LOVELY - I

PROGRAM NO. 55

THERMAL ANALYSIS ON THE IBM 650

AEC Contract # AT(30-3)-326

Issued November 26, 1958

J. D. Love
C. J. Stueck

Alco Products, Inc.
Post Office Box 414
Schenectady, N. Y.

DISCLAIMER

DISCLAIMER

DISTRIBUTION

Copies

Copies	
1-2	New York Operations Office U. S. Atomic Energy Commission 70 Columbus Avenue New York 23, New York ATTENTION: Capt. Richard L. Harris (V. J. Del Vecchia for C)
3-4	U. S. Atomic Energy Commission Washington 25, D. C. ATTENTION: Classified Technical Library for Col. D. G. Williams
~~4~~ 5-7	U. S. Atomic Energy Commission Army Reactors Branch Division of Reactor Development Washington 25, D. C. ATTENTION: Major Paul H. Ugis
8	U. S. Atomic Energy Commission Chief, Patents Branch Washington 25, D. C. ATTENTION: Roland A. Anderson
9	U. S. Atomic Energy Commission Chicago Operations Office P. O. Box 59 Lamont, Illinois ATTENTION: Captain J. Schweizer
10	U. S. Atomic Energy Commission Idaho Operations Office Phillips Petroleum Company, NRTS Technical Library P. O. Box 1250 Idaho Falls, Idaho ATTENTION: Major Robert L. Ednie

DISTRIBUTION (CONTINUED)

Copies

11 Nuclear Power Field Office
USERDL
Fort Belvoir, Virginia

ATTENTION: Major W. R. Wray

12 Union Carbide Nuclear Corporation
Oak Ridge National Laboratory
Y-12 Building 9704-1
P. O. Box "Y"
Oak Ridge, Tennessee

ATTENTION: A. L. Boch

13 District Engineer, Alaska District
U. S. Army Corps of Engineers
P. O. Box 7002
Anchorage, Alaska

ATTENTION: NPAVG-N

14 The Martin Company
P. O. Box 5042
Middle River, Maryland

ATTENTION: AEC Contract Document Custodian

15-39 U. S. Atomic Energy Commission
Reference Branch
Technical Information Services Extension
P. O. Box 62
Oak Ridge, Tennessee

40-41 Alco Products, Inc.
P. O. Box 145
Fort Belvoir, Virginia

ATTENTION: H. L. Weinberg

42-50 Alco Products, Inc.
Post Office Box 414
Schenectady, N. Y.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLES

NOMENCLATURE

Symbols			Units
a_i	=	internal flow area per element	ft^2
a_L	=	lattice flow area per element, i.e., lattice flow area within one unit cell	ft^2
A_{HT}	=	total heat transfer area in core	ft^2
A_{L_P}	=	total lattice flow area in pass "p"	ft^2
b	=	heat transfer area per water gap	ft^2
C	=	constant, function of system pressure (Ref. p. 52, ANL-4627)	
CC_P	=	number of control rods in pass "p"	
D	=	equivalent diameter of a water gap	ft
f_{P1}	=	fraction of the total power generated in the first pass	
F_L	=	lattice hot channel factor [1]	
$F_{n\Delta T}$, $F_{n\Delta\theta}$		nuclear uncertainty factors, to be applied to the bulk coolant temperature rise and film temperature gradient, respectively	
F_{inst}	=	instrumentation factor for core power	
F_{avg}, F_{loc}		mechanical hot channel factors to be applied to bulk coolant temperature rise and film temperature gradient, respectively.	
$(F_{R\Delta T})_{CR}$, $(F_{R\Delta\theta})_{CR}$		nuclear radial factors, representing the normalized radial power distribution and flux peaking factors, of the control rod element with the highest factors, [2] to be applied to the coolant temperature rise and film gradient, respectively.	

1 - The lattice hot channel factor represents the tolerances on a lattice flow channel which are in addition to those already existing in an internal flow channel.

2 - Calculations are performed for the control rod element with the highest factors only, since the control rod elements are not orificed.

Symbols			Units
$(F_{R\Delta T})_{FE_e}$, $(F_{R\Delta\theta})_{FE_e}$	}	nuclear radial factors for type "e" stationary fuel element.	
G	=	mass flow rate of coolant	$\#/ft^2$-hr
$G_{assum.}$	=	mass flow rate corresponding to W_{assum}	$\#/ft^2$-hr
G_{max_p}	=	mass flow rate corresponding to the maximum stationary element internal flow in the pass	$\#/ft^2$-hr
h_{assum}	=	heat transfer coefficient corresponding to G_{assum}	Btu/ft^2-hr ^oF
H. G.	=	fraction of the total core power generated in the fuel plates	
$(H.C.F.)_{BO}$	=	hot channel factor caused by tolerances on uranium content and meat thickness	
k_c	=	thermal conductivity of fuel plate cladding material	Btu/ft-hr ^oF
k_m	=	thermal conductivity of the fuel plate meat	Btu/ft-hr ^oF
m	=	constant function of system pressure (Ref. p. 52, ANL-4627)	
n_{CR}, n_{FE}	}	number of fuel plates per element	
N_{CR}, N_{FE}	}	total number of control rod and stationary fuel elements, respectively	
N_{FE_e}	=	number of stationary elements of type "e"	
P	=	total power of core (not including heat generated in the reflector)	MW
PPPP	=	problem number	
$P_0 \rightarrow P_n$	=	values of the normalized axial power distribution from the windowshade output	

Symbols			Units
P_z	=	value of the windowshade ouput at some mesh index "z"	
Q	=	mesh point index of the top of the active core	
Q_{R1}	=	heat generated in reflector whose coolant flow is in parallel with the first pass	Btu/hr
R_1	=	number of different types[3] of stationary fuel elements in pass one	
R_t	=	total number of different types of stationary elements in pass one and two combined	
$(R_{BO})_p$		maximum ratio of operating to burnout heat flux in pass "p"	
T_{in_p}	=	inlet temperature to pass "p"	^oF
T_{int_p}	=	maximum internal temperature in pass "p"	^oF
$T_{s_{allow}}$	=	maximum allowable surface temperature[4]	^oF
$(T_{s_{max}})_Z$	=	maximum possible surface temperature at a position "Z" from the inlet	^oF
T_{sat}	=	saturation temperature corresponding to system pressure	^oF
Δt_o, Δt_i	=	temperature difference across the fuel plate cladding and meat, respectively	^oF
ΔT_Z	=	maximum possible bulk coolant temperature rise from pass inlet to "Z"	^oF
$\Delta \Theta_Z$	=	maximum possible film temperature gradient at position "Z"	^oF

3 - Stationary elements of different types are distinguished by their "F_R" factors.

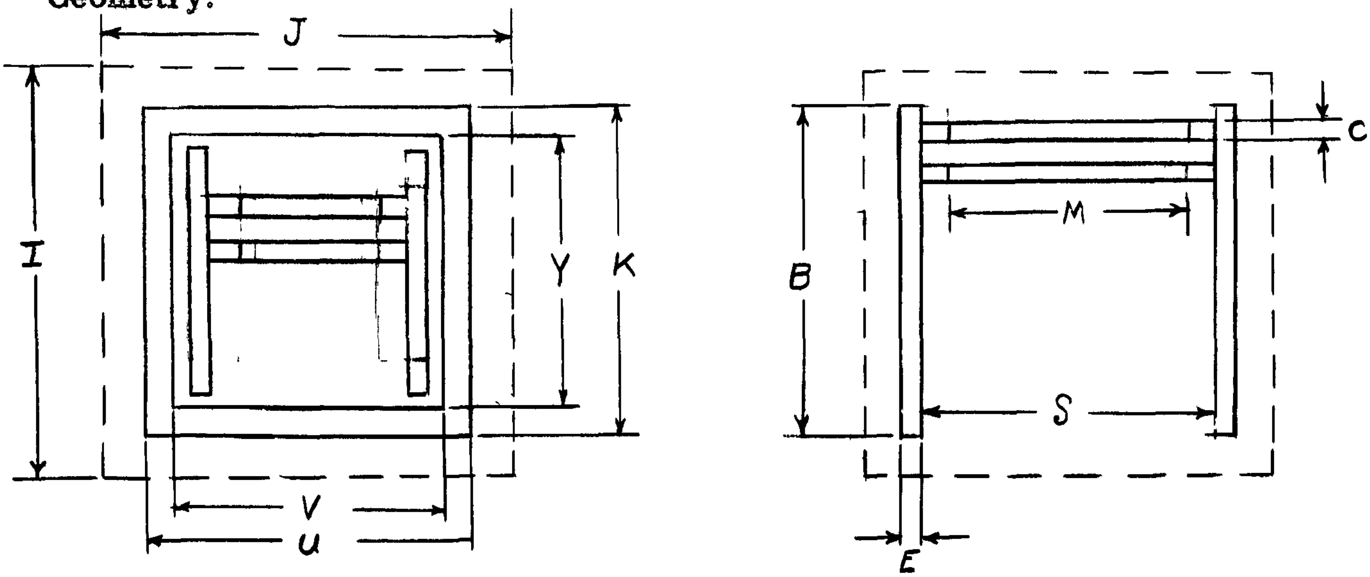
4 - Maximum allowable surface temperature is normally taken as the saturation temperature reduced by instrumentation tolerances on system pressure and inlet temperature.

Symbols			Units
W_{FE_e}	=	required coolant flow per element for stationary element type "e"	gpm
W_{CR}	=	required coolant flow per control rod element	gpm
W_{assum}	=	a first approximation for flow per element	lb/hr
$(W_i)_p$	=	total internal flow required in pass "p"	gpm
$(W_L)_p$	=	total lattice flow required in pass "p"	gpm
$(W_R)_p$	=	reflector flow in parallel with pass "p"	gpm
$(W_T)_p$	=	total flow required for pass "p"	gpm
X	=	number of spaces between end mesh points (x + 1 = number of mesh points) [5]	
ΔX	=	fuel plate clad thickness	ft
$\Delta Y'$	=	fuel plate meat thickness	ft
φ	=	average core heat flux, based on total core power and total heat transfer area	Btu/ft^2-hr
φ'	=	average heat flux based on fraction of total power generated in the fuel plates	Btu/ft^2-hr
$(\varphi_{op})_{max_{FE_p}}$	=	maximum operating heat flux in a stationary element in pass "p"	Btu/ft^2-hr
φ_{BO_p}	=	burnout heat flux in pass "p"	Btu/ft^2-hr
φ_{max_p}	=	maximum operating heat flux in pass "p" in either stationary or control rod element	Btu/ft^2-hr
		Coolant properties evaluated at the mean coolant temperature in pass "p"	
C_{P_p}	=	specific heat	Btu/lb ^{o}F
k_p	=	thermal conductivity	Btu/ft hr ^{o}F

5 - Mesh points refer to windowshade output.

Symbols			Units
ρ_p	=	density	lb/ft^3
μ_p	=	viscosity	#/ft-hr

Geometry:



I, J	=	dimensions of unit cell	ft
V, Y	=	inside control rod basket dimensions	ft
K, U	=	outside control rod basket dimensions	ft
B	=	width of side plate	ft
C	=	fuel plate thickness	ft
E	=	side plate thickness	ft
S	=	width of element water gap	ft
t	=	thickness of element water gap	ft
M	=	active meat width of a fuel plate	ft
H	=	active meat length of a fuel plate	ft
i_{CR}	=	meat length of control rod fuel plates inserted in the active core[6]	ft

6 - If all the control rod elements are not inserted at the same level, this should be a weighted average.

Subscripts

1	=	pass number 1
2	=	pass number 2
C. R.	=	control rod fuel element
F. E.	=	stationary fuel element
P	=	pass number $(0 < p \leq 2)$
e	=	stationary fuel element type number $(e \leq 16)$

INTRODUCTION

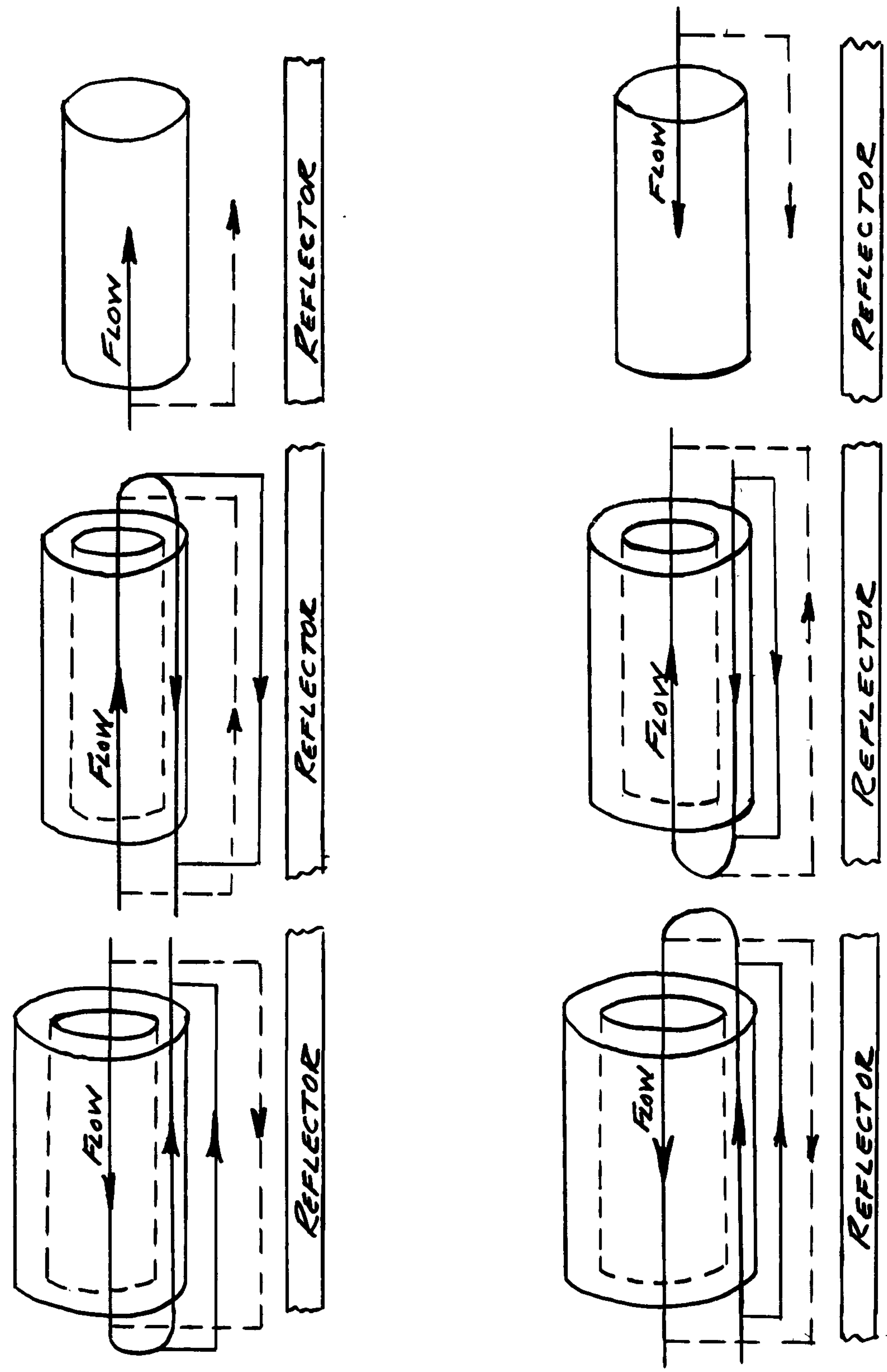
This program is intended to be utilized for the establishment of flow requirements of a tailored flow core. It is capable of handling either one or two-pass cores, with flow direction optional in each pass, and a reflector coolant flow in parallel with either pass. The various configurations which may be investigated are illustrated in Figure 1. Although the program is specifically intended for APPR-type elements, flows may be established for any set of dimensions, pressure and temperature conditions, and corresponding to any desired maximum allowable surface temperature. It is expected that, due to pressure drop considerations, for two-pass flow all control rods will be in the same pass.

Calculated results include flow requirements of each individual type of element, as well as total internal flow, lattice flow, and finally the total required flow for each pass.

Calculation of the maximum ratio of operating to burnout heat flux and maximum internal temperature is optional.

FIGURE 1

Core Configurations Which May Be Investigated



ANALYSIS

Surface Temperature

The following equations are used to determine the maximum possible plate surface temperature corresponding to any particular flow rate and at any position axially along the core:

(1) $$(T_s)_z = T_{in_p} + (\Delta T)_z + (\Delta \theta)_z$$

For a control rod:

(2a) $$(\Delta T)_{z_{CR}} = (F_{avg})_{CR} (F_{R_{\Delta T}})_{CR} (F_{n_{\Delta T}}) \left[\frac{b_{CR}\, \varphi\, (a_i)_{CR}}{(C_p)_p (W_{assum})_{CR} (S)_{CR} (t)_{CR}} \right] \sum_{z=1}^{z=z} \frac{P_{z-1} + P_z}{2}$$

(3a) $$(\Delta \theta)_{z_{CR}} = (F_{loc})_{CR} (F_{R_{\Delta\theta}})_{CR} (F_{n_{\Delta\theta}}) \left[\frac{\varphi'}{h_{assum_{CR}}} (X\, P_z) \right]$$

For a stationary element:

(2b) $$(\Delta T)_{z_{FE_e}} = (F_{avg})_{FE} (F_{R_{\Delta T}})_{FE_e} (F_{n_{\Delta T}}) \left[\frac{b_{FE}\, \varphi\, (n_{FE} - 1)}{(C_p)_p (W_{assum})_{FE}} \right] \sum_{z=1}^{z=z} \frac{P_{z-1} + P_z}{2}$$

(3b) $$(\Delta \theta)_{z_{FE_e}} = (F_{loc})_{FE} (F_{R_{\Delta\theta}})_{FE_e} (F_{n_{\Delta\theta}}) \left[\frac{\varphi'}{h_{assum_{FE}}} (X\, P_z) \right]$$

Equation (1) is evaluated at each mesh point axially along the core, in the direction of flow, to determine Ts_{max} corresponding to a particular flow rate. Iteration of flow rate is required to establish the flow corresponding to the desired value of Ts_{allow}

Flow Determination

Assuming some flow (W_{assum}), the corresponding heat transfer coefficient is calculated by use of equations (4) and (5) below:

(4) $$G_{assum} = \frac{(W_{assum})}{(a_i)_{CR \text{ or } FE}}$$

(5) $$h_{assum} = 0.021 \frac{k_p}{D_{CR \text{ or } FE}} \left(\frac{G_{assum} D_{CR \text{ or } FE}}{\mu_p} \right)^{0.8} \left(\frac{C_p \mu}{K} \right)_p^{0.4}$$

The results are substituted into equations (1) through (3) and $T_{s_{max}}$ corresponding to W_{assum} determined. Iteration on (W_{assum}) is continued until $T_{s_{max}} \approx T_{s_{allow}}$. The corresponding (W_{assum}) will be the required element flow rate (W).

Second Pass Inlet Temperature

The inlet temperature to the second pass is calculated by the mixing equation:

(6) $$T_{in_2} = T_{in_1} + \left[\frac{Q_{R_1} + (P)(f_{r_1})(3,413,000)}{(W_{T_1})(C_{p_1})} \right]$$

Once the inlet temperature is calculated, equations for the second pass are identical with those for the first pass.

General Constants

The following general constants are evaluated for use in the previous equations:

(7) $$A_{HT} = 2 \left[(M_{FE})(H_{FE})(n_{FE})(N_{FE}) + (M_{CR})(i_{CR})(n_{CR})(N_{CR}) \right]$$

(8) $$\varphi = \frac{P \times F_{inst} \times 3,413,000}{A_{HT}}$$

(9) $$\varphi' = (\varphi) \text{ (H. G.)}$$

(10) $$b_{FE} = 2 \ (M_{FE}) \ (H_{FE})$$

(11) $$b_{CR} = 2 \ (M_{CR}) \ (H_{CR})$$

(12) $$D_{FE} = \frac{2 (S)_{FE} (t)_{FE}}{(S_{FE} + t_{FE})}$$

(13) $$t_{FE} = \left(\frac{I - (n_{FE})(C_{FE})}{n_{FE}}\right)$$

(14) $$D_{CR} = \frac{2\,(s)_{CR}\,(t)_{CR}}{(s_{CR} + t_{CR})}$$

(15) $(a_i)_{FE} = (n_{FE}-1)\,(S_{FE})\,(t_{FE})$

(16) $$(a_{i_{CR}}) = \left[(Y)(V) - 2(B_{CR})(E)_{CR} - (n)_{CR}(S)_{CR}(C)_{CR}\right]$$

(17) $$(a_L)_{FE} = \left[(J)(I) - (a_i)_{FE} - 2(B)_{FE}(E)_{FE} - (n)_{FE}(S)_{FE}(C)_{FE}\right]$$

(18) $$(a_L)_{CR} = \left[(J)(I) - (K)(U)\right]$$

Total Internal Flow

The total internal flow for a pass with n types of stationary elements is determined by:

(19) $$(W_i)_P = CC_P\,(W_{CR}) + N_1 W_1 + N_2 W_2 + \cdots\cdots N_n W_n$$

Lattice Flow

The lattice flow area of a pass is calculated by:

(20) $$(A_L)_P = (a_L)_{CR}(CC)_P + (a_L)_{FE}(N_1 + N_2 + \cdots\cdots N_n)$$

The corresponding lattice flow requirement is determined by (See Section 4, AP Memo #157):

(21) $$(W_L)_P = (W_{max}) \left[\frac{(A_L)_P}{(a_i)_{FE}}\,(F_L)\right]$$

where:

(W_{max}) = maximum stationary fuel element flow in the pass, gpm.

Total Required Flow

The total required flow for a pass is then the summation of the calculated internal and lattice flows, and the assumed reflector flow:

(22) $$(W_T)_p = (W_I)_p + (W_L)_p + (W_R)_p$$

For a two-pass core the total required core flow is the larger total required pass flow.

Burnout Heat Flux Ratio

The maximum stationary element operating heat flux in a pass is calculated by:

(23) $$(\varphi_{op})_{max\,FE} = \varphi'(F_{K\Delta\theta})_{max\,FE}(X)(P_{3})_{max}(H.C.F.)_{B.O.}$$

The corresponding burnout heat flux is determined by:

(24) $$\frac{\varphi_{B.O}}{10^6} = C\left(\frac{G_{max}}{10^6}\right)^m (t_{sat} - t_b)^{0.22}$$

where:

$(F_{R\Delta\theta})_{max\,FE}$, G_{max} = the values corresponding to the highest stationary element flow in the pass.

$t_b = T_{in} + \Delta T$, corresponding to G_{max}

The maximum ratio of operating to burnout heat flux is then:

(25) $$R_{BO} = \frac{(\varphi_{OP})_{max\,FE}}{(\varphi_{BO})}$$

Maximum Internal Temperature

The maximum internal temperature in a pass is calculated by the following equations:

(26) $$(\varphi_{max})_p = \varphi'(F_{R\Delta\theta})_{max\,CR\,or\,FE}(X)(P_3)_{max}(H.C.F.)_{B.O.}$$

(27) $$\Delta t_o = \frac{(\varphi_{max})_p (\Delta X)}{k_c}$$

(28) $$\Delta t_i = \frac{(\varphi_{MAX})_P \, (\Delta Y')}{4 k_m}$$

(29) $$\left(T_{INT}\right)_{MAX} = T_{SAT} = \Delta t_o + \Delta t_i$$

where $(F_{R\Delta\Theta})_{max \ CR \ or \ FE}$ is the maximum nuclear radial factor for any element in the pass.

PROGRAM DETAILS

650 Computation

The machine calculation consists of iterating on flow rate and evaluating equation (1) for each type of element until $(T_{s_{max}}) = T_{s_{allow}}$.

The calculations are made while using flow expressed as #/hr, and converted to gpm as a final step.

The computer may be instructed to develop answers for either one or two-pass flow, with direction of flow variable on either pass.

Limitations

$0 < e < 17$ (1 to 16 different types of fuel elements)
$0 < p < 3$ (1 or 2 pass flow)

Variations and Modifications

Tolerance

The program has a convergence criterion between $(T_{s_{max}})$ and $T_{s_{allow}}$ equal to ± 1.00 °F.

If it is desired to modify the convergence criterion, enter into location (0181) a floating point number equal to the maximum deviation desired.

A tolerance of ± 0.25 °F has been used very successfully.

Evaluation of Equation

To prevent the required flow from being based on a spike in the power distribution, which frequently occurs at the bottom of the core within the last inch of active meat, the evaluation of equation (1) is not started until the third mesh point of the power distribution, and terminated on the third from last mesh point.

This spike in the power distribution is normally neglected since for upward flow it is compensated for by inlet effects and for downward flow it is expected that flux suppressors will be utilized to reduce it.

If it is desired to modify the starting and ending point of the evaluation of equation (1), enter into location (1732) a floating point number equal in size to the number of starting and ending mesh points it is desired to bypass.

A value of zero may be entered.

Lattice Flow Factor

The lattice flow area is determined by calculating the lattice area within a unit cell of each type, and multiplying by the number of unit cells. In some cases, however, the inner skirt dimensions do not coincide with the outer boundary of the unit cell scheme, and additional lattice flow area exists. This may be considered in determining lattice flow, if desirable, by inserting in floating point form the ratio of the actual lattice area to that calculated on the unit cell basis in location (0848).

Variation of t_{CR}

t_{CR} is the thickness of the control rod water gap, in feet. If a floating point value is entered for t_{CR} as input, the machine will use that value for all further calculations involving t_{CR}.

If zeros are entered for t_{CR} as input, the machine will equate $t_{CR} = t_{FE}$, and use this value for all further calculations involving t_{CR}.

Variation of Flow Direction

Location (1728) contains the control word F_1F_2BT, occupying the four left-handed digits of the word.

To control flow direction:

$$\text{First Pass} = \begin{cases} = 0 & \text{for upward flow} \\ = 1 & \text{for downward flow} \end{cases}$$

$$\text{Second Pass} = \begin{cases} = 0 & \text{for upward flow} \\ = 1 & \text{for downward flow} \end{cases}$$

When only one-pass flow is used, a digit must still be entered into F_2. (any digit)

Optional Calculation of the Ratio of Operating to Burnout Heat Flux

$$B \begin{cases} = 0 \text{ do not calculate} \\ = 1 \text{ do calculate} \end{cases}$$

Optional Calculation of Maximum Internal Temperature

$$T \begin{cases} = 0 \text{ do not calculate} \\ = 1 \text{ do calculate} \end{cases}$$

Input Format for the 650

Power Distribution

The power distribution desired is taken from the Windowshade Program (APAE Memo 88) output with no modifications. Cards numbered 2131xxxx32 through 2131xxxx46 are used.

Input Cards - L1

The input is punched into cards and loaded into the computer by use of the L1 loading routine.

Problem identification number (PPPP) occupies the four left-hand digits of location (1606).

Control word (F_1F_2BT) occupies the four left-hand digits of location (1728).

All other input is in floating point form.

Succeeding sets of input will be operated on by the computer - separate input sets by a blank card.

The location of the input may be found in TABLE I.

TABLE I

LOCATION OF INPUT

1600	$(FR\Delta T)_{CR}$	1623	N_5	1646	$(FR\Delta\theta)_{13}$
01	$(FR\Delta\theta)_{CR}$	24	$(FR\Delta T)_6$	47	N_{13}
02	CC_1	25	$(FR\Delta\theta)_6$	48	$(FR\Delta T)_{14}$
03	CC_2	26	N_6	49	$(FR\Delta\theta)_{14}$
04	T_{in_1}	27	$(FR\Delta T)_7$	1650	N_{14}
05	P	28	$(FR\Delta\theta)_7$	51	$(FR\Delta T)_{15}$
06	PPPP	29	N_7	52	$(FR\Delta\theta)_{15}$
07	R_1	1630	$(FR\Delta T)_8$	53	N_{15}
08	R_t	31	$(FR\Delta\theta)_8$	54	$(FR\Delta T)_{16}$
09	$(FR\Delta T)_1$	32	N_8	55	$(FR\Delta\theta)_{16}$
1610	$(FR\Delta\theta)_1$	33	$(FR\Delta T)_9$	56	N_{16}
11	N_1	34	$(FR\Delta\theta)_9$	57	Not used
12	$(FR\Delta T)_2$	35	N_9	58	$(T_s)_{allow}$
13	$(FR\Delta\theta)_2$	36	$(FR\Delta T)_{10}$	59	$(F_{avg})_{FE}$
14	N_2	37	$(FR\Delta\theta)_{10}$	1660	$(F_{loc})_{FE}$
15	$(FR\Delta T)_3$	38	N_{10}	61	$(F_{avg})_{CR}$
16	$(FR\Delta\theta)_3$	39	$(FR\Delta T)_{11}$	62	$(F_{loc})_{CR}$
17	N_3	1640	$(FR\Delta\theta)_{11}$	63	$F_{n_{\Delta T}}$
18	$(FR\Delta T)_4$	41	N_{11}	64	$F_{n\Delta\theta}$
19	$(FR\Delta\theta)_4$	42	$(FR\Delta T)_{12}$	65	Q
1620	N_4	43	$(FR\Delta\theta)_{12}$	66	X
21	$(FR\Delta T)_5$	44	N_{12}	67	M_{FE}
1622	$(FR\Delta\theta)_5$	1645	$(FR\Delta T)_{13}$	1668	H_{FE}

TABLE I

LOCATION OF INPUT

1669	M_{CR}	1690	W_{R2}	1711	S_{CR}
1670	H_{CR}	91	Q_{R1}	12	t_{CR}
71	Not used	92	Not Used	13	Not Used
72	i_{CR}	93	Not Used	14	W'_{assum}
73	H. G.	94	f_{P1}	15	C
74	F_{inst}	95	F_L	16	M
75	n_{FE}	96	I	17	$(H.C.F.)_{BO}$
76	n_{CR}	97	J	18	$(P_Z)_{max_1}$
77	N_{FE}	98	Y	19	$(FR\Delta\theta)_{max_{FE_1}}$
78	Not Used	99	Not Used	1720	Not Used
79	N_{CR}	1700	V	21	t_{sat}
1680	C_{P_1}	01	K	22	ΔX
81	k_1	02	U	23	$\Delta Y'$
82	ρ_1	03	B_{FE}	24	k_c
83	μ_1	04	B_{CR}	25	k_m
84	C_{P_2}	05	C_{FE}	26	$(FR\Delta\theta)_{max_{1(FE\ or\ CR)}}$
85	Not Used	06	Not Used	27	Not Used
86	k_2	07	C_{CR}	28	F_1F_2BT
87	ρ_2	08	E_{FE}	29	$(P_z)_{max_2}$
88	μ_2	09	E_{CR}	1730	$(FR\Delta\theta)_{max_{2_{FE}}}$
1689	W_{R1}	1710	S_{FE}	1731	$(FR\Delta\theta)_{max_{2(FE\ or\ CR)}}$

Output Format for the 650

All output is in floating point form.

Preceding each output set will be punched the input set that created it.

The first four digits of an output card contains the input identification number (PPPP).

The sixth digit is either 1 for first pass answers or 2 for second pass answers.

The ninth and tenth digits contain the card count, starting with 01.

A listing of the output is contained in TABLE II.

TABLE II

OUTPUT FORMAT

Number of Cards	CARD COLUMN							
	1 — 10	11 — 20	21 — 30	31 — 40	41 — 50	51 — 60	61 — 70	71 — 80

One or two pass flow

FIRST PASS

1	PPPP010001	W_{CR}	$(W_i)_1$	$(W_L)_1$	$(W_R)_1$	$(W_T)_1$	$(R_{BO})_1$	T_{int_1}
$\frac{R_1}{7}$	PPPP010002	W_{FE_1}	W_{FE_2}	W_{FE_3}	W_{FE_4}	W_{FE_5}	$W_{FE_{R1}}$	0 — 0

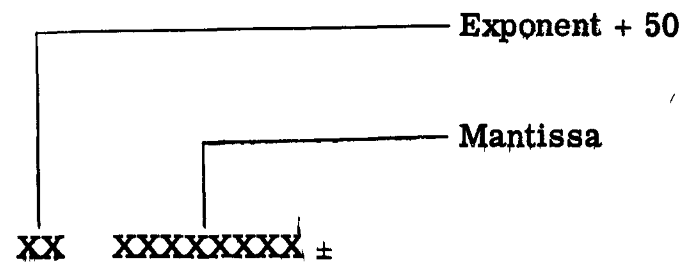
Two pass flow only

SECOND PASS

1	PPPP020003	W_{CR}	$(W_i)_2$	$(W_L)_2$	$(W_r)_2$	$(W_T)_2$	$(R_{BO})_2$	T_{int_2}
$\frac{R_t - R_1}{7}$	PPPP020004	$W_{FE(R_1 + 1)}$	$W_{FE(R_1 + 2)}$	$W_{FE_{R_t}}$	0 — 0	0 — 0	0 — 0	0 — 0

Floating Point Number Form

Number form:



Example:

- 0.00012345678 = 46 12345678 -
+ 12.34567890 = 51 12345678 +

All zeros and signs must be punched.

The sign is punched over the last digit of each number, an 11 punch for minus, a 12 punch for plus.

L1 Loading Routine

To use the L1 loading routine, the first word (cols 1 - 10) of each L1 input card must specify the memory location that the first word of input (cols 11 - 20) is to be stored into, and the number of words that are to be stored from that card. The first word of an L1 input card would have the form

(00 LLLL 0000S)

where,

LLLL is the memory location of the first word to be stored.

S is the number of words in the card to be stored ($0 < S < 8$).

L1 input cards must have a 12 punched in cols 1 and 10, and an 11 or 12 punch to indicate sign punched in the last column of each word to be stored. (11 = minus, 12 = plus)

Special Loading Requirements

In addition to the ordinary L1 requirements, it is necessary for the operation of this program to punch zeros with signs into words that are ordinarily blank on the L1 load cards. Do not change S.

Operating Instructions

Input Deck

(a) Lovely I program deck.

(b) Specified axial windowshade power distribution (from 2131xxxx32 through 2131xxxx46).

(c) Input load cards, each set followed by a blank card.

533 Read-Punch Unit

(a) Ready read feed with input deck.

(b) Ready punch feed with blanks.

650 Console

(a) Set programmed switch to STOP
Set half-cycle switch to RUN
Set control switch to RUN
Set display switch to PROGRAM REGISTER
Set overflow switch to STOP
Set error switch to STOP

(b) Set (70 1951 xxxx +) in storage entry switches.

(c) Press computer reset key

(d) Press computer start key

(e) When read hopper empties, press end of file key.

When the problem is completed the machine will stop with (70 1994 1250) in the program register.

To load a new power distribution:

(00 0000 1350)

To load L1 input cards:

(00 0000 1395)

To restart a calculation:

(00 0000 1250)

Programmed Stops

There is one stop instruction in the Lovely I program (01 0940 0940) Power distribution cards out of sequence.

Stoppages may occur if the limits imposed by the use of SIR are exceeded. In such cases, see SIR manual for explanation.

Calculation Time

For variance $= \pm 1.0\ ^{o}F$

$\text{Time}_{(\text{minutes})} = .035\ (X)\ (R_t + 1)$

For variance $= \pm 0.25\ ^{o}F$

$\text{Time}_{(\text{minutes})} = .04\ (X)\ (R_t + 1)$