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THE NUCLEAR CORE DESIGN MANUAL
Krško NPP

Operation CORlib file from INCORE analysis

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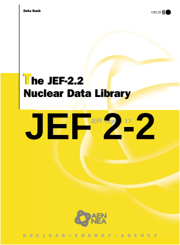
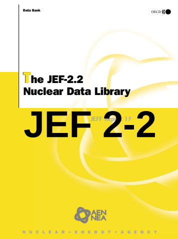


Contents



1 Procedure Specifications

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2 Objectives

Reactor core operation is monitored by several systems. One of the important surveilance programs is the measurement of core power distribution, which is performed periodically with a set of movable detectors. The measurements are analysed by codes such as `INCORE` from Westinghouse to determine the assembly radial and axial power distribution, peaking factors etc.

The main objective is to define the procedure for processing the `INCORE` output, extract the power distribution data (radial and axial for each assembly) and write the distributions in CORlib format. The resulting file can then be used to update the Operation CORlib file and to calculate the curent burnup of each assembly region. The Operation CORlib file is important for monitoring the consistency of the predicted data with the measurements and for updating the FASlib library based on the operating data at the end of the cycle.

3 Prerequisites

Hardware: The software is currently operational on VAX under VMS or Open-VMS and on PC under DOS.

Software: The following external programs are assumed:

- `INCORE` output is the standard interface file which is required for the procedure. `INCORE` Version `3D 3.8.4.C` is assumed.
- `FOLLOW` output is optionally processed to obtain a detailed boron letdown curve and to monitor some selected parameters in relative terms as a function of burnup.
- `PLOTTAB` program for preparing graphical plots is suggested for the optional monitor plots of the axial power distributions.

The following CORD-2 programs are required:

- `INTOCO` to convert the `INCORE` output in CORlib format.

CORDEDT to insert the CORlib file produced by INTOCO at a particular burnup step into the Operation CORlib file. The assembly burnup distribution is also updated at the same time.

FOTOPT to process FOLLOW output and produce the critical boron concentration curve as a function of burnup. The data format is compatible with the PLOTTAB graphics code. The use of this code is optional.

CORBRN to extract various burnup dependent data, particularly the critical boron concentration as a function of burnup for comparison with the output of FOTOPT. The use of this code is optional.

CORDSP to compare the Design and the Operation CORlib files for verification purposes.

Data Files: The following interface input files are required:

INCORE.OUT the full INCORE output file is required.

FOLLOW.OUT if the critical boron concentration is to be monitored in detail.

KnnDSN.COR the Operation Design CORlib file which is to be updated.

The following auxilliary, intermediate and output files are produced:

PWRn.COR the output of INTOCO containing the information from the current INCORE output in CORlib format. The suggested filename is defined from input interactively where "n" is the consecutive INCORE analysis number.

PWR.PNT the output of INTOCO, giving the axial power distribution of assemblies which differ from the average in excess of a specified amount.

PWR.P92 the PLOTTAB input instructions file. This file is necessary only if the PLOTTAB code is used for presenting the results.

FOLLOW.PNT the FOTOPT output containing the boron letdown as a function of burnup.

FOLLOW.P92 the PLOTTAB input instructions file for displaying the burnup dependent data with the PLOTTAB code.

CORBRN.CUR the output of CORBRN containing the predicted critical boron concentration as a function of burnup from the Design CORlib file.

F1.CUR the FOTOPT output containing the relative power as a function of burnup.

F2.CUR the FOTOPT output containing the relative coolant temperature as a function of burnup.

F3.CUR the FOTOPT output containing the relative control rod position as a function of burnup.

4 Precautions

The information, which can not be extracted from the INCORE output, must be entered manually. They usually appear as a comment in the INCORE output, which is also displayed by the INTOCO code when processing the file. It is advisable to cross check the following parameters from the FOLLOW output, if possible.

- cycle number,
- burnup step,
- critical boron concentration,
- control rod position,
- power level.

When the power distribution data are entered into the Operation CORlib file and when the calculation of the burnup increment is requested, the current cycle burnup step must be equal or greater than the last burnup step in the Operation CORlib file. Since burnup is an accumulative quantity, modifying an intermediate burnup step would cause an inconsistency in the next burnup step on the file.

5 Reference Documentation

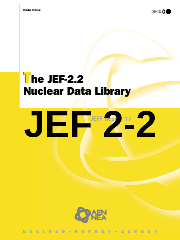
1. The CORD-2 User's Manual
2. PLOTTAB Manual

6 Description of Calculational Procedures

The INTOCO code searches the INCORE output and extracts the power level from the file, if possible. Most of the other information is ignored, including the evaluated radial power distributions. The axial power distributions for each assembly are processed. The distributions are averaged into the standard ten-region slices by integration. The relative slice thicknesses are (1,1,2,4,4,4,4,2,1), respectively. If power level is greater than 15%, equillibrium xenon is assumed.

On the CORlib header record the cycle number, the current burnup step, the power leve, the control rod position and the critical boron concentration are enterd. The axially averaged power distribution for all assemblies are written under the keyword "$* PWRXY". Similarly, the axial power distributions for each assembly are written under the keyword "$* PWRAX". The entries contain the relative power and are not normalized for each assembly separately.

The Operation CORlib file is similar to the Design CORlib file, except that it contains the core information during cycle burnup, based on the actual measurements. At BOC, the starting file contains the information on the loading pattern and the data from the FASlib library, such as prepared by the CORLOA code. The data for the current burnup step in CORlib format prepared by INTOCO are entered



into the Operation CORlib file with the COREDT code. The burnup increment for each region of each assembly is also calculated. The assumed average power for the calculation is the linear average of the appropriate assembly axial region power of the current and the previous step. The actual mass of heavy metal (including any axial variations) is accounted for explicitly.

7 Instructions

7.1 Running INTOCO

The INTOCO converts the INCORE output into CORlib format. The following parameters must be defined from keyboard interactively, in response to the prompts on the screen:

- The source INCORE output filename is requested. Usually the filename is INCORE.OUT.
- The CORlib output filename is requested. It is suggested to specify the filename PWRn.COR where "n" is the full flux map consecutive number for the current cycle.
- Additional parameters which can not be determined from the INCORE output are requested. They include:
  - cycle number,
  - cycle burnup step [MWd/tU],
  - core power level [%],
  - control rod position [Xnnn]
  - boron concentration [*ppm*]

  In defining the control rod position, "X" is the control rod bank identifier and "nnn" is the control rod position in [*steps*].
- The remaining instructions refer to the special monitor printout of the normalized axial power distributions of assemblies, which differ from the average by more than a specified amount. This is useful for checking for anomalies in the axial power distribution data either due to problems in correctly interpreting the measured data in the INCORE code or due to real perturbations, such as caused by the presence of the control rods. The following parameters are required:
  - The filename is requested to contain the anomalous axial power distributions in PLOTTAB format. If blank is entered, this option is skipped. It is suggested to specify the filename PWR.CUR.
  - The fractional difference threshold is requested. If the normalized power distribution at any point differs from the average by more than this threshold, the axial power distribution for this assembly is added to the above defined file. The value of 0.15 is suggested.

– The nuber of curves per plot m is required. On the output file every m^{th} data set corresponds to the average axial power distribution. This is convenient for PLOTTAB to be able to display the axial power distributions for a number of anomalous assemblies in comparison with the average on the same graph. It is recommended to enter $m = 4$. To suppress the printout of the average power distribution, set $m = 1$.

From here onwards, file processing continues automatically. Consult the INTOCO manual for further details.

7.2 Running COREDT

The COREDT code enters the power distribution data at a particular burnup step into the master Operation CORlib library. The manual mode of entering the input parameters for COREDT is utilized (rather than from a predefined general input file. The following input parameters are required:

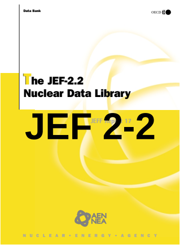
- Enter blank for the general input file to activate the manual option of entering data for COREDT.
- Define the Operation CORlib master filename which is to be updated. The filename of the form "XnnINC.COR" is suggested where "X" is a single letter designation for the plant and "nn" is the cycle number.
- The updated Operation CORlib filename can be entered blank, unless a different output filename is explicitly requested.
- The Edit CORlib filename is the PWRn.COR file produced by INTOCO beforehand.
- The symmetry flag for the Edit CORlib file follows the usual conventions:

  1 - no symmetry,
  4 - reflective quadrant symmetry,
  -4 - cyclic quadrant symmetry,
  8 - octant symmetry.

- The reference burnup on the source CORlib file is the previous cycle burnup step from burnup increment to the current burnup step. If blank is entered, the last burnup step on the file is assumed.
- The burnup on the edit file defines the cycle burnup of the data which are to be entered into the master CORlib file, unless the burnup is defined on the file.
- The current burnup step must be specified to activate the option of calculating the burnup increment and updating the assembly burnup data.

7.3 Running other codes

A number of other utility codes are useful to help with the presentation of the results, namely FOTOPT, CORBRN and CORDSP. Examples of their use are described in the next section. For further details consult the appropriate CORD-2 manuals.



8 Sample cases

Below is a command sequence which can serve as an example for updating an Operation CORlib file:

INTOCO run: Convert INCORE output into CORlib format.

```
$ CD2E INTOCO                 ! Activate the INTOCO code
  INCORE.OUT                  ! INCORE output to be processed,
  PWR8.COR                    ! Output CORlib file,
  12                          ! cycle number,
  5645                        ! cycle burnup step [MWd/tU],
  100                         ! core power level [%],
D195                          ! CR pos.(blank for ARO) [steps]
  502                         ! boron concentration [ppm]
  PWR.CUR                     ! anomalous ax.power distrib.file,
  0.15                        ! threshold level fraction,
  4                           ! number of curves per frame.
```

COREDT run: Update the Operation CORlib file.

```
$ CD2E COREDT                 ! Activate the COREDT code
                              ! BLANK - no general input
  [-]K12INC.COR               ! Source CORlib filename
                              ! Use same filename for output
  PWR8.COR                    ! Edit CORlib filename
  0                           ! Ref.BU is the last BU step
  0                           ! BU on the Edit file from header
  5645                        ! Desired burnup edit to step [MWd/tU]
  -4                          ! Cyc.qud.symm.flag for the edit file
```

FOTOPT run: Process the measured data as a function of burnup for the critical boron concentration, the average moderator temperature and the control rod position. Fixed filename FOLLOW.OUT is read and processed. File FOLLOW.PNT is written and contains corrected critical boron concentrations as a function of burnup, averaged over an internally defined number of readings. Also, files F1.CUR, F2.CUR and F3.CUR are written, which contain the relative power level, average moderator temperature and control rod position as a function of burnup (each data set normalized to one). The command to run the code is:

```
$ CD2E FOTOPT
```

CORBRN run: From the Design CORlib file extract the critical boron concentration as a function of burnup.

CORDSP run: Activate the CORDSP code in the usual way. Define the newly updated Operation CORlib file as reference. Quarter core display in quadrant or octant symmetry is usually adequate. Window width can be used to control the number of digits on output. For the Krško quarter core display, a 64 characters width is convenient (it is rounded to multiples of 8). Select the power-xy distribution at the last burnup step. Note that several entries can appear, if measurements at different burnup steps were performed at different power levels or control rod positions. After displaying the power distribution, define the Design CORlib file for comparison. Write the comparison page to a log-file.

9 Verification of results

Analysis of INCORE output: If assemblies are found which differ from the average by more than the specified amount, check if they correspond to the rodded assemblies and check for the specified control rod position. If necessary, plot the axial power distributions for the rodded assemblies on the same diagram and check for rod misalignment.

If no physical cause of the deviation from the average can be found, check the `INCORE` output for any reported difficulties in processing the measured data.

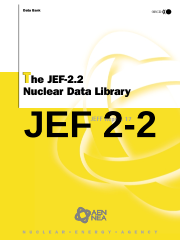
Updating the Operation CORlib file: Check the log file `COREDT.LOG` for any warnings or error messages.

Checking the updated Operation CORlib file: Use the `CORDSP` code to compare the power distribution data at the last burnup step between the Operation and the Design CORlib files. The Operation CORlib file is assumed to be the reference. Some discrepancy is expected due to:

- different boron concentration,
- different power level,
- partly inserted control rods,
- deviation from equillibrium xenon,
- error in the measurements,
- error in the interpretation and the interpolation of the measured data (this depends on the Alucard constants which are input to `INCORE` and on the processing methods defined within the code).

If the discrepancy can not be explained by any of the abve, proceed with steps which are to be taken when discrepancies between measurements and calculations are observed.

Checking the critical boron concentration: Compare the measured critical boron concentration as a function of burnup with the predicted values. The measured values are found on the `FOLLOW.PNT` file produced by the `FOTOPT` code. The predicted values are on the `CORBRN.CUR` file produced by the `CORBRN` code. The data format is compatible with the `PLOTTAB` graphics program.



10 Presentation of results

As a proof of the validation process present the following results:

- Diagrams of the normalized axial power distributions in the assemblies, which differ from the average by more than the specified tolerance limit.
- The log file from `COREDT`.
- The log file from `CORDSP`, comparing the measured power distribution at the last burnup step with the predicted distribution.
- A diagram comparing the measured and the predicted critical boron concentration as a function of burnup.

References

[1] D.E.Cullen: *PROGRAM PLOTTAB: A Code Designed to Plot Continuous and/or Discrete Physical Data*, Lawrence Livermore Laboratory, Livermore, CA 94550, UCRL-ID-110240, (1992).