	1.77C3E C2	1.0563E C2				
1.75C0E CC	6.8151E C2	1.9596E C2	1.1618E C2				
1.85C0F CC	6.8921E C2	2.1327E C2	1.2544E C2				
1.95C0E CC	6.9710F C2	2.2820E C2	1.3289E C2				
2.05C0F CC	7.0485E C2	2.4087E C2	1.3863F C2				
2.15C0E CC	7.1223F C2	2.5188F C2	1.4306F C2				
2.25C0E CC	7.1919F C2	2.6189E C2	1.4666E C2				
2.35C0E CC	7.2575E C2	2.7147E C2	1.4985E C2				
2.45C0F CC	7.3148E C2	2.8099E C2	1.5293E C2				
2.55C0F CC	7.3798E C2	2.9066E C2	1.5610E C2				
2.65C0E CC	7.4382E C2	3.0059E C2	1.5947E C2				
2.75C0F CC	7.4958E C2	3.1080E C2	1.6308E C2				
2.85C0F CC	7.5530F C2	3.2124E C2	1.6691F C2				
2.95C0E CC	7.61C1E C2	3.3187E C2	1.7094E C2				
3.05C0E CC	7.6672E C2	3.4261E C2	1.7513E C2				
3.15C0E CC	7.7244E C2	3.5340E C2	1.7941E C2				
3.25C0F CC	7.7817E C2	3.6419E C2	1.8377E C2				
3.35C0F CC	7.8390E C2	3.7496E C2	1.8816E C2				

TIME	F 12	F 13	F 14	F 8	F 9	F 10	F 11
3.4500E 00	7.8961E 02	3.8568E 02	1.9257E 02				
3.5500E 00	7.9530E 02	3.9634E 02	1.9699E 02				
3.6500E 00	8.0097E 02	4.0696E 02	2.0142E 02				
3.7500E 00	8.0661E 02	4.1753E 02	2.0585E 02				
3.8500E 00	8.1222E 02	4.2805E 02	2.1029E 02				
3.9500E 00	8.1781E 02	4.3855E 02	2.1475E 02				
4.0500E 00	8.2336E 02	4.4902E 02	2.7153E 02				
4.1500E 00	8.2888E 02	4.5949E 02	2.7351E 02				
4.2500E 00	8.3439E 02	4.7004E 02	2.7649E 02				
4.3500E 00	8.3989E 02	4.8055E 02	2.9561E 02				
4.4500E 00	8.4536E 02	4.9092E 02	3.0636E 02				
4.5500E 00	8.5079E 02	5.0116E 02	3.1691E 02				
4.6500E 00	8.5617E 02	5.1130E 02	3.2729E 02				
4.7500E 00	8.6151E 02	5.2140E 02	3.3752E 02				
4.8500E 00	8.6680E 02	5.3147E 02	3.4764E 02				
4.9500E 00	8.7205E 02	6.7075E 02	3.5767E 02				
5.0000E 00	8.7468E 02	6.7284E 02	3.6304E 02				
5.0500E 00	8.7737E 02	6.7645E 02	3.6892E 02				
5.1500E 00	8.8296E 02	6.9738E 02	3.8039E 02				
5.2500E 00	8.8843E 02	7.0936E 02	3.8861E 02				
5.3500E 00	8.9311E 02	7.1380E 02	3.9222E 02				
5.4500E 00	8.9650E 02	7.1210E 02	3.9205E 02				
5.5500E 00	8.9851E 02	7.0649E 02	3.8948E 02				
5.6500E 00	8.9926E 02	6.9862E 02	3.8550E 02				
5.7000E 00	8.9925E 02	6.9447E 02	3.8338E 02				
5.7500E 00	8.9903E 02	6.9039E 02	3.8129E 02				
5.8500E 00	8.9814E 02	6.8245E 02	3.7724E 02				
5.9500E 00	8.9685E 02	6.7486E 02	3.7339E 02				
6.0500E 00	8.9532E 02	6.6763E 02	3.6975E 02				
6.1500E 00	8.9366E 02	6.6082E 02	3.6634E 02				
6.2500E 00	8.9195E 02	6.5445E 02	3.6319E 02				
6.3500E 00	8.9026E 02	6.4858E 02	3.6033E 02				
6.4500E 00	8.8862E 02	6.4325E 02	3.5778E 02				
6.5500E 00	8.8709E 02	6.3854E 02	3.5561E 02				
6.6500E 00	8.8569E 02	6.3453E 02	3.5384E 02				

APPENDIX C

NAA-SR-MEMO-9800
page 65

AIREK3B-HNPF-\$1/SEC.

TIME	F 12	F 13	F 14	F 8	F 9	F 10	F 11
6.7500E CC	8.8444E C2	6.3129E 02	3.5253E 02				
6.8500E CC	8.8340E C2	6.2895E 02	3.5176E C2				
6.9500E CC	8.8258E C2	6.2762E 02	3.5159E 02				
7.0500F CC	8.8203E C2	6.2746E 02	3.5213E 02				
7.1500E CC	8.8180E C2	6.2864E 02	3.5347E 02				
7.2500F CC	8.8192E C2	6.3133E 02	3.5572E 02				
7.3500E CC	8.8246E C2	6.3571E C2	3.5900E 02				
7.4500F CC	8.8347E C2	6.4196E 02	3.6341E 02				
7.5500E CC	8.8501E C2	6.5019E 02	3.6901E C2				
7.6500E CC	8.8711E C2	6.6041E 02	3.7582E 02				
7.7500F CC	8.8980E C2	6.7253E 02	3.8378E 02				
7.8500E CC	8.9309E C2	6.8630F 02	3.9274E C2				
7.9500E CC	8.9694E C2	7.0138E 02	4.0249E C2				
8.0500E CC	9.0128E C2	7.1733E 02	4.1276E 02				
8.1500F CC	9.0605E C2	7.3376E C2	4.2331E 02				
8.2500E CC	9.1112E C2	7.5031E 02	4.3392E 02				
8.3500E CC	9.1642E C2	7.6675E 02	4.4447E C2				

RLN TIME - COMPLETE PHASE	-	8.0	SECONDS
- PRINT PHASE	-	3.0	SECONDS
- GRAPH PHASE	-	0.	SECONDS
- TOTAL CODE	-	11.0	SECONDS

TOTAL NUMBER OF POINTS CALCULATED	-	87
-----------------------------------	---	----

APPENDIX C

MAA-SR-MEMO-9800
page 67

AIREK3B-HNPF- $\$1/\text{SEC.}$

AIREK3B-HNPF- $\frac{1}{\text{SEC.}}$

AIREK3B-HNPF- $\frac{1}{\text{SEC}}$.

AIREK3B-HNPF- $\$1/\text{SEC.}$

AIREK3B-HNPF-1/SEC.

AIREK3B-HNPF- $\frac{1}{\text{SEC}}$.

AIREK3B-HNPF- $\$1/\text{SEC.}$

AIREK3B-HNPF-1/SEC.