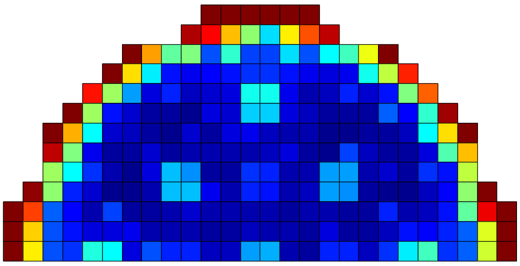
RESEARCH REPORT

VTT-R-02177-10



A new output option in TRAB-3D: dry-out margin in a radial map

Authors: Hanna Räty

Confidentiality: public

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Customer, contact person, address SAFIR2010 Research programme (VTT, VYR)	Order reference
Project name TRICOT 2010/Safir	Project number/Short name
Author(s) Hanna Räty	Pages 8
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The work has been carried out in the TRICOT project of the SAFIR2010 Research programme, with the funding of VTT and VYR.

Confidentiality	Public

Espoo 17.3.2010

Written by	Reviewed by	Accepted by
Hanna Räty Senior research scientist	Antti Daavittila Team Leader	Timo Vanttola Technology Manager

VTT's contact address

Distribution (customer and VTT)
SAFIR2010 Reference group 3
VTT: Daavittila, Hämäläinen, Rintala, Seppälä, Syrjälahti

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Contents

1 Introduction

In VTT's reactor analysis code system DNB/CHFR is calculated in separate hot channel or hot rod analyses, and the three-dimensional core calculations do not include options for DNB/CHFR calculation. The separate hot channel analyses enable e.g. fast and repeated calculation of many fuel bundles allowing extensive sensitivity studies.

In some occasions the calculation of DNB/CHFR already in the three-dimensional core calculation would be beneficial, and a new output option has been included in TRAB-3D /1, 2/: DNB/CHFR may be calculated for selected fuel rods, and output in map form.

The new option is not, however, a substitute to separate hot channel analyses. To emphasize this, a short discussion on hot channel calculations is included in this report.

The work has been carried out in the TRICOT project of the SAFIR2010 Research programme, with the funding of VTT and VYR.

2 The new output option for MCPR/CHF in TRAB-3D

Calculation of DNB/CHFR has been added into the calculations for one fuel rod at a time in TRAB-3D. Thus the normal output conventions of the code are available. The results are stored in a corewide table, and can be printed out as a radial charts for minima for bundles, or as corewide single variables of the minima and its location. Different correlations for different fuel can be defined, but presently only one correlation per fuel location can be calculated.

Changes in the code are documented in /3/. New correlation subroutines can easily be added, and they obey the same form as used in the one-dimensional TRAB-code.

The notation for input and output below obeys that of the TRAB-3D User's Manual /2/

2.1 New input

The fuel locations in which the DNB/CHFR will be calculated, are given in a new keyword /DNBCOR explained below.

/DNBCOR / JDNBC (IDFR) >0 calculate the correlation indicated by the number for fuel IDFR (radial map)
=0 do not calculate for fuel IDFR
/ FRADXX(IDFR) = radial peaking for fuel IDFR (radial map)
/ RXLXX(IDFR) = parameter for the correlation for fuel IDFR (radial map)

An input example for a half core layout (the numbers are meaningless) is given below:

```
/DNBCOR  /   JDNBC INDICATOR OF CORRELATION, IF ZERO, NOT CALCULATED
  ONE: CORR1
  TWO: CORR2
                         2 2 1 2 2 2
                       2 2 2 1 1 2 2 2
                 2 1 1 2 1 2 1 1 1 1 1 1 1 2
               2 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2
             2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2
           2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 2
         2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 2
         2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 1 2 1
         1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
       2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2
     2 2 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 2 2 2
     2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
     2 2 1 1 1 1 1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2

/                 FRADXX RADIAL PEAKING FACTOR FOR BUNDLE

                                 1. 1. 1. 1. 1. 1.
                              1. 1. 1. 1. 1. 1. 1. 1.
                     1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
                  1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
               1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
            1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
         1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
         1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
         1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
      1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
   1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
   1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
   1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.

/                  R-FACTOR FOR BUNDLE

                                 1. 1. 1. 1. 1. 1.
                              1. 1. 1. 1. 1. 1. 1. 1.
                     1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
                  1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
               1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
            1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
         1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
         1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
         1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
      1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
   1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
   1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
   1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
```

2.2 New output

New output in radial chart form is defined in keyword H-TABLE (Section 3.9): table CCPR3D is added as TRAB3D node variable for printout, with LSDAT1 = 13.

An example input defining output in map form for burnup and DNB in the same map is given below:

```
/OUTPUT
/H-TABLE/  5 /  MAP  1    7  13   ASSEMBLY TYPE   BURNUP  DNB
/HEXOUT/  (5)   1    0     10*0
```

New time-dependent output variables can be chosen for keyword /TIME-D (Section 3.7)

single variables (FUNTIM)

TCCPRM = whole core minimum critical channel power ratio
ZZCPRM = axial position of TCCPRM from bottom of fuel
RNCPRM = node from bottom for TCCPRM
RLCPRM = location for TCCPRM
RFCPRM = fuel for TCCPRM
CHCPRM = channel for TCCPRM

Note: the node number output variables are not integers but real, because time-d output does not print out integer numbers.

table variables (DISLA)

CCPRM(IDFR) = minimum critical channel power ratio for IDFR

table variables (NODESL)

CCPR node values for time-dependent storing and plotting e.g. in horizontal or vertical planes, order of variable = 172

An example input for output of single variables and a radial chart of CPR-minima is given below:

```
/TIME-DEP  / -6   1   DNB
  /     ' TRAB-3D                        '
  /(1) ' TIME      ' '           ' '    (S)     ' TPH     10000   3 12242  0 1.  -0.1
   (2) 'TCCPRM    ' '           ' '              ' TCCPRM 10000 14 34101  0 0.   0.
   (3) 'ZZCPRM    ' 'AXIAL POS.' 'FROM BOT       ' ZZCPRM 10000 14 34102  0 0.   0.
   (4) 'NNCPRM    ' 'MESH POINT' 'FROM BOT       ' NNCPRM 10000 14 34103  0 0.   0.
   (5) 'LLCPRM    ' 'LOCATION  ' '              ' LLCPRM 10000 14 34104  0 0.   0.
   (6) 'JFCPRM    ' 'FUEL      ' '              ' JFCPRM 10000 14 34105  0 0.   0.
   (7) 'CHCPRM    ' 'CHANNEL   ' '              ' LLCPRM 10000 14 34106  0 0.   0.

/TIME-DEP  / 700     DISLA ASSEMBLY VARIABLES
  /     ' TRAB-3D                        '
  /(1) '    TIME   ' '           ' '    (S)     ' TPH     10000   3   12242    0 0.  0.0
        ...
    (8) ' MCCPR    ' '           ' '             ' CCPRM   10000   14 27341 249 0.   0.
```

An example of the output listing for the radial chart in printout is given below:

```
H-TABLE MAP OUTPUT (AN EXCERPT)

1 TRAB-3D ***  Olkiluoto-1  BOC of cycle30

 MAP EDITION (    LOCATION NUMBER   /     MATERIAL NUMBER   / CCPR    OR    CHFR       )  ASSEMBLYWISE AVERAGES
                                                                                              VERTICAL SECTION  1  OF  2
                                                                                            HORIZONTAL SECTION  1  OF  1

                                                                                   1/P      2/P      3/P
                                                                                   1/M      2/M      3/M
                                                                                5.0000   5.0000   5.0000

                                                                          7/P      8/P      9/P     10/P
                                                                          7/M      8/M      9/M     10/M
                                                                       4.7714   4.4941   3.7374   3.0675

                                                 15/P     16/P     17/P     18/P     19/P     20/P     21/P
                                                 15/M     16/M     17/M     18/M     19/M     20/M     21/M
                                               5.0000   3.8539   2.9106   3.0487   1.9038   2.7250   1.8185

                                        29/P     30/P     31/P     32/P     33/P     34/P     35/P     36/P
                                        29/M     30/M     31/M     32/M     33/M     34/M     35/M     36/M
                                      5.0000   3.6364   2.4666   1.6653   1.5258   1.5769   1.6284   1.7387

                               45/P     46/P     47/P     48/P     49/P     50/P     51/P     52/P     53/P
                               45/M     46/M     47/M     48/M     49/M     50/M     51/M     52/M     53/M
                             4.4122   3.1410   2.1920   1.4350   1.6778   1.3369   1.3675   1.4783   2.5973

   ...

 MINIMUM VALUE OF  CCPR   OR   CHFR          1.1234E+00 IN LOCATION  69
```

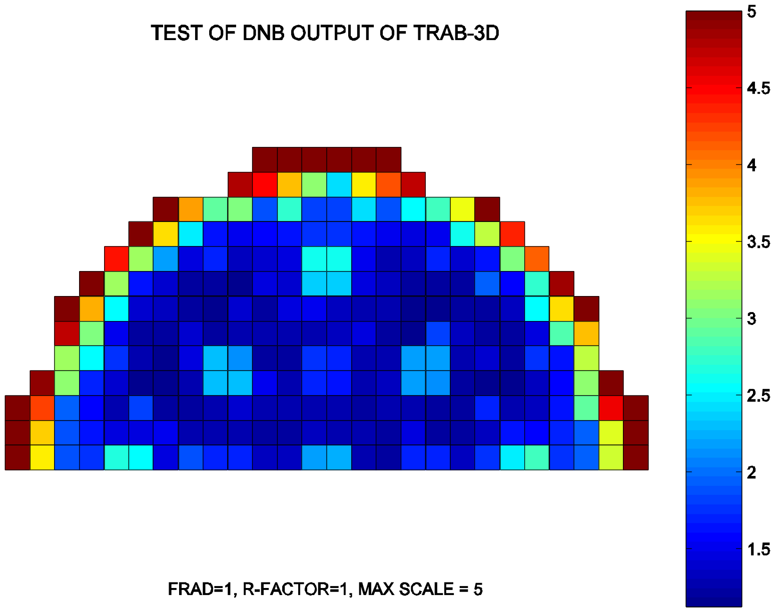
An example of the output listing for time-dependent variables is given below:

```
TIME-DEPENDENT OUTPUT (AN EXCERPT):

    TIME          TCCPRM       ZZCPRM      NNCPRM      LLCPRM      JFCPRM          CHCPRM
                               AXIAL POS.  MESH POINT  LOCATION    FUEL            CHANNEL
      (S)                      FROM BOT    FROM BOT

  0.0000E+00       1.548        3.091       27.00       69.00       69.00           69.00
  0.5000E-01       1.550        3.091       27.00       69.00       69.00           69.00
  0.1000           1.560        3.091       27.00       69.00       69.00           69.00
  0.1500           1.571        3.238       28.00       69.00       69.00           69.00
  0.2000           1.581        3.238       28.00       69.00       69.00           69.00
```

An example of a radial chart based on TRAB-3D output is given below (the maximum output value is limited to 5 for plotting purposes):



2.3 Discussion

In VTT the hot channel analyses for the three-dimensional reactor analysis codes are carried out with the one-dimensional TRAB code /4, 5/. Hot rod analyses may also be carried out with the coupled FRAPTRAN-GENFLO code /6, 7, 8/.

In comparison with these hot channel and hot rod analyses, the new output option of TRAB-3D is just an output option. It is not a substitute for hot channel analyses. It can be seen as a calculation for a hot rod situated in the chosen bundle, not affecting the behaviour in the bundle. The interaction of fuel and coolant, calculated in the hot channel analyses, is missing.

Furthermore, the corewide three-dimensional model does not include such specific models which are available in the separate hot channel analyses, as transition and film boiling, film boiling collapse, and oxidation of the cladding.

The DNB/CHFR results for the whole core can, however, be illustrative or serve as an additional tool in choosing locations for a more thorough hot channel analysis.

For an accurate three-dimensional output of BWR hot rod CPR with vendor specific XL-correlations, relevant hot rod factors and the fuel dependent R-factors would be needed.

Finally, the separate hot channel analyses are very fast, and can be carried out automatically utilizing a sensitivity analysis tool /9/, allowing to study a large number of positions and parameter variations in a systematic way.

3 Conclusions

A new output option has been added into VTT’s three-dimensional reactor analysis code TRAB-3D, allowing calculation of DNB/CHFR for selected fuel rods and their output in map form. The new option is not, however, a substitute to separate hot channel analyses, which apply models, methodology and sensitivity studies not applicable in the present three-dimensional core calculation

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