J. G. Shaw

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HOTSTICK, KARE Axial Power Distribution Program for the Philco 2000

Donald E. Goodman

December, 1962

KNOLLS
ATOMIC POWER
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United States Atomic
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Title: HOTSTICK - KARE Axial Power Distribution Program for the Philco 2000

Originator:	F. D. Judge	Source Language:	TAC
Programmer:	D. E. Goodman	Computer:	Philco 2000
Date:	December, 1962	Category:	Physics, Diffusion Theory

Abstract:

The determination of axial power distributions in suspected "hot channels" is of major interest in nuclear reactor design. HOTSTICK is a Philco 2000 computer program which operates as part of the KARE system to obtain these distributions as a useful adjunct to normal KARE calculations.

HOTSTICK

KARE Axial Power Distribution Program for the Philco 2000

D. E. Goodman

I. INTRODUCTION

HOTSTICK is a program which calculates axial power distributions and total power in designated "hot sticks" in a reactor core. It is a portion of the EDIT 2 segment of the KARE system and is effective only for Class 1, R-Z geometry problems.

The reactor core is considered to be composed of from one to seven axial channels. Channel number one corresponds to the central cell and channels two through seven are surrounding rings. Each channel may or may not contain a rod and may contain 0, 1, or more hot sticks. The hot sticks are axial sub-channels within the rod channels in which "hot spots" may occur due to peaking of the neutron flux. Hot sticks are numbered from 1 to M across the core from channel 1 through N. The position of each stick in the channel is predetermined.

II. THE HOTSTICK MODEL

The HOTSTICK model is built around the Class 1 R-Z (windowshade) KARE model. In addition to the usual KARE description [(1)], information describing the problem hot sticks is also necessary.

For the purpose of describing local power factors, the KARE model is divided into axial zones defined by height increments Δh_i (see Figure 1). The local power factors are considered spatially constant over the zone for any one hot stick. In the input, the zones are specified by J values where the axial splitting into zones is to occur.

Radially the core is divided into channels. There may be any number of hotsticks in a channel.

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(1) KAPL-M-JA-6, "KARE Input", J. A. Archibald and F. L. Fletcher, Revision IV, August 15, 1962.

III. HOTSTICK CALCULATIONS

The axial power, P, at any point in a hot stick is calculated as

$$P_{m,n,h} = \bar{P}_{n,h} Q_m (\bar{U}_{n,h}, S_{n,h})$$

where

$P_{m,n,h}$ = axial power for stick m, in channel n, at a distance h from the bottom of the fuel

$\bar{P}_{n,h}$ = average power density in channel n at height h (obtained from KARE output)

Q_m = calculated local power factor for stick m

$\bar{U}_{n,h}$ = average fuel depletion fraction in channel n at height h (obtained from KARE output)

$S_{n,h}$ = rod-present factor in channel n at height h

m = stick index

n = channel index

h = distance from bottom of fuel (expressed as j index)

In the case where the problem geometry is such that, for a given h, the channel contains more than one actual region radially, i.e. across the channel, the program averages by volume the values for these regions. The program will accommodate up to 4 actual regions radially in a channel. If more than 4 actual regions exist across the channel, HOTSTICK terminates via an error exit.

The values averaged by volume are

$$\bar{P}_{n,h} = \frac{\sum_{k=1}^{K} V_k(n,h)\ PD_k(n,h)}{\sum_{k=1}^{K} V_k(n,h)}$$

$$\bar{U}_{n,h} = \frac{\sum_{k=1}^{K} V_k(n,h)\ U_k(n,h)}{\sum_{k=1}^{K} V_k(n,h)}$$

where

$V_k(n,h)$ = volume of actual region k in channel n at height h

$PD_k(n,h)$ = power density in actual region k in channel n at height h

$U_k(n,h)$ = fuel depletion fraction in actual region k in channel n at height h

k = radial actual region index in channel n: $k = 1$ to K, $K_{max} = 4$

In order to determine the appropriate local power factor, Q, for stick m at height h, a table of values must be supplied as part of the input. The independent variable in the table is up to ten values of fuel depletion, U_ℓ, ranging in value from zero to one. Associated with the set of U_ℓ values are sets of power factors as follows:

a) Primary Data

For each zone height, Δh_i, 2L values of Q are supplied for each stick, reflecting the rod-present factor S(n,h).

b) ARD (Adjacent Rod Dependent) Data

For each zone height, Δh_i, values of Q are supplied for each stick, reflecting the effect of rods in an adjacent channel.

L is the total number of U_ℓ values, maximum L being 10.

The appropriate value of Q is obtained for stick m in channel n at height h by using the averaged fuel depletion, $\bar{U}_{n,h}$, geometry, and rod-present data to interpolate in the table. Selection of the proper set in the table depends upon the height, h, and the rod configuration (see Section IV, Input).

Total power in a hot stick is calculated by volume averaging the calculated P values for each point common to a stick

$$P_m = \frac{\sum_{h=a}^{b} P_{m,n,h} \sum_{k=1}^{K} V_k(n,h)}{\sum_{h=a}^{b} \sum_{k=1}^{K} V_k(n,h)}$$

where a and b are bottom and top of the core.

IV. INPUT

Local power factors, Q, must be supplied for M sticks for each height increment, Δh. These power factors are functions of the fuel fraction remaining, U, and a rod present factor, S (the program takes into account the presence or absence of control rods in the channel containing the stick being calculated). If additional input is supplied (termed here as Adjacent Rod Dependent input, ARD), the effect of control rods in an adjacent channel is also considered. The "adjacent channel" is defined as the channel to the left of the channel containing the stick being calculated, i.e., present channel-1, unless the "present channel" is number 1, in which case the "adjacent channel" is channel number 2.

The core is divided into height increments, Δh, over which certain input Q's are valid (see core model, Fig. 1).

Input description and format is best understood from the sample input with one preliminary specific explanatory note --

The indication of rod configuration is as follows:

S_o - no rods current channel, no rods adjacent channel S_1 - rods current channel, no rods adjacent channel	} Primary Input
S_2 - no rods current channel, rods adjacent channel S_3 - rods current channel, rods adjacent channel	} ARD Input

The input Q values are symbolically designated by the form:

$$Q_{\Delta hi,m}$$

SAMPLE INPUT (See core model, Fig 1)

Locations 18000 and 18011 - 18039 are fixed point integers (no decimal points); only the U_j's (18001 - 18010) are floating point numbers (with decimal points).

18000	2	Number of U_j entries (max no. of entries = 10).
18001	1.0 , 0.5	Values of U_j to which corresponding input Q's apply. (U_1 = 1.0; U_2 = 0.5 in this example)
18011	2	Number of height increments into which the core is divided. (max = 19)
18012	11 , 17	J values for vertical splitting (height division lines). First input number is J for first height division line above bottom of core. Last input number should be J for top of core. (max = 19 values). (In this example: Δh_1 includes all actual regions between J=4 and J=11, Δh_2 includes all actual regions between J=11 and J=17). Do not split an actual region.
18031	2	Total number of hot sticks in the core (no max).
18032	4	Total number of channels in the core (max = 7).
18033	1,0,0,1	Number of sticks in each channel by channels. (no max) Example: Stick 1 is in channel 1; no sticks in channel 2; no sticks in channel 3, stick 2 is in channel 4. Note that sticks do not necessarily have to be in all channels.

PRIMARY INPUT			
18040	$Q_{1,1}\ (U_1,S_0)$	Stick 1	Δh_1
18041	$Q_{1,1}\ (U_2,S_0)$	Stick 1	Δh_1
18042	$Q_{1,1}\ (U_1,S_1)$	Stick 1	Δh_1
18043	$Q_{1,1}\ (U_2,S_1)$	Stick 1	Δh_1
18044	$Q_{1,2}\ (U_1,S_0)$	Stick 2	Δh_1
18045	$Q_{1,2}\ (U_2,S_0)$	Stick 2	Δh_1
18046	$Q_{1,2}\ (U_1,S_1)$	Stick 2	Δh_1
18047	$Q_{1,2}\ (U_2,S_1)$	Stick 2	Δh_1

ARD INPUT			
22840	$Q_{1,1}\ (U_1,S_2)$	Stick 1	Δh_1
22841	$Q_{1,1}\ (U_2,S_2)$	Stick 1	Δh_1
22842	$Q_{1,1}\ (U_1,S_3)$	Stick 1	Δh_1
22843	$Q_{1,1}\ (U_2,S_3)$	Stick 1	Δh_1
22844	$Q_{1,2}\ (U_1,S_2)$	Stick 2	Δh_1
22845	$Q_{1,2}\ (U_2,S_2)$	Stick 2	Δh_1
22846	$Q_{1,2}\ (U_1,S_3)$	Stick 2	Δh_1
22847	$Q_{1,2}\ (U_2,S_3)$	Stick 2	Δh_1

18048	$Q_{2,1}\ (U_1,S_0)$	Stick 1	Δh_2
18049	$Q_{2,1}\ (U_2,S_0)$	Stick 1	Δh_2
18050	$Q_{2,1}\ (U_1,S_1)$	Stick 1	Δh_2
18051	$Q_{2,1}\ (U_2,S_1)$	Stick 1	Δh_2
18052	$Q_{2,2}\ (U_1,S_0)$	Stick 2	Δh_2
18053	$Q_{2,2}\ (U_2,S_0)$	Stick 2	Δh_2
18054	$Q_{2,2}\ (U_1,S_1)$	Stick 2	Δh_2
18055	$Q_{2,2}\ (U_2,S_1)$	Stick 2	Δh_2

22848	$Q_{2,1}\ (U_1,S_2)$	Stick 1	Δh_2
22849	$Q_{2,1}\ (U_2,S_2)$	Stick 1	Δh_2
22850	$Q_{2,1}\ (U_1,S_3)$	Stick 1	Δh_2
22851	$Q_{2,1}\ (U_2,S_3)$	Stick 1	Δh_2
22852	$Q_{2,2}\ (U_1,S_2)$	Stick 2	Δh_2
22853	$Q_{2,2}\ (U_2,S_2)$	Stick 2	Δh_2
22854	$Q_{2,2}\ (U_1,S_3)$	Stick 2	Δh_2
22855	$Q_{2,2}\ (U_2,S_3)$	Stick 2	Δh_2

Primary Q input always starts at 18040 and ARD Q input starts at 22840. Q in the ARD input is always 4800 locations higher than its corresponding Q in the primary input. All Q input is in floating point form. The ARD input for height 1 could be omitted in this example because it is known that there will not be rods in an adjacent channel anywhere within this height. Thus, the first ARD input supplied would start at 22848.

Note that the tabular Q values are entered a) as a function of fuel depletion, U_j, and b) based on height from the bottom of the core. Primary Q input must be supplied completely and consecutively for all sticks, heights, U_j's, and rod present factors. Therefore, only the first Q supplied need be addressed (18040 in cols. 11-15). Since any part (or all) of the ARD input may be omitted, the first Q supplied following the omitted input must be addressed with the correct location in cols. 11-15. These addresses do not conflict with the regular KARE input addresses. If ARD input should have been supplied (according to the rod present factor) but is omitted, the primary input Q for the point is used in the calculation.

The input is punched in the same manner as the regular KARE input: a) addresses in cols. 11-15, b) decimal input in cols. 17-80, c) fixed point integers should not contain decimal points, d) floating point numbers must be punched with a decimal point, e) as many consecutive numbers as will fit may be placed on one card, f) separators between numbers may be spaces or commas.

The sentinel to do HOTSTICK is the "I" position of the 16800 card. (Edit Input).

16800 EDITmfps = do not do HOTSTICK (phase I or IIO

16800 ED1Tmfps = do HOTSTICK; input is supplied with this job (phase I or II)

16800 ED2Tmfps = do HOTSTICK; input has been supplied at a previous time step and is on 14T, (phase II only, with no change, i.e., input is still valid).

If input is valid for more than one time step, it is not necessary to supply it for every time step. That is, supply input at time 0 and thereafter only when it is required that the input be changed. Be sure to use the proper 16800 card.

There is one exception to the above statement. If the R-Z Synthesis is requested along with HOTSTICK, then HOTSTICK input must be supplied for every time step for which R-Z Synthesis input is supplied. However, HOTSTICK input may be changed at any time step without re-supplying the R-Z Synthesis input. HOTSTICK can not be used with KLAG synthesis calculations.

Input must be arranged in the following order:

1. Regular KARE decimal input.
2. Blank.
3. R-Z Synthesis decimal input.
4. Blank.
5. HOTSTICK decimal input.
6. Blank.

Items 3 and 4 are omitted if it is not an R-Z Synthesis problem, or if the R-Z Synthesis input has been supplied at a previous time step.

Since the R-Z Synthesis and HOTSTICK input are written and saved on 14T (not the History tape), problems in a lifestudy must be run consecutively at the same time unless input is supplied for each time step. If R-Z Synthesis and/or HOTSTICK input is not to be supplied at each time step (i.e., input supplied at a previous time step is to be used) and jobs are not to be run consecutively, operators should be requested to save the logical 14 tape for use in subsequent problems of the lifestudy to be run at a later date.

V. OUTPUT

1. P for each point for each stick.
2. Q (interpolated) for each point for each stick.
3. Sum of P x actual region volume(s) for each stick.
4. Sum of actual region volume(s) for each channel containing a stick = total volume of all fuel regions in the channel (by sticks).
5. P averaged by volume (power distribution over the whole stick) for each stick.

P and Q for each stick are printed columnwise for each actual region above J from bottom to top of the core. Results 3, 4, 5 above are printed after last P and Q for each stick. There are 6 stick columns across the page.

VI. ERROR EXIT

If an error exists in the HOTSTICK input, the program will give a dump and continue to the next KARE segment. Thus, an input error will not prevent the normal completion of the job. Therefore, it is suggested that before a whole lifestudy is run (in which HOTSTICK output is needed), the output from the first job be examined to determine if the HOTSTICK input is correct.

CORE MODEL FOR SAMPLE INPUT

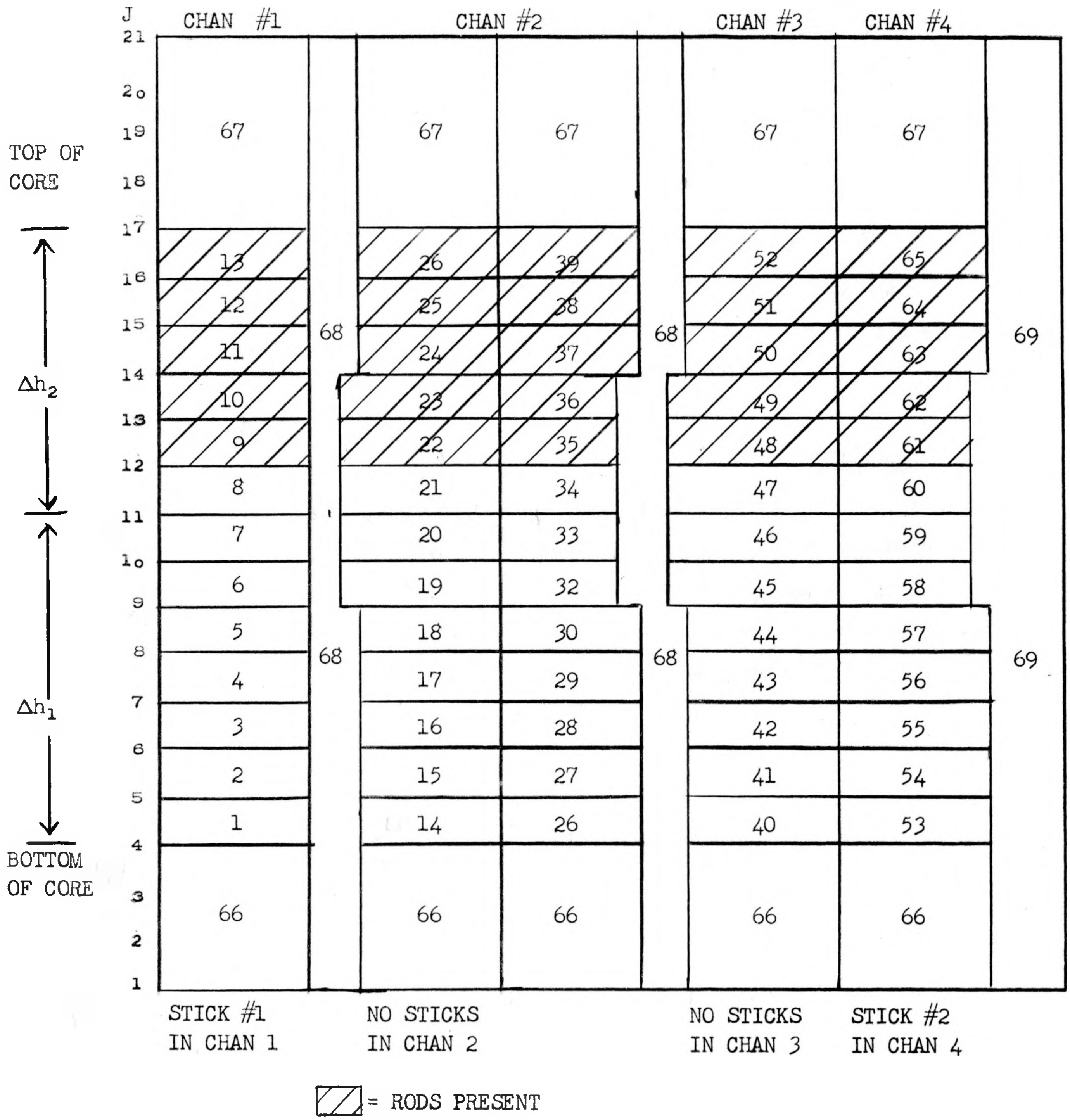

FIGURE I

CORE MODEL FOR SAMPLE PROBLEM