MASTER. 15

**ATBAC CHECK CALCULATION
ON THE IBM - 650
PROGRAM No. 303**

**ALCO PRODUCTS, INC.
POST OFFICE BOX 414
SCHENECTADY, N. Y.**

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ON THE IBM 650

PROGRAM NO. 303

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ABSTRACT

This program, using the IBM 650 electronic data processing machine is used primarily as a tool in order to prepare input data for an IBM 704 code, entitled ATBAC. The code calculates steady state thermal characteristics of a plate type fuel element for both a nominal and adverse channel.

I INTRODUCTION

The purpose of this work is to present a tool to be used in conjunction with the ATBAC Code (WAPD-TM-20) in predicting the steady state temperature profiles in both nominal and adverse channels.

The principle quantities involved in this analysis are coolant flow rates, heat transfer coefficients, and local and average heat fluxes.

The nominal case offers an approximate indication of reactor conditions as they would be if most of the uncertainties were eliminated. In addition, it offers a stable "base" for the design factors which frequently change as the design of the core progresses. However, definition of the nominal case is somewhat arbitrary.

This report shows how the IBM 650 calculates both adverse and nominal temperature distributions, for either one or two pass cores in any flow direction combination with the assumption of perfect mixing.

II EQUATIONS SOLVED

1. $W_{ni} = \frac{W_{Ti}}{n_f - 1}$
2. $G_{ni} = \frac{W_{ni}}{d_n Y_n} \times 144$
3. $q_{av} = \frac{2 q''_{av} S_f H_f}{144}$
4. $q''_{av} = \frac{3.413 \times 10^6 Po}{2 [S_f H_f n_f N_f + S_c H_c n_c N_c]} \times 144$
5. $F_{weng} = \left(\frac{d_{minav}}{d_n} \right)^{\frac{5}{3}} \times \frac{Y_{minav}}{Y_n} \times \left(\frac{L_{nom}}{L_{max}} \right)^{\frac{5}{9}}$
6. $F_{heng} = \frac{(d_{minav})^{\frac{4}{3}}}{d_{max}(d_n)^{\frac{1}{3}}} \times \left(\frac{L_{nom}}{L_{max}} \right)^{\frac{4}{9}} \times \left(\frac{Y_{minav}}{Y_{max}} \right)^{\frac{4}{5}}$
7. $h_{ni} = K_i \cdot \frac{(G_{ni})^{0.8}}{(d_n/6)^{0.2}}$
8. $W_{min i} = W_{ni} \times F_{weng} \times F_{pl}$
9. $G_{min i} = \frac{W_{mini}}{d_{max} Y_{max}} \times 144$
10. $h_{mini} = h_{ni} \times F_{heng} \times (F_{pl})^{\frac{4}{5}} \times F_h$
11. $h_{avmini} = \left(\frac{d_{minav}}{d_n} \right)^{\frac{1}{3}} \times F_h \times h_{ni}$
12. $E_{max avi} = \frac{\frac{2}{h_{avmini}} + \frac{c_{maxav}}{6k_{cl}} + \frac{b_{maxav}}{12k_m}}{\frac{2}{h_{avmini}} + \frac{c_{maxav}}{12k_{cl}} + \frac{b_{maxav}}{12k_m} + \frac{a_{minav}}{12k_{cl}}}$
13. $E_{max loci} = \frac{\frac{2}{h_{mini}} + \frac{c_{maxloc}}{6k_{cl}} + \frac{b_{maxloc}}{12k_m}}{\frac{2}{h_{mini}} + \frac{c_{maxloc}}{12k_{cl}} + \frac{b_{maxloc}}{12k_m} + \frac{a_{minloc}}{12k_{cl}}}$
14. $F_{qengi} = E_{maxavi} \times \frac{b_{maxav}}{b_{nom}} \times \frac{D_{maxav}}{D_n} \times \frac{S_{maxav}}{S_f}$

II EQUATIONS SOLVED (Cont)

15. $F_{q"engi} = E_{maxloci} \times \frac{b_{maxloc}}{b_{nom}} \times \frac{D_{maxloc}}{D_n}$
16. $Re_{min} = \frac{d_n G_{ni}}{6\mu}$
17. $Re_{max} = \frac{d_{minav} G_{mini}}{6\mu}$
18. $T_{wni}(Z) = T_{in-nomi} + \frac{q_{av} F_{cpi}(Z)}{W_{ni} C_{pi}}$
19. $T_{sni}(Z) = T_{wni}(Z) + \frac{q_{av} F_{rlpi}(Z)}{h_{ni}}$
20. $T_{wmaxi}(Z) = T_{inmaxi} + \frac{q_{av} F_{cpipi}(Z) F_{qengi}}{W_{mini} C_{pi}}$
21. $T_{smaxi}(Z) = T_{wmaxi}(Z) + \frac{q_{av} F_{rlpi}(Z) F_{q"engi}}{h_{mini}}$
22. $T_{in\ nom2} = T_{in\ max2} = T_{wni}(Z = L)$

III PROGRAM INSTRUCTIONS

A. Calculation Flow (see flow chart)

1. Equations 1 through 17 are solved for the first pass ($i = 1$).
2. Results thus far are punched out.
3. Equations 18 through 21 are solved and results are punched out for $Z = 0$ through L .
4. Equation 22 is satisfied and steps 1 through 3 are repeated for the second pass (Z goes from L to 0).
5. After the 2nd pass (or 1st if only 1 pass), machine goes to read the next case input.

B. Input Format

All input is entered into the 650 in 7 values/card Fortran format. Forms are available for the input. All input except I and N are in floating point form.

1. Floating Point Form

.XXXXXXXXPP

PP = cc + 50

Example 127.3 = $.1273 \times 10^3 \rightarrow 1273000053$

.0876 = $.876 \times 10^{-1} \rightarrow 8760000049$

-.00294 = $-.294 \times 10^{-2} \rightarrow -2940000048$

2. Fixed Point Form

.XXXXXXXXXX

Example 3 $\rightarrow$ 00 0000 0003

93276 $\rightarrow$ 00 0009 3276

-22 $\rightarrow$ -00 0000 0022

C. Output Format

All output occurs three values per card with associated identification. All output is in floating point form except the number of pass and the Z index.

D. Machine Operation

1. Deck consists of:

a. Program deck

b. Input

2. Console settings:

70 1952 9999 STOP, RUN, ANYTHING, RUN, UPPER, SENSE, STOP

3. Control Panel:

IT-SOAP

IV NOMENCLATURE

C_p	=	Average specific heat, hot channel, Btu/lb ^o F
$\bar{C}_p$	=	Average specific heat, nominal channel, Btu/lb ^o F
D	=	Relative uranium density
E	=	Eccentricity Factor: Accounts for increased heat flux away from fuel element in one particular direction.
F_h	=	Film coefficient factor, accounts for inaccuracy in the correlation of h
F_{pl}	=	Plenum Factor: Accounts for the maldistribution of flow among fuel boxes and channels
$F_{rl}(Z)$	=	Average power at a particular level of a specified fuel element/Average power of reactor
$F_{rlp}(Z)$	=	Maximum power at a particular level of a specified fuel element/Average power of reactor
$F_{cp}(Z)$	=	$\frac{1}{L} \int_0^Z F_{rl}(Z) dZ$ Average cumulative power per unit length developed up to a particular level of a specified fuel element/ Average power of reactor.
$F_{cpp}(Z)$	=	$\frac{1}{L} \int_0^Z F_{rlp}(Z) dZ$ Maximum cumulative power per unit length developed up to a particular level of a specified fuel element/ Average power of reactor
F_{h-eng}	=	Engineering factor applied to film coefficient

IV NOMENCLATURE (Con't)

$F_{q-\text{eng}}$	=	Engineering factor applied to q_{av}	
$F_{q''-\text{eng}}$	=	Engineering factor applied to q''_{av}	
$F_{w-\text{eng}}$	=	Engineering factor applied to flow rate	
G	=	Mass flow rate ,	lb/hr-ft ²
H	=	Length of uranium in fuel element ,	inches
K	=	Average value of physical properties in film coefficient,	
	and is	$= \left(\frac{\mu C_p}{k} \right)^{0.4} \frac{k}{\mu^{0.8}}$	
L	=	Length of coolant channel ,	inches
N	=	Number of fuel elements or control rods	
P_o	=	Power or reactor ,	MW
Re	=	Reynolds number	
S	=	Meat width ,	inches
T	=	Temperature ,	°F
W	=	Flow rate ,	lb/hr
Z	=	Variable channel height ,	inches
a	=	Clad thickness, one side of meat,	inches
b	=	Meat thickness ,	inches
c	=	Clad thickness, other side of meat,	inches
d	=	Channel gap ,	inches
h	=	Coolant film coefficient ,	Btu/hr-ft ² -°F
k	=	Thermal conductivity ,	Btu/hr-ft-°F
n	=	Number of channels per fuel element or control rod	
q	=	Heat addition rate,	Btu/hr

IV NOMENCLATURE (Con't)

q''	=	Heat flux	Btu/hr-ft ²
ρ	=	Density of coolant	lb/ft ³
μ	=	Viscosity of coolant	lb/ft-hr

Subscripts

av	=	Average
eng	=	Based on engineering tolerances
loc	=	Based on local extreme
max	=	Maximum (local)
min	=	Minimum (local)
n	=	Nominal
w	=	Bulk water
S	=	Surface
i	=	Pass number
f	=	Fuel element
c	=	Control rod
T	=	Total
cl	=	Cladding

TABLE 1
INPUT FORMAT

Word 1	Word 2	Word 3	Word 4	Word 5	Word 6	Word 7	Word 8
02 0251 0007	$a_{\min \text{ av}}$	b_{nom}	$b_{\max \text{ av}}$	$b_{\max \text{ loc}}$	$c_{\max \text{ av}}$	d_n	$d_{\max}$
02 0258 0007	$d_{\min \text{ av}}$	$D_{\max \text{ av}}$	$D_{\max \text{ loc}}$	D_n	H_f	H_c	L_{nom}
02 0265 0007	$L_{\max}$	N_f	N_c	N_f	N_c	S_f	S_c
02 0272 0007	$S_{\max \text{ av}}$	$T_{\text{in nom}}$	$T_{\text{in max}}$	Y_n	$Y_{\max}$	$Y_{\min \text{ av}}$	$a_{\min \text{ loc}}$
02 0279 0007	$c_{\max \text{ av}}$	Zeros	P_o	μ	k_c	k_m	F_{p1}
02 0286 0007	F_h	K_1	K_2	C_{p1}	C_{p2}	$\bar{C}_{p1}$	$\bar{C}_{p2}$
02 0051 0007	$F_{cp1}(0)$	$F_{cp2}(0)$	$F_{cp1}(Z_1)$	$F_{cp2}(Z_1)$	$F_{cp1}(Z_2)$	$F_{cp2}(Z_2)$	$F_{cp1}(Z_3)$
02 0058 0007	$F_{cp2}(Z_3)$	etc. for all Z values					
02 0101 0007	F_{r1} values in same fashion as F_{cp}						
02 0151 0007	F_{cpp} values in same fashion as F_{cp}						
02 0201 0007	F_{rlp} values in same fashion as F_{cp}						
01 0004 0002	No. Z values No. passes						
02 0293 0002	W_{T1}	W_{T2}					

Table 1 continued on following page

1. As many as 8 cards may be used for the F_{cp} array. Similarly for F_{rl} , F_{cpp} , and F_{rlp} . Maximum number of values of each is 25/pass. On the last card of each set, the number 7 should be replaced with the number of values on the card. Values 0051, 0058, 0101, 0151, 0201 index by 7.
2. The maximum number of Z values is 25. The first value should be for $Z = 0$.
3. After a calculation is complete, additional values of W_{T1} and W_{T2} may be read into the 650 for additional calculation.
4. For a completely new calculation, the program deck must be read in after resetting the computer.

TABLE 2
OUTPUT FORMAT

Word 1	Word 2	Word 3	Word 4	Word 5	Word 6
02 0007 0008-	q"av	02 0008 0008	qav	02 0011 0008	F _{weng}
02 0013 0008-	F _{heng}				
02 0293 0010-	W _{T1}	02 0194 0010	W _{T2}	01 0002 0010	Pass No.
02 0003 0010-	W _{ni}	02 0004 0010	G _{ni}	02 0014 0010	h _{ni}
02 0015 0010-	W _{mini}	02 0016 0010	G _{mini}	02 0017 0010	h _{mini}
02 0018 0010-	h _{av mini}	02 0021 0010	F _{qeng}	02 0022 0010	Fq"eng
02 0023 0010-	Re _{min}	02 0024 0010	Re _{max}		
01 0003 0017-	Z#	02 0025 0017	T _{wni}	02 0026 0017	T _{sni}
01 0003 0017-	Z#	02 0027 0017	T _{wmaxi}	02 0028 0017	T _{smaxi}
01 0003 0017-	Z#	02 0025 0017	T _{wni}	02 0026 0017	T _{sni}

)
In Pairs

Z# begins with 1 for the Z=0 value

The above output is repeated for the second pass if a second pass is specified