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An optimization and prediction method has been developed that allows automatic calculation of a rod sequence to obtain a prescribed power distribution in a BWR. During the sequence ~~all them~~ thermal margins are tested in order to obtain a feasible rod withdrawal table. Comparisons are made with Oyster Creek cycle 8 data and successful results can be reported.

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Appendix

1. INTRODUCTION

THe purpose of this working paper is to discuss and present results concerning optimization of control rod ~~resuences~~ sequences during large power manuevers in BWR's. An algorithm has been developed and tested, that will find a rod manuevring procedure to go from one prescribed to another prescribed power distribution. Constraints due to technical specifications and fuel considerations are included into the system.

The optimization routine is considered part of a larger start-up optimization problem and solves the statical optimization problem, when the xenon concentration in the core is considered constant (not necessarily in equilibrium).

An essential part of the overall problem has been to find suitable approximations of power changes caused by rod movements. A nonlinear predictor of local power changes has been developed and presented in a separate working paper (1).

The report is presented in the following way. Section 2 describes shortly the overall start-up reactor optimization problem and its characterization by a series of smaller optimization problems.
~~The rod optimization algorithm is outlined in section 3 and proper references are made to the metnioned prediction method.~~
~~In section~~ 4

Section 3 describes a general formulation of the optimization problem. The performance index as well as the different constraints are discussed.

Section 4 gives an outline of the optimization method that has been used. The methods to find feasible directions ~~Both the calculation of search directions and~~ are described.

Some optimization results, comparing real operating data from the Oyster Creek cycle 8 are presented in section 5. There are several parameters that the user can manipulate in order to influence the optimization procedure. These choices are discussed in section 6. Suggestions for further work are ~~suggested~~ mentioned in section 7.

2. BWR START- UP OPTIMIZATION

The problem of large power maneuvers has been considered within the PSMS project (Power Shaper Monitoring System) supported by EPRI. However, with the current version of PSMS the user has to supply information about the rod withdrawal sequence to the PSMS program package. To find such a sequence that is feasible may be an awkward and cumbersome task considering the huge number of constraints and independent control variables. The paper presents the results of an algorithm that will systematically search for the best rod withdrawal sequence in order to achieve a specified power distribution.

Typical start-up at beginning of cycle

A typical start-up path is shown in Fig. 1. A more detailed description of such a preconditioning cycle has been discussed elsewhere, see (2). Let it suffice to describe the path just in such a detail, that the present optimization problem is clearly illustrated and put into the proper perspective.

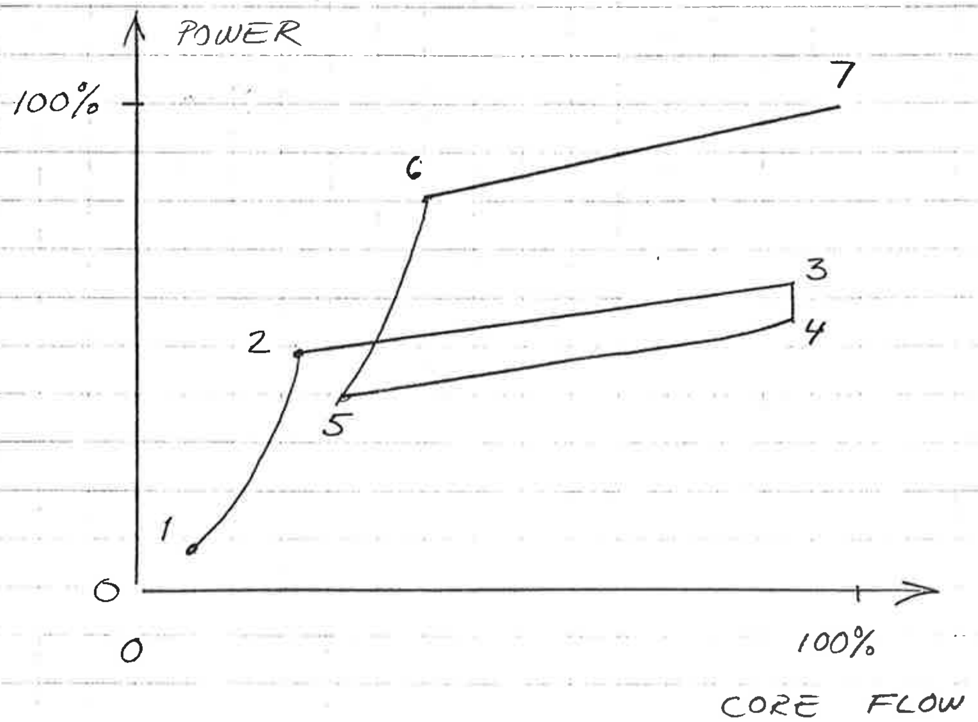

Fig. 1. Typical start-up path with one cycle.

The optimization path from (1) to (7) can be split up according to the independent variables available. Nothing is known a priori about the boundary conditions in the intermediate points (2) - (6). Therefore, in order to find solutions of the subproblems, some boundary conditions for the intermadiate points have to be calculated.

The path from (6) to (7) is straightforward, and basicly the core flow is increased with maximum speed, limited only by the envelope characteristics. Therefore, knowing the desired rod pattern and desired power distribution at (7) the reactor equations can be integrated backwards to (6), where an envelope can be established. As a safe approximation, the xenon concentration can be considered time-invariant during this procedure.

The rod withdrawal from (1) to (2) is the subject of this report. The time for the rod withdrawal is very short in comparison with the total start-up time. Therefore, no preconditioning is made during this phase. If the power distribution at (6) has larger values than that of (2), then preconditioning is necessary. This is sketched in Fig. 2.

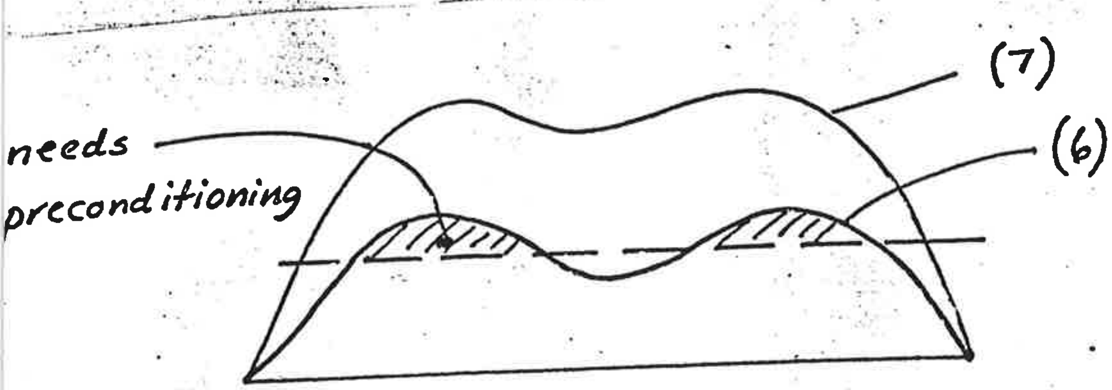

Fig 2. Decision about preconditioning.

The loop from (2) to (5) is time variable, but simplified by the fact, that only one independent variable is involved. As the core flow is increased at the maximum allowable speed between (2) and (3) Fig. 3 illustrates, that only two time points of the flow maximum have to be determined in this search. The criterion for this phase of the optimization would be to obtain such a xenon build-up, that the envelope at (6) could be reached with the prescribed rod configuration.* Still no algorithms have been developed for this phase, since the xenon concentration has to be considered time-variable.

* This has to be done with a minimum of productivity loss.

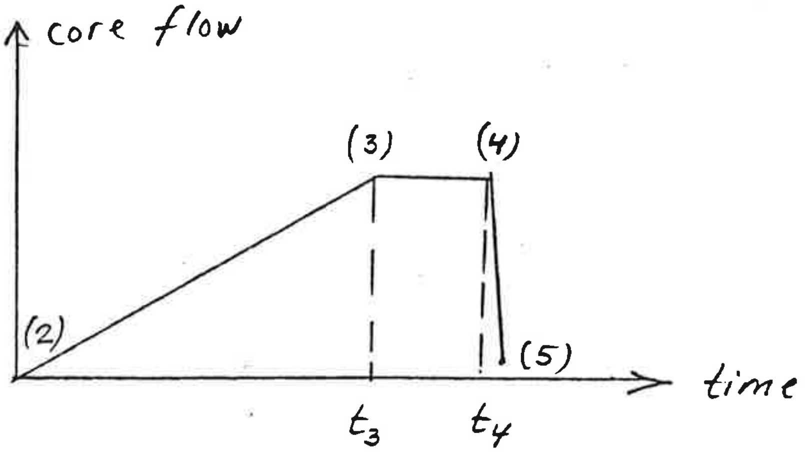

Figure 3. The xenon build-up phase (2) - (5).

A more detailed account of the decisions to make considering the overall optimization is indicated in the flow diagram of Appendix 1. Note, that these programs have not been written yet; only the steady state part of them.

3. FORMULATION OF THE OPTIMIZATION PROBLEM

Basicly the problem consists of finding a strategy for rod withdrawal so that the power shape will approach a desired distribution. This has to be done, so that all constraints for rod movements and fuel properties are taken into consideration.

Performance index

The performance index for the optimization part (1) to (2) (see fig 1) can be expressed as a statical relation ~~between~~

$$PI = \sum_{ijk} \left(p^{*} \cdot s^{*}_{ijk} - p^{c} \cdot s_{ijk} \right)^{2} \qquad (3.1)$$

where s^{*}_{ijk} = the target nodal power in node i,j,k, normalized by the core average power

s_{ijk} = the actual calculated normalized power in node i,j,k

p^{*} = desired bulk power

p^{c} = calculated actual average power

The structure of the performance index is crucial for the success of the optimization. A slightly different from of performance index has also been tested, that compensate for average power errors more efficiently,

$$PI = \sum_{ijk} \left(s^{*}_{ijk} - \left(\frac{P^{C}}{P^{*}} \right)^{n} \cdot s_{ijk} \right)^{2} \qquad (3.2)$$

where

P^{*} = the bulk power at the target

P^{C} = the calculated bulk power

n = an integer exponent

In the tests the target power distribution has been the same for all fuel bundles, i.e.

$$s^{*}_{ijk} = s^{*}_{k} \qquad (3.3)$$

in both (3.1) and (3.2).

However, the radial distribution of the target distribution can be taken into consideration, subroutine WEITPI, appendix 2.

A consequence of this is, that the contributions from fuel bundles at the periphery will be significant, as the target distibution is constant in the radial direction. The terms from the peripheral elements therefore may distort the optimization too much. One way to deal with this problem is to average the actual power distribution before it is compared with the target, i.e.

$$PI = \sum_{k} \left(s_k^* - \left(\frac{P^c}{P^*} \right)^N s_k \right)^2 \qquad (3.4)$$

where

$$s_k = \frac{1}{n} \sum_{ij} s_{ijk}$$

n = number of fuel elements in one horizontal plane

The results in section ~~will show the difference between the caused by the different~~ will demonstrate the difference between the cost function assumptions.

Active rods

The rod participating in the rod withdrawal scheme are divided into groups, where all rods within each group behave identically. The rods acting as independent control variables are called 'active rods'. The grouping of the rods has to be made in such a way that the superposition principle can be applied with reasonable accuracy. This means, that the rod tips of two adjacent groups are separated at least a distance corresponding to four nodes, see further ref (1).

Moreover, in the power prediction it is assumed, that each rod only influences the 4 x 4 neighbouring fuel bundles. Thus, the fuel bundles influenced by each rod are listed in a file, see subroutine BUNSER, appendix 2.

For each rod group there is a maximum and minimum insertion depth defined, which creates constraints of the control variables. Moreover, in the algorithm a precaution is made to avoid "ringing", i.e. the oscillation of a rod between two positions. Such a problem might appear close to an optimum point.

Fuel property constraints

The following margins have to be tested for each indiviaul rod movement,

APLHGR - average planar linear heat generation ratio

LHGR - linear heat generation rate

CPR - critical power ratio

envelope

The calculation of all these properties has to be made for each node and will be very cumbersome unless suitable approximations are made. Such approximation methods are discussed in (1) and will be further described in section 4 .

Initial values

As the optimization starts with core power and thermal margin calculation with the DCAM code all initial conditions for DCAM naturally have to be supplied. In particular, the rod pattern and the thermal power and core flow are given. Moreover, the actual xenon concentration is specified and is assumed to be stationary during the optimization.

In appendix 1 an input procedure is indicated, that will be implemented soon in the future. The present input format is different.

Final values

Only the target value of the power distribution and the bulk power are given. The final rod pattern is not specified. It will be a function of the given target power distribution.

4. OUTLINE OF THE OPTIMIZATION METHOD

The philosophy of the search ~~method~~ scheme is basicly a feasible direction ~~search~~ method. There are, however, two features that characterize the problem and demands special solutions. One is the discrete nature of the rod withdrawals. The other is the large number of constraints to be checked. The first condition makes it possible to search only ~~############~~ integer values of the independent variables. The other condition makes it unrealistic to find the feasible direction by any standard method. Instead it is found by a relatively simple numerical search method.

The ~~s######~~ ~~description~~ outline of the method is divided into several parts, the initial calculations, ~~the~~ search direction calculations, the linear search procedure, the test for constraints and the determination of the final solution. A systematic description of the flow of the program is found in appendix ~~B.~~ 2.

Initial calculations

The initial power distribution and corresponding values of the thermal margins are calculated, using the DCAM code. This calculation constitutes the starting point (or reference point), which will be called the "origin" in the following discussions. The calculation is made in routine ORIGIN, see appendix ~~B.~~ 2.

Gradient calculation for the unconstrained problem

There is no analytical way to determine the partial derivatives of the cost function with respect to the active rod groups. Instead they are calculated numerically. One rod group at a time is withdrawn one node, and DCAM calculates the power and thermal margin changes. ~~The maximum negative change is calculated~~ The changes are calculated and determine the gradient, see the subroutine DIRDER, appendix 2.

If the absolute value of the gradient is small enough, or if the gradient is positive, then a further ~~search~~ attempt is made in the "feasible direction search", ~~see below.~~ to find a search direction, see below.

The reason for the renewed attempt is the numerical accuracy. The DCAM core calculation of course has a limited accuracy. Close to the minimum ~~When the gradient has a small value~~ the influence of power calculation errors is amplified in the gradient calculation.

As the rod movements are defined only by integers, the calculated gradient is truncated to the nearest integers. This can be illustrated by fig. 4, showing the case for two rod groups r_1 and r_2.

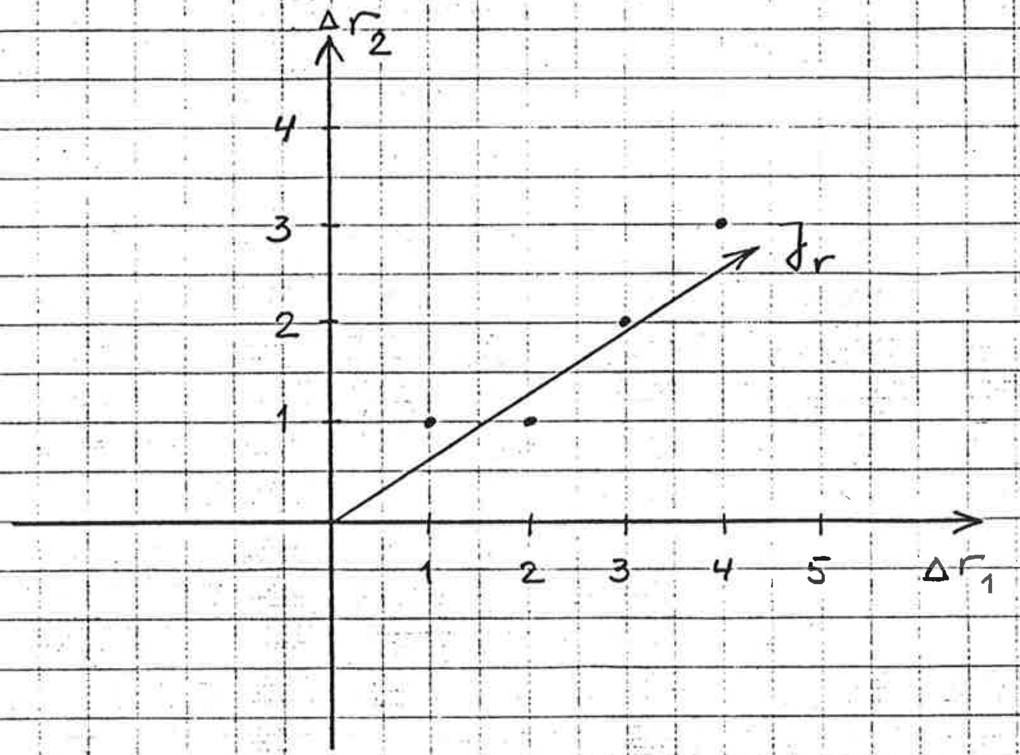

Fig 4. Illustration of the truncation along the gradient direction.

The gradient direction J_r is truncated to the points, ~~These~~ that ~~points~~ will define the path for the linear search, see below.

The thermal margin is tested ~~for~~ at the first point along the path. The power ~~change~~ and thermal margin changes ~~is~~ are calculated ~~from~~ based on superspo~~x~~sition of the changes caused by each indivi~~xxx~~dual rod group. This is shown to be relevant, as long as the ~~long~~ rod groups or rod tips of the different groups are sufficiently separated in space, see (1).

If any thermal margin is violated at the first point along the path, then a feasible direction is calculated, see below.

~~The~~ gradient calculations are performed in routine CALGRD, appendix ~~B~~ 2.

Calculation of feasible direction

The feasible direction ~~has to be calculated~~ is searched if any thermal margin has been violated at the first step along the path, defined by the gradient calculation. As there is no analytical expression of the constraints an exhaustive search for the feasible direction is made. The "partial derivatives", calculated earlier are used once more. Each control rod group is tried in three positions, one node withdrawal or insertion or the origin position. ~~For M groups this means~~ As the superposition principle is applied the computation is fast. The feasible direction is simply defined as the allowed direction that gives the maximum decrease of the cost function. ~~The search direction is then truncated in a~~ An illustration is made in fig 5, where the dashed lines indicate the search for the feasible direction.

If the change of the cost function is not sufficiently negative in any direction the search will still continue. This is made in order to avoid local minima and to overcome possible numerical inaccuracies. ~~Particularly close to the global minimum the calculation of the gradient may contain significant relative errors.~~ The complete search is ~~now~~ made for the minimum value of the cost function in a grid, containing two rod withdrawals or insertions for each rod group. The power and thermal margin calculations are made with ~~now based on~~ the non-linear prediction, based on the one node DCAM calculations, see "linear search" below.

~~The maximum point hav~~

The point having the minimum value of the cost function will now be defined as the origin for the next search direction. The subroutine performing the calculations is called FEADIR.

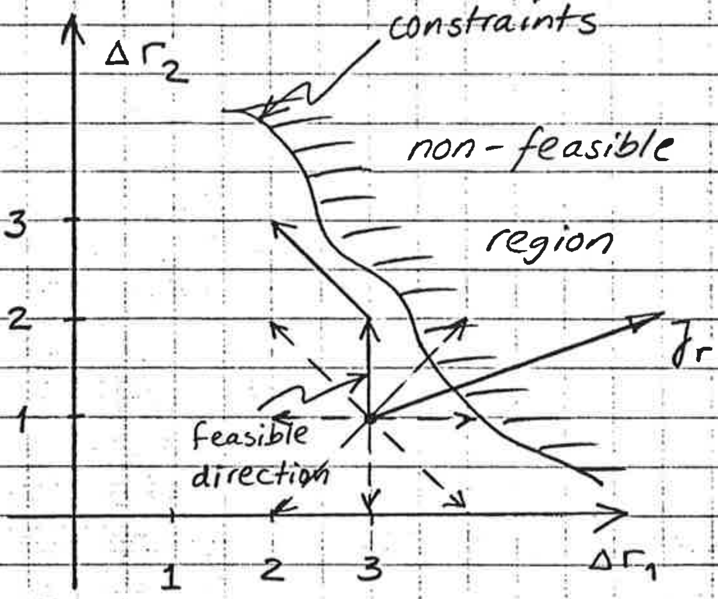

Fig 5., Illustration of the feasible direction.

~~Linear change a~~

Linear search and power change prediction

The rod withdrawals or insertions have been defined from the feasible direction or the gradient calculations, and the possible path is stored. The path is defined, so that the rod group with the largest movement is changed one node for each step, see figure 4.

In subroutine TMTEST (see appendix 2) the power prediction and the thermal margin prediction are performed according to the method described in ref (1).

Before the power prediction is made it is examined if the rod withdrawal or insertion is allowed according to the rod movement constraints subroutine DIRTET. If any rod movement violates the rules the action will be the same as if a thermal margin has been violated.

~~The power is predicted for the~~

For one step at a time along the search path the power is predicted based on the previous one step calculations and the thermal margins are tested. If no thermal margin is violated, then the prediction continues along the path for NSMAX steps, where NSMAX typically may be 5-8. (NSMAX=5 has been used in the tests, section 5). There a 'target' is defined, see below.

If any thermal margin is violated in a ~~specific~~ certain step, then a new search direction has to be found. The previous step, where no margin was violated will be defined as a new origin. If this new origin is close enough to the old one (normally less than 3 steps =NSTEP1),then the new gradient is calculated without making any new DCAM calculation.

This is called an "approximate direction derivative", and is described below. If the new origin is more than about three steps away from the old one, then the new origin is defined as the 'target'.

If no constraint is found along the linear search the minimum point along the linear path is found. Again if this minimum is close enough to the reference point (less than NSTEP1 steps) the approximative derivative is calculated. Otherwize the minimum point is defined as the target.

Approximate direction derivative

~~In principle~~ The approximate direction derivative ~~DSRSS~~ calculates the gradient analogous to the first gradient calculation. The only difference is, that DCAM calculations are not used to find the performance index changes for one node rod withdrawals from the ~~########~~ reference point. Instead the nonlinear power prediction method is used. ~~to find these changes.~~ As soon as the gradient is calculated the same kind of truncations of the search path and tests of thermal margins are performed as described earlier.

Target calculation and power change correction

After 5-8 steps from the reference point, a new DCAM calculation has to be performed in order to keep the accuracy of the calculations. This point ~~, where the DCAM calculation is made is defined as~~ is called the 'target'. The actual power predicted by DCAM is compared with the approximate prediction at the target, and the difference forms the base for the correction of the previous predictions.

Each power and thermal margin prediction between the ~~origin~~ last reference point and the target are ~~now~~ corrected and the thermal margins are tested once more. If still no thermal margin ~~still~~ is ~~not~~ violated along the path then the target is defined as the new origin in subroutine TGTINT, appendix 2. If, however, any thermal margin is violated along the path then a new DCAM calculation is made at the last feasible point along the path. In other words, the control is given back to subroutine ORIGIN, see appendix 2.

From the new origin the calculation of the search direction is repeated all over again and a new linear search can subsequently be performed.

<u>Determination of final solution</u>

Several parameters are defined, that will determine if the final solution has been reached.

The 'natural' stop of the algorithm is, when the gradient is small enough, In a feasible direction calculation it may not be possible to find any feasible direction that will make the cost function decrease. Then a variable MTEST is set 0 and the optimization stops.

The maximum number of steps taken, i.e. the total number of rows in the rod withdrawal table is given by the user (NSMAX) and limits the calculation.

5. RESULTS

The performance of the optimization algorithm has been tested by using Oyster Creek data, cycle 8. Different number of rod groups ~~has been used~~ as well as different rod groupings have been ~~tested~~ used in the calculations. Several initial conditions were tried in order to examine the risks to get trapped in local minima.

The problem of local minima will be illustrated by the figures 6 and 7. Five rod groups were used, and their positions are indicated in the diagrams. The initial conditions are the same and the target is defined as the axial distribution at the ~~96%~~ 99% bulk power as indicated in the figures.

The first four steps are identical. In figure 6 then a local minimum is found. In figure 7 the feature of the feasible ~~The change of the feasible~~ direction was ~~then~~ changed, that allowed a search of all changes within two nodes instead of one. Thus the local minimum could be avoided, and the algorithm found exactly the same target distribution as the one used in Oyster Creek.

In figure ~~7~~ 8 and ~~8~~ 9 different initial conditions have been applied, but the target axial distribution is now a trapezoidal shape, similar for all fuel bundles, i.e. the performance index of (3.1) with (3.3) taken into account.

For the two different initial conditions the same final rod pattern is achieved. Even if the final distribution looks satisfactory, the bulk power is too much different from the desired value only 94% instead of 99%. This gives the motive to change the performance index slightly.

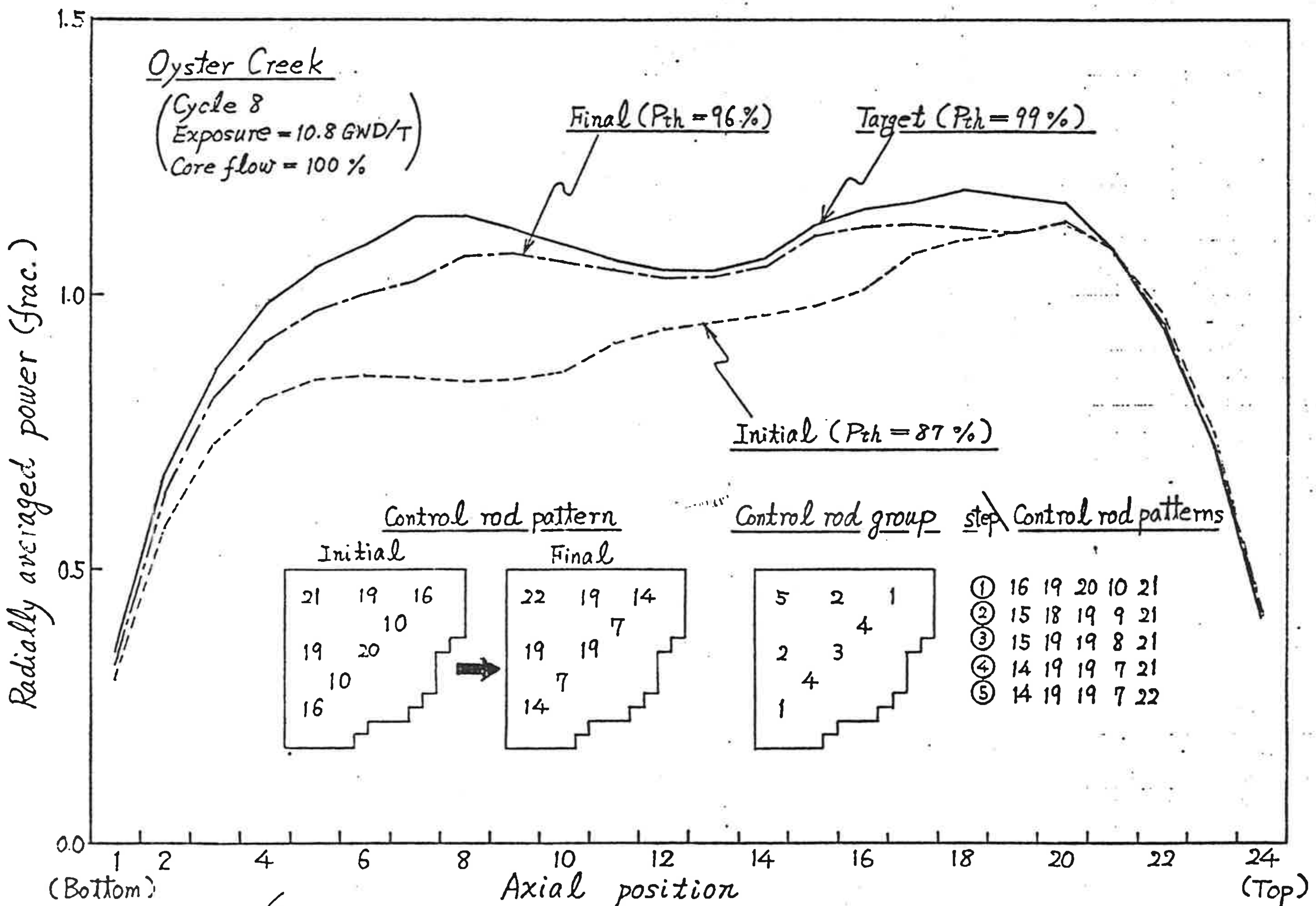

Fig. 6 An example that the search is stoped at local minimum point
(The rated axial distribution of Oyster Creek is given as the target)

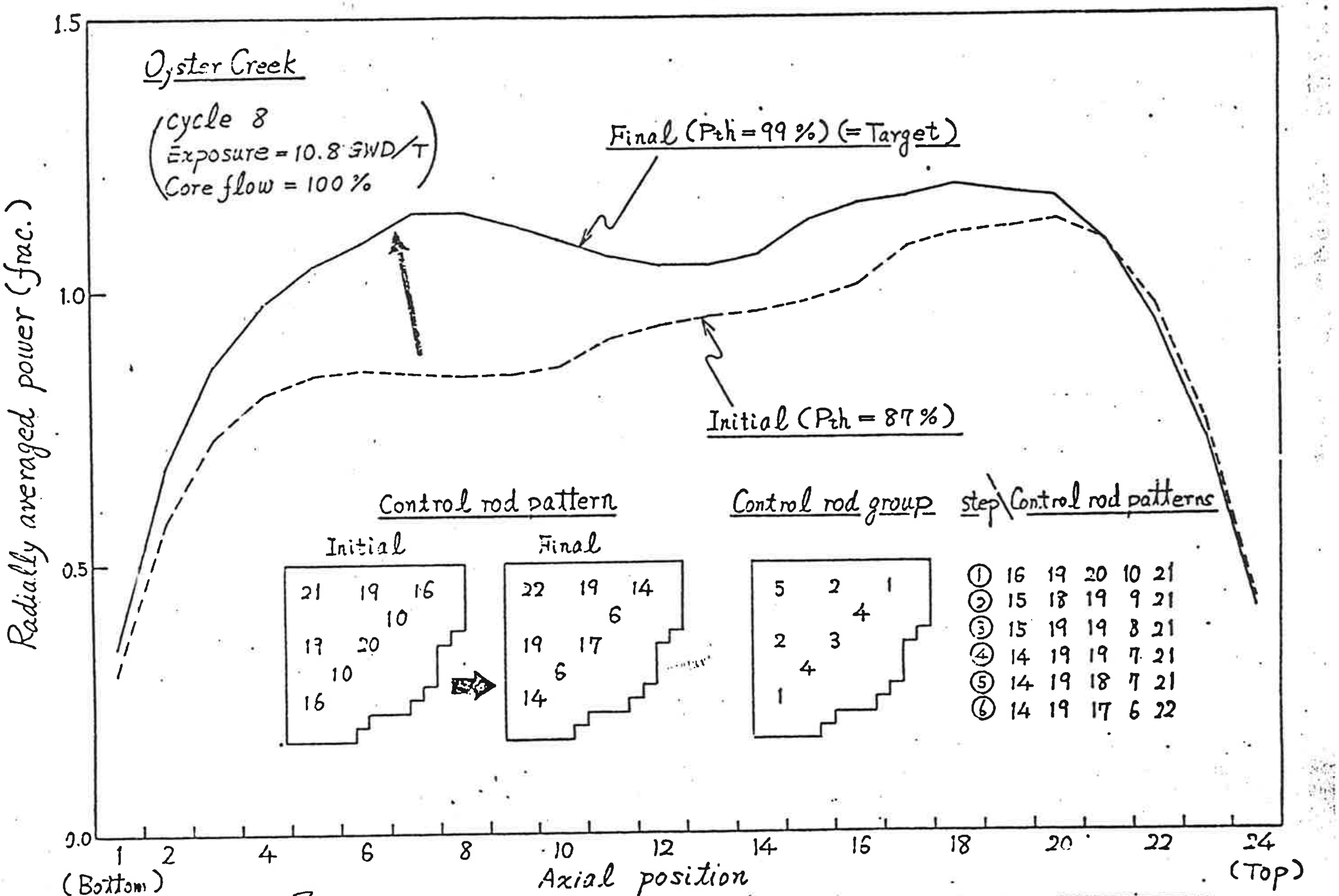

Fig. 7 An example that the optimal point is searched.
(The rated axial distribution of Oyster Creek is given as the target)

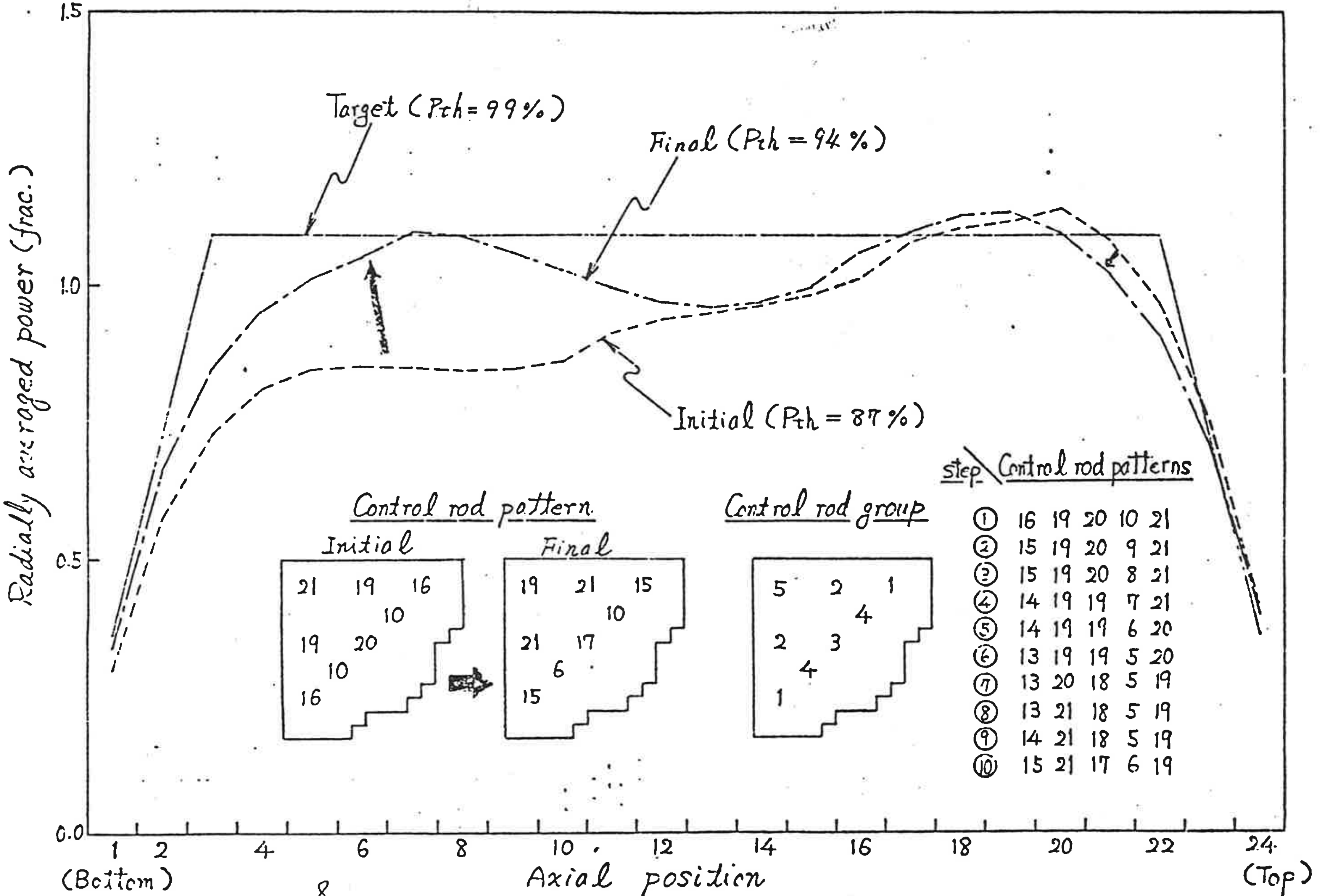

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Fig. β Optimization result of control rod pattern
(The rectangular power distribution for each fuel bundle is given as the target)

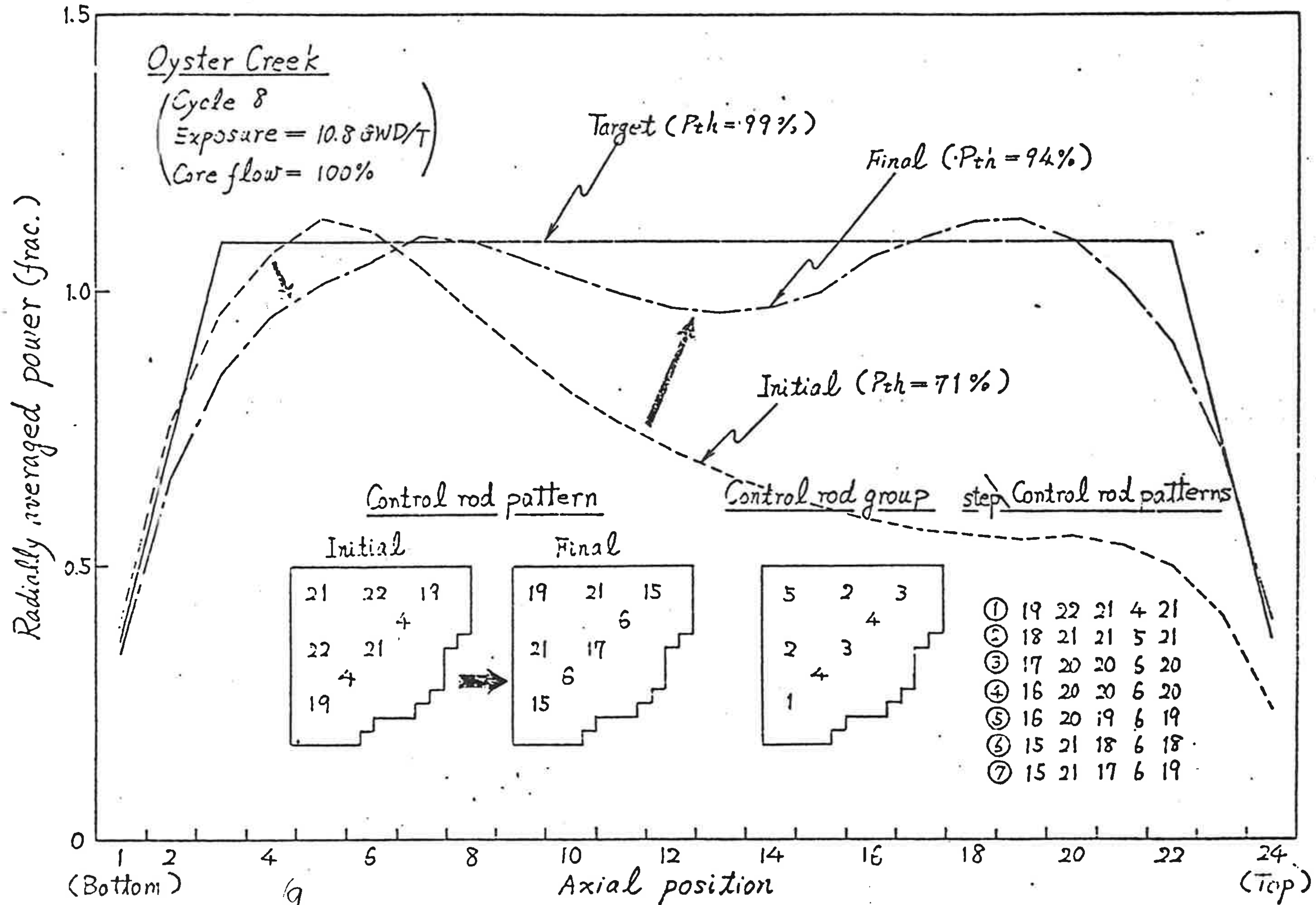

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Fig. 4. Optimization result of control rod pattern
(The rectangular power distribution for each fuel bundle is given as the target)

The cost function (3.2) has been applied in figure 10. The initial condition and the rod configuration is the same as those of fig 9. For a performance index with N=1 the results are identical between figures 9 and 10. For N=2 and N=3, however, the final bulk power is becoming much closer to the desired bulk power. N=3 seems to be a satisfactory exponent in order to achieve good resulting target distributions.

The optimization of figure 10 with N=3 is further illustrated by figures 11 and 12. The target radial distribution has been uniform, The resulting radial distribution calculated from the algorithm is shown in figure 11 and is compared with the actual distribution, achieved in Oyster Creek. The actual change of the cost function along the search path is demonstrated in figure 12. Notice the dramatic break after 4 steps.

A further improvement of the final distribution can be achieved if the performance index is changed to the form (3.4). The peripheral elements contribute too much to the previous cost functions, causing distorted optimum values of the distribution. With the cost function (3.4) and keeping N=3 the resulting distribution is demonstrated in figure 13.

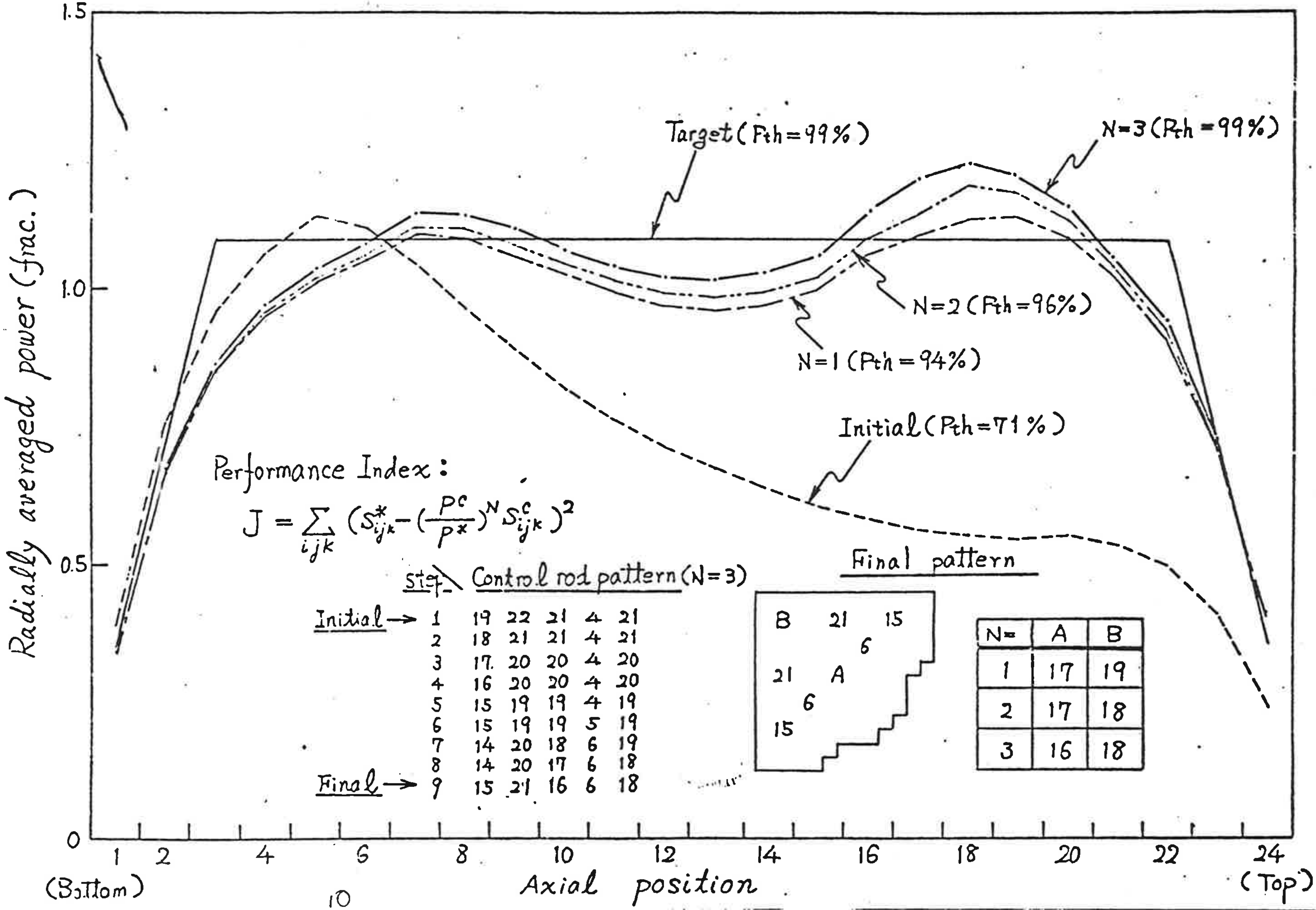

Fig. 10 Effect of Performance index

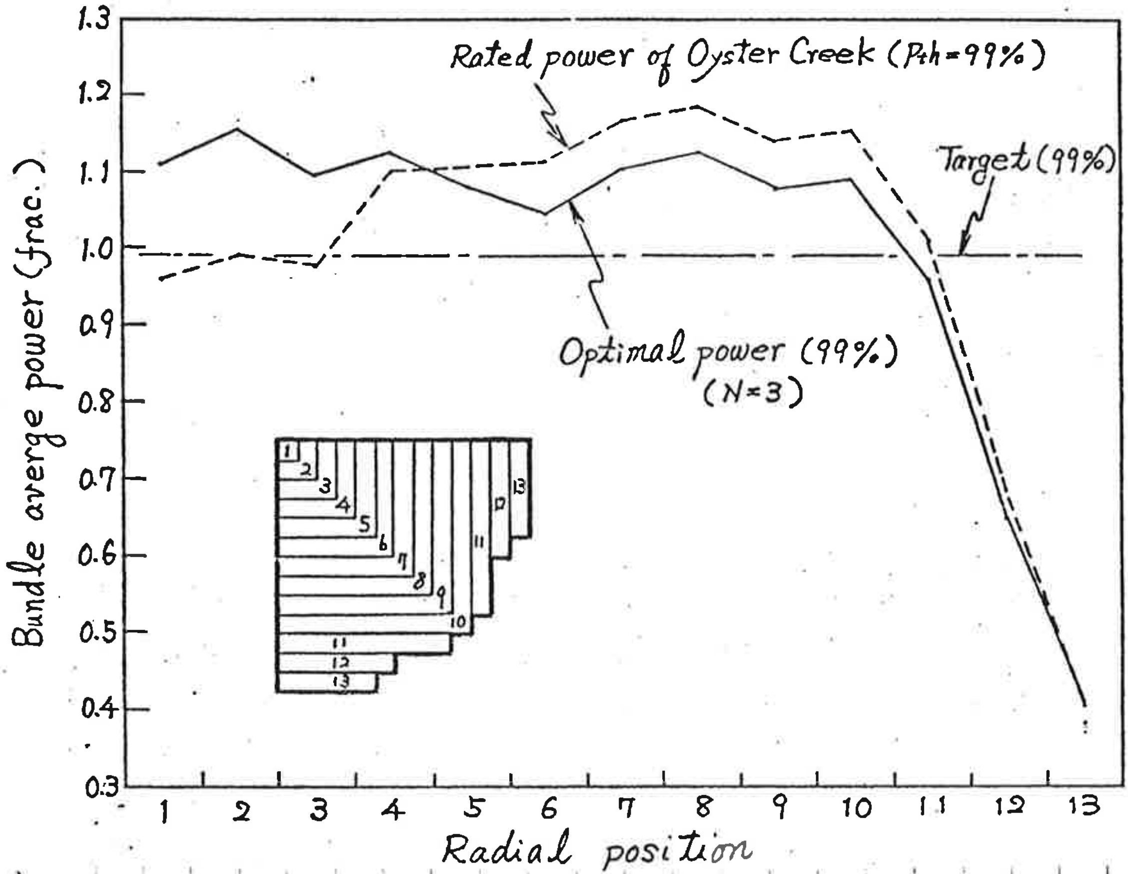

Fig. 11 Radial power distribution for optimal control rod pattern (N=3)

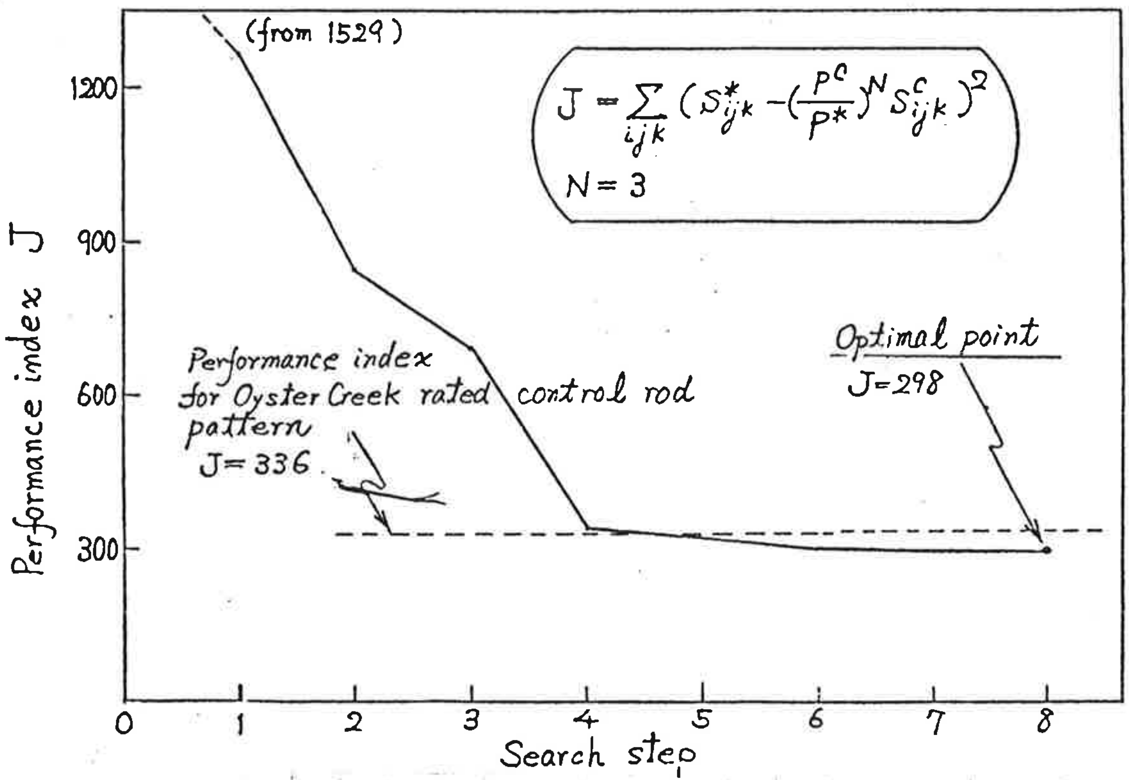

Fig. 12 The change of cost function

6. PARAMETER CHOICES

There are several parameters that will affect the result of the optimization. Here the parameters for the DCAM calculation are not mentioned, only those of the optimizer.

The performance index has been described in section 3. It may, however, be easily changed, if a more favourable structure would be found. It is defined in a separate subroutine. The possibilities with the existing structure of the cost function have not been exhausted. The radial wieghting function may also be used as a tool to obtain better results.

The control rod configuration has to be chosen by the user. Not only the number of rod groups, but also their location ~~and their constraints~~ can be set differently. During the computation different rod groups may be set active and others passive. One example may be, that only shallow rods are allowed to move at all during the first phase of the optimization. Not until any constraint has been hit the deep rods are set active.

The parameter NSTEP1 (allowing the approximative derivative to be used within a certain distance from the origin) or the NSTEP (maximum number of steps between the origin and the target) may be chosen differently when more experience of different cores has been gained.

7. SUGGESTIONS FOR FURTHER RESEARCH

The steady state optimization may certainly be improved further. Naturally a crucial point is the accuracy of the non linear power prediction that now allows 6-8 steps of prediction. Even if this is #### superior to any other known predictor it may be further improved. Particularly the prediction of the LHGR and the envelope may be made even more accurate, if more structure of the margin coefficients is taken into account.

Further experiences have to be obtained about local minima. och possible to ways to avoid them. ?

As described in section 2 the ~~optimization~~ steady state optimization is only a part of the transient optimization, that will be the ultimate goal for this ##### work. However, it appears that the steady state optimization may be the crucial step on the way to solve the overall reactor start-up problem.

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(2) Frogner B., N. Sechan and A. Cohen: "Core power distribution control for BWRs during large power maneuvers", working paper SCI project 7429, EPRI project RP 1120-2, Systems Control Inc., Jan 1979

APPENDIX 2

FLOW DIAGRAM OF THE OPTIMIZATION METHOD

The outline of the method has been made in section 4, where part of the flow diagram is commented. Some important parameters for the control logic of the program will be futther commented here.

<u>MCORR</u>

MCORR = 1 when the prediction of power and thermal margins is made without correction, i.e. before the target has been calculated. MCORR = 0 indicates that correction terms will be added.

~~This means~~

Actually the power predictions along the part from the origin to the target are not stored on the computer memory. Instead they are recalculated after the target has been reached, and subroutine TMTEST is used once more. However, the rod withdrawal table between the origin and the target is stored. This means, that the feasible direction (FEADIR) or the approximate derivative (APPDIR) only have to be calculated during the prediction without correction (MCORR=1). To ensure that the feasible direction is only used once MCORR = 3 after FEADIR has been called. Likewize MCORR = 2 after the approximative derivative has been calculated (APPDIR) to make sure, that APPDIR is used only once from the reference point to the target.

MTEST

MTEST) MEST is a local variable, that tells how many feasible steps have been reached after the ####### last origin. MTEST = 0 means, that no feasible path was found along the gradient, and a feasible direction is searched. However, # if MTEST = 0 during the correction phase (MCORR=0), then there is no more feasible point, and the calculation stops.

NTT

$$$$$$$

Tells how many nodes that the rods are allowed to be moved. If NTT > NTEST (the maximum number of steps from the origgin to the target, usually about 6-8), then NTT is set equal to ##### NTEST.

APPDIR

Subroutine APPDIR

This subroutine is onle called if four conditions are satisfied simultaneously:

(1-2) (#) MTEST ≠ .NE.NTEST and .AND.MEST < .LT.NSTEP1

This means, that The approximate derivate is only calculated close to the reference point. ## NSTEP1 is usually 3-4 and ##### NTEST 6-8. In other works, the graidne (ent) based on appro ximate predictions is only allowed 3-4 steps from the DCAM reference point.

(3) MCORR = 1 The approximate derivative is only corrected once from the reference point to the target. After APPDIR has been used once, then MCORR = 2 that ensures this condition.

(4) NTT ≥ .EQ.NTEST

The####### APPDIR is only called, if there is no limitation for the rod movements from the last reference point.

CALL REAROD : searches the number of control rod group
MAXGRP = the number of rod group

CALL BUNSER : defines the fuel bundles (4×4) influenced by the control rod movement
WEIFAC (J, I, g) = 1 or 0 g : control rod group number

CALL WEITPI : defines (reads) the radial weighting factor of the target power distribution
WEIGHT (J, I) = the weighting factor specified by user

NSTEP = 1

NSTEP : the row (withdrawal sequence) number of realized rod withdrawal table

(100)

NSTEP . GE. NSMAX → STOP

NSMAX : maximum number of NSTEP

CALL ORIGIN (NSTEP) : makes DCAM calculation for reference case

(200)

NSTEP . GE. NSMAX → STOP

CALL DIRDER (NSTEP) : calculates the change in power, thermal margins and performance index after one-node control rod withdrawal

NTEST = MAXSTP
MCORR = 1

MAXSTP : maximum number of steps that any rod can be moved during a linear search. (= 5)
MCORR = 1 : prediction without correction

(A)

(A)

CALL CALGRD(NSTOP, NSTEP, NTT) : defines the gradient of rod withdrawal search.
If any thermal margin is violated or the performance index is increasing for the first step, the rod withdrawal path along the feasible direction is defined (CALL FEADIR, CALL DIRTET).

IDJ(I, J) = the change of control rod position for group I at search step J
NTT = If any rod will be completely withdrawn, NTT will be set to the allowed number of steps (NTT ≤ MAXSTP).
NSTOP = If the gradient is too small, then NSTOP is set to 1.

NSTOP.EQ.1 → STOP

(300) CALL TMTEST(NTT, MTEST, MCORR, NSTEP, 0.0, 0) : predicts the change in power and thermal margins for rod movement from a reference case

MTEST = If any thermal margin is violated before NTT steps, then MTEST is set to the largest feasible step (MTEST ≤ NTT)

(B)

(B)

MTEST.EQ.0 .AND. MCORR.EQ.1

CALL FEADIR(NSTOP, NSTEP) : evaluates the performance index for all combination of rod patterns within the range of model validity

IDJ(I,J) = the change of control rod position for rod group I at search step J.

NSTOP = If the change of performance index is too small, then N is set to 1

NSTOP.EQ. 1 — STOP

CALL DIRTET(NTT, NSTEP, 0) : tests how far each control rod can be moved without hitting any boundary. (0 ≦ rod position ≦ 48)

NTT = The number of steps that can be taken before a boundary is reached.

MCORR = 3

MERGE 300

MTEST.EQ.0 — STOP

(C)

(C)

CALL RODPAT (MTEST, NTEST) : defines the control rod pattern by using IDJ(I,J) and writes them onto UFD

MTEST. NE. NTEST .AND.
MCORR. EQ. 1 .AND.
NTT. EQ. NTEST .AND.
MTEST. LT. NSTEP1 (=3)

CALL APPDIR (MTEST, NTEST, NTT, NSTEP, NTARGR)
: calculates the approximative direction derivative

IDJ(I,J) = the change of control rod position for rod group I at calculation step J

NTARGR = If the change of performance index is too small, then NTARGR is set to 1

MCORR = 2

NTARGR.EQ.1 — MERGE 320

MERGE 300

(320)

CALL TARGET (NSTEP, MTEST) : makes DCAM calculation of target case and calculates the error of predicted value.

MCORR = 0

(D)

(D)

CALL TMTEST (NTEST, MR, MCORR) : predicts the power change and thermal margin change with correction for rod insertion or withdrawal

MR = If any thermal margin is violated before NSTEP steps, then MR is set to the largest feasible step.

NSTEP = NSTEP + MR

MTEST + NSTEP .NE. NSTEP — MERGE 100

CALL TGTINT : sets the reference value equal to the target value.

MERGE 200