KAERI/TR-803/97

Conversion of the COBRA-IV-I Code from CDC CYBER to HP 9000/700 Version

CDC CYBER Version COBRA-IV-I 코드의 HP 9000/700 Version 으로의 변환

1997. 1

Korea Atomic Energy Research Institute

한국원자력연구소

제 출 문

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본 보고서를 "CDC CYBER Version COBRA-IV-I 코드의 HP 9000/700 Version 으로의 변환" 에 관한 기술 보고서로 제출합니다.

1997 년 1 월

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Abstract

COBRA-IV-I is a multichannel analysis code for the thermal-hydraulic analysis of rod bundle nuclear fuel elements and cores based on the subchannel approach. The existing COBRA-IV-I code is the Control Data Corporation (CDC) CYBER version, which has limitations on the computer core storage and gives some inconvenience to the user interface. To solve these problems, we have converted the COBRA-IV-I code from the CDC CYBER mainframe to an Hewlett Packard (HP) 9000/700-series workstation version, and have verified the converted code. As a result, we have found almost no difference between the two versions in their calculation results. Therefore we expect the HP 9000/700 version of the COBRA-IV-I code to be the basis for the future development of an improved multichannel analysis code under the more convenient user environment.

요 약

COBRA-IV-I는 부수로 해석에 근거하여 핵연료 집합체 및 원자로 노심의 열수력 특성을 분석하기 위한 다수로 해석 코드이다. 기존의 COBRA-IV-I는 CDC CYBER용 코드로서, 컴퓨터 기억 용량의 한계와 다소 불편한 사용자 환경을 가지고 있다. 이러한 문제들을 해결하기 위하여, CDC CYBER 메인프레임용 COBRA-IV-I 코드를 HP 9000/700 계열 워크스테이션용으로 변환하고, 이와 같이 변환된 코드에 대한 검증 작업을 수행하였다. 그 결과, 두 버전들의 계산 결과 사이에는 차이가 거의 없었으며, 따라서 HP 9000/700용으로 변환된 COBRA-IV-I 코드는 앞으로 보다 편리한 사용자 환경하에서 보다 개선된 다수로 해석 코드 개발을 위한 토대가 될 것으로 기대한다.

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1. Introduction

In the mid-1970's when the COBRA-IV-I code was firstly developed, there were many difficulties in developing application software due to the limitations on the computer hardware and the operating system (OS) which is the software managing the hardware resources. For example, the COBRA-IV-I code which is one of the engineering application software based on CDC CYBER Network Operating System (NOS) uses the particular techniques such as the overlapping variable storage technique by using the EQUIVALENCE statement and the use of peripheral storage devices, to utilize more capacities of the limited hardware resources, that is, to reduce the computer core storage requirements of the code [1]. These techniques have resulted in the difficulty in understanding and modifying the code.

At present, however, the rapid enhancement of the computer hardware and the OS sufficiently reduces the limitations on developing application software. The conversion of the COBRA-IV-I code from the existing- to an enhanced-environment-based version, thus, is also inevitable to developing an improved multichannel analysis code. This conversion will provide the code with improved capabilities, and the users and programmers with more convenient working environments.

This report describes the conversion items of the COBRA-IV-I code from the CDC CYBER mainframe to an HP 9000/700-series workstation version in Chapter 2, the procedure of calculation by the converted code in Chapter 3, the verification results of the converted code in Chapter 4, and conclusions in Chapter 5. In addition, the verification procedure of the converted code, the input of the COBRA-IV-I code used in its verification, and the comparison results of the output for the two versions are shown in Appendices A, B, and C, respectively.

2. Conversion of COBRA-IV-I

The CDC CYBER system using 60 bits as one word adopts NOS as an OS and CDC CYBER FORTRAN 4 [2] as a FORTRAN language, where NOS uses the physical real memory concept, and CDC CYBER FORTRAN 4 is CDC's implementation of the American National Standards Institute (ANSI) 66 FORTRAN language, running on CDC CYBER NOS systems. As contrasted, the HP 9000/700 system using 32 bits as one word adopts HP-UX as an OS and HP FORTRAN/9000 [3] as a FORTRAN language, where HP-UX uses the virtual memory concept, and HP FORTRAN/9000 is HP's implementation of the ANSI 77 standard FORTRAN language, running on HP 9000 HP-UX systems. To compensate for these various differences between the two systems in the hardware, OS, and FORTRAN language, we have performed the following conversion procedures. For convenience' sake, we categorized the conversion procedures into five categories such as precision, convenience, emulation, syntax, and equivalence, and itemized each category.

2.1 Precision

(1) Addition of IMPLICIT statements

The number of significant decimal digits of a real constant for CDC CYBER is approximately 14, while that for HP 9000/700 is approximately 7. This is attributed to the difference between CDC CYBER and HP 9000/700 in the number of bits constituting a word. That is, a real constant for CDC CYBER occupies one 60-bit word and has the approximate range of -10^{322} to -10^{-293}, 0, and 10^{-293} to 10^{322}, while a real constant for HP 9000/700 occupies one 32-bit word and has the range of -3.402823×10^{39} to -1.175495×10^{-39}, 0, and 1.175495×10^{-39} to

3.402823×10^{39}. Meanwhile, a double precision real constant for HP 9000/700 occupies two consecutive 32-bit words and has the range of $-1.79769313486231 \times 10^{308}$ to $-2.22507385850721 \times 10^{-308}$, 0, and $2.22507385850721 \times 10^{-308}$ to $1.79769313486231 \times 10^{308}$, and its number of significant decimal digits is approximately 16. For HP 9000/700, thus, to obtain the precision similar to that for CDC CYBER, all of the single precision real variables and functions should be converted to the double precision real data type. Therefore the IMPLICIT REAL*8 (DOUBLE PRECISION) statements have been added to the main program and all of the subprograms.

HP :

```
      IMPLICIT REAL*8 (A-H,O-Z)
```

(2) Conversion of intrinsic functions

Owing to the background mentioned in Subsection (1) of Section 2.1, the names of intrinsic functions should be converted to the specific names corresponding to the double precision real data type. Therefore the single precision real functions have been converted to the double precision real functions as follows :

CDC		HP
ABS (R*4→R*4)	→	DABS (R*8→R*8)
ALOG (R*4→R*4)	→	DLOG (R*8→R*8)
AMAX1 (R*4→R*4)	→	DMAX1 (R*8→R*8)
AMIN0 (I*4→R*4)	→	DBLE(AMIN0( )) (I*4→R*8)
AMIN1 (R*4→R*4)	→	DMIN1 (R*8→R*8)
COS (R*4→R*4)	→	DCOS (R*8→R*8)
DIM (R*4→R*4)	→	DDIM (R*8→R*8)

EXP (R*4→R*4) → DEXP (R*8→R*8)
FLOAT (I*4→R*4) → DFLOAT (I*4→R*8)
IFIX (R*4→I*4) → IDINT (R*8→I*4)
SIGN (R*4→R*4) → DSIGN (R*8→R*8)
SQRT (R*4→R*4) → DSQRT (R*8→R*8)

where 'I' and 'R' in parentheses denote INTEGER and REAL, respectively, and the numeric following an asterisk (*) means the number of bytes (6 bits/byte for CDC CYBER ; 8 bits/byte for HP 9000/700).

(3) Conversion of data types for constants

Some of the constants used as the operands of expressions or the arguments of functions have been converted to the double precision real data type.

(4) Replacement of constant values of calculation parameters to avoid overflows

The number of significant decimal digits of an integer constant for CDC CYBER is approximately 18, while that for HP 9000/700 is approximately 10. This is attributed to the difference between CDC CYBER and HP 9000/700 in the number of bits constituting a word. That is, an integer constant for CDC CYBER occupies one 60-bit word and has the range of $-(2^{59}-1)$ to $2^{59}-1$ (=576460752303423487), while an integer constant for HP 9000/700 occupies one 32-bit word and has the range of -2^{31} to $2^{31}-1$ or -2147483648 to 2147483647. Meanwhile, when an integer constant for CDC CYBER is used in multiplication, division, and exponentiation, and is converted to or from a real constant in an expression or an assignment statement, its valid range is from $-(2^{48}-1)$ to $2^{48}-1$ (=281474976710655) and its number of significant decimal digits is approximately

15. The value of the real variable EINTEG, 10^{10} (an arbitrarily large value), to be undergone arithmetic operations and converted to the integer data type in the subroutines AREA and FORCE, thus, is permitted for CDC CYBER, but not permitted for HP 9000/700 because the value of the converted integer variable is out of its valid range for HP 9000/700 and causes an overflow. Therefore the value of the real variable EINTEG should be reduced and has been replaced by 10^8.

2.2 Convenience

(1) Replacement of specification statements common to various program units by INCLUDE statements

The specification statements common to various program units have been replaced by the INCLUDE statements causing the compiler to include and process subsequent source statements from the specified files.

HP :

```
INCLUDE 'SPEC/SPECXX'
```

2.3 Emulation

(1) Conversion of system functions

The CDC CYBER system functions DATE and TIME referenced in the subroutine TODS have been replaced by the HP 9000/700 system subroutines DATE and TIME, respectively.

(2) Conversion of intrinsic functions specific to CDC CYBER FORTRAN 4

The CDC CYBER specific intrinsic functions LOCF and SECOND can be emulated using the HP 9000/700 specific functions %LOC and SECNDS, respectively. That is, the function LOCF referenced in the subroutines CLEAR, DUMPIT, LOADER, and NAMTAB has been replaced by the user-defined function LOCF referencing the HP 9000/700 built-in function %LOC, and the function SECOND referenced in the subroutine ELAP has been replaced by the user-defined function SECOND referencing the HP 9000/700 system function SECNDS. Meanwhile, the unnecessary CDC CYBER specific intrinsic functions MASK and SHIFT referenced in the subroutine TODS have been deleted.

(3) Conversion of input/output functions specific to CDC CYBER FORTRAN 4

The CDC CYBER specific input/output function EOF referenced in the subroutine READ has been replaced by the 'END=' specifier in the READ statement.

2.4 Syntax

(1) Modification of PROGRAM statement and addition of OPEN statements

For CDC CYBER FORTRAN 4, all of the files used in any program units can be specified in the PROGRAM statement in the main program. For HP FORTRAN/9000, however, all of the files should be opened using the OPEN statements. Therefore the file names specified in the PROGRAM statement in the main program have been deleted from the argument list and, instead, specified in the OPEN statements.

<u>CDC</u> :

```
      PROGRAM COBRA (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
                              TAPE8,TAPE16,TAPE17,TAPE9)
```

<u>HP</u> :

```
      PROGRAM COBRA
                 :
      OPEN (UNIT=5,FILE='TAPE5',STATUS='OLD')
      OPEN (UNIT=6,FILE='TAPE6',STATUS='UNKNOWN')
      OPEN (UNIT=8,FILE='TAPE8',FORM='UNFORMATTED',STATUS=
            'UNKNOWN')
      OPEN (UNIT=16,FORM='UNFORMATTED',STATUS='SCRATCH')
      OPEN (UNIT=17,FORM='UNFORMATTED',STATUS='SCRATCH')
```

where the file TAPE9 is omitted from the OPEN statements because it is the optional and alternative file from which some part of the input card groups 4, 7, and 8 are to be read for the CDC CYBER version of COBRA-IV-I, and for the present, it is not necessary for the HP 9000/700 version.

(2) Modification of edit descriptors

The edit descriptors * ··· * (asterisks) for literal editing in the FORMAT statements have been replaced by the edit descriptors ' ··· ' (single quotation marks), and the edit descriptors incompatible with HP FORTRAN/9000 have been properly modified.

(3) Modification of statements related to alternate returns

The alternate return used only within a subroutine subprogram transfers control to the calling program unit at a labeled executable statement other than the next executable statement immediately following the CALL statement. The RETURNS statement following the CALL or SUBROUTINE statement allowed for CDC CYBER is not permitted for HP 9000/700. Each alternate return point for HP 9000/700 is specified as an asterisk (*) followed by a label of an executable statement in the actual argument list in the CALL statement, and is specified as a single asterisk in the formal argument list in the SUBROUTINE statement. In the RETURN statement in the called subroutine, the value of the alternate return number identifies the order of the alternate return to which control is to be transferred. For example, in the following subroutine XXX, RETURN 2 would transfer control to the statement label specified by the second alternate return, in this case, the statement labeled 20. The statements related to the alternate returns used in the subroutines CHAIN and READ, thus, have been modified according to the syntax mentioned above.

CDC :

```
CALL XXX (A1,A2,A3), RETURNS (10,20)
-------------------------------------
SUBROUTINE XXX (F1,F2,F3), RETURNS (J1,J2)
          ⋮
IF (···) RETURN J2
```

HP :

```
CALL XXX (A1,A2,A3,*10,*20)
-------------------------------------
SUBROUTINE XXX (F1,F2,F3,*,*)
          ⋮
IF (···) RETURN 2
```

(4) Replacement of subroutine names

The name of the subroutine LOOP duplicated with the name of the common block /LOOP/ has been replaced by LOOPS.

(5) Replacement of input statements

Some of the CALL statements calling the subroutine LOAD or LOADL have been replaced by the READ statements due to some run-time errors, and the necessary FORMAT statements have been added.

(6) Modification of syntax of implied DO loops in input/output statements

The syntax of implied DO loops in input/output statements has been modified as follows :

CDC :

```
      WRITE (I3,1880) ((H1,NCH(J),H3),J=N,NN)
```

HP :

```
      WRITE (I3,1880) (H1,NCH(J),H3,J=N,NN)
```

(7) Modification of syntax of DATA statements

The syntax of DATA statements has been modified as follows :

CDC :

```
      DATA (XXX= ··· )
```

HP :

```
      DATA XXX/ ··· /
```

(8) Addition of formal arguments to ENTRY statements

The same formal argument as that in the SUBROUTINE statement in the subroutine TODS has been added to the ENTRY statement.

2.5 Equivalence

(1) Conversion of data types for variables and arrays

Some of the integer-type arrays specified in the EQUIVALENCE statements included in the files 'SPEC/SPEC*XX*' as mentioned in Subsection (1) of Section 2.2 have been converted to the double precision real data type to avoid equivalencing the integer- and the real-type arrays. The relevant arrays are as follows :

LC(MC,4)	in the file 'SPEC/SPEC01' ;
CCHANL(M1,ME)	in the file 'SPEC/SPEC05' ;
IFTYP(M1,ME)	in the file 'SPEC/SPEC05' ;
MODE(M1,ME)	in the file 'SPEC/SPEC05' ;
MARK(M1,ME)	in the file 'SPEC/SPEC14' ;
IFDIV(MG)	in the file 'SPEC/SPEC14' ;
ISTAR(MG)	in the file 'SPEC/SPEC14'.

The existing REAL statements have been replaced by the REAL*8 statements. The relevant variables and arrays are as follows :

LENGTH(MG), KIJ, IDTGC	in the file 'SPEC/SPEC02' ;

KKF(MP), KPOUT(MP) in the file 'SPEC/SPEC09' ;
KF in the file 'SPEC/SPEC10' ;
KFUEL(MT), KCLAD(MT) in the file 'SPEC/SPEC12' ;
MCHFR(MX) in the file 'SPEC/SPEC13' ;
KD in the function CHF1 ;
KWALL, KG in the subroutine HTCOR ;
KCXTWO, KCDX2, KF, KFDXM, KFDXP, KFI in the subroutine TEMP.

(2) Modification of dummy variables and arrays used in the subroutines CLEAR, DUMPIT, and RESTRT

The first variable in each common block has been replaced by the integer-type dummy variable IBGN*XX*, and the last real-type dummy variable in each common block, END*XX*, has been replaced by the integer-type dummy variable IEND*XX*. The integer-type dummy array for each common block, ISPC*XX*(*), has been replaced by the integer-type dummy array IDMY*XX*(*), and the real-type dummy array for each common block, SPC*XX*(*), has been deleted. The EQUIVALENCE statement for equivalencing the first elements of SPC*XX*(*) and ISPC*XX*(*) and the first variable in each common block has been modified to that for equivalencing the first element of IDMY*XX*(*) and IBGN*XX* in each common block.

(3) Deletion of unused variables and arrays

The EQUIVALENCE statement for equivalencing the integer-type array LIST(80) and the real-type array ARRAY(80) in the subroutines LOAD and LOADL has been deleted because the two arrays have different types and the array LIST(80) is unused. The EQUIVALENCE statement for equivalencing the variables N, TYM, and DAY in the subroutine TODS has been deleted because the variables are unused due to the conversion of system functions as mentioned in Subsection (1) of Section 2.3.

(4) Explicit type declaration of character variables and arrays

The character variables and arrays declared implicitly as type integer or real have been declared explicitly as type character.

HP :

CHARACTER*8 *XXX*

(5) Addition of integer array KEYSI(33) to common block /NAMLST/

To avoid the mixed use of the implicitly declared integer array KEYS(33) as both types character and integer, the existing array KEYS(33) has been declared explicitly as type character, and the new integer array KEYSI(33) has been added to the common block /NAMLST/. In addition, the elements of the array KEYS(33) used as type integer have been replaced by the elements of the array KEYSI(33).

(6) Deletion of EQUIVALENCE statements of arrays with different types

The EQUIVALENCE statement for equivalencing the real-type dummy array ZDUM(15) and the integer-type dummy array IZDUM(15) in the subroutine SETUP has been deleted due to the different types. In addition, the mixed uses of ZDUM(15) and IZDUM(15) as both types integer and real have been avoided, that is, the elements of the array IZDUM(15) used as type real have been replaced by the elements of the array ZDUM(15) and vice versa.

3. Calculation Procedure by HP 9000/700 Version of COBRA-IV-I

The existing CDC CYBER version of the COBRA-IV-I code uses the auxiliary preprocessing program SPECSET, which automatically sets up a consistent set of dimensions for COBRA-IV-I and calculates the appropriate equivalence starting locations based on the problem size information supplied by the user to minimize the computer core storage requirements. Although this preprocessing program has been inevitably developed due to the limitations on the computer hardware and OS when the COBRA-IV-I code was firstly developed, and at present, it appears unnecessary, we have decided to use this program because it helps COBRA-IV-I to utilize memory efficiently, that is, to utilize only that portion of core storage necessary to solve a particular problem. By the way, only the execution program of SPECSET is available, but the FORTRAN source program is unavailable, so we could not help reconstructing the program SPECSET. We have verified the reconstructed program SPECSET through the comparison with the result of the existing execution program (CSPECK).

As mentioned in Section 2.2 of Chapter 2, the specification statements common to various program units have been replaced by the INCLUDE statements as the inserted files to avoid being specified duplicately among the program units. Therefore we have developed the auxiliary preprocessing program SPECSPL, which splits SPECFIX, one of the output files generated by the program SPECSET, consisting of the specification statements into the files to be included in the program units of COBRA-IV-I by using the INCLUDE statements.

The procedure of the preprocessing mentioned above and the calculation by COBRA-IV-I is schematically represented in Fig. 3.1, where the corresponding file names for CDC CYBER version are shown in parentheses.

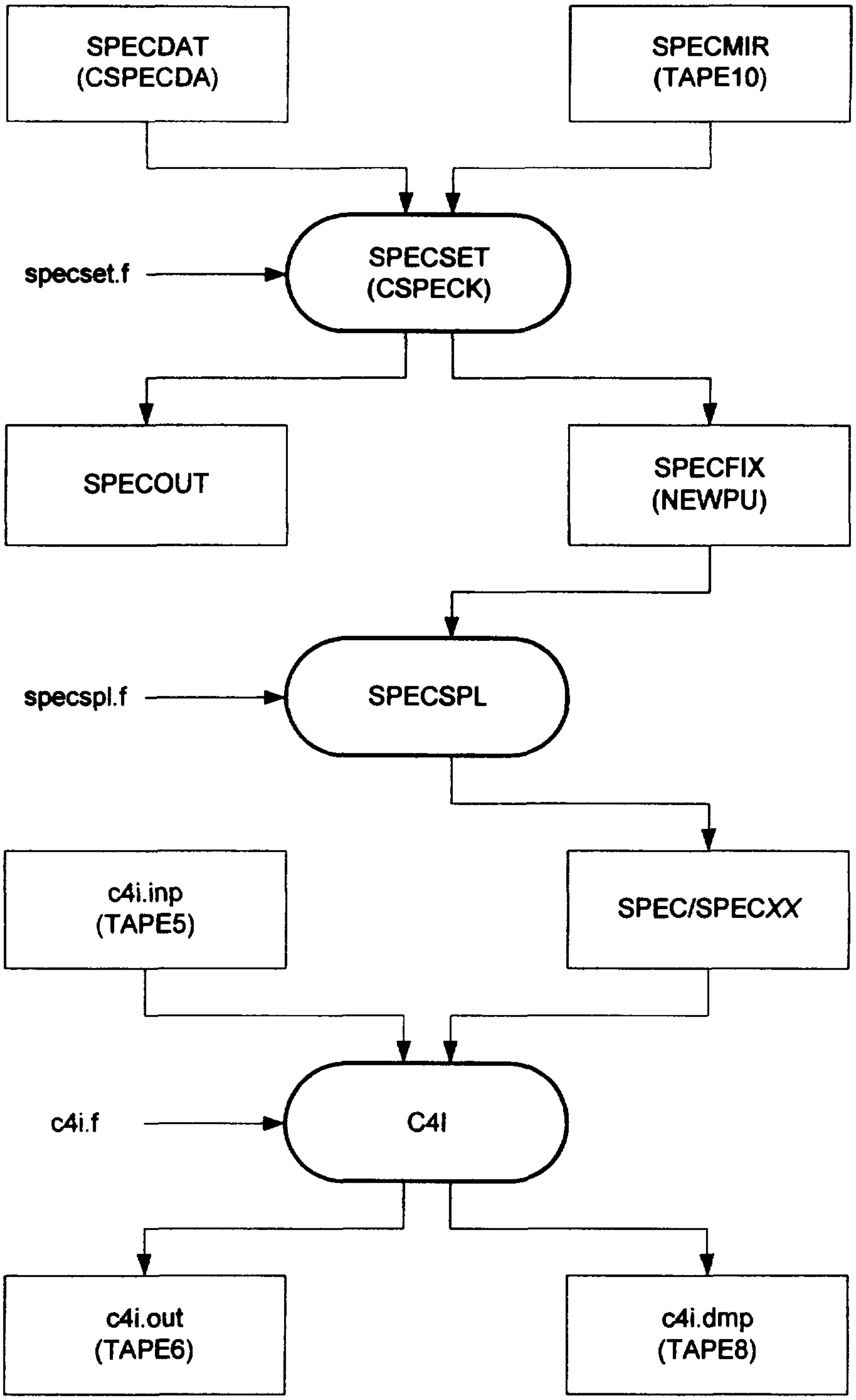

Fig. 3.1 Calculation Procedure by HP 9000/700 Version of COBRA-IV-I

4. Verification of HP 9000/700 Version of COBRA-IV-I

The differences between the CDC CYBER and HP 9000/700 versions in their calculation results are mainly attributed to the difference between the two versions in their levels of precision. It is recommended that the differences between the CDC and Apollo versions be within ±0.001% except for a few cases [4]. To verify the converted COBRA-IV-I code, thus, we have applied this criterion to the following three typical cases :

(1) Kori-3/4 core loaded with 17 × 17 VANTAGE 5H fuel assemblies under the limiting core condition of 118% overpower [5,6] ;
(2) EPRI's hexagonal test section no. 104 loaded with 19 rods with grid spacers [7] ;
(3) EPRI's hexagonal test section no. 103 loaded with 19 rods with wire wraps [7].

These three cases can be represented by using the major characteristics from the thermal-hydraulic viewpoint as follows :

(1a) Square lattice with grid spacers ;
(2a) Triangular lattice with grid spacers ;
(3a) Triangular lattice with wire wraps.

We have performed a series of executions described in the verification procedure file in Appendix A to verify the converted COBRA-IV-I code. With the input data for the three cases shown in Appendix B, we have run the converted COBRA-IV-I code, and have obtained the results shown in Appendix C through the comparison of output files for the two versions of the COBRA-IV-I code.

Based on these comparison results, we have obtained the maximum relative error in each parameter for the three cases, and shows them in Tables 4.1 through 4.3, respectively.

As shown in Tables 4.1 and 4.2, in the case of using grid spacer option, the maximum relative error in each parameter is distributed around the recommended criterion, i.e., $\pm 0.001\%$ ($\pm 10^{-5}$), except for χ (3.58×10^{-3}) in Table 4.1 and w (1.64×10^{-3}) in Table 4.2. The deviation of the maximum relative errors in χ and w from the recommended criterion is attributed to the small number of significant decimal digits of the printed output data : $0.279 \rightarrow 0.280$ for χ ; $0.00611 \rightarrow 0.00612$ ($\mathrm{lb_m}$/sec-ft) for w. Therefore the differences between the CDC CYBER and HP 9000/700 versions in their calculation results in the case of using grid spacer option can be said to be acceptable.

As shown in Tables 4.3, however, in the case of using wire wrap option, the maximum relative error in each parameter is deviated from the recommended criterion. This is attributed to the model of the forced diversion crossflow due to wire wrap [8] implemented in the COBRA-IV-I code. The diversion crossflow through the gap between adjacent subchannels, in the COBRA-IV-I code, can be obtained by solving the combined (axial and lateral) linear momentum equation for the gap through which the wire wrap does not cross at each axial location. For the gap through which the wire wrap crosses, however, the diversion crossflow is obtained from the physical model of the forced diversion crossflow due to wire wrap implemented in the code. By the way, the results of the discriminant, which is the logical expression in a logical IF statement, for discriminating the gap through which the wire wrap crosses are different between the two versions of the COBRA-IV-I code, where the result of the HP 9000/700 version is correct considering the calculation logic. The gaps through which the wire wrap crosses in each axial location, thus, are different between the two versions, and this resulted in the difference in their calculation results. Although the existing model of the forced diversion crossflow due to wire wrap need to be refined, for the present, the differences between the CDC CYBER and HP 9000/700 versions in their calculation results in the case of using wire wrap option can be said to be acceptable.

Table 4.1 Maximum Relative Errors in Parameters for the Case of Square Lattice with Grid Spacers

Parameter	Maximum relative error
Δp (Pressure drop)	5.08×10^{-6}
h (Enthalpy)	1.25×10^{-5}
χ (Equilibrium quality)	3.58×10^{-3}
v (Velocity)	3.46×10^{-6}

Table 4.2 Maximum Relative Errors in Parameters for the Case of Triangular Lattice with Grid Spacers

Parameter	Maximum relative error
Δp (Pressure drop)	3.59×10^{-5}
v (Velocity)	4.85×10^{-6}
w (Diversion crossflow)	1.64×10^{-3}

Table 4.3 Maximum Relative Errors in Parameters for the Case of Triangular Lattice with Wire Wraps

Parameter	Maximum relative error			
	Channel exit	Bundle average	Channel data	Total
Δp (Pressure drop)	—	1.05×10^{-3}	4.80×10^{-1}	4.80×10^{-1}
h (Enthalpy)	1.67×10^{-4}	1.66×10^{-5}	1.83×10^{-3}	1.83×10^{-3}
T (Temperature)	—	1.70×10^{-5}	1.33×10^{-3}	1.33×10^{-3}
ρ (Density)	1.24×10^{-3}	5.76×10^{-4}	4.16×10^{-2}	4.16×10^{-2}
χ (Equilibrium quality)	1.16×10^{-2}	—	1.00×10^{0}	1.00×10^{0}
α (Void fraction)	2.13×10^{-3}	5.38×10^{-3}	3.87×10^{-1}	3.87×10^{-1}
$\dot{m}$ (Mass flow rate)	3.98×10^{-3}	—	2.28×10^{-1}	2.28×10^{-1}
G (Mass velocity)	4.04×10^{-3}	—	1.18×10^{-1}	1.18×10^{-1}
v (Velocity)	—	3.38×10^{-4}	8.23×10^{-2}	8.23×10^{-2}
A (Flow area)	—	—	3.64×10^{-1}	3.64×10^{-1}
w (Diversion crossflow)	—	—	—	6.75×10^{0}
DNBR	—	—	—	1.27×10^{-2}
MDNBR	—	—	—	1.01×10^{-3}

5. Conclusions

We have converted the COBRA-IV-I code from CDC CYBER to HP 9000/700 version to overcome the limitations on the computer core storage and inconvenience to the user interface for CDC CYBER version. We compares the features for the two versions of the COBRA-IV-I code in the aspect of the hardware, OS, and FORTRAN language in Fig. 5.1. We have verified the converted code with the three typical cases : square lattice with grid spacers ; triangular lattice with grid spacers ; and triangular lattice with wire wraps. As a result, we have found almost no difference between the two versions in their calculation results. This conversion will provide the code with improved capabilities, and the users and programmers with more convenient working environments. Therefore we expect the HP 9000/700 version of the COBRA-IV-I code to be the basis for the future development of an improved multichannel analysis code.

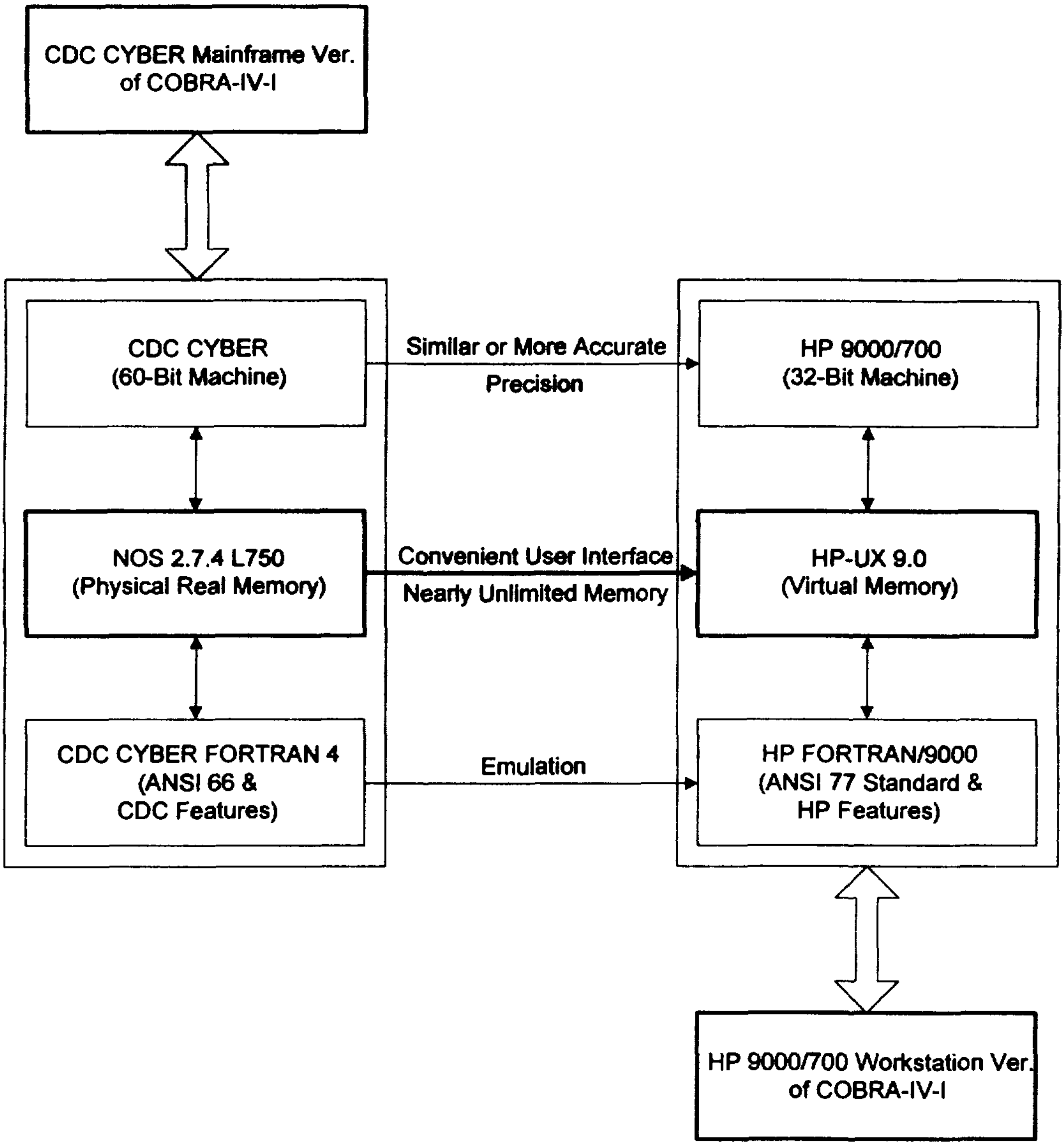

Fig. 5.1 Comparison of Features for Two Versions of COBRA-IV-I

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4. "ABB/CE 원전설계코드의 Workstation 설치기법 분석," KAERI/AR-358/92, KAERI, November 1992.
5. "Reload Transition Safety Report for Kori Nuclear Power Plant, Unit 3&4," KAERI and Siemens/KWU, June 1988.
6. "AP600 Standard Safety Analysis Report," Vol. 3, Westinghouse Electric Corporation, June 26, 1992.
7. C. F. Fighetti and D. G. Reddy, "Parametric Study of CHF Data Volume 3, Part 1 : Critical Heat Flux Data," EPRI NP-2609, Volume 3, Part 1, Columbia University, September 1982.
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Appendix A. Verification Procedure File

```
#=====================================================================
#
#         PROCEDURE FOR VERIFICATION OF HP 9000/700 VERSION OF
#
#                          C O B R A - IV - I
#
#
#                                 BY
#                              Y. J. YOO
#                           (042-868-2634)
#
#                                 IN
#               KOREA ATOMIC ENERGY RESEARCH INSTITUTE
#
#                          OCTOBER 25, 1996
#
#=====================================================================
#
#    THERE MUST BE
#
#       THIS PROCEDURE FILE  : 'PROC'
#       FORTRAN SOURCE FILES : 'specset.f'
#                              'specspl.f'
#                              'c4i.f'
#       INPUT FILES          : 'SPECDAT'
#                              'SPECMIR'
#                              'k34v5hi.hp'
#                              'chexgsi.hp'
#                              'chexwwi.hp'
#
#    IN THE CURRENT WORKING DIRECTORY (FOR EXAMPLE, 'HP'), AND
#
#       OUTPUT FILES FOR CDC CYBER VER. OF COBRA-IV-I : 'k34v5ho.cdc'
#                                                       'chexgso.cdc'
#                                                       'chexwwo.cdc'
#
#    IN THE DIRECTORY '../CDC'.
#
#---------------------------------------------------------------------
#
#    FOR : DIRECTORY OF FORTRAN SOURCE FILES :
#          specset.f
#          specspl.f
#          c4i.f
#    EXE : DIRECTORY OF EXECUTION FILES :
#          SPECSET
#          SPECSPL
#          C4I
#    INP : DIRECTORY OF INPUT FILES :
```

```
#          SPECDAT
#          SPECMIR
#          k34v5hi.hp
#          chexgsi.hp
#          chexwwi.hp
#    OUT : DIRECTORY OF OUTPUT FILES :
#          SPECOUT
#          SPECFIX
#          k34v5ho.hp
#          chexgso.hp
#          chexwwo.hp
#    DIF : DIRECTORY OF DIFFERENTIAL FILES :
#          k34v5ho.ch
#          chexgso.ch
#          chexwwo.ch
#    DMP : DIRECTORY OF DUMP FILES :
#          k34v5hd.hp
#          chexgsd.hp
#          chexwwd.hp
#    ERR : DIRECTORY OF COMPILATION AND RUN-TIME ERROR FILES :
#          SPECSET_ERR_CL
#          SPECSET_ERR_R
#          SPECSPL_ERR_CL
#          SPECSPL_ERR_R
#          C4I_ERR_CL
#          C4I_ERR_R_k34v5h
#          C4I_ERR_R_chexgs
#          C4I_ERR_R_chexww
#   SPEC : DIRECTORY OF SPEC FILES TO BE INCLUDED IN COBRA-IV-I :
#          SPECSC
#          SPECSS
#          SPEC01
#          SPEC02
#          SPEC03
#          SPEC04
#          SPEC05
#          SPEC06
#          SPEC07
#          SPEC08
#          SPEC09
#          SPEC10
#          SPEC11
#          SPEC12
#          SPEC13
#          SPEC14
#          SPEC15
#          SPEC16
#          SPEC17
#          SPEC18
#          SPEC19
#          SPEC20
#          SPEC21
#          SPEC22
```

```
#           SPEC23
#           SPEC24
#           SPEC25
#           SPEC26
#           SPEC27
#
#  ../CDC : DIRECTORY OF OUTPUT FILES FOR CDC CYBER VER. OF COBRA-IV-I :
#           k34v5ho.cdc
#           chexgso.cdc
#           chexwwo.cdc
#
#-----START OF PROCEDURE
#
#-----------------------------------------------------------------------
#
#     REDIMENSION THE COMMON BLOCKS OF THE COBRA-IV-I CODE.
#
#-----------------------------------------------------------------------
#
mkdir FOR EXE INP OUT DIF DMP ERR SPEC
f77 -K -g -o SPECSET specset.f 2> ERR/SPECSET_ERR_CL
mv specset.f FOR
rm specset.o
SPECSET 2> ERR/SPECSET_ERR_R
mv SPECDAT SPECMIR INP
mv SPECSET EXE
mv SPECOUT OUT
#
#-----------------------------------------------------------------------
#
#     SPLIT THE FILE 'SPECFIX' GENERATED BY THE PROGRAM 'SPECSET'
#     INTO THE FILES TO BE INCLUDED IN THE COBRA-IV-I CODE.
#
#-----------------------------------------------------------------------
#
f77 -K -g -o SPECSPL specspl.f 2> ERR/SPECSPL_ERR_CL
mv specspl.f FOR
rm specspl.o
SPECSPL 2> ERR/SPECSPL_ERR_R
mv SPECFIX OUT
mv SPECSPL EXE
mv SPEC* SPEC
#
#-----------------------------------------------------------------------
#
#     RUN THE COBRA-IV-I CODE.
#
#-----------------------------------------------------------------------
#
fsplit c4i.f
mv c4i.f FOR
f77 +E1 -K -g -o C4I *.f 2> ERR/C4I_ERR_CL
rm *.f
```

```
rm *.o
#
#-----CASE 1 : k34v5h
#
mv k34v5hi.hp c4i.inp
mv c4i.inp TAPE5
C4I 2> ERR/C4I_ERR_R_k34v5h
mv TAPE5 c4i.inp
mv TAPE6 c4i.out
mv TAPE8 c4i.dmp
mv c4i.inp INP/k34v5hi.hp
mv c4i.out OUT/k34v5ho.hp
mv c4i.dmp DMP/k34v5hd.hp
diff ../CDC/k34v5ho.cdc OUT/k34v5ho.hp > DIF/k34v5ho.ch
#
#-----CASE 2 : chexgs
#
mv chexgsi.hp c4i.inp
mv c4i.inp TAPE5
C4I 2> ERR/C4I_ERR_R_chexgs
mv TAPE5 c4i.inp
mv TAPE6 c4i.out
mv TAPE8 c4i.dmp
mv c4i.inp INP/chexgsi.hp
mv c4i.out OUT/chexgso.hp
mv c4i.dmp DMP/chexgsd.hp
diff ../CDC/chexgso.cdc OUT/chexgso.hp > DIF/chexgso.ch
#
#-----CASE 3 : chexww
#
mv chexwwi.hp c4i.inp
mv c4i.inp TAPE5
C4I 2> ERR/C4I_ERR_R_chexww
mv TAPE5 c4i.inp
mv TAPE6 c4i.out
mv TAPE8 c4i.dmp
mv c4i.inp INP/chexwwi.hp
mv c4i.out OUT/chexwwo.hp
mv c4i.dmp DMP/chexwwd.hp
diff ../CDC/chexwwo.cdc OUT/chexwwo.hp > DIF/chexwwo.ch
#
mv C4I EXE
#
#-----END OF PROCEDURE
#
#-----------------------------------------------------------------
```

Appendix B. Input of COBRA-IV-I

B.1 Kori-3/4 Core Loaded with 17 × 17 VANTAGE 5H Fuel Assemblies under the Limiting Core Condition of 118% Overpower

```
 5000
 1000     1 LIM. CORE COND. (118% OVERPOWER) V5H KORI-3/4 CIVI W-3 T=630F
    1   30    1    0
 100.327.8    .01774  4.43103   298.58  1187.17   .39840   .39310   .00313
 200.381.8    .01839  2.28728   355.55  1198.33   .33308   .38534   .00267
 300.417.3    .01889  1.54274   394.03  1202.88   .30101   .37741   .00236
 400.444.6    .01934  1.16095   424.22  1204.59   .28039   .36981   .00212
 500.467.0    .01975   .92762   449.57  1204.67   .26534   .36254   .00192
 600.486.2    .02013   .76975   471.74  1203.66   .25352   .35556   .00175
 700.503.1    .02050   .65556   491.65  1201.84   .24376   .34883   .00160
 800.518.2    .02087   .56896   509.85  1199.39   .23542   .34230   .00146
 900.532.0    .02123   .50091   526.75  1196.39   .22809   .33594   .00134
1000.544.6    .02159   .44596   542.59  1192.94   .22152   .32974   .00123
1100.556.3    .02195   .40058   557.59  1189.06   .21554   .32366   .00112
1200.567.2    .02232   .36245   571.89  1184.81   .21002   .31769   .00103
1300.577.4    .02269   .32991   585.61  1180.22   .20486   .31182   .00094
1400.587.1    .02307   .30178   598.86  1175.31   .20000   .30604   .00086
1500.596.2    .02346   .27718   611.71  1170.08   .19538   .30034   .00078
1600.604.9    .02387   .25544   624.23  1164.52   .19095   .29471   .00070
1700.613.1    .02428   .23604   636.48  1158.61   .18669   .28916   .00064
1800.621.0    .02472   .21858   648.51  1152.31   .18255   .28367   .00057
1900.628.6    .02517   .20273   660.37  1145.54   .17850   .27825   .00051
2000.635.8    .02565   .18824   672.12  1138.27   .17453   .27290   .00045
2100.642.8    .02615   .17492   683.80  1130.43   .17060   .26762   .00040
2200.649.4    .02669   .16260   695.47  1122.01   .16669   .26243   .00035
2220.650.8    .02680   .16025   697.80  1120.25   .16591   .26140   .00034
2240.652.1    .02692   .15794   700.14  1118.48   .16512   .26037   .00033
2260.653.3    .02703   .15565   702.48  1116.67   .16434   .25935   .00032
2280.654.6    .02715   .15340   704.83  1114.85   .16355   .25834   .00031
2300.655.9    .02727   .15119   707.18  1113.00   .16276   .25733   .00030
2400.662.1    .02790   .14059   719.02  1103.44   .15877   .25234   .00025
2500.668.1    .02860   .13074   731.10  1093.39   .15465   .24749   .00021
2600.673.9    .02940   .12160   743.62  1082.95   .15030   .24285   .00017
    2    1    1    1    1    0    0
0.184 -0.2  0.0
    3   27
 .000 .033 .038 .217 .077 .398 .115 .573 .154 .740 .192 .897
 .2311.041 .2691.170 .3081.283 .3461.377 .3851.452 .4231.506
 .4621.539 .5001.550 .5381.539 .5771.506 .6151.452 .6541.377
 .6921.283 .7311.170 .7691.041 .808 .897 .846 .740 .885 .573
 .923 .398 .962 .2171.000 .033
    4   19   19    0    0    0    0
    1.31543.0552.497    2.2440          4.0720
    2.20421.7621.762    3.1220          5.1220
```

```
     3.0598.6267.4406     6.0720
     4.39183.6033.231     5.2440          8.1220          11.1220          12.1220
     5.13621.1751.175     6.1220
     6.11951.253.8812     7.0720          8.1220
     7.0598.6267.4406     9.1220
     8.13621.1751.175     9.1220         12.1220
     9.13621.1751.175    10.1220         13.1220
    10.0598.6267.4406    14.0720
    11.87707.7947.050    12.4880         16.2000
    12.51134.8574.112    13.0720         16.0720
    13.11951.253.8812    14.1220         16.0720
    14.11951.253.8812    15.0720         17.1220
    15.0598.6267.4406    18.1220
    16.54484.7784.406    17.2440         19.2000
    17.13621.1751.175    18.1220
    18.20421.7621.762    19.2440
    19.59134.8474.847
     7     2     0    12     2     0     0
.0564     1.1991     1.2742     2.3418     1.4165     2.4845     1
.5596     2.6272     1.7019     2.7699     1.8450     2.9126     1
     1 1.33
     2 1.33
     3 1.33
     4 1.33
     5 1.33
     6 1.33
     7 1.33
     8 1.33
     9 1.33
    10 1.33
    11 1.33
    12 1.33
    13 1.33
    14 1.33
    15 1.33
    16 1.33
    17 1.33
    18 1.33
    19 1.33
     1 0.89
     2 0.89
     3 0.89
     4 0.89
     5 0.89
     6 0.89
     7 0.89
     8 0.89
     9 0.89
    10 0.89
    11 0.89
    12 0.89
    13 0.89
    14 0.89
```

```
   15 0.89
   16 0.89
   17 0.89
   18 0.89
   19 0.89
    8   19   19    0    0    2    0    0    0    0
    1.37401.480    12.155
    2.37401.482    21.516
    3.37401.482    3.3822
    4.37401.480    42.782
    5.37401.482    51.015
    6.37401.490    6.7621
    7.37401.490    7.3835
    8.37401.490    81.013
    9.37401.490    91.023
   10.37401.490   10.3835
   11.37401.473   115.887
   12.37401.488   123.496
   13.37401.490   13.7657
   14.37401.490   14.7585
   15.37401.446   15.3802
   16.37401.467   163.654
   17.37401.467   17.9968
   18.37401.446   181.473
   19.37401.381   194.113
    9    0    0    0    0    0
144.0  0.0
   40          200  200
   10    0    0    0
0.059
   11    1    0    0    0    0    0    0    0
    2280.0     630.0    2.3483   0.22352
   12    3    0    0    0    0    0    0    0
```

B.2 EPRI's Hexagonal Test Section No. 104 Loaded with 19 Rods with Grid Spacers

```
5000
1002    0 EPRI 19-ROD HEXAGONAL GRID SPACER TS 104 C4I W-3
   1   50    0    0
100.327.8    .01774   4.43103    298.58   1187.17    .39840    .39310    .00313
150.358.4    .01809   3.01392    330.69   1194.08    .35841    .38934    .00287
200.381.8    .01839   2.28728    355.55   1198.33    .33308    .38534    .00267
250.401.0    .01865   1.84317    376.19   1201.09    .31495    .38135    .00251
300.417.3    .01889   1.54274    394.03   1202.88    .30101    .37741    .00236
350.431.7    .01912   1.32554    409.88   1203.99    .28977    .37357    .00224
400.444.6    .01934   1.16095    424.22   1204.59    .28039    .36981    .00212
450.456.3    .01954   1.03179    437.37   1204.79    .27235    .36614    .00202
```

```
 500.467.0    .01975    .92762    449.57   1204.67    .26534    .36254    .00192
 550.476.9    .01994    .84177    460.99   1204.28    .25912    .35902    .00183
 600.486.2    .02013    .76975    471.74   1203.66    .25352    .35556    .00175
 650.494.9    .02032    .70843    481.94   1202.84    .24843    .35217    .00167
 700.503.1    .02050    .65556    491.65   1201.84    .24376    .34883    .00160
 750.510.8    .02069    .60949    500.94   1200.69    .23944    .34554    .00153
 800.518.2    .02087    .56896    509.85   1199.39    .23542    .34230    .00146
 850.525.2    .02105    .53302    518.45   1197.95    .23164    .33910    .00140
 900.532.0    .02123    .50091    526.75   1196.39    .22809    .33594    .00134
 950.538.4    .02141    .47205    534.79   1194.72    .22472    .33282    .00128
1000.544.6    .02159    .44596    542.59   1192.94    .22152    .32974    .00123
1050.550.5    .02177    .42224    550.18   1191.05    .21847    .32668    .00118
1100.556.3    .02195    .40058    557.59   1189.06    .21554    .32366    .00112
1150.561.8    .02214    .38073    564.82   1186.98    .21273    .32066    .00108
1200.567.2    .02232    .36245    571.89   1184.81    .21002    .31769    .00103
1250.572.4    .02250    .34556    578.82   1182.56    .20740    .31474    .00098
1300.577.4    .02269    .32991    585.61   1180.22    .20486    .31182    .00094
1350.582.3    .02288    .31535    592.29   1177.80    .20240    .30892    .00090
1400.587.1    .02307    .30178    598.86   1175.31    .20000    .30604    .00086
1450.591.7    .02327    .28908    605.33   1172.73    .19766    .30318    .00082
1500.596.2    .02346    .27718    611.71   1170.08    .19538    .30034    .00078
1550.600.6    .02366    .26598    618.00   1167.34    .19315    .29752    .00074
1600.604.9    .02387    .25544    624.23   1164.52    .19095    .29471    .00070
1650.609.0    .02407    .24547    630.38   1161.62    .18880    .29193    .00067
1700.613.1    .02428    .23604    636.48   1158.61    .18669    .28916    .00064
1750.617.1    .02450    .22709    642.52   1155.51    .18460    .28641    .00060
1800.621.0    .02472    .21858    648.51   1152.31    .18255    .28367    .00057
1850.624.8    .02494    .21047    654.46   1148.99    .18051    .28095    .00054
1900.628.6    .02517    .20273    660.37   1145.54    .17850    .27825    .00051
1950.632.2    .02541    .19533    666.26   1141.97    .17651    .27557    .00048
2000.635.8    .02565    .18824    672.12   1138.27    .17453    .27290    .00045
2050.639.3    .02590    .18144    677.97   1134.42    .17256    .27025    .00042
2100.642.8    .02615    .17492    683.80   1130.43    .17060    .26762    .00040
2150.646.1    .02642    .16864    689.63   1126.30    .16865    .26501    .00037
2200.649.4    .02669    .16260    695.47   1122.01    .16669    .26243    .00035
2250.652.7    .02698    .15679    701.31   1117.58    .16473    .25986    .00032
2300.655.9    .02727    .15119    707.18   1113.00    .16276    .25733    .00030
2350.659.0    .02758    .14579    713.08   1108.29    .16077    .25481    .00028
2400.662.1    .02790    .14059    719.02   1103.44    .15877    .25234    .00025
2450.665.1    .02824    .13558    725.02   1098.47    .15673    .24989    .00023
2500.668.1    .02860    .13074    731.10   1093.39    .15465    .24749    .00021
2550.671.0    .02898    .12609    737.29   1088.21    .15251    .24514    .00019
    2    1    1    1    1    0    0
 .184  -.2   0.
    3    2
   0.   1.   1.   1.
    4   42   42   60    0    0    0
     1.0839.6629.6629    2.1740        6.1740        8.1740
     2.0839.6629.6629    3.1740       11.1740
     3.0839.6629.6629    4.1740       14.1740
     4.0839.6629.6629    5.1740       17.1740
     5.0839.6629.6629    6.1740       20.1740
     6.0839.6629.6629   23.1740
```

```
 7.0839.6629.6629   8.1740        24.1740        25.1740
 8.0839.6629.6629   9.1740
 9.0839.6629.6629  10.1740        26.1740
10.0839.6629.6629  11.1740        27.1740
11.0839.6629.6629  12.1740
12.0839.6629.6629  13.1740        28.1740
13.0839.6629.6629  14.1740        29.1740
14.0839.6629.6629  15.1740
15.0839.6629.6629  16.1740        30.1740
16.0839.6629.6629  17.1740        31.1740
17.0839.6629.6629  18.1740
18.0839.6629.6629  19.1740        32.1740
19.0839.6629.6629  20.1740        33.1740
20.0839.6629.6629  21.1740
21.0839.6629.6629  22.1740        34.1740
22.0839.6629.6629  23.1740        35.1740
23.0839.6629.6629  24.1740
24.0839.6629.6629  36.1740
25.12261.259.6629  26.1120        37.1120
26.12261.259.6629  38.1120
27.12261.259.6629  28.1120        38.1120
28.12261.259.6629  39.1120
29.12261.259.6629  30.1120        39.1120
30.12261.259.6629  40.1120
31.12261.259.6629  32.1120        40.1120
32.12261.259.6629  41.1120
33.12261.259.6629  34.1120        41.1120
34.12261.259.6629  42.1120
35.12261.259.6629  36.1120        42.1120
36.12261.259.6629  37.1120
37.0369.5939.2210
38.0369.5939.2210
39.0369.5939.2210
40.0369.5939.2210
41.0369.5939.2210
42.0369.5939.2210
 1  30.   2 150.   3 270.   4  90.   5 330.
 6 150.   7  30.   8 210.   9  90.  10 270.
11 150.  12 210.  13  30.  14 150.  15 270.
16 330.  17  30.  18 270.  19  90.  20 330.
21  30.  22  90.  23 330.  24 150.  25  30.
26  90.  27 150.  28  30.  29 210.  30  90.
31 150.  32 210.  33  90.  34 270.  35 150.
36 210.  37 270.  38 150.  39 330.  40 210.
41 270.  42 210.  43   0.  44 180.  45   0.
46  60.  47 240.  48  60.  49 120.  50 300.
51 120.  52 180.  53   0.  54 180.  55 240.
56  60.  57 240.  58 300.  59 120.  60 300.
 7   2   0   4   1   0   0
.05    1 .30    1 .55    1 .80    1
 1  1.
 2  1.
 3  1.
```

```
  4   1.
  5   1.
  6   1.
  7   1.
  8   1.
  9   1.
 10   1.
 11   1.
 12   1.
 13   1.
 14   1.
 15   1.
 16   1.
 17   1.
 18   1.
 19   1.
 20   1.
 21   1.
 22   1.
 23   1.
 24   1.
 25   1.
 26   1.
 27   1.
 28   1.
 29   1.
 30   1.
 31   1.
 32   1.
 33   1.
 34   1.
 35   1.
 36   1.
 37   1.
 38   1.
 39   1.
 40   1.
 41   1.
 42   1.
  8   19   19    0    0    2    0    0    0    0
  1 .422 .942     7.1667   24.1667   25.2500   36.2500   37.1667
  2 .422 .942     7.1667    8.1667    9.1667   25.2500   26.2500
  3 .422 .942     9.1667   10.1667   26.2500   27.2500   38.1667
  4 .422 .942    10.1667   11.1667   12.1667   27.2500   28.2500
  5 .422 .942    12.1667   13.1667   28.2500   29.2500   39.1667
  6 .422 .942    13.1667   14.1667   15.1667   29.2500   30.2500
  7 .422 .942    15.1667   16.1667   30.2500   31.2500   40.1667
  8 .422 .942    16.1667   17.1667   18.1667   31.2500   32.2500
  9 .422 .942    18.1667   19.1667   32.2500   33.2500   41.1667
 10 .422 .942    19.1667   20.1667   21.1667   33.2500   34.2500
 11 .422 .942    21.1667   22.1667   34.2500   35.2500   42.1667
 12 .422 .942    22.1667   23.1667   24.1667   35.2500   36.2500
 13 .4221.100     1.1667    6.1667    7.1667    8.1667   23.1667   24.1667
```

```
  14 .4221.100    1.1667    2.1667    8.1667    9.1667   10.1667   11.1667
  15 .4221.100    2.1667    3.1667   11.1667   12.1667   13.1667   14.1667
  16 .4221.100    3.1667    4.1667   14.1667   15.1667   16.1667   17.1667
  17 .4221.100    4.1667    5.1667   17.1667   18.1667   19.1667   20.1667
  18 .4221.100    5.1667    6.1667   20.1667   21.1667   22.1667   23.1667
  19 .4221.100    1.1667    2.1667    3.1667    4.1667    5.1667    6.1667
   9    0    0    0    0    0
 60.   0.                                            .1    .1    .1
  50        200  200
  10    0    0    0
.005
  11    1    0    0    0    0    0    0    0
    1500.      540.      1.995      .617
  12    3    0    0    0    0    0    0    0
```

B.3 EPRI's Hexagonal Test Section No. 103 Loaded with 19 Rods with Wire Wraps

```
5000
1001    0 EPRI 19-ROD HEXAGONAL WIRE WRAP TS 103 C4I W-3
   1   50    0    0
100.327.8     .01774   4.43103    298.58   1187.17    .39840    .39310    .00313
150.358.4     .01809   3.01392    330.69   1194.08    .35841    .38934    .00287
200.381.8     .01839   2.28728    355.55   1198.33    .33308    .38534    .00267
250.401.0     .01865   1.84317    376.19   1201.09    .31495    .38135    .00251
300.417.3     .01889   1.54274    394.03   1202.88    .30101    .37741    .00236
350.431.7     .01912   1.32554    409.88   1203.99    .28977    .37357    .00224
400.444.6     .01934   1.16095    424.22   1204.59    .28039    .36981    .00212
450.456.3     .01954   1.03179    437.37   1204.79    .27235    .36614    .00202
500.467.0     .01975    .92762    449.57   1204.67    .26534    .36254    .00192
550.476.9     .01994    .84177    460.99   1204.28    .25912    .35902    .00183
600.486.2     .02013    .76975    471.74   1203.66    .25352    .35556    .00175
650.494.9     .02032    .70843    481.94   1202.84    .24843    .35217    .00167
700.503.1     .02050    .65556    491.65   1201.84    .24376    .34883    .00160
750.510.8     .02069    .60949    500.94   1200.69    .23944    .34554    .00153
800.518.2     .02087    .56896    509.85   1199.39    .23542    .34230    .00146
850.525.2     .02105    .53302    518.45   1197.95    .23164    .33910    .00140
900.532.0     .02123    .50091    526.75   1196.39    .22809    .33594    .00134
950.538.4     .02141    .47205    534.79   1194.72    .22472    .33282    .00128
1000.544.6    .02159    .44596    542.59   1192.94    .22152    .32974    .00123
1050.550.5    .02177    .42224    550.18   1191.05    .21847    .32668    .00118
1100.556.3    .02195    .40058    557.59   1189.06    .21554    .32366    .00112
1150.561.8    .02214    .38073    564.82   1186.98    .21273    .32066    .00108
1200.567.2    .02232    .36245    571.89   1184.81    .21002    .31769    .00103
1250.572.4    .02250    .34556    578.82   1182.56    .20740    .31474    .00098
1300.577.4    .02269    .32991    585.61   1180.22    .20486    .31182    .00094
1350.582.3    .02288    .31535    592.29   1177.80    .20240    .30892    .00090
1400.587.1    .02307    .30178    598.86   1175.31    .20000    .30604    .00086
```

```
1450.591.7    .02327    .28908    605.33   1172.73    .19766    .30318    .00082
1500.596.2    .02346    .27718    611.71   1170.08    .19538    .30034    .00078
1550.600.6    .02366    .26598    618.00   1167.34    .19315    .29752    .00074
1600.604.9    .02387    .25544    624.23   1164.52    .19095    .29471    .00070
1650.609.0    .02407    .24547    630.38   1161.62    .18880    .29193    .00067
1700.613.1    .02428    .23604    636.48   1158.61    .18669    .28916    .00064
1750.617.1    .02450    .22709    642.52   1155.51    .18460    .28641    .00060
1800.621.0    .02472    .21858    648.51   1152.31    .18255    .28367    .00057
1850.624.8    .02494    .21047    654.46   1148.99    .18051    .28095    .00054
1900.628.6    .02517    .20273    660.37   1145.54    .17850    .27825    .00051
1950.632.2    .02541    .19533    666.26   1141.97    .17651    .27557    .00048
2000.635.8    .02565    .18824    672.12   1138.27    .17453    .27290    .00045
2050.639.3    .02590    .18144    677.97   1134.42    .17256    .27025    .00042
2100.642.8    .02615    .17492    683.80   1130.43    .17060    .26762    .00040
2150.646.1    .02642    .16864    689.63   1126.30    .16865    .26501    .00037
2200.649.4    .02669    .16260    695.47   1122.01    .16669    .26243    .00035
2250.652.7    .02698    .15679    701.31   1117.58    .16473    .25986    .00032
2300.655.9    .02727    .15119    707.18   1113.00    .16276    .25733    .00030
2350.659.0    .02758    .14579    713.08   1108.29    .16077    .25481    .00028
2400.662.1    .02790    .14059    719.02   1103.44    .15877    .25234    .00025
2450.665.1    .02824    .13558    725.02   1098.47    .15673    .24989    .00023
2500.668.1    .02860    .13074    731.10   1093.39    .15465    .24749    .00021
2550.671.0    .02898    .12609    737.29   1088.21    .15251    .24514    .00019
    2    1    1    1    1    0    0
  .184  -.2   0.
    3    2
   0.   1.   1.   1.
    4   42   42   60    0    0    0
     1.0839.6629.6629    2.1740        6.1740        8.1740
     2.0839.6629.6629    3.1740       11.1740
     3.0839.6629.6629    4.1740       14.1740
     4.0839.6629.6629    5.1740       17.1740
     5.0839.6629.6629    6.1740       20.1740
     6.0839.6629.6629   23.1740
     7.0839.6629.6629    8.1740       24.1740       25.1740
     8.0839.6629.6629    9.1740
     9.0839.6629.6629   10.1740       26.1740
    10.0839.6629.6629   11.1740       27.1740
    11.0839.6629.6629   12.1740
    12.0839.6629.6629   13.1740       28.1740
    13.0839.6629.6629   14.1740       29.1740
    14.0839.6629.6629   15.1740
    15.0839.6629.6629   16.1740       30.1740
    16.0839.6629.6629   17.1740       31.1740
    17.0839.6629.6629   18.1740
    18.0839.6629.6629   19.1740       32.1740
    19.0839.6629.6629   20.1740       33.1740
    20.0839.6629.6629   21.1740
    21.0839.6629.6629   22.1740       34.1740
    22.0839.6629.6629   23.1740       35.1740
    23.0839.6629.6629   24.1740
    24.0839.6629.6629   36.1740
    25.12261.259.6629   26.1120       37.1120
```

```
26.12261.259.6629   38.1120
27.12261.259.6629   28.1120        38.1120
28.12261.259.6629   39.1120
29.12261.259.6629   30.1120        39.1120
30.12261.259.6629   40.1120
31.12261.259.6629   32.1120        40.1120
32.12261.259.6629   41.1120
33.12261.259.6629   34.1120        41.1120
34.12261.259.6629   42.1120
35.12261.259.6629   36.1120        42.1120
36.12261.259.6629   37.1120
37.0369.5939.2210
38.0369.5939.2210
39.0369.5939.2210
40.0369.5939.2210
41.0369.5939.2210
42.0369.5939.2210
 1  30.    2 150.    3 270.    4  90.    5 330.
 6 150.    7  30.    8 210.    9  90.   10 270.
11 150.   12 210.   13  30.   14 150.   15 270.
16 330.   17  30.   18 270.   19  90.   20 330.
21  30.   22  90.   23 330.   24 150.   25  30.
26  90.   27 150.   28  30.   29 210.   30  90.
31 150.   32 210.   33  90.   34 270.   35 150.
36 210.   37 270.   38 150.   39 330.   40 210.
41 270.   42 210.   43   0.   44 180.   45   0.
46  60.   47 240.   48  60.   49 120.   50 300.
51 120.   52 180.   53   0.   54 180.   55 240.
56  60.   57 240.   58 300.   59 120.   60 300.
 7    1   60    0    0    0    0
    15.       .422       .112
 1.0800-.583 .083
 2.0800 .417-.917
 3.0800-.250 .750
 4.0800-.750 .250
 5.0800-.417 .917
 6.0800-.917 .417
 7.0800-.583 .083
 8.0800-.083 .583
 9.0800-.750 .250
10.0800-.250 .750
11.0800-.917 .417
12.0800 .583-.083
13.0800-.583 .083
14.0800 .417-.917
15.0800-.250 .750
16.0800-.417 .917
17.0800-.583 .083
18.0800-.250 .750
19.0800-.750 .250
20.0800-.417 .917
21.0800-.583 .083
22.0800-.750 .250
```

```
23.0800-.417 .917
24.0800-.917 .417
25.0800-.583 .083
26.0800-.750 .250
27.0800-.917 .417
28.0800-.583 .083
29.0800-.083 .583
30.0800-.750 .250
31.0800-.917 .417
32.0800-.083 .583
33.0800-.750 .250
34.0800-.250 .750
35.0800-.917 .417
36.0800-.083 .583
37.0800-.250 .750
38.0800-.917 .417
39.0800-.417 .917
40.0800-.083 .583
41.0800-.250 .750
42.0800 .583-.083
43.0800 1.00
44.0800-1.00
45.0800 1.00
46.0800 .167
47.0800-.167
48.0800 .167
49.0800 .333
50.0800-.333
51.0800 .333
52.0800 .500
53.0800-.500
54.0800 .500
55.0800 .667
56.0800-.667
57.0800 .667
58.0800 .833
59.0800-.833
60.0800 .833
 1    0    1    0    1    0    1    0    1    0
 1    0    1    0    1    0    1    0    1    0
 1    0    1    0    1    1    1    1    0    0
 0    0    0    0    1    1    0    1    0    0
 0    0
 8   19   19    0    0    2    0    0    0    0
 1 .422 .942    7.1667   24.1667   25.2500   36.2500   37.1667
 2 .422 .942    7.1667    8.1667    9.1667   25.2500   26.2500
 3 .422 .942    9.1667   10.1667   26.2500   27.2500   38.1667
 4 .422 .942   10.1667   11.1667   12.1667   27.2500   28.2500
 5 .422 .942   12.1667   13.1667   28.2500   29.2500   39.1667
 6 .422 .942   13.1667   14.1667   15.1667   29.2500   30.2500
 7 .422 .942   15.1667   16.1667   30.2500   31.2500   40.1667
 8 .422 .942   16.1667   17.1667   18.1667   31.2500   32.2500
 9 .422 .942   18.1667   19.1667   32.2500   33.2500   41.1667
```

```
   10 .422 .942   19.1667   20.1667   21.1667   33.2500   34.2500
   11 .422 .942   21.1667   22.1667   34.2500   35.2500   42.1667
   12 .422 .942   22.1667   23.1667   24.1667   35.2500   36.2500
   13 .4221.100    1.1667    6.1667    7.1667    8.1667   23.1667   24.1667
   14 .4221.100    1.1667    2.1667    8.1667    9.1667   10.1667   11.1667
   15 .4221.100    2.1667    3.1667   11.1667   12.1667   13.1667   14.1667
   16 .4221.100    3.1667    4.1667   14.1667   15.1667   16.1667   17.1667
   17 .4221.100    4.1667    5.1667   17.1667   18.1667   19.1667   20.1667
   18 .4221.100    5.1667    6.1667   20.1667   21.1667   22.1667   23.1667
   19 .4221.100    1.1667    2.1667    3.1667    4.1667    5.1667    6.1667
    9    0    0    0    0    0
  60.   0.                                          .1   .1   .1
   50       200  200
   10    0    0    0
.005
   11    1    0    0    0    0    0    0    0
     1500.      540.     1.995      .617
   12    3    0    0    0    0    0    0    0
```

Appendix C. Comparison of Output for Two Versions of COBRA-IV-I

C.1 Kori-3/4 Core Loaded with 17 × 17 VANTAGE 5H Fuel Assemblies under the Limiting Core Condition of 118% Overpower

```
Compare: (<) Output for CDC CYBER Version of COBRA-IV-I
   with: (>) Output for HP 9000/700 Version of COBRA-IV-I

235,248c235,248
<
<     1        6517        41     38   1738.6095     .9990     .0222     .0131
<     2        4512        38      0    213.2269     .5439     .0012     .0001
<     3        5379        22      0     96.0921     .2001     .0002     .0000
<     4        5598        19      0     49.2279     .1554     .0001     .0000
<     5        5729        20      0     37.0098     .1393     .0000     .0000
<     6        5696        20      0     74.9578     .1171     .0000     .0000
<     7        5601        20      0     30.0544     .1191     .0000     .0000
<     8        5574        20      0    189.9063     .1119     .0000     .0000
<     9        5443         0      0     16.5939     .0974     .0000     .0000
---
>
>     1        6517        41     38   1738.7497     .9990     .0222     .0131
>     2        4512        38      0    210.1472     .5439     .0012     .0001
>     3        5379        22      0     96.0975     .2001     .0002     .0000
>     4        5598        19      0     50.8312     .1554     .0001     .0000
>     5        5729        20      0     37.0406     .1393     .0000     .0000
>     6        5696        20      0     74.8856     .1171     .0000     .0000
>     7        5601        20      0     29.6970     .1191     .0000     .0000
>     8        5574        20      0    191.9273     .1119     .0000     .0000
>     9        5443         0      0     16.6593     .0974     .0000     .0000
251c251
<      MASS FLOW ERROR   -.10842E-08 LB/SEC          FLOW ENERGY OUT      .17874E+05 BTU/SEC
---
>      MASS FLOW ERROR   -.10818E-08 LB/SEC          FLOW ENERGY OUT      .17874E+05 BTU/SEC
498c498
<  86.4    19.3081    771.30    654.60    22.39    .163    .476    1.7587    2.3270    28.8676    .39180
---
>  86.4    19.3081    771.30    654.60    22.39    .163    .476    1.7587    2.3270    28.8677    .39180
551c551
< 104.4    12.5421    799.96    654.60    19.90    .233    .559     .6154    2.3423    32.6946    .13620
---
> 104.4    12.5421    799.97    654.60    19.90    .233    .559     .6154    2.3423    32.6946    .13620
638c638
<  72.0    22.5817    745.36    654.60    25.21    .099    .383     .2652    2.2994    25.3366    .05980
---
>  72.0    22.5818    745.36    654.60    25.21    .099    .383     .2652    2.2994    25.3366    .05980
671c671
<  18.0    35.9172    669.65    634.29    39.14    .000    .000     .6223    2.3688    16.8110    .13620
```

```
---
>  18.0    35.9173    669.65    634.29    39.14    .000    .000    .6223    2.3688    16.8110    .13620
774c774
<  43.2    31.1942    696.95    650.29    33.21    .000    .119    .2634    2.2832    19.0955    .05980
---
>  43.2    31.1943    696.95    650.29    33.21    .000    .119    .2634    2.2832    19.0955    .05980
797c797
< 126.0     5.0157    818.74    654.60    18.51    .279    .604    .2641    2.2891    34.3511    .05980
---
> 126.0     5.0157    818.74    654.60    18.51    .280    .604    .2641    2.2891    34.3511    .05980
929c929
<  82.8    19.6934    762.35    654.60    23.31    .141    .446    .5311    2.3040    27.4533    .11950
---
>  82.8    19.6935    762.35    654.60    23.31    .141    .446    .5311    2.3040    27.4533    .11950
1166c1166
<  72.0    22.5781    742.08    654.60    25.74    .091    .366    .9356    2.3751    25.6303    .20420
---
>  72.0    22.5782    742.08    654.60    25.74    .091    .366    .9356    2.3751    25.6303    .20420
```

C.2 EPRI's Hexagonal Test Section No. 104 Loaded with 19 Rods with Grid Spacers

```
Compare: (<) Output for CDC CYBER Version of COBRA-IV-I
   with: (>) Output for HP 9000/700 Version of COBRA-IV-I

224,242c224,242
<     1         4140        51     0    519.4812      .9997     .0056     .0090
<     2         4177        51     0    267.4773    17.9716     .0051     .0075
<     3         3665        44     0     55.9756     1.3581     .0046     .0009
<     4         5770        44     0     37.9851      .2929     .0042     .0001
<     5         2330        16     0     23.9118     3.0694     .0051     .0002
<     6         4240        44     0      5.8375      .2290     .0046     .0001
<     7         3019         4     0     27.2999      .2753     .0041     .0001
<     8         2399         4     0     26.0847      .3443     .0037     .0001
<     9         2443        44     0      9.8948      .4469     .0033     .0001
<    10         1955        44     0     38.1652      .4507     .0030     .0001
<    11         2687        44     0     44.0162      .3565     .0027     .0001
<    12         1903         4     0     19.4290      .6420     .0025     .0001
<    13         2841        44     0      6.3954      .3820     .0022     .0001
<    14         3680        44     0     16.7094      .2611     .0020     .0001
<    15         4499        44     0     80.3619      .1951     .0019     .0001
<    16         4988        44     0      7.7857      .1535     .0017     .0001
<    17         5690        45     0      8.4123      .1255     .0016     .0001
<    18         6227        45     0      8.2650      .1049     .0015     .0001
<    19         6275         0     0      4.0456      .0919     .0015     .0001
---
>     1         4140        51     0    516.2326      .9997     .0056     .0090
>     2         4177        51     0    267.4001    17.9716     .0051     .0075
```

```
>     3       3665       44     0    55.9899   1.3581    .0046    .0009
>     4       5770       44     0    38.0676    .2929    .0042    .0001
>     5       2330       16     0    23.8111   3.0694    .0051    .0002
>     6       4240       44     0     6.1897    .2290    .0046    .0001
>     7       3019        4     0    27.2192    .2753    .0041    .0001
>     8       2399        4     0    26.0904    .3443    .0037    .0001
>     9       2443       44     0     9.8965    .4469    .0033    .0001
>    10       1955       44     0    37.8570    .4507    .0030    .0001
>    11       2687       44     0    44.0044    .3565    .0027    .0001
>    12       1903        4     0    19.4287    .6420    .0025    .0001
>    13       2841       44     0     6.3913    .3820    .0022    .0001
>    14       3680       44     0    16.7224    .2611    .0020    .0001
>    15       4499       44     0    80.0542    .1951    .0019    .0001
>    16       4988       44     0     7.7061    .1535    .0017    .0001
>    17       5690       45     0     8.4366    .1255    .0016    .0001
>    18       6226       45     0     8.3577    .1049    .0015    .0001
>    19       6274        0     0     4.0449    .0919    .0015    .0001
249c249
<      MASS FLOW ERROR    -.14779E-10 LB/SEC          FLOW ENERGY OUT      .94768E+04 BTU/SEC
---
>      MASS FLOW ERROR    -.12891E-10 LB/SEC          FLOW ENERGY OUT      .94768E+04 BTU/SEC
684c684
<  39.6    3.2196    643.60    596.20    25.36    .057    .442    .3150    1.9465    21.3194    .08390
---
>  39.6    3.2195    643.60    596.20    25.36    .057    .442    .3150    1.9465    21.3194    .08390
919c919
<  43.2    2.8926    637.27    596.20    26.92    .046    .403    .3232    1.9973    20.6118    .08390
---
>  43.2    2.8926    637.27    596.20    26.92    .046    .403    .3232    1.9973    20.6119    .08390
948c948
<   8.4    7.3569    558.17    556.74    42.54    .000    .002    .3125    1.9310    12.6080    .08390
---
>   8.4    7.3568    558.17    556.74    42.54    .000    .002    .3125    1.9310    12.6080    .08390
1217c1217
<  52.8     .7339    659.10    596.20    23.55    .085    .489    .3225    1.9925    23.5049    .08390
---
>  52.8     .7339    659.10    596.20    23.55    .085    .489    .3225    1.9925    23.5050    .08390
1561c1561
<  48.0    2.4468    648.09    596.20    25.15    .065    .448    .3232    1.9970    22.0562    .08390
---
>  48.0    2.4468    648.09    596.20    25.15    .065    .448    .3232    1.9970    22.0563    .08390
1731c1731
<  43.2    2.8926    637.23    596.20    26.92    .046    .402    .3232    1.9971    20.6056    .08390
---
>  43.2    2.8926    637.23    596.20    26.92    .046    .402    .3232    1.9971    20.6057    .08390
1902c1902
<  39.6    3.2183    604.65    591.22    34.60    .000    .206    .4808    2.0328    16.3206    .12260
---
>  39.6    3.2184    604.65    591.22    34.60    .000    .206    .4808    2.0328    16.3206    .12260
2370c2370
<  44.4    2.7817    613.07    596.20    32.53    .002    .259    .4809    2.0334    17.3632    .12260
---
>  44.4    2.7818    613.07    596.20    32.53    .002    .259    .4809    2.0334    17.3632    .12260
```

```
2630c2630
<   8.4     7.3582     551.57     551.59    45.86    .000    .000    .1383    1.9423   11.7635   .03690
---
>   8.4     7.3583     551.57     551.59    45.86    .000    .000    .1383    1.9423   11.7635   .03690
2797,2811c2797.2811
<    .0 -  1.2    .00000   -.00000   -.00755   -.00000   -.00755   -.00000   -.00755   -.00000   -.00755    .00000
<   1.2 -  2.4    .00000   -.00000   -.00749   -.00000   -.00749   -.00000   -.00749   -.00000   -.00749    .00000
<   2.4 -  3.6   -.00000   -.00000    .00048   -.00000    .00048   -.00000    .00047   -.00000    .00047   -.00000
<   3.6 -  4.8    .00000   -.00001   -.00576   -.00000   -.00576   -.00000   -.00576   -.00000   -.00576    .00000
<   4.8 -  6.0    .00000   -.00001    .00610   -.00000    .00610   -.00000    .00610   -.00000    .00609    .00000
<   6.0 -  7.2   -.00000   -.00000    .14278   -.00000    .14278   -.00000    .14278   -.00000    .14278    .00000
<   7.2 -  8.4   -.00000   -.00000   -.02977   -.00000   -.02977    .00000   -.02977   -.00000   -.02977   -.00000
<   8.4 -  9.6   -.00000    .00000   -.04575    .00000   -.04576    .00000   -.04575    .00000   -.04575   -.00000
<   9.6 - 10.8   -.00000    .00001    .00185    .00000    .00185    .00000    .00185    .00000    .00185   -.00000
<  10.8 - 12.0   -.00000    .00001    .01050    .00000    .01051    .00001    .01051    .00000    .01051   -.00000
<  12.0 - 13.2   -.00000    .00001    .01465    .00000    .01465    .00001    .01466    .00000    .01466   -.00000
<  13.2 - 14.4   -.00000    .00000    .00916    .00000    .00915    .00000    .00916    .00000    .00916   -.00000
<  14.4 - 15.6   -.00000   -.00000   -.03136   -.00000   -.03137   -.00000   -.03137   -.00000   -.03137   -.00000
<  15.6 - 16.8   -.00000   -.00002    .01432   -.00001    .01430   -.00001    .01430   -.00001    .01430   -.00000
<  16.8 - 18.0   -.00000   -.00004    .02919   -.00001    .02916   -.00002    .02915   -.00001    .02915   -.00000
---
>    .0 -  1.2    .00000    .00000   -.00755    .00000   -.00755    .00000   -.00755    .00000   -.00755    .00000
>   1.2 -  2.4    .00000    .00000   -.00749    .00000   -.00749    .00000   -.00749    .00000   -.00749    .00000
>   2.4 -  3.6    .00000    .00000    .00048    .00000    .00048    .00000    .00047    .00000    .00047    .00000
>   3.6 -  4.8    .00000   -.00001   -.00576    .00000   -.00576    .00000   -.00576    .00000   -.00576    .00000
>   4.8 -  6.0    .00000   -.00001    .00610    .00000    .00610    .00000    .00610    .00000    .00609    .00000
>   6.0 -  7.2    .00000    .00000    .14278    .00000    .14278    .00000    .14278    .00000    .14278    .00000
>   7.2 -  8.4    .00000    .00000   -.02977    .00000   -.02977    .00000   -.02977    .00000   -.02977    .00000
>   8.4 -  9.6    .00000    .00000   -.04575    .00000   -.04576    .00000   -.04575    .00000   -.04575    .00000
>   9.6 - 10.8    .00000    .00001    .00185    .00000    .00185    .00000    .00185    .00000    .00185    .00000
>  10.8 - 12.0    .00000    .00001    .01050    .00000    .01051    .00001    .01051    .00000    .01051    .00000
>  12.0 - 13.2    .00000    .00001    .01465    .00000    .01465    .00001    .01466    .00000    .01466    .00000
>  13.2 - 14.4    .00000    .00000    .00916    .00000    .00915    .00000    .00916    .00000    .00916    .00000
>  14.4 - 15.6    .00000    .00000   -.03136    .00000   -.03137    .00000   -.03137    .00000   -.03137    .00000
>  15.6 - 16.8    .00000   -.00002    .01432   -.00001    .01430   -.00001    .01430   -.00001    .01430    .00000
>  16.8 - 18.0    .00000   -.00004    .02919   -.00001    .02916   -.00002    .02915   -.00001    .02915    .00000
2821,2823c2821.2823
<  28.8 - 30.0   -.00001   -.00041    .01356   -.00012    .01327   -.00015    .01318   -.00013    .01313   -.00000
<  30.0 - 31.2   -.00000   -.00041    .01590   -.00012    .01561   -.00015    .01552   -.00013    .01547   -.00000
<  31.2 - 32.4   -.00000   -.00040    .02688   -.00012    .02660   -.00015    .02651   -.00012    .02646   -.00000
---
>  28.8 - 30.0   -.00001   -.00041    .01356   -.00012    .01327   -.00015    .01318   -.00013    .01313    .00000
>  30.0 - 31.2    .00000   -.00041    .01590   -.00012    .01561   -.00015    .01552   -.00013    .01547    .00000
>  31.2 - 32.4    .00000   -.00040    .02688   -.00012    .02660   -.00015    .02651   -.00012    .02646    .00000
2854,2858c2854.2858
<    .0 -  1.2   -.00755   -.00755    .00822   -.00000   -.01854   -.00822    .00000   -.01854    .00822   -.01854
<   1.2 -  2.4   -.00749   -.00749    .00812   -.00000   -.01818   -.00812    .00000   -.01818    .00812   -.01818
<   2.4 -  3.6    .00047    .00047   -.00097   -.00000    .00348    .00096   -.00000    .00348   -.00097    .00348
<   3.6 -  4.8   -.00577   -.00577    .00685   -.00000   -.01677   -.00685   -.00000   -.01677    .00685   -.01677
<   4.8 -  6.0    .00609    .00609    .00061   -.00000   -.01267   -.00061   -.00000   -.01267    .00061   -.01267
---
>    .0 -  1.2   -.00755   -.00755    .00822    .00000   -.01854   -.00822    .00000   -.01854    .00822   -.01854
>   1.2 -  2.4   -.00749   -.00749    .00812    .00000   -.01818   -.00812    .00000   -.01818    .00812   -.01818
```

```
>    2.4 -   3.6    .00047    .00047   -.00097    .00000    .00348    .00096    .00000    .00348   -.00097    .00348
>    3.6 -   4.8   -.00577   -.00577    .00685    .00000   -.01677   -.00685    .00000   -.01677    .00685   -.01677
>    4.8 -   6.0    .00609    .00609    .00061    .00000   -.01267   -.00061    .00000   -.01267    .00061   -.01267
2872c2872
<   21.6 -  22.8    .01920    .01906   -.01697    .00019    .01891    .01660   -.00000    .01873   -.01684    .01896
---
>   21.6 -  22.8    .01920    .01906   -.01697    .00019    .01891    .01660    .00000    .01873   -.01684    .01896
2911,2915c2911,2915
<     .0 -   1.2   -.00822   -.00000   -.01854    .00822   -.01854   -.00822   -.00000   -.01854    .00822   -.01854
<    1.2 -   2.4   -.00812   -.00000   -.01818    .00812   -.01818   -.00812   -.00000   -.01818    .00812   -.01818
<    2.4 -   3.6    .00096   -.00000    .00348   -.00096    .00348    .00096   -.00000    .00348   -.00096    .00348
<    3.6 -   4.8   -.00686   -.00000   -.01677    .00685   -.01678   -.00686   -.00000   -.01677    .00685   -.01678
<    4.8 -   6.0   -.00061   -.00000   -.01267    .00061   -.01267   -.00061   -.00000   -.01267    .00061   -.01267
---
>     .0 -   1.2   -.00822    .00000   -.01854    .00822   -.01854   -.00822    .00000   -.01854    .00822   -.01854
>    1.2 -   2.4   -.00812    .00000   -.01818    .00812   -.01818   -.00812    .00000   -.01818    .00812   -.01818
>    2.4 -   3.6    .00096    .00000    .00348   -.00096    .00348    .00096    .00000    .00348   -.00096    .00348
>    3.6 -   4.8   -.00686    .00000   -.01677    .00685   -.01678   -.00686    .00000   -.01677    .00685   -.01678
>    4.8 -   6.0   -.00061    .00000   -.01267    .00061   -.01267   -.00061    .00000   -.01267    .00061   -.01267
2944c2944
<   39.6 -  40.8    .00570    .00020    .00275   -.00634    .00373    .00568    .00022    .00270   -.00630    .00372
---
>   39.6 -  40.8    .00570    .00020    .00275   -.00634    .00373    .00568    .00022    .00270   -.00631    .00372
2958c2958
<   56.4 -  57.6    .00266    .00033   -.00178   -.00363    .00002    .00261    .00037   -.00187   -.00357   -.00000
---
>   56.4 -  57.6    .00266    .00033   -.00178   -.00363    .00002    .00261    .00037   -.00187   -.00357    .00000
2968,2972c2968,2972
<     .0 -   1.2   -.00822   -.00000   -.01854    .00822   -.01854   -.00822    .00000   -.01854    .00822   -.01854
<    1.2 -   2.4   -.00812   -.00000   -.01818    .00812   -.01818   -.00812    .00000   -.01818    .00812   -.01818
<    2.4 -   3.6    .00096   -.00000    .00348   -.00096    .00348    .00096   -.00000    .00348   -.00096    .00347
<    3.6 -   4.8   -.00686   -.00000   -.01677    .00686   -.01678   -.00686   -.00000   -.01677    .00686   -.01678
<    4.8 -   6.0   -.00061   -.00000   -.01267    .00061   -.01267   -.00061   -.00000   -.01267    .00061   -.01267
---
>     .0 -   1.2   -.00822    .00000   -.01854    .00822   -.01854   -.00822    .00000   -.01854    .00822   -.01854
>    1.2 -   2.4   -.00812    .00000   -.01818    .00812   -.01818   -.00812    .00000   -.01818    .00812   -.01818
>    2.4 -   3.6    .00096    .00000    .00348   -.00096    .00348    .00096    .00000    .00348   -.00096    .00347
>    3.6 -   4.8   -.00686    .00000   -.01677    .00686   -.01678   -.00686    .00000   -.01677    .00686   -.01678
>    4.8 -   6.0   -.00061    .00000   -.01267    .00061   -.01267   -.00061    .00000   -.01267    .00061   -.01267
3001,3002c3001,3002
<   39.6 -  40.8    .00564    .00020    .00269   -.00627    .00367    .00554    .00008    .00271   -.00621    .00349
<   40.8 -  42.0    .00622    .00024    .00416   -.00691    .00528    .00611    .00011    .00418   -.00683    .00507
---
>   39.6 -  40.8    .00564    .00020    .00269   -.00628    .00367    .00554    .00008    .00271   -.00621    .00349
>   40.8 -  42.0    .00622    .00024    .00416   -.00691    .00528    .00612    .00011    .00418   -.00683    .00507
3025c3025
<     .0 -   1.2   -.00822   -.01854    .00000   -.01165   -.01165   -.00000   -.01165   -.01165   -.00000   -.01165
---
>     .0 -   1.2   -.00822   -.01854    .00000   -.01165   -.01165    .00000   -.01165   -.01165    .00000   -.01165
3031,3032c3031,3032
<    7.2 -   8.4    .06507    .02913   -.00000   -.00451   -.00451   -.00000   -.00450   -.00451   -.00000   -.00450
<    8.4 -   9.6   -.05347    .07228   -.00000    .00084    .00083   -.00001    .00086    .00082   -.00001    .00086
---
```

```
>   7.2 -   8.4   .06507   .02913   .00000  -.00451  -.00451   .00000  -.00450  -.00451   .00000  -.00450
>   8.4 -   9.6  -.05347   .07228   .00000   .00084   .00083  -.00001   .00086   .00082  -.00001   .00086
3037c3037
<  14.4 -  15.6  -.04129  -.10932  -.00000   .01311   .01309  -.00003   .01320   .01308  -.00004   .01321
---
>  14.4 -  15.6  -.04129  -.10932   .00000   .01311   .01309  -.00003   .01320   .01308  -.00004   .01321
3082c3082
<    .0 -   1.2  -.01165  -.00000  -.01165  -.01165  -.00000  -.01165  -.01165   .00000  -.01165  -.01165
---
>    .0 -   1.2  -.01165   .00000  -.01165  -.01165   .00000  -.01165  -.01165   .00000  -.01165  -.01165
3088c3088
<   7.2 -   8.4  -.00451  -.00000  -.00450  -.00451  -.00000  -.00450  -.00451  -.00000  -.00450  -.00451
---
>   7.2 -   8.4  -.00451   .00000  -.00450  -.00451   .00000  -.00450  -.00451   .00000  -.00450  -.00451
3094c3094
<  14.4 -  15.6   .01307  -.00004   .01321   .01308  -.00003   .01321   .01309  -.00000   .01320   .01318
---
>  14.4 -  15.6   .01307  -.00004   .01321   .01308  -.00003   .01321   .01309   .00000   .01320   .01318
```

C.3 EPRI's Hexagonal Test Section No. 103 Loaded with 19 Rods with Wire Wraps

Omitted due to long lines

서지정보양식

수행기관보고서번호	위탁기관보고서번호	표준보고서번호	INIS 주제코드
KAERI/TR-803/97			

제목 / 부제	CDC CYBER Version COBRA-IV-I 코드의 HP 9000/700 Version 으로의 변환
연구책임자 및 부서명 (AR, TR 일 경우 주저자)	손 동 성 (미래형핵연료설계기술개발분야) 유 연 종 (미래형핵연료설계기술개발분야) (주저자)
연 구 자 및 부서명	남 기 일 (노심열수력설계분야) 황 대 현 (미래형핵연료설계기술개발분야)

발 행 지	대전	발행기관	한국원자력연구소	발 행 일	1997. 1
페 이 지	49 p.	도 표	유 (O), 무 ( )	크 기	26 cm
참고사항					

비밀여부	공개 (O), 대외비 ( ), __급 비밀	보고서종류	기술보고서
연구위탁기관		계약 번호	

초록 (15-20 줄 내외)

COBRA-IV-I 는 부수로 해석에 근거하여 핵연료 집합체 및 원자로 노심의 열수력 특성을 분석하기 위한 다수로 해석 코드이다. 기존의 COBRA-IV-I 는 CDC CYBER 용 코드로서, 컴퓨터 기억 용량의 한계와 다소 불편한 사용자 환경을 가지고 있다. 이러한 문제들을 해결하기 위하여, CDC CYBER 메인프레임용 COBRA-IV-I 코드를 HP 9000/700 계열 워크스테이션용으로 변환하고, 이와 같이 변환된 코드에 대한 검증 작업을 수행하였다. 그 결과, 두 버전들의 계산 결과 사이에는 차이가 거의 없었으며, 따라서 HP 9000/700 용으로 변환된 COBRA-IV-I 코드는 앞으로 보다 편리한 사용자 환경하에서 보다 개선된 다수로 해석 코드 개발을 위한 토대가 될 것으로 기대한다.

주제명 키워드 (10 단어 내외)	COBRA-IV-I, 부수로 해석, 노심 열수력, 다수로 해석 코드, CDC CYBER 메인프레임, HP 9000/700 계열 워크스테이션, 코드 변환, 코드 검증

BIBLIOGRAPHIC INFORMATION SHEET

Performing Org. Report No.	Sponsoring Org. Report No.	Standard Report No.	INIS Subject Code
KAERI/TR-803/97			

Title / Subtitle	Conversion of the COBRA-IV-I Code from CDC CYBER to HP 9000/700 Version
Project Manager & Department	D. S. Sohn (Future Fuel Design Technology Development Department)
Researcher & Department	Y. J. Yoo (Future Fuel Design Technology Development Department) K. Y. Nahm (Core Thermal-Hydraulic Design Department) D. H. Hwang (Future Fuel Design Technology Development Department)

Pub. Place	Taejon	Pub. Org.	KAERI	Pub. Date	1997. 1
Page	49 p.	Ill. & Tab.	Yes (O), No ( )	Size	26 cm
Note					
Classified	Open (O), Restricted ( ), __Class Doc.		Report Type		Technical Report
Sponsoring Org.			Contract No.		

Abstract (15-20 Lines)

COBRA-IV-I is a multichannel analysis code for the thermal-hydraulic analysis of rod bundle nuclear fuel elements and cores based on the subchannel approach. The existing COBRA-IV-I code is the Control Data Corporation (CDC) CYBER version, which has limitations on the computer core storage and gives some inconvenience to the user interface. To solve these problems, we have converted the COBRA-IV-I code from the CDC CYBER mainframe to an Hewlett Packard (HP) 9000/700-series workstation version, and have verified the converted code. As a result, we have found almost no difference between the two versions in their calculation results. Therefore we expect the HP 9000/700 version of the COBRA-IV-I code to be the basis for the future development of an improved multichannel analysis code under the more convenient user environment.

Subject Keywords (About 10 Words)	COBRA-IV-I, Subchannel Analysis, Core Thermal-Hydraulics, Multichannel Analysis Code, CDC CYBER Mainframe, HP 9000/700-Series Workstation, Code Conversion, Code Verification