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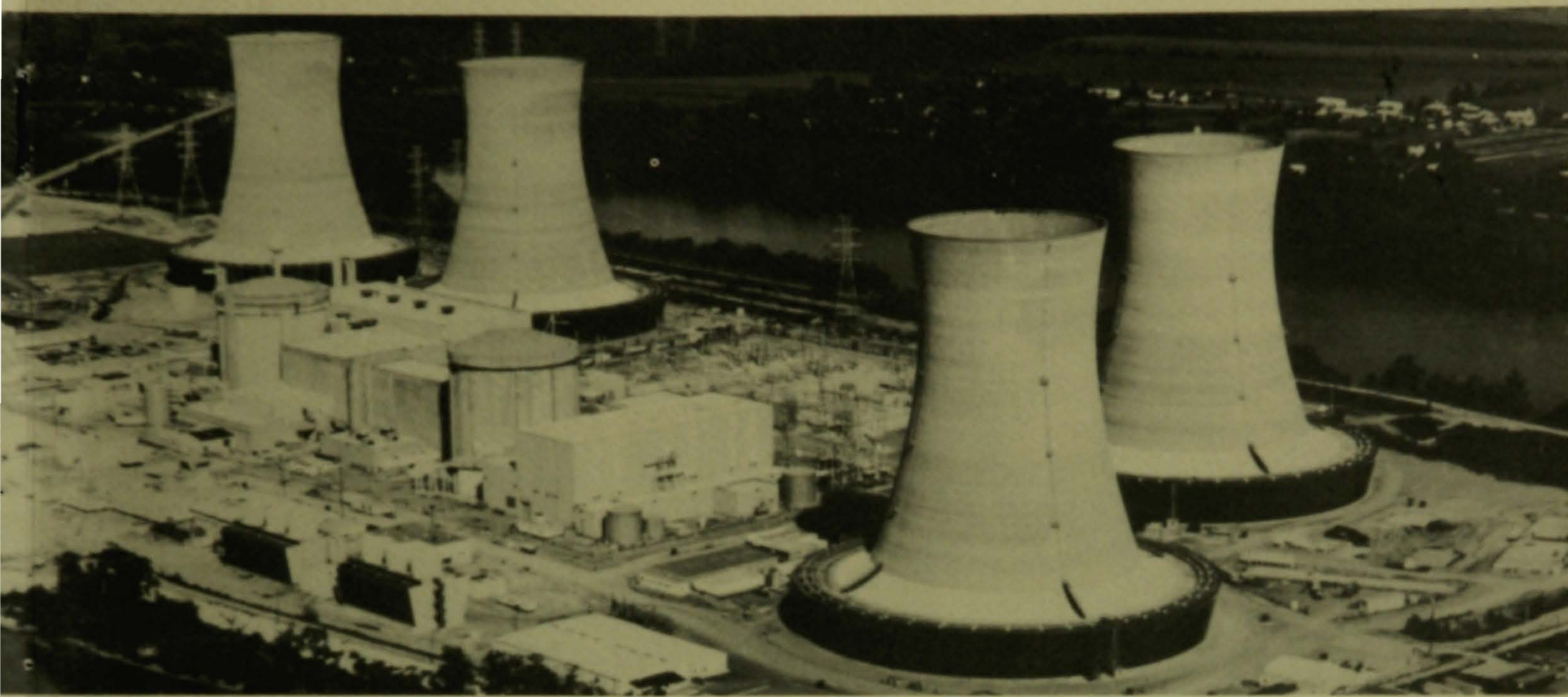

This is an informal report intended for use as a preliminary or working document

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General Public Utilities • Electric Power Research Institute • U.S. Nuclear Regulatory Commission • U.S. Department of Energy

CB VERSION 2.0

TMI-2 CORE BORE (CB) DATA BASE

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Prepared for the
U.S. Department of Energy
Three Mile Island Operations Office
Under Contract No. DE-AC07-76ID01570

DISCLAIMER

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CB, Version 2.0

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Data Base

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Idaho National Engineering Laboratory
EG & G Idaho, Inc.

August 1987

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EXECUTIVE SUMMARY

The Core Bore data base (CB) has been developed to present graphic data describing the end-state of the TMI-2 core. It is a personal computer based system whose contents are the results of research performed within the TMI-2 Accident Evaluation Program sponsored by the U. S. Department of Energy. CB contents represent the best-estimate core end-state configuration through analyses of all data collected through the end of 1986 (through the core bore sampling operation and initial core defueling). Updates to these estimates will continue to take place until all data on the plant have been obtained and analyzed.

CB contents include:

Drilling parameters (drill speed, energy rate, penetration rate, and torque) of the core bore machine during sample acquisition operations in July and August, 1986;

Gross gamma scans of 9 core bore samples performed at the Idaho National Engineering Laboratory (INEL);

Graphic summaries of the core bore drilling operations;

Contour maps of the interfaces between the void, upper debris bed, previously molten material and standing fuel rod assembly regions of the damaged core (plus the surface of the lower plenum debris bed);

Cross sectional views of the core end-state configuration through fuel assembly columns (B, C, D, E, F, G, H, K, L, M, N, O, and P) and row 6;

Miscellaneous figures (e.g., fission product escape paths) which promote understanding of core end-state configuration; and

Explanatory notes that provide additional insight into the graphical presentations.

Corrections to the data base or comments on its content or operation are welcomed. Revisions of this data base product will be limited to the inclusion of new/revised graphics which promote understanding of the TMI-2 core end-state, the correction of data base errors/problems reported by users and routine maintenance.

TMI-2 CORE BORE DATA BASE

USER DOCUMENT

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FIGURES

1.0 INTRODUCTION

The Core Bore data base (CB) is a personal computer (PC) based system which has been developed by the Three Mile Island (TMI) Accident Evaluation Program to archive graphic information depicting the end-state configuration of the damaged TMI-2 core. The data base name was derived from the very important core bore drilling samples collected July and August of 1986. The data base is intended solely to provide information and the results of analyses; it does not contain processing capability.

Version 2.0 of CB contains distance function data consisting of (1) processed drilling parameters from the core boring operation (drill speed, energy rate, penetration rate, and torque) and (2) gross gamma scan analyses of the core bore samples. Graphical data included are (1) drilling summaries of each core bore operation, (2) contour maps of the major regional intersections within the core, (3) cross sectional views, through fuel element columns B - P and row 6, which illustrate core composition, and (4) figures which improve understanding of the end-state condition of the core.

Drilling data from the core bore drilling machine (see reference 1) for the 10 core bore holes (D04, D08, G08, G12, K06, K09, N05, N12, O07, and O09) and the reference calibration hole were placed on the INEL Cyber-176 computers where the data with a time base were converted to distance functions. A penetration rate function (in./sec) was then calculated by taking the distance between points and dividing by the time increment; an energy rate function (ft-lb/in) was produced by integrating the product of drill speed (RPM) and torque (ft-lb) over time increments and dividing by the distance the drill bit moved in that time. To save space on the PC these functions were then smoothed by computing a 20 point block average. The files were then modified to remove those data points where the distance reversed itself when the drill bit was stopped, withdrawn and then the drilling operation continued.

The gross gamma scan data were generated at INEL in the Test Area North hot shop facility using a gross gamma ray spectrometer. These data were recorded as a continuous analog signal on a strip chart device and later digitized by the TMI Accident Evaluation Program staff in Idaho Falls (see reference 2).

Distance function data have been transformed to a common set of coordinates and are cross-referenced to explanatory notes. Users may view the data with respect to three references: sea level (ft.), inches with respect to the bottom of the fuel stack (elevation 298.97 ft.) and inches with respect to the top of the fuel stack (elevation 310.94 ft.).

Data acquired from investigations performed during the reactor defueling operations have provided sufficient data to estimate the end-state core configuration with reasonable certainty. The core can be depicted as consisting of four distinct regions:

a cavity at the top of the core with a volume of approximately 9.3 m^3;

a region of loose debris resting on a hard crust;

a region of previously molten material consisting of (a) uniform, homogeneous ceramic material and (b) ceramic material surrounding degraded fuel pellets and/or fuel rods (called agglomerate material); and

standing fuel rods extending from the lower surface of the previously molten material to the bottom of the fuel stack. (1,3)

Observations were made with a video camera for each core bore hole drilled and then were summarized on drawings. CB contains these summaries; it has been necessary to include most of the observation comments as notes with callout letters on the diagrams denoting location. Printouts of the notes can be obtained by exercising user options.

Contour maps of the intersections between the major core regions have been estimated from analyses of acoustical surface data, debris bed probe data and video inspections. These figures are present in CB with notes that describe their source and the prominent features of the four core regions.

Using the contour map data, cross sectional configurations depicting the four core regions through columns (or rows) of fuel assemblies were sketched. An option is available to view the cross sectional data (and the core bore summaries) in a sequenced operation.

Included in CB are additional figures felt to be informative in describing the core end-state configuration.

This data base has been developed to operate on an IBM personal computer system (PC, XT, AT or PS/2) or on a 100% compatible facility. An EG&G Idaho scientific data base product, SAGE, has been chosen as the data base management system. Applications routines are written (using overlay segmentation) in the Modula-2 structured programming language. All graphical data was produced first on the INEL main frame computer systems and were then downloaded onto the personal computers in a vector format.

This report discusses user interaction with the data base. The following section (2.0) is concerned with how to acquire CB and how to install it. CB operations requires that the PC system on which it is installed have some specific hardware features; these requirements are listed in section 2.0. Section 3.0 is a brief description of the data base structure. User interaction with the data base to produce outputs of the contained data are discussed in Section 4.0.

2.0 CB INSTALLATION

2.1 Data Base Acquisition - The TMI-2 Core Bore data base may be acquired free of charge to agencies connected with DOE sponsored TMI-2 research by making request in writing to:

J. M. Broughton
Manager, DOE Severe Accident Research Programs
EG&G Idaho, Inc.
P. O. Box 1625
Idaho Falls, Idaho, 83415

2.2 Personal Computer Hardware Requirements - The personal computer system on which CB Version 2.0 is to be installed must be an IBM system (PC, XT, AT or PS/2) or 100% IBM compatible system. The host PC system must be operated under IBM Disk Operating System Version 2.1 (DOS 2.1), or newer software. In addition, the following hardware features are necessary:

a diskette drive, double sided (320/360KB) or high capacity (1.2MB)

a display with graphics adapter (color preferred). Note that use of an IBM enhanced graphics adapter also requires that the system have a 16 color IBM memory expansion card (P/N 1501201)

a 20MB internal fixed (hard) disk unit

640KB memory

a math co-processor (8087 for PC, XT; 80287 for AT)

The CB data base produces outputs (e.g. plots, reports) that are hardware dependent. The data base supports those devices that are in common use at EG&G Idaho. In particular, plotted hardcopy output of CB data requires:

a. an EPSON FX series plotter (or 100% compatible unit), and/or

b. a Hewlett-Packard plotter (Model HP7450, HP7470, HP7475 or HP7550).

The data base software routines for output generation require that PC system hardware be defined in a file (PCSYS.CFG) located within the \DOS directory of the system on which they operate. When a user attempts to perform any output option, this file is interrogated to determine if the user's PC system has an acceptable output device. Appropriate error indications are issued if the operation is not permitted.

The user is required to generate this file using two configuration forms prior to their initial attempt to use a TMI-2 SAGE data base product. The two forms are shown in Figures 1 and 2, respectively. Once the file exists, it need not be regenerated for installation of additional TMI-2 data base products. Should a user's hardware change, he may select an option from the main menu which will permit him to change the PCSYS.CFG file.

Please note that CB 1.1 plotting requires considerable memory and will not, in general, operate on a system with the IBM network software running at the same time.

2.3 <u>Data Base Installation</u> - CB 1.1 is transported on seven double sided (320/360KB) diskettes with the following contents:

Diskette 1:

INSTALL	BAT	INSTALLX	BAT	CB	BAT
CB	DFL	HP7475	EXE	COREBOR	LOD

Diskette 2:

CBDATA	BLK	CBDATA	DAT	CBDATA	IDX
SHOWPIC	LOD	REFER	IDX	REFER	DAT

Diskette 3:

M2	EXE	CROSS	TAB	CORE	TAB
HP7550	EXE	CUSER	DAT	CUSER	IDX
FUNCT	DAT	FUNCT	IDX	HPPLOT	LOD
DISKCB	LOD	EDITCB	LOD	CORP	LOD

Diskette 4:

DSUM	DAT	DSUM	IDX	DSUM	BLK
FIG	DAT	FIG	IDX	CORPM	LOD

Diskette 5:

XSEC	DAT	XSEC	IDX	XSEC	BLK
CORPD	LOD				

Diskette 6:

PICTUR	DAT	PICTUR	IDX	PICTUR	BLK

Diskette 7:

NOTES	DAT	NOTES	IDX	NOTES	BLK
HALORLM	EXE	THALO	EXE	HALOPLHP	EXE
HALOMSMI	COM	HALOKBDI	COM	HALOSDTI	COM
MARK	COM	RELEASE	COM	HALOSDTI	LOC
HALOMSMI	LOC	HALOKBDI	LOC	HALO106	FNT
HALOIBME	DEV	HALOIBM	DEV	HALOIBMG	DEV
HALOESPN	PRN	HALOLJTP	PRN		

CB is available to users with IBM AT systems equipped with the 1.2MB floppy drives on two diskettes. The first contains the .BAT files and the .LOD files; all other files are on the second.

Total storage requirement for CB Version 2.0 is 2.2 Mbytes. The '.DAT' files contain the Initial and Boundary Conditions data; the '.IDX' files are associated indices. M2.EXE is the Modula-2 executable driver and the '.LOD' files are overlay routines which contain the applications software to operate the data base. Those files with 'HALO' in the filename are for plotting of time series data.

The file named INSTALL.BAT on diskette 1 is used to install CB on the user's fixed disk system. To perform this installation, insert diskette 1 into the diskette drive (hereafter termed drive A: in this report) and type the command 'A:INSTALL'. The installation batch file, INSTALL, will create a \CB directory on the fixed drive (hereafter termed drive C:) and will copy all files from diskette 1 onto drive C:. Following this transfer from diskette 1, the user will be instructed to remove it and insert the second diskette for transfer of its contents to C:.

SAGE PC SYSTEM HARDWARE CONFIGURATION

<C>ontinue / Generate <R>eport / <E>xit .... [C]

The TMI-2 data base products developed by EG&G Idaho, Inc. have outputs (e.g., plots, reports,) which are device dependent. The data base software routines require that PC system hardware be defined in a file (PCSYS.CFG) located within the \DOS directory of the system on which they operate. Users must generate this file prior to their initial attempt to use a TMI-2 SAGE data base product but not thereafter unless their hardware changes.

The file is created through interaction with a form produced by entering "C" in the field at the top of this form. The main menu of each data base includes an option to edit hardware information in PCSYS.CFG. An "R" entry in the above option field generates a copy of the form in a file named SCREEN.CPY which will be written in the \CB subdirectory of your system.

Use the ALT-H key combination to get general help or the ESC key to obtain specific field help while completing this procedure.

Figure 1. Instructions to Generate the PCSYS.CFG File

SAGE PC SYSTEM HARDWARE CONFIGURATION

<C>ontinue / Generate <R>eport / <E>xit .... [C]

1. PRINTER 0 Other 1 Other w/IBM font 2 EPSON printer 3 EPSON w/IBM font Definition [3]	2. DISPLAY (for plotting purposes) 0 No graphics capability 1 Low resolution 2 Enhanced graphics board 3 Professional graphics Definition [2]
3. PLOTTER (Hewlett Packard only) 0 None 1 HP7450 3 HP7475 2 HP7470 4 HP7550 Definition [2] Serial Port [2]	To obtain help, place the cursor in a field and depress the ESC key; use ENTER to return.

Figure 2. Identification of PC Hardware

The CB data base operates from the PC batch area and will therefore operate when called by the command 'CB' from within any directory. All files (default RPT.RPT or user defined) produced by CB will be located on disk in the CB subdirectory. Since the normal return from CB will invoke the batch menu function, the user will be required to change directories (CD\CB) to direct output of CB created files.

3.0 CB STRUCTURE

The SAGE DBMS system is relational; that is, the information is stored in "flat" files or tables (known as relations) of row versus column structure. Each relation has a companion index file which contains the sorted indexes used to relate information within the data base. The CB data base has 5 principal data relations as follows:

Function - Contains parameters, descriptions of distance series functions (e.g., core bore drilling parameters, gross gamma scans of core bore materials) stored in block form within the data base. These include function identification, acquisition date, a long description, the physical unit code, and function statistics (min and max values, distance range and number of points). The relation also includes parameters for the qualification and uncertainty assessments of the data.

Graphics - Contains identifications, descriptions and the diagrams, stored in block form, for drill summary, contour map, cross section configuration, and miscellaneous end-state graphics. These data are stored in three data relations.

Notes - Textual data which pertain to one or more records within the function or graphics relations.

In addition there is an imbedded physical unit code table, a user relation used to provide data base security and a utility relation used by applications software.

User interface with CB is through a hierarchical system of menus and forms. User interaction is accomplished via a fill-in-the-blank operation which is discussed in detail in the next section.

4.0 USER INTERACTIONS

This section discusses each of the menu forms which the user interacts with in the Core Bore (CB) data base, explaining the options available to the user and the actions which result from each. The fields in which the user inputs his response are shown in reverse video on a monochrome display and in a different color on a color monitor. A cursor (blinking dash) is used to identify the current field position within the form.

Movement between input fields is accomplished by (1) completely filling in a field or by depressing the <TAB> key which causes a sequential transfer to the next field; (2) by using the backtab keys <Shift/TAB> to move to the previous field or, (3) by selecting the <HOME> key to transfer to the form entry field. The four cursor control arrows (up, down, left, and right) may also be used to move about the displayed form. A carriage return <Enter> entry causes the user supplied information to be interpreted by the data base software and requested operations to be performed.

User entries are processed for legitimate response. When an error is detected (such as an incorrect format, an entry out of range, or <Enter> when cursor is not in an entry field), a bell is sounded and a brief error statement is displayed at the bottom of the display screen.

On-line help is available from the various fields of the forms by striking the <ESC> key. This causes a brief message to be printed on one/more overlay screens which describe the options available/information to be entered for the field in which the cursor is currently located. An <Enter> is used to return from help messages to the original position within the form (note that when multiple <ESC> key operations are required to complete a user help request, an equivalent number of <Enter> operations are required to return to the form). Some general form options provided by SAGE are available in CB; these options can be reviewed at any time by depressing the <ALT> and <H> keys simultaneously.

4.1 Entry Form - This form (see Figure 3) permits a user to enter a set of initials and a password for entry into the data base environment. The data base logs the number of times each user/password entry pair is exercised. Users are divided into two classes: 'M'aster users who have permission (specific password required) to edit data base relations and 'R'egular users who cannot edit data (password need not be entered). Master user status is reserved to only those individuals responsible for the update and maintenance of the CB data base in accordance with established policy.

4.2 CB Main Menu - The main menu (Figure 4) gives thê user option to edit data base records, generate function plots, view end-state core configuration diagrams, enter data from disk files, and to change the PC system configuration table.

4.3 Edit Menu - All users are permitted to select the edit option and to inspect, but not modify, record contents. A main edit form (see Figure 5) permits the user to access the records within the different data base relations. Edit menu options are of two general classes; those which retrieve record contents and display them on the PC screen and those which alter record contents. Figures 6 and 7 show two forms produced by selecting edit option 1. They are used to edit distance function parameters. The <L>ocate, <N>ext,

<P>revious and <E>xit options (in the upper box) retrieve and display record contents; they can be exercised by all users.

```
TMI-2 CB, VERSION 2.0
THREE MILE ISLAND, UNIT 2
CORE BORE DATA BASE

Welcome to the TMI-2 data base system.  Please enter your initials
and your  password  for  entry  permission to be granted.   If you
have  not  yet  entered  the system,   your initials  and selected
password will be recorded.

Initials  [ANY]
Password  [USER      ]
```

Figure 3. CB Entry Form

```
TMI-2 CB 2.0

TMI-2 CORE BORE DATA BASE
```

```
Enter Option ... [0]

  0)  Exit
  1)  Edit data base records
  2)  Plot drilling or gamma scan data
  3)  Display End-State Core Configuration Diagrams
  4)  Enter data from disk
  5)  Change PC system configuration table

Use ALT-H for SAGE (general) help; Use ESC for CB (field) help
```

Figure 4. Main CB Option Menu

The <A>dd, <M>odify, and <D>elete options require master status since they alter contents of the distance function relation. The <C>ontinue option is used as a form control parameter, switching back and forth between the Figures 6 and 7 forms. Figure 7 illustrates appearance of a help form (inner box) overlayed on the edit form (it was placed there by striking the ESC key).

Other edit options available are: Edit option 2 - a capability to associate notes with the core bore or gross gamma functions; edit option 3 - forms to input descriptive notes; edit option 4 - the user specification option only used by the data base administrator to define master users.

```
                    EDIT SELECTION
             TMI-2 CORE DRILLING AND
             EXAMINATIONS DATA BASE


    Enter option ... [1]

       0)  Exit
       1)  Edit distance function parameters
       2)  Edit distance function references
       3)  Edit notes
       4)  Edit user (Master user status required)
       5)  Edit diagram parameters
```

Figure 5. CB Edit Form

```
                    EDIT DISTANCE FUNCTION DATA (1 of 2)

      <L>ocate / <N>ext / <P>revious / <A>dd / <M>odify / <D>elete
      <C>ontinue / <B>lank / <E>xit ........................... [ ]

1.  FUNCTION DESCRIPTION:
    Grid Location     [D04]  Data Type [DISTANCE        ]
    Function Name     D04DISTANCE
    Description       [DIST CHANNEL CORE BORE D04 DRILLING FUNCTIONS    ]
                      [                                                 ]
    Date Obtained     [         ]          Unit Code    [ 2]  ft

2.  EVALUATION OF DISTANCE FUNCTION:
    Qualification     [            ]
    Qual Statement    [                                                 ]
                      [                                                 ]
    Uncertainty       [            ]
    Status            [                                                 ]
```

Figure 6. Distance Function Edit Form (1 of 2)

Please note that by convention all data within CB are stored in English units. Users are given the option in all data processing or output operations to select metric units. This is accomplished by attributing a unit code to each physical data record and conversion using an internal table.

4.4 Plotting Capabilities - Within the CB data base users may plot any of the core bore drilling functions or the gross gamma scans. Plot generation is started by selecting option 2 from the main menu (Figure 4); this, in turn, produces a plot selection menu as shown in Figure 8.

```
EDIT DISTANCE FUNCTION DATA (2 of 2)

<L>ocate / <N>ext / <P>revious / <A>dd / <M>odify / <D>elete
<C>ontinue / <B>lank / <E>xit .......................... [C]

    Function Name  D04DISTANCE

3.  DATA BASE STORAGE:
    Relation       [CBData   ]        Data Pointer       150
    Number Pts     [  489]
    Data Minimum   [ 6.000E-001]      Data Maximum    [ 1.202E+002]
    Min Elevation  [ 2.97583E+002]    Max Elevation   [ 3.05702E+002]
```

Figure 7. Distance Function Edit Form (2 of 2)

Four plot formats may be selected from the plot menu: Single variable distance function plots with (1) linear or (2) semi-log ordinates; (3) Multiple (up to 5) plots of core bore functions of the same physical type on a common set of x, y axes; and, (4) Two functions with dissimilar ordinates on a common time axis. CB plot operations will be illustrated using option 4 and plotting the K09 core bore drill energy and gross gamma functions.

```
CB PLOT SELECTION

Select plot type:
    0)  Exit
    1)  Single variable, linear
    2)  Single variable, semi-log
    3)  Multiple variables (<=5)
    4)  Two dissimilar variables
 [4] ... Enter Option

 Pick Core Elevation Reference            [2]
 Choose <E>nglish or <M>etric Units       [E]
 Display Grid Spacer Locations <Y>        [Y]

Change desired option by using the arrow or tab keys or entering
the number of the option.  Execute desired option by depressing
the "Enter" key.
```

Figure 8. CB Plot Selection Menu

Exercising option 4 brings up another menu on which the user specifies the data identifications, time and amplitude window, and labelling he wants on his plot (see Figure 9). If he does not elect to specify ranges for the axes, the program defaults to the entire data set (note that ordinate ranges and a distance range were specified). Default labels are also supplied for the time and ordinate axes if not specified (note no ordinate label specified in example).

At the top of the plot setup menus are some options available to the user in determining what functions are available in the data base. The first (the <F>ind option) produces another form (see Figure 10) on which the user is able

```
                              TWO PLOT SETUP
  <F>ind ID / <R>etrieve characteristics / <S>creen / <H>P Plotter
  <P>rinter (EPSONFX) / <L>ist / <C>omments / <N>ext / <E>xit ....... [R]

  Function ID's      1 - [K09GROSS GAMMA      ] 2 - [K09ENERGY           ]
  Dist Axis:  Start      [---------E----]     Stop  [---------E----]
  Ordinate:   Min    1   [------E----]          2 - [------E----]
              Max    1   [------E----]          2 - [------E----]
  Plot Labels:
    Main Title           [                                          ]
    Distance Label       [                                          ]
    Ordinate Label   1 - [                                ]
                     2 - [                                ]

              Pts        Plot 1 -    859      Plot 2 -    176
              Start          -1.59816E+001        -1.59816E+001
              Stop            6.75384E+001         6.75384E+001
              Ymin            1.600E+000           2.734E+001
              Ymax            6.673E+001           4.673E+005
              Units          38 Intensity         34 ft-lb/in
```

Figure 9. Option 4 (Two Dissimilar Variables) Plot Setup Screen

```
                  IDENTIFICATION OF CORE DRILLING FUNCTIONS

       List data base drilling or core bore analysis functions by:
       Core Matrix Location [K09]; Data Type [                ]; All [ ]

Select
 [--] K09DISTANCE           DIST CHANNEL K09 CORE BORE DRILLING FUNCTIONS

 [--] K09DRILL SPEED        DRILL SPEED CORE BORE K09

 [--] K09ENERGY             DRILL BIT ENERGY CORE BORE K09

 [--] K09GRGAMMADIST        DIST CHANNEL K09 GROSS GAMMA SCAN

 [--] K09GROSS GAMMA        GROSS GAMMA SCAN CORE BORE K09 (EG&G Idaho)
                            Relative Gamma Intensity
 [--] K09PENETRATION RATE   DRILL PENETRATION RATE CORE BORE K09

 [--] K09TORQUE             DRILL BIT TORQUE CORE BORE K09

                                     <N>ext / <P>revious / <E>xit ... [F]
```

Figure 10. Display Screen for CB Distance Functions

to locate functions. When the form is initially entered, the identification and description fields are blank, an 'F' appears in the lower right field. The user moves to the double lined box at the top (using the 'Home', tab or arrow keys) and specifies the data functions to list by entering information in the fields for (1) core bore matrix location, (2) the type of function (example - drill speed) or (3) all (any character = the default condition). NOTE: Refer to the help messages for these fields by typing ESC when the cursor is within the field. Identifications and descriptions are then retrieved and displayed (7 at a time) on the form. The retrieved information is sent to a report RPT.RPT in the \CB subdirectory of the PC system where it may be disposed of as the user desires (note that RPT.RPT is used in many data base output situations and is written over frequently). The user may page through the screen list using <N>ext and <P>revious options. He may also select data he wishes to plot by marking the select boxes to the left of the function IDs. Up to 10 functions may be selected at one time; they must be numbered 1 - 10 if <F>ind is executed from the single plot menus, from 1 - 5 in pairs if <F>ind selected from the two plot menu (example case), or in two groups, 1 or 2 for the multiple selection form. In Figure 10, we have selected the desired two functions and marked them with a '1'.

The <R>etrieve characteristics option (default when entering a plot generation form) causes the named function(s) to be accessed on disk to determine the time and amplitude ranges, number of points and the unit code. These data are placed in the box at the bottom of the screen (see Figure 9).

The <S>creen, <D>isk, and <P>rinter selections direct the defined plot to the appropriate output device. Error messages are displayed at the bottom of the screen if the user attempts to send a plot file to a device not specified in the PCSYS.CFG file. Messages are presented at the bottom of the plot setup screen when the user sends a plot to a specified device reminding him of actions he must perform (for example, if his output choice is <P>rinter the message "Is printer ready (Y/N)?" is displayed and the program pauses waiting for an appropriate response). The plot specified in Figure 9 which was output to a Hewlett Packard 7475 plotter is reproduced in Figure 11.

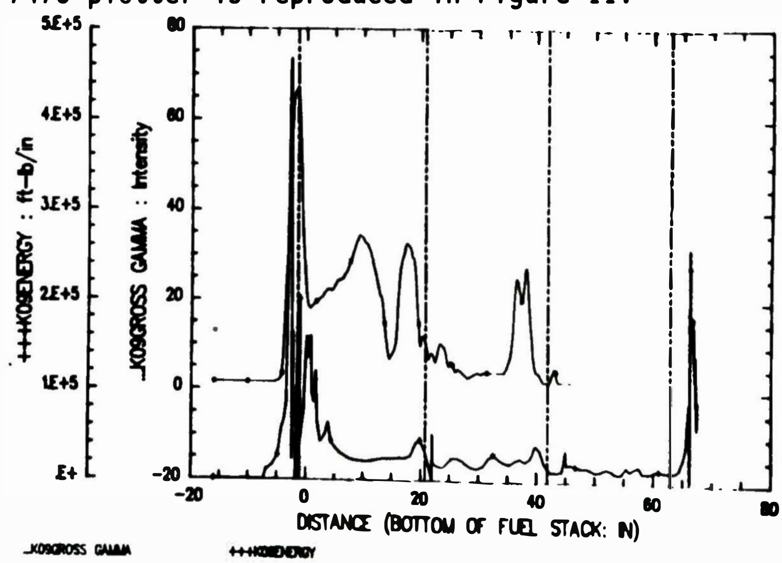

Figure 11. Plot of K09 Core Bore Drill Energy and Gross Gamma Scan Functions

The <L>ist data option produces a formatted report of the function data defined on the plot generation screen. This listing is sent to file RPT.RPT in the \CB subdirectory. In Figure 12 a partial listing of the K09 gross gamma function is presented as an illustration.

Data Listing for K09ENERGY

Distance Interval -2.004E+001 to 4.956E+001 Reference

Distance	Value	Distance	Value	Distance	Value
-1.60E+01	7.30E+02	-1.59E+01	7.80E+01	-1.55E+01	4.91E+01
-1.47E+01	6.66E+01	-1.40E+01	6.20E+01	-1.33E+01	4.34E+01
-1.25E+01	4.76E+01	-1.18E+01	5.80E+01	-1.10E+01	5.55E+01
-1.03E+01	5.41E+01	-9.53E+00	3.85E+01	-8.79E+00	2.73E+01
-8.06E+00	4.42E+01	-7.34E+00	8.88E+01	-6.81E+00	1.18E+04
-6.56E+00	1.23E+04	-5.77E+00	1.64E+04	-4.85E+00	2.74E+04
-4.17E+00	5.83E+04	-3.78E+00	6.63E+04	-3.17E+00	8.44E+04
-2.90E+00	3.65E+05	-2.75E+00	4.54E+05	-2.62E+00	4.67E+05
-2.49E+00	2.64E+05	-2.42E+00	1.29E+05	-2.39E+00	2.26E+04
-2.23E+00	1.63E+05	-2.21E+00	3.44E+04	-1.78E+00	4.37E+04
-1.69E+00	7.74E+02	-1.64E+00	1.03E+05	-1.51E+00	9.99E+06
-1.21E+00	1.93E+05	-1.07E+00	2.01E+05	-1.01E+00	2.51E+03
-1.01E+00	9.17E+04	-9.08E-01	4.57E+04	-3.83E-01	7.51E+04
6.35E-03	1.39E+05	2.26E-01	1.59E+05	4.23E-01	1.35E+05
6.53E-01	1.47E+05	8.60E-01	1.59E+05	1.06E+00	9.68E+04
1.39E+00	8.61E+04	1.74E+00	1.21E+05	2.01E+00	6.35E+04
2.54E+00	4.24E+04	3.28E+00	4.94E+04	3.86E+00	6.38E+04
4.37E+00	4.36E+04	5.11E+00	3.58E+04	5.95E+00	3.01E+04
6.82E+00	2.66E+04	7.71E+00	2.36E+04	8.62E+00	2.19E+04
9.54E+00	2.13E+04	1.05E+01	2.07E+04	1.14E+01	2.17E+04

Figure 12. Partial Listing of Data for K09 Gross Gamma Function

4.5 Core End-State Graphics - The reactor defueling work completed over the past few years and inspection of the lower core regions during the core-boring operation have provided sufficient data to estimate the end-state core configuration with reasonable certainty. These data define four distinct regions within the original core volume, as shown in Figure 13 [3]:

Core void - A cavity which existed at the top of the core with a volume of 9.3 m^3.

Upper debris bed - A region of various sized, loose particles, ranging from 0.6 to 1.0 m in depth, which rested on a solid crust which was located at about the core mid-plane.

Previously molten material - A region containing (1) relocated previously molten material in which some fuel rod structure is discernible (cladding and/or fuel pellets); such material is referred to as "agglomerate" and (2) uniformly molten material with no evident fuel rod structures at the center of the previously molten region; this material is referred to as "ceramic".

Standing fuel rod assemblies - Fuel rod stubs extend the full height of the core at its periphery. Elsewhere, stubs extend from the bottom of the core upward to the previously molten core region.

CB contains graphics data of four types, extracted from the reference documents, which are considered useful in the understanding of the core end-state. These are:

End-State Core Configuration - 1987

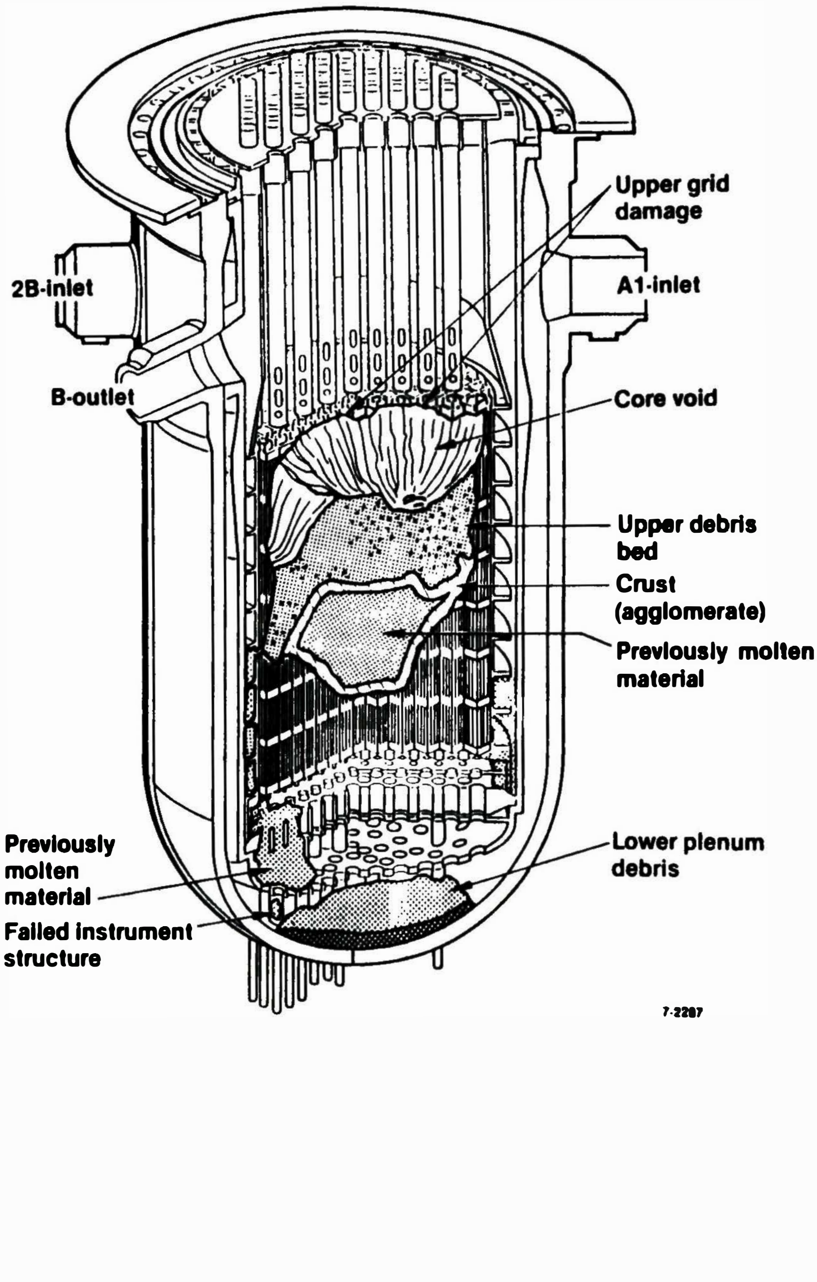

Figure 13. TMI-2 Known End-state Core Configuration (Sept. 1987)

Core bore drill summaries - Summaries of observations made during the drilling operations for the 10 core bore samples. These summaries have been extracted from reference 1. Many important features are identified by letters which refer to textual notes available through option selection. This descriptive method was selected since the PC CRT has insufficient resolution to clearly present text in the small size that would be necessary. Figure 14 is an example of a core bore summary diagram from a central core location, K09.

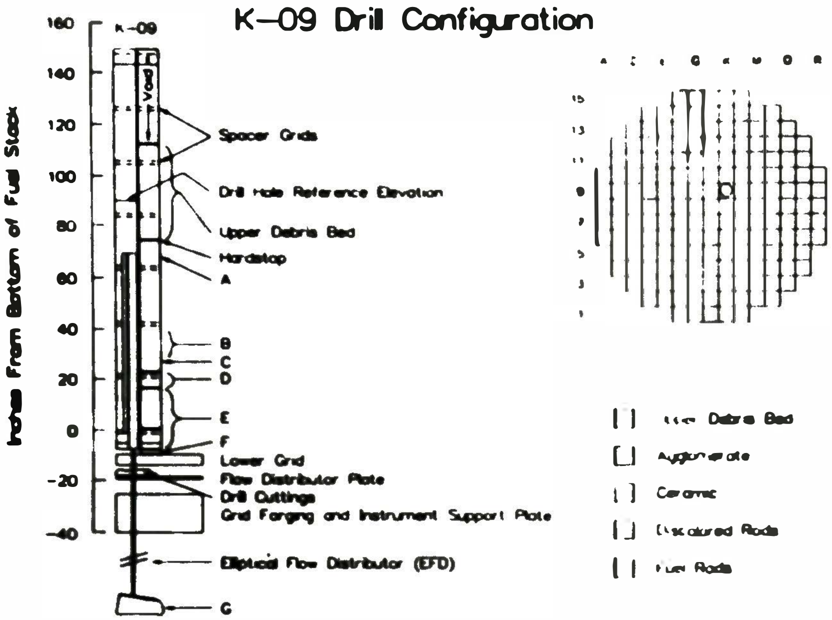

Figure 14. Observation Summary From Central Core Bore Location (K09)

Contour maps - Contour maps of the interfaces between the four core regions have been estimated from careful analyses of end-state analyses. An example of the interface between the upper debris bed and the upper surface of the previously molten core region is shown in Figure 15.

Cross section configurations - Based on the interface contours, core cross section configuration diagrams have been prepared for fuel assembly columns B through P plus row 6. The cross section through the row 6 fuel assemblies is shown in Figure 16.

Miscellaneous diagrams - CB contains some miscellaneous diagrams which promote understanding of the accident. They include a map of the upper grid damage, a fission product escape path figure, locations of in-core thermocouple instrumentation, and locations of core bore drill holes identified together with the visible area of the core support assembly noted.

Appendix A contains the names and descriptions of the CB graphic data. These figures were first produced on the INEL main frame computers and have been downloaded to the PC using existing software capability. A vector file is produced on the PC requiring that the figures be 'drawn' on the CRT. Future plans will provide a bit map file which will speed the presentation of graphics; as this technology will be incorporated into CB when available.

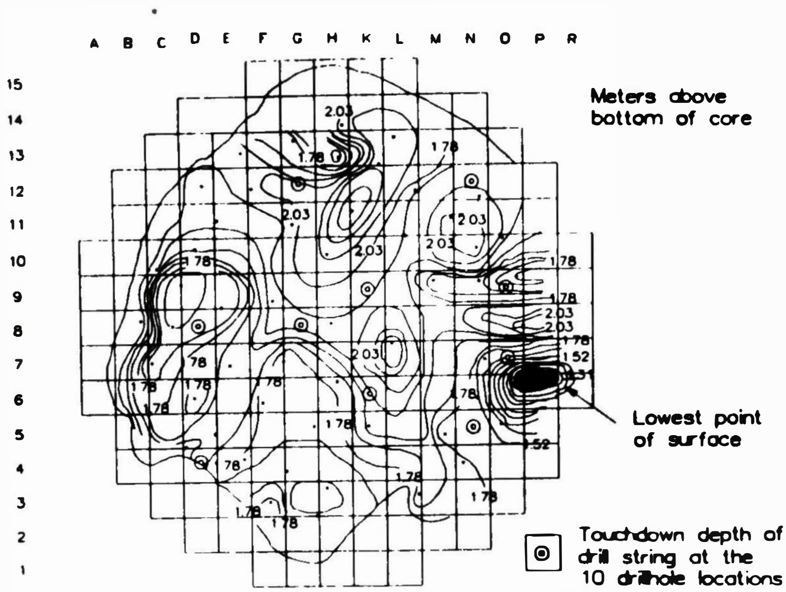

Figure 15. Contour Map of the Upper Surface of the Previously Molten Region in TMI-2

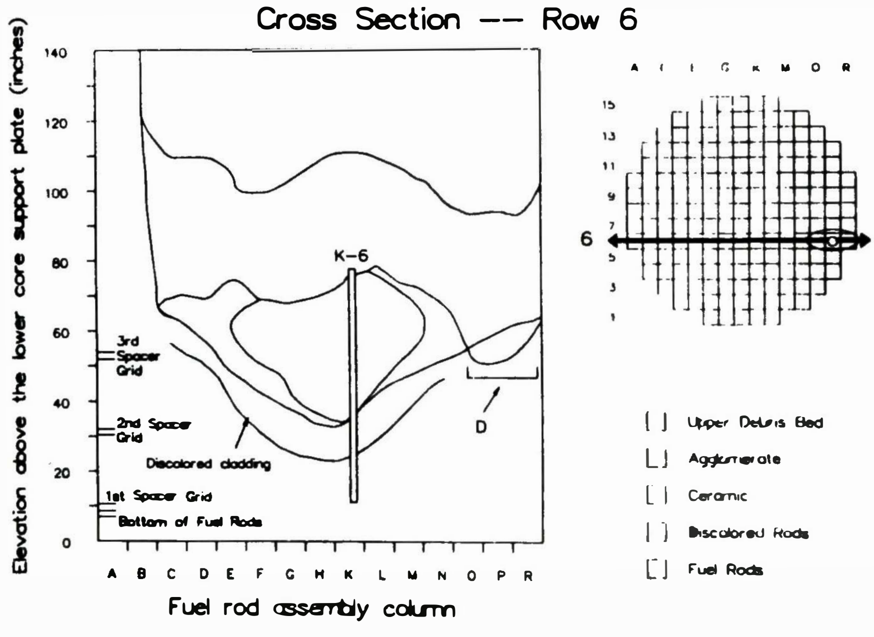

Figure 16. TMI-2 End-state Configuration Through the 6 Row of Fuel Assemblies

The graphics data are accessed through selection of option 3 from the main menu (see Figure 4). This operation produces the selection menu shown in Figure 17. Options are available to direct the diagram, whose identification is shown in the field below, to (1) the CRT screen, (2) an Epson FX series printer, (3) a Hewlett-Packard plotter (models 7450, 7475, 7470 or 7550) or (4) to a Hewlett-Packard LaserJet printer (Plus or Series II). The blank option merely clears all fields in the lower rectangle. The comments option causes all notes

```
                    DIAGRAM OUTPUT SELECTION
<F>ind ID / <B>lank / <S>creen / <P>rinter (EPSONFX) / <H>P Plotter
Laser <J>et / <N>ext / <C>omments / <E>xit ........................ [S]
```

```
A.  Diagram ID                                 [COL6XSEC      ]

B.  Sequenced Viewing:  (5 sec delay between views)
      1)  Cross section end-state configuration
      2)  Core bore drill summaries
     [-]  ... Enter Option

    Added delay (10, 20 sec or P = pause)      [  ]

    Print diagram comments (Y = yes)           [ ]
```

Figure 17. CB Diagram Selection Menu

associated with the diagram specified to be written to a file NOTE.RPT in the CB subdirectory. Sequenced viewing of the core bore drill summary data (order is D04, D08, G08, G12, K06, K09, N05, N12, O07, and O09) or cross section end-state configuration diagrams (order is column B, C, D, E, F, G, H, K, L, M, N, O, P, row 6). Added time delays may be added to the sequences or a pause between diagram displays may be selected which requires an <Enter> signal to continue. Notes for the figures may be produced by entry of 'Y' in the comment field; this option will send all comments to the NOTE.RPT file in the CB subdirectory. Each different note is printed only once; thus, if a note applies to more than one diagram, it will be attributed to the first diagram presented. This should not cause confusion since the text of the note will be sufficient to clarify its application.

The <F>ind option works as it does in the function plotting portion of CB. Identifications and descriptions of the CB graphic diagrams may be obtained by specifying the type as CORE BORE SUM (for drill hole summaries), CONTOUR MAP, CROSS SECTION, DRAWING (for miscellaneous figures) or A (for all which is the default case). In Figure 18, type = DRAWING has been selected to produce the listing of four miscellaneous CB figures. The diagram lists are written to the RPT.RPT file.

Diagrams may be identified on the find menus for display and distribution to an output device by entering a number 1 through 10 in the select field to the left of the diagram identification. When the exit option is exercised, the name of the first diagram selected will appear in the identification field of the selection menu (Figure 17) and it can be dispositioned as the user desires. If the user now enters an 'N' in the option field, the next selected diagram identification will become available in the Diagram ID field.

```
                    IDENTIFICATION OF CB DIAGRAMS

                 List CB diagrams by specification of:
             The diagram type [CONTOUR MAP     ] or All [ ]

Select
 [--] LOW. MOLTEN CONT    Interface - prev. molten mat. & intact fuel rods

 [--] LP DEBRIS BED       Lower plenum debris bed contour

 [--] OVERLAY TE POSIT    In-core thermocouple positions

 [--] TOP DEBRIS SURF.    Upper core debris top surface contour

 [--] UP. MOLTEN CONT.    Previously molten core contour surface

 [--]

 [--]

                               <N>ext / <P>revious / <E>xit ... [F]
```

Figure 18. Find Option Display List for CB Diagrams

5.0 SUMMARY

The Core Bore data base (CB) has been developed to present data describing the end-state of the TMI-2 core. Its contents are the results of research performed within the TMI-2 Accident Evaluation Program and represent the best-estimate core end-state configuration through analyses of all data collected through the end of 1986 (through the core bore sampling operation and initial core defueling). Updates to these estimates will continue to take place until all data on the plant have been obtained and analyzed.

The data base operates on IBM PC systems (PC, XT, AT or PS/2) or 100% compatible systems. It is constructed using an INEL data base management system called SAGE and operates from options selected from a hierarchical system of menus. User documentation is provided within this report and through on-line help messages (overlay forms) available in the data base.

The data base product may be acquired by any agency connected with TMI-2 research programs sponsored by DOE. Corrections to the data base or comments on its content or operation are welcomed. Revisions of this data base product will be limited to the inclusion of new/revised graphics which promote understanding of the TMI-2 core end-state, the correction of data base errors/problems reported by users and routine maintenance.

REFERENCES

1. Tolman, E. L., Smith, R. P., Martin, M. R., McCardell, R. K., Broughton, J. M., TMI-2 Core Bore Acquisition Summary Report, EG&G Idaho, Inc, EGG-TMI-7385, Rev. 1, February 1987.

2. Akers, D. W., Procter, A. E., Marley, A. W. Royval, G. S., Core Bore Gamma Spectroscopy Analysis, EG&G Idaho, Inc., (report to be published 1987).

3. Tolman, E. L., Adams, J. P., Anderson, J. L., Kuan, P., McCardell, R. K., Broughton, J. M., TMI-2 Accident Scenario Update, EG&G Idaho, Inc, EGG-TMI-7489, December 1986.

APPENDIX A

CONTENTS OF THE CB DATA BASE WITH DESCRIPTIVE NOTES

APPENDIX A INDEX

Description		Page

APPENDIX A - DESCRIPTION OF CONTENTS

Table A-1 on the following 5 pages is a table of contents for the distance function data contained in the CB data base. It has been produced by executing the <F>ind option from one of the CB plot menus and using the default 'all' selection criterion. Note that the listing could have been restrictive had an entry of core matrix location or data type been entered (see page headings). The report is alphanumerically sorted and includes the distance (x-axis) functions associated with the various functions.

Table A-2 (pages A-9 through A-11) is a listing of the end-state configuration figures contained in CB. It has been formed by exercising the diagram type option (type = CORE BORE SUM, CONTOUR MAP, CROSS SECTION, AND DRAWING).

The CB content listings are sent to the file RPT.RPT in system subdirectory \CB when a <F>ind option is selected from a plot setup menu (or the diagram selection menu) and a selection basis is specified on the function (or diagram) identification form. When the <F>ind option is executed from an identification form with an <Enter>, a message appears at the bottom of the screen "Report sent to default file RPT.RPT". NOTE: TMI-2 data base products use RPT.RPT as a scratch file; each time an action using that file is executed, the file is erased and rewritten. For this reason, a user wishing to keep the file for other use, should exit CB after generating the file and rename or disposition it.

Tables A-3 and A-4 contain the reference notes associated with the CB distance function data and the graphic data, respectively. These tables were generated by selection of the comments option on the plot or diagram disposition menus which sent the text data to file RPT.RPT. Some manipulation of the RPT.RPT files has taken place using a full-screen editing program.

TABLE A-1: IDENTIFICATION OF CB DATA BASE FUNCTIONS

List data base drilling or core bore analysis functions by:
Core matrix location [ ]; Data Type [ ]; All [A]

Identification	Description
D04DISTANCE	DIST CHANNEL CORE BORE D04 DRILLING FUNCTIONS
D04DRILL SPEED	DRILL SPEED CORE BORE D04
D04ENERGY	DRILL BIT ENERGY CORE BORE D04
D04GRGAMMADIST	DIST CHANNEL D04 GROSS GAMMA SCAN
D04GROSS GAMMA	GROSS GAMMA SCAN CORE BORE D04 (EG&G Idaho) Relative Gamma Intensity
D04PENETRATION RATE	DRILL PENETRATION RATE CORE BORE D04
D04TORQUE	DRILL BIT TORQUE CORE BORE D04
D08DISTANCE	DIST CHANNEL CORE BORE D08 DRILLING FUNCTIONS
D08DRILL SPEED	DRILL SPEED CORE BORE D08
D08ENERGY	DRILL BIT ENERGY CORE BORE D08
D08GRGAMMADIST	DIST CHANNEL D08 GROSS GAMMA SCAN
D08GROSS GAMMA	GROSS GAMMA SCAN CORE BORE D08 (EG&G Idaho) Relative Gamma Intensity
D08PENETRATION RATE	DRILL PENETRATION RATE CORE BORE D08
D08TORQUE	DRILL BIT TORQUE CORE BORE D08
G08DISTANCE	DIST CHANNEL CORE BORE G08 DRILLING FUNCTIONS
G08DRILL SPEED	DRILL SPEED CORE BORE G08

TABLE A-1: IDENTIFICATION OF CB DATA BASE FUNCTIONS

List data base drilling or core bore analysis functions by:
Core matrix location [   ]; Data Type [   ]; All [A]

Identification	Description
G08ENERGY	DRILL BIT ENERGY CORE BORE G08
G08GRGAMMADIST	DIST CHANNEL G08 GROSS GAMMA SCAN
G08GROSS GAMMA	GROSS GAMMA SCAN CORE BORE G08 (EG&G Idaho) Relative Gamma Intensity
G08PENETRATION RATE	DRILL PENETRATION RATE CORE BORE G08
G08TORQUE	DRILL BIT TORQUE CORE BORE G08
G12DISTANCE	DIST CHANNEL CORE BORE G12 DRILLING FUNCTIONS
G12DRILL SPEED	DRILL SPEED CORE BORE G12
G12ENERGY	DRILL BIT ENERGY CORE BORE G12
G12GRGAMMADIST	DIST CHANNEL G12 GROSS GAMMA SCAN
G12GROSS GAMMA	GROSS GAMMA SCAN CORE BORE G12 (EG&G Idaho) Relative Gamma Intensity
G12PENETRATION RATE	DRILL PENETRATION RATE CORE BORE G12
G12TORQUE	DRILL BIT TORQUE CORE BORE G12
K06DISTANCE	DIST CHANNEL CORE BORE K06 DRILLING FUNCTIONS
K06DRILL SPEED	DRILL SPEED CORE BORE K06
K06ENERGY	DRILL BIT ENERGY CORE BORE K06
K06PENETRATION RATE	DRILL PENETRATION RATE CORE BORE K06

TABLE A-1: IDENTIFICATION OF CB DATA BASE FUNCTIONS

List data base drilling or core bore analysis functions by:
Core matrix location [ ]; Data Type [ ]; All [A]

Identification	Description
K06TORQUE	DRILL BIT TORQUE CORE BORE K06
K09DISTANCE	DIST CHANNEL K09 CORE BORE DRILLING FUNCTIONS
K09DRILL SPEED	DRILL SPEED CORE BORE K09
K09ENERGY	DRILL BIT ENERGY CORE BORE K09
K09GRGAMMADIST	DIST CHANNEL K09 GROSS GAMMA SCAN
K09GROSS GAMMA	GROSS GAMMA SCAN CORE BORE K09 (EG&G Idaho) Relative Gamma Intensity
K09PENETRATION RATE	DRILL PENETRATION RATE CORE BORE K09
K09TORQUE	DRILL BIT TORQUE CORE BORE K09
N05DISTANCE	DIST CHANNEL CORE BORE N05 DRILLING FUNCTIONS
N05DRILL SPEED	DRILL SPEED CORE BORE N05
N05ENERGY	DRILL BIT ENERGY CORE BORE N05
N05GRGAMMADIST	DIST CHANNEL N05 GROSS GAMMA SCAN
N05GROSS GAMMA	GROSS GAMMA SCAN CORE BORE N05 (EG&G Idaho) Relative Gamma Intensity
N05PENETRATION RATE	DRILL PENETRATION RATE CORE BORE N05
N05TORQUE	DRILL BIT TORQUE CORE BORE N05
N12DISTANCE	DIST CHANNEL N12 CORE BORE DRILLING FUNCTIONS

TABLE A-1: IDENTIFICATION OF CB DATA BASE FUNCTIONS

List data base drilling or core bore analysis functions by:
Core matrix location [ ]; Data Type [ ]; All [A]

Identification	Description
N12DRILL SPEED	DRILL SPEED CORE BORE N12
N12ENERGY	DRILL BIT ENERGY CORE BORE N12
N12GRGAMMADIST	DIST CHANNEL N12 GROSS GAMMA SCAN
N12GROSS GAMMA	GROSS GAMMA SCAN CORE BORE N12 (EG&G Idaho) Relative Gamma Intensity
N12PENETRATION RATE	DRILL PENETRATION RATE CORE BORE N12
N12TORQUE	DRILL BIT TORQUE CORE BORE N12
007DISTANCE	DIST CHANNEL 007 CORE BORE DRILLING FUNCTIONS
007DRILL SPEED	DRILL SPEED CORE BORE 007
007ENERGY	DRILL BIT ENERGY CORE BORE 007
007GRGAMMADIST	DIST CHANNEL 007 GROSS GAMMA SCAN
007GROSS GAMMA	GROSS GAMMA SCAN CORE BORE 007 (EG&G Idaho) Relative Gamma Intensity
007PENETRATION RATE	DRILL PENETRATION RATE CORE BORE 007
007TORQUE	DRILL BIT TORQUE CORE BORE 007
009DISTANCE	DIST CHANNEL 009 CORE BORE DRILLING FUNCTIONS
009DRILL SPEED	DRILL SPEED CORE BORE 009
009ENERGY	DRILL BIT ENERGY CORE BORE 009

TABLE A-1: IDENTIFICATION OF CB DATA BASE FUNCTIONS

List data base drilling or core bore analysis functions by:
Core matrix location [ ]; Data Type [ ]; All [ ]

Identification	Description
009GRGAMMADIST	DIST CHANNEL 009 GROSS GAMMA SCAN
009GROSS GAMMA	GROSS GAMMA SCAN CORE BORE 009 (EG&G Idaho) Relative Gamma Intensity
009PENETRATION RATE	DRILL PENETRATION RATE CORE BORE 009
009TORQUE	DRILL BIT TORQUE CORE BORE 009
REFDISTANCE	DIST CHANNEL CALIBRATION HOLE DRILLING FUNCTIONS
REFDRILL SPEED	DRILL SPEED CALIBRATION CORE BORE
REFENERGY	DRILL BIT ENERGY CALIBRATION CORE BORE
REFPENETRATION RATE	DRILL PENETRATION RATE CALIBRATION CORE BORE
REFTORQUE	DRILL BIT TORQUE CALIBRATION CORE BORE

TABLE A-2: IDENTIFICATION OF CB DIAGRAMS

List data base drilling or core bore analysis functions by:
Core matrix location [ ]; Data Type [CORE BORE SUM]; All [ ]

Identification	Description
D04SUMMARY	D04 drill configuration and inspection summary
D08SUMMARY	D08 drill configuration and inspection summary
DRILLBACK	Background for drill pictures
G08SUMMARY	G08 drill configuration and inspection summary
G12SUMMARY	G12 drill configuration and inspection summary
K06SUMMARY	K06 drill configuration and inspection summary
K09SUMMARY	K09 drill configuration and inspection summary
N05SUMMARY	N05 drill configuration and inspection summary
N12SUMMARY	N12 drill configuration and inspection summary
O07SUMMARY	O07 drill configuration and inspection summary
O09SUMMARY	O09 drill configuration and inspection summary

List data base drilling or core bore analysis functions by:
Core matrix location [ ]; Data Type [CONTOUR MAP]; All [ ]

Identification	Description
LOW. MOLTEN CONT	Interface - prev. molten mat. & intact fuel rods
LP DEBRIS BED	Lower plenum debris bed contour
OVERLAY TE POSIT	In-core thermocouple positions

TABLE A-2: IDENTIFICATION OF CB DIAGRAMS

TOP DEBRIS SURF.	Upper core debris top surface contour
UP. MOLTEN CONT.	Previously molten core contour surface

List data base drilling or core bore analysis functions by:
Core matrix location [ ]; Data Type [CROSS SECTION]; All [ ]

Identification	Description
COL6XSEC	End-state damage configuration through 6 row
COLBXSEC	End-state damage configuration through B column
COLCXSEC	End-state damage configuration through C column
COLDXSEC	End-state damage configuration through D column
COLEXSEC	End-state damage configuration through E column
COLFXSEC	End-state damage configuration through F column
COLGXSEC	End-state damage configuration through G column
COLHXSEC	End-state damage configuration through H column
COLKXSEC	End-state damage configuration through K column
COLLXSEC	End-state damage configuration through L column
COLMXSEC	End-state damage configuration through M column
COLNXSEC	End-state damage configuration through N column
COLOXSEC	End-state damage configuration through O column
COLPXSEC	End-state damage configuration through P column

TABLE A-2: IDENTIFICATION OF CB DIAGRAMS

SMILE Cartoon

List data base drilling or core bore analysis functions by:
Core matrix location [ ]; Data Type [DRAWING]; All [ ]

Identification	Description
CB INSPECTIONS	Approx area of CSA visible during CB inspections
DRILL LOCATIONS	Ten core bore drilling locations
FP ESCAPE	Fission product escape paths
UP. GRID DAMAGE	Damage map of TMI-2 fuel assembly upper grid plate

TABLE A-3, TMI-2 CORE BORE DATA BASE NOTES (Core Bore Drill Holes)

****

Table A-2 contains notes associated with the core bore drilling functions. These notes were produced by executing the <C>omments option from the single plot setup menu with the D04ENERGY, etc. identifications. The notes were sent to the file 'NOTE.RPT' in the CB subdirectory and modifications (this memo plus page numbers, etc.) with a text editing program. NOTE.RPT is appended to so long as a user remains inside the CB program and is available for disposition when leaving the data base; however, the file is initialized each time the user enters CB. The notes below are tied to all functions from the same drill hole and would not be duplicated in NOTE.RPT if already there. If, for example, one were to request the note for O07PENETRATION RATE and later ask for the note associated with O07TORQUE a message would appear at the bottom of the PC display stating "Note was already printed" and the text would not be added to NOTE.RPT.

****

Note for D04ENERGY Number 2

Relationship to Other Drill Holes D04 represents the drill location closest to the west periphery of the reactor vessel. The axial variation in core damage suggests that D04 is near the edge of the degraded core zone.

Core Region Observations - Standing intact fuel rods are observed from the lower fuel assembly endfitting to slightly above the third spacer grid. No previously molten material is observed between the lower rod stubs.

The degraded core regions are observed to have alternating axial zones of agglomerate and intact but damaged (oxidized, distorted) rods. A region of agglomerate material was encountered above the upper core hard stop surface. This previously molten material was located at the edge of the drill hole and was encountered in two axial elevations. These data suggest that previously molten material exists above the hard stop (in the region of the debris bed) at this drill location.

Core Support Assembly and Lower Plenum Observations - The CSA was inspected down to the top of the elliptical flow distributor. A single, relatively large (1/2 in. across) particle was observed on the grid forging. The particle is thought to be either a piece of drilling debris or previously molten core debris. No significant amount of previously molten material was observed.

Inspection of the lower plenum debris was generally consistent with observations from the other inspection locations. The debris bed appears to consist of loose, rather fine particles. A few larger, solidified pieces (3-4 in. across) were observed on the surface. These larger pieces of lower plenum debris were not observed in the other drill locations. The debris bed height is estimated to be approximately 15 in. below the elliptical flow distributor plate.

Drilling Data - Automatic drilling started at about 85 in. from the rod bottom. Three unique material regions are characterized by abrupt changes in drilling resistance. The first two are located between the fourth and fifth spacer grids (at about 82-85 in. and 72-75 in.), both in the region of the "cliff" material above the core hard stop. The third is located just above the third spacer grid, very near the fuel/agglomerate interface. The drilling data suggest that this interface may have considerable metal content.

TABLE A-3, TMI-2 CORE BORE DATA BASE NOTES (Core Bore Drill Holes)

Note for DOBENERGY Number 3

Relationship to Other Drill Holes - Metallic segregations were common in this hole and were also observed in the central core locations (GOB, K09, K06) and the peripheral location (O09). These fuel assemblies lie in a general east-west band across the core.

No molten ceramic region was observed in D08, consistent with the other peripheral drill location observations. This drill location had the smallest agglomerate thickness of any drill location.

Core Region Observations - Standing intact fuel rods are observed from the lower fuel assembly endfitting to above the third spacer grid. The upper 6 in. of rods (next to the rod/agglomerate interface) appeared discolored.

The agglomerate region of fuel pellets and/or rods surrounded by previously molten material is only about 5-6 in. thick. The fuel pellets in the agglomerate region are well defined, and in some cases the vertical structure of the fuel pellets is discernible. At about the axial midplane of the agglomerate region, several different metallic-like structures were observed, having various shapes ranging from small, irregular segregations to "vein-line" structures oriented in different directions.

Core Support Assembly Observations - The CSA was inspected down to the top of the elliptical flow distributor. Fine sandy material, probably drill cuttings, was observed on the flow distributor plate and the inside surface of the elliptical distributor. No previously molten material was observed in the regions inspected.

Drilling Data - Automatic drilling started at about 60 in. from the rod bottom, near the top of the agglomerate region. There appear to be significant increases in drill resistance at about 56-58 in. and again at 48-50 in. above the bottom of the fuel rod. These distances are generally consistent with the upper and lower surfaces of the agglomerate.

Note for GOBENERGY Number 4

Relationship to Other Drill Holes - The observations at GOB are generally consistent with the other central core locations (K09 and K06) and show the molten ceramic material to fill the region between the second and fourth grids. The ceramic material at all three locations has metallic segregations. GOB showed the most "vein-like" metallic structures of any of the central drill locations. The metallic structures in K06 location were irregular, "glob-like" structures.

Core Region Observations - Standing intact fuel rods are observed from the lower fuel assembly endfitting up to the second spacer grid and show some discoloration near the agglomerate interface. Also, some solidified, previously molten material is observed between rods in this region.

The agglomerate region was only slightly discernible and is limited to the very bottom and possibly the very top of the drill hole.

Note for G08ENERGY Number 4

Most of the material above the standing fuel rods appear to be uniformly molten ceramic. This region appears to be over 40 in. thick and shows the following evidences of thorough melting:

- The only fuel pellet remnant is within an inch or so of the top of fuel rods.
- Most of the observed metal-like structure in the ceramic shows evidence of having been melted; i.e., vein-like structure as if the ceramic solidified and fractured, allowing the molten metal to fill the fractures. The only exceptions are (a) a metallic grid-like structure (possibly a spacer grid remnant) and (b) a large metallic segregation near the top of the hole.
- The bottom 12-14 in. of ceramic is free of metal segregations or veins.

Core Support Assembly Observations - Fine material, probably drill cuttings, was observed on the flow distributor plate, the grid forging, and the instrument support plate. A cylindrical metallic plug was seen lodged in a hole in the grid distributor plate and is likely a piece of the lower grid or fuel assembly endfitting that was previously drilled and had fallen to the CSA region. Previously molten core material was not observed in the CSA at this drill location.

Drilling Data - Material in the G08 location was difficult to drill and resulted in frequent alignment difficulties. As a result, almost the entire core bore was drilled in the manual drilling mode.

Note for G12ENERGY Number 5

Relationship to Other Drill Holes - This drill location is about mid-core radius, and the thickness of the agglomerate/ceramic region is greater (25-30 in.) than observed at the peripheral locations (15-20 in.). The disoriented nature of fuel pellets in the upper part of the agglomerate in G12 was similar to that observed at D08.

Core Region Observations - Standing intact fuel rods are observed from the lower fuel assembly endfitting to the third spacer grid. The rods appeared discolored next to the agglomerate/rod interface. A small cavity was observed at the rod/agglomerate interface and may have been caused by the drilling operation.

In the lower agglomerate region, standing rod remnants were observed surrounded by previously molten core material. In the upper region, fuel pellets were also discernible, although they did not show a vertical structure but have a more random orientation. Near the lower regions of the agglomerate, a grid-like metallic pattern was observed.

The video data are inadequate to clearly discern whether or not a molten ceramic region in the middle of the agglomerate region is present.

TABLE A-3, TMI-2 CORE BORE DATA BASE NOTES (Core Bore Drill Holes)

Note for G12ENERGY Number 5

Core Support Assembly Observations - Loose, fine debris (most likely drill cuttings) was observed on the flow distributor plate, grid forging, and the elliptical flow distributor. No solidified previously molten material was observed in the CSA area.

Drilling Data - The automatic drilling started at about the rod/agglomerate interface, just above the third spacer grid. A significant increase in drilling resistance was encountered for 2-3 in. about mid-way between the second and third spacer grids. However, the change also is coincident with drill start-up; therefore, it is difficult to conclude that the change in drill data is related to a localized change in material structure.

Note for K06ENERGY Number 6

Relationship to Other Drill Holes - The observations from K06 and K09 (central core region) are similar relative to the material structures in agglomerate and molten ceramic regions and the oxidation of the lower intact rod stubs. The relocated core materials penetrated to approximately the second spacer grid (approximately 20 in. above the bottom of the fuel rods) in both these locations. The discoloration of the lower fuel rod stubs indicates that the reactor vessel coolant level was below the fuel rods during the initial core heatup.

Core Region Observations - Standing intact fuel rods are observed from the lower fuel assembly endfitting to above the second spacer grid. Discoloration of the cladding occurs in the upper regions of the fuel rod stubs below the agglomerate interface. Previously molten material is observed between the lower rod stubs and appears to be present in the lower fuel assembly endfitting. The interface between the lower rod stubs and the agglomerate is not well defined but appears to cover an axial region approximately 5-10 in. below the second spacer grid to approximately 5-10 in. above the second spacer grid.

The molten ceramic region extends from about midway between the second and third spacer grids to the fourth spacer grid (approximately 30-35 in.). Rounded, irregular metallic segregations occur in the upper regions of the molten ceramic.

Core Support Assembly Observations - Loose, gravel-type debris, most likely from the drilling, was observed on the elliptical flow distributor. Similar drill cuttings and a small piece of previously molten material was observed on the flow distributor plate; however, large quantities of previously molten material were not observed in the regions inspected.

Drilling Data - Automatic drilling started at about 60 in. from the rod bottom, several inches into the agglomerate region. The data show significant localized variations in the drilling resistance between the second the third spacer grids. This is consistent with the transition region between the agglomerate and intact rods.

TABLE A-3, TMI-2 CORE BORE DATA BASE NOTES (Core Bore Drill Holes)

Note for K09ENERGY Number 7

Relationship to Other Drill Holes - The observations in the core region at K09 indicate that the center regions of the core experienced the most severe temperatures and degradation. This is consistent with the observations at the other drill locations near the core center (K06 and G08). The agglomerate/rod interface at K09 was at the lowest axial elevation of any of the core bore locations.

The region of discolored lower fuel rod stubs extends farther downward than in any other drill location, and the quantity of solidified previously molten material between the lower rod stubs is also greater than observed at any other drill location, except perhaps K06. The lower rod stub discoloration suggests that the reactor vessel water level was below the lower fuel assembly endfitting during the initial core heatup. K09 is the only location in which solidified melt was observed in and just below the lower endfitting.

Core Region Observations - Standing intact fuel rods are observed from the lower fuel assembly endfitting to the second spacer grid. Previously molten material is observed between rods near the first spacer grid and is also observed in the spaces around the lower endfitting.

The lower agglomerate region is relatively thin (approximately 4-6 in.), with observable standing fuel rod remnants surrounded by previously molten core material.

The molten ceramic zone is approximately 50 in. thick and appears for the most part homogeneous. Metal segregations and vein-like structures that appear to be fully or partially previously molten were observed in the lower 20 in. of the ceramic mass. A large metallic-like structure that appeared partially or perhaps fully molten was observed near the top several inches of the drill hole.

Core Support Assembly and Lower Plenum Observations - Fine, loose particles, probably drill cuttings, were observed on the flow distributor plate. No significant quantities of previously molten core material were observed.

The lower plenum debris appears as a bed of loose pebbles with diameters less than 0.5 in., much the same as observed in N12. Based on the inspection data (obtained after the lower plenum core bore was taken), the upper surface of the debris bed is estimated to be about 8 in. below the elliptical flow distributor. Pieces of fuel rods were observed on the surface of the debris and most likely fell during the drilling operation.

Drilling Data - The automatic drilling started at about 70 in. from the rod bottom near the top of the molten ceramic region. There appears to be some variability in the material composition, as inferred from the changes in the drilling parameters between the second/third and the third/fourth spacer grids. The localized changes in drill resistance are consistent with observed metallic-like structures interlaced with the ceramic material.

TABLE A-3, TMI-2 CORE BORE DATA BASE NOTES (Core Bore Drill Holes)

Note for N05ENERGY Number 8

Relationship to Other Drill Holes - The agglomerate structure with vertical fuel rod remnants surrounded by resolidified material is similar to that observed at other drill holes near the core periphery, e.g., 007, N12, 009, and D04.

Core Region Observations - Standing rods extend from the lower fuel assembly endfitting to the third spacer grid (located about 47 in. from the bottom of the fuel rod). The upper 6 in. of the fuel rods appear to have localized regions of discoloration. However, the rods do not appear distorted. The third spacer grid (in contact with the agglomerate) appears to have undergone some melting on one side but appears to be intact on the opposite side.

The agglomerate above the third spacer grid extends to at least 50 in. and includes previously molten material. Above 50 in., no useful video data were recorded. The previously molten material fills most of the spaces between the fuel rods. Since some vertical fuel rod structure is discernible, it appears that the relocated core material did not completely melt the original fuel rods. The cladding material surrounding the intact rods in many cases is indistinguishable from the surrounding previously molten material. Occasional metallic (shiny) pieces are observed next to the fuel pellets in the orignal cladding region. Fuel pellet boundaries are commonly discernible where the drill bit cut into the fuel rods.

Core Support Assembly Observations - The video camera was lowered into the CSA region but was blocked by loose debris at the flow distributor plate. The debris, most likely from the drilling operation, consists of irregular size drill cuttings, broken and split fuel rods, and a solid cylinder about the size of the core bore sample that is most likely a piece of the lower grid.

The smaller diameter drilling hardware was used to drill through the debris above the flow distributor plate in an attempt to obtain a sample of any previously molten material above the elliptical flow distributor. The drilling parameters indicated no significant drilling resistance below the distributor plate. After CSA drilling, the drill hole was still blocked with drill cuttings preventing visual characterization of the CSA below the distributor plate.

Solidified previously molten material nearly fills the space between the lower grid and the flow distributor plate. The material is located to the north, east, and northeast of the drill hole (in the regions of 004, 005, 006, and N06). An observable instrument guide tube appears to have some surface damage.

Drilling Data - The automatic drilling started in the lower agglomerate region just above the third spacer grid. The torque and RPM data are uniform below the third grid (until the lower fuel assembly endfittings are encountered). The penetration rate and energy data show that the material between the second and third spacer grids has significantly lower drilling resistance than the material between the first and second spacer grids. This data trend suggests that the materials between the two spacer grids may be different. One source of this difference may be oxidation of the rods between the second and third grid.

TABLE A-3, TMI-2 CORE BORE DATA BASE NOTES (Core Bore Drill Holes)

Note for N12ENERGY Number 9

Relationship to Other Drill Holes - The agglomerate structure with vertical fuel rod remnants surrounded by resolidified material is similar to that observed at other drill holes near the core periphery, e.g. 007, N05 and 009. The form and pattern of molten material in the CSA is similar to that observed in locations N05, 007 and 009. However, no significant amounts of previously molten material were observed on the upper surface of the elliptical flow distributor, suggesting that this location was not a direct flow path to the lower plenum.

Core Region Observations - Standing intact fuel rods are observed from the lower fuel assembly endfitting to the third spacer grid. Discoloration of the standing fuel rods is observed from below the third spacer grid to the rod/agglomerate interface. The discoloration appears to become more pronounced toward the agglomerate interface.

An agglomerate region of previously molten material surrounding fuel rod remnants is observed starting above the third spacer grid and extending to the top of the drill hole. The cladding is generally non-discernible from the surrounding previously molten material. There were a few metallic remnants observed in the region of the cladding (adjacent to fuel pellets). The usefulness of the video images was limited above about 48 in. because of poor lighting and focus.

Core Support Assembly and Lower Plenum Observations - The lower plenum debris appears as a bed of loose pebbles with diameters less than 0.5 in. The upper surface of the debris bed is estimated to be about 18 in. below the elliptical flow distributor. The debris particles appeared to "bounce" away as the camera was lowered and contacted the debris bed.

"Cascades" of solidified, previously molten material were observed in areas to the northeast of N12 just above and below the lower grid flow distributor plate. The material appears to be similar in texture to the molten ceramic material in the core region and looks like it froze in the CSA regions as it flowed downward, thus resembling a "wall" or "curtain".

Drilling Data - The automatic drilling data for N12 started above the upper crust hard stop location. The abrupt change in drill resistance about midway between the third and fourth grid spacers likely indicates the lower agglomerate interface and may indicate a metallic rich crust.

Note for 007ENERGY Number 10

Relationship to Other Drill Holes - The agglomerate region in the core is similar to that in other peripheral drill locations (D04, N05 and N12). The form and pattern of molten material in the CSA are similar to that observed in locations N05, N12 and 009. More previously molten material was observed in the CSA region at this location than at any other location. The 007 data suggest that a core material flow path to the lower plenum was to the southeast, most likely in fuel assembly P06 and/or P07.

TABLE A-3, TMI-2 CORE BORE DATA BASE NOTES (Core Bore Drill Holes)

Note for 007ENERGY Number 10

Core Region Observations - Standing intact fuel rods are observed from the lower fuel assembly endfitting to the third spacer grid.

The agglomerate region consists of fuel pellets and/or rods surrounded by previously molten material and is estimated to be about 15 in. thick, between the third and fourth spacer grids.

Core Support Assembly and Lower Plenum Observations - The amount of previously molten core material observed in this location is greater than at any other location. The material resembles the molten ceramic materials observed in the core region and looks like it froze in the CSA regions as it flowed downward, thus resembling a "wall" or "curtain". The material appears to encircle the hole in the grid forging plate.

Based on the CSA observations from N05 and N12, it was anticipated that previously molten core material was likely in the CSA region. The small-diameter drilling hardware was used to sample the material in the CSA region below 007. However, the drilling parameters indicated no significant drilling resistance and no CSA sample material was retrieved in the sample canister.

There appeared to be some damage to a core support post and in-core instrument guide tube above the flow distributor plate. The forging structure was discolored in places, indicating high temperatures.

Drilling Data - Automatic drilling started at about 60 in. from the rod bottom, near the top of the agglomerate region. There appear to be significant changes in drill resistance; however, because the drill was stopped several times, inferences relative to material composition are not too meaningful.

Note for 009ENERGY Number 11

Relationship to Other Holes - 009 is similar to N05 and 007, showing significant amounts of previously molten core material in the CSA regions, particularly in the 'P' row of fuel assemblies. These data suggest that core (crust) failure may have occurred extensively in the east quadrant of the core.

Core Region Observations - Standing intact fuel rods are observed from the lower fuel assembly endfitting to just below the third spacer grid.

The agglomerate region consists of fuel pellets and/or rods surrounded by previously molten material and is estimated to be about 15 in. thick between the third and fourth spacer grids. The rod remnant structure in the lower few inches of the agglomerate is well defined. Because of poor image quality in the upper regions, the structure cannot be determined; however, metallic segregations are observed in the upper regions.

Core Support Assembly Observations - The CSA was inspected down to the top of the elliptical flow distributor. Fine, sandy material, probably drill cuttings, was observed on the grid distributor plate and the inside surface of the elliptical flow distributor. Although no physical damage to the structures is discernible, significant amounts of previously molten material are observed, particularly to the east in fuel assemblies P08, P09 and P10.

TABLE A-3, TMI-2 CORE BORE DATA BASE NOTES (Core Bore Drill Holes)

Note for 009ENERGY Number 11

Drilling Data - Automatic drilling started at about 60 in. from the rod bottom, near the top of the agglomerate region. There were several shutdown periods, so possible differences in material structure are difficult to identify. One area between the second and third spacer grids, between approximately 8-12 in., appears to have a significant increase in drilling resistance. This area may contain relocated metallic material.

TABLE A-4: NOTES ASSOCIATED WITH CB DIAGRAMS

Note for D04SUMMARY

Note D04 A - Varying damage zone. Agglomerate zones are standing rods with solidified melt filling spaces. Rods between agglomerate zones are distorted, discolored and contain varying amounts of solidified melt between them.

Note for D04SUMMARY

Note D04 B - No solidified melt in open spaces.

Note for D04SUMMARY

Note D04 C - Chunk of material - possibly solidified melt or drilling debris.

Note for D04SUMMARY

D04 Note D - Top of lower plenum debris bed 15 inches below EFD; gravelly debris bed with larger, lava-like chunks on top.

Note for D08SUMMARY

D08 Note A - Agglomerate with fuel pellets preserved and surrounded by prior molten meterial.

Note for D08SUMMARY

Note D08 C - Drill cuttings or fine sandy debris.

Note for G08SUMMARY

G08 Note A - Large metallic segregation.

Note for G08SUMMARY

G08 Note B - Nearly vertical network of metallic "veins".

Note for G08SUMMARY

G08 Note C - Metallic "vein".

TABLE A-4: NOTES ASSOCIATED WITH CB DIAGRAMS

Note for G08SUMMARY

G08 Note D   Metallic "veins" or remnants.

Note for G08SUMMARY

G08 Note E - Possible remnant of spacer grid.

Note for G08SUMMARY

G08 Note F - Fuel pellet remnant.

Note for G08SUMMARY

G08 Note G - Standing fuel rods, possible some solidified melt between rods. Some discoloration of rods.

Note for G08SUMMARY

G08 Note H - Drill cuttings or sandy debris.

Note for G08SUMMARY

G08 Note I - Large cylindrical fragment, likely drilling debris.

Note for G08SUMMARY

G08 Note J - Camera's descent blocked above elliptical flow distributor (EFD not seen).

Note for G12SUMMARY

Note G12 A - Fuel remnants seem to be disoriented in this zone (individual fuel pellets).

Note for G12SUMMARY

Note G12 B - Possible thin zone of homogeneous ceramic.

TABLE A-4: NOTES ASSOCIATED WITH CB DIAGRAMS

Note for G12SUMMARY

Note G12 C - Possible grid pattern of metal in agglomerate (spacer grid?).

Note for G12SUMMARY

Note G12 D - Small cavity at top of rod stubs.

Note for G12SUMMARY

Note G12 E - Rods partially discolored in this region.

Note for G12SUMMARY

Note G12 F - Loose fine debris, probably drill cuttings.

Note for K06SUMMARY

K06 Note A - Rounded irregular metallic segregations in this region.

Note for K06SUMMARY

K06 Note B - Solidified melt droplets between rods and some remnant rod structure in agglomerate in this region.

Note for K06SUMMARY

K06 Note C - Possible melt globule in slot in end fittings.

Note for K06SUMMARY

K06 Note D - Possible solidified melt globule.

Note for K06SUMMARY

K06 Note E - Loose debris resembling gravel.

Note for K09SUMMARY

K09 Note A - Porous metallic segregation.

TABLE A-4: ·NOTES ASSOCIATED WITH CB DIAGRAMS

Note for K09SUMMARY

K09 Note B - Several intersecting irregular "veins" of metal with irregular segregations.

Note for K09SUMMARY

K09 Note C - Partially molten spacer grid.

Note for K09SUMMARY

K09 Note D - Rod structure visible only for 4 to 6 inches above interface.

Note for K09SUMMARY

K09 Note E - Rods are discolored in this zone. Some solidified melt between rods at lower spacer grid.

Note for K09SUMMARY

K09 Note F - Solidified melt in this space and in slots in lower end fitting.

Note for K09SUMMARY

K09 Note G - Lower plenum debris bed.

Note for N05SUMMARY

N05 Note A - Debris bed surface determined from sonar survey before top of fuel assembly was removed.

Note for N05SUMMARY

Note N05 B - Debris bed removed to top of agglomerate mass before drilling hole N05.

Note for N05SUMMARY

N05 Note C - Remnants of fuel rod structure - spaces between filled with

TABLE A-4: NOTES ASSOCIATED WITH CB DIAGRAMS

Note for NO5SUMMARY

previously molten material. Occasional metallic remnants observed near fuel pellets.

Note for NO5SUMMARY

NO5 Note D - Slight discoloration of rods here.

Note for NO5SUMMARY

NO5 Note E - Camera stopped here because of debris blocking hole in plate.

Note for NO5SUMMARY

NO5 Note F - Solidified fuel melt observed east, northeast and north of drill hole.

Note for N12SUMMARY

N12 Note A - Agglomerate - Vertical fuel rod structure with solidified prior molten material between. Rods not totally oxidized. Fused material fills most space between rods.

Note for N12SUMMARY

Note N12 8 - Discoloration occurs in some areas.

Note for N12SUMMARY

Note N12 C - Solidified prior molten material in area north, northeast and south of N12.

Note for N12SUMMARY

Note N12 D - Drill cuttings or sand size debris.

Note for N12SUMMARY

Note N12 E - Top of lower plenum debris bed.

TABLE A-4: NOTES ASSOCIATED WITH CB DIAGRAMS

Note for N12SUMMARY

Note N12 F - Loose pebbles (1/2 inch or less) and a fragment of fuel rod spring. Pebbles move when camera touches them. Spring and rod fragments probably fell from drill string after it broke through end fittings.

Note for 007SUMMARY

007 Note A - Agglomerate - many rod remnants still standing with most open space filled with fused material that ran down rods from above.

Note for 007SUMMARY

007 Note B - Cascades, curtains, piles, flows of molten material congealed in process of flowing through holes in flat plate distributor and forgings. Large volumes of material, especially to the east, southeast, and south.

Note for 007SUMMARY

007 Note C - Top of lower debris bed composed of loose pebbly material.

Note for 009SUMMARY

009 Note A - Cavity with loose sandy material cascading out.

Note for 009SUMMARY

009 Note B - Metallic chunk or segration.

Note for 009SUMMARY

009 Note C - Metallic segregation makes up one wall of drill hole.

Note for 009SUMMARY

009 Note D - Remnant rod structure visible in agglomerate (image quality is so poor that remnant rod structure cannot be confirmed in agglomerate above this zone).

TABLE A-4: NOTES ASSOCIATED WITH CB DIAGRAMS

Note for 009SUMMARY

009 Note E - Some possible solidified melt between rods.

Note for LP DEBRIS BED

Data from the lower plenum inspections have been compiled and evaluated to construct the contour map. It is estimated that the debris bed contains between 10 and 20 metric tons of previously molten material. This is consistent with previous estimates that were based on neutron measurements made before visual access was available, suggesting that between 5 to 24 metric tons of fuel were present in the lower plenum.

Selected debris particles retrieved from the lower plenum have been examined with the following major findings:

- Density of the previously molten material ranged from 6.6 to 8.1 g/cc. (The original density of the fuel pellets was about 10 g/cc.)
- Particle porosity varied from 5 to 40%.
- The material is composed mostly of UO_2 and ZrO_2 with small metallic inclusions composed primarily of Al_2O_3, FeO, Cr_2O_3, SiO_2, and NiO.
- The estimated peak temperature reached by the material is approximately 3100 K, which is basically equivalent to the melting point of UO_2.
- Cesium-134 was substantially retained (10 to 20%) in the previously molten material; retention of antimony and ruthenium was less than 10%; and europium and cerium were retained at nearly 100%.

Note for OVERLAY TE POSIT

Coolant flow into the reactor vessel at the time of the pump transient was substantiated by both the in-core thermocouple alarm data and the source range monitor response. The locations of those core thermocouples that were cooled (alarmed on-scale) as a result of the pump transient are shown in the figure. Also shown is the best-estimate contour map of the end-state of the lower crust (see also LOW. MOLTEN CONT). Notice that only those thermocouples generally on the periphery of the the lower crust were cooled. Thermocouples towards the center of the core would have been severely damaged, probably melted, and their relocated junctions located within the higher-temperature regions of the consolidated core material. The thermocouple alarm data suggest that coolant flow through the core occurred only at the core periphery which is consistent with the damaged core configuration shown in the end-state diagrams. Subsequent alarm data between 180 and 200 min. show that all the peripheral core thermocouples, initially cooled by the pump transient, again alarmed off-scale high prior to emergency core coolant injection at 200 min.

Note for TOP DEBRIS SURF.

The upper core debris top surface contour marks the boundary between the core

TABLE A-4: NOTES ASSOCIATED WITH CB DIAGRAMS

Note for TOP DEBRIS SURF.

void region and the debris bed. The cavity volume represents approximately 26% of the original core volume and extends nearly across the full diameter of the upper core region. The average depth of the cavity is approximately 1.5 meters; in places the maximum depth approaches 2 meters. Standing fuel rod assemblies remained only on the core periphery, with no more than two of the 177 original fuel assemblies appearing to be totally intact. Only 42 fuel assemblies had full-length fuel rods intact.

The contour of the upper surface of the debris bed was determined using acoustic topography.

Note for UP. MOLTEN CONT.

The upper previously molten material contour map marks the boundary between the upper core debris bed and the previously molten material. The debris material was extensively probed to determine its depth and the contour map was derived from this data.

The debris bed was sampled in eleven regions. The particles were analyzed to determine that:

Most contained regions of U-Zr-O melt --> temperatures > 2200K.
Many of these were (U,ZR)O2 --> temperatures > 2800 K.
A few examples of UO2 were found --> temperatures up to 3100K.
Based on the relatively unstructured appearance observed for much of the fuel, much of the fuel remained at <2000 K or was exposed to high temps for only a short time.

Note for COL6XSEC

Fuel assemblies O, P and R: The best-estimate end-state configuration of the degraded core, the relative timing of the in-core instrument alarms, and the inspection of the CSA region all indicate core failure in the southeast quadrant of the reactor vessel in the bracketed area shown.

Note for COL6XSEC

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******************************************************************************
*   NOTE: The following note for core cross section configurations applies   *
*   to all cross section diagrams - COLBXSEC, COLCXSEC, COLDXSEC, COLEXSEC,  *
*   COLFXSEC, COLGXSEC, COLHXSEC, COLKXSEC, COLLXSEC, COLMXSEC, COLNXSEC,    *
*   COLOXSEC, and COLPXSEC.                                                  *
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TABLE A-4: NOTES ASSOCIATED WITH CB DIAGRAMS

CORE CROSS SECTION CONFIGURATIONS

Cross section configuration diagrams have been drawn based on contour maps of the upper core debris bed, the molten core region and the lower standing fuel rod stubs. These cross sections, for fuel columns B through P plus row 6, depict four distinct regions within the original core volume:

Core void - A cavity which existed at the top of the core with a volume of 9.3 cubic meters;

Upper debris bed - Various sized particles, ranging from 0.6 to 1.0 meters in depth, which rested on a solid crust that was located at about the core mid-plane;

Previously molten material - A region containing "agglomerate" and "ceramic" previously molten core materials; and

Standing fuel rods assemblies - Fuel rod stubs which extend from the bottom of the core upward to the previously molten core material.

Refer to data base figures TOP DEBRIS SURF., UP. MOLTEN CONT. and LOW. MOLTEN CONT for the contour maps and to the notes associated with these figures for additional information.

Note for CB INSPECTIONS

The core bore visual inspections provided the first opportunity for assessment of possible damage to the core support assembly. Visual inspection of the CSA was performed by lowering a camera into each core bore hole. Approximately 50% of the CSA region was visible from the ten core bore locations; these areas are identified by the circles on the drawing.

Note for FP ESCAPE

The principal fission product repositories are the reactor building components; they contain approximately 98% of the total inventory of non-gaseous fission products. About 1% of the radioactive cesium and 2% of the radioactive iodine were transported from the reactor building to the auxiliary building, mainly by continued operation of the letdown system. Of this, only very small amounts of radioactive iodine and cesium were released to the environment during the accident (approximately 15 Ci of iodine 131 and less than 1 Ci of cesium, or 10**-4 and 10**-10% of the total core inventory, respectively). Approximately 1% of the radioactive fission gases was released to the environment during the accident. The krypton content of the reactor building, 45% of the total core inventory, was vented to the atmosphere in 1980 as a controlled release. Those components outside of the reactor building that have been sampled for fission products are the makeup-purification (MUP) demineralizers in the auxiliary building and the submerged demineralizer system (SDS) components in the fuel handling building. The MUP system was operated for a time during the accident until the demineralizer became clogged. After this time, the

TABLE A-4: NOTES ASSOCIATED WITH CB DIAGRAMS

Note for FP ESCAPE

MUP system was operated with the demineralizer bypassed. The total amounts of fission products that were deposited in the MUP were very small, typically less than 1% of the total inventory of specific isotopes. The SDS was used to remove fission products from the reactor coolant. Therefore, the radioactivity that was deposited in this system was transported to the fuel handling building in a controlled manner and does not represent accident release from the reactor building.

Three reactor building components were examined that were outside of the RCS. The air coolers were expected to contain significant amounts of fission products since they contain large surface areas and a large volume of contaminated air flowed through them during and following the accident. Based on the fission product measurements, it was determined that less than 1% of any isotope was deposited on their surfaces. The reactor coolant drain tank was expected to contain significant amounts of fission products, since over half of all reactor coolant which flowed out of the RCS flowed through this tank. Again, less than 1% of any isotope was found in the samples extracted from this tank. The reactor building sump was not sampled until after cleanup operations of its contents (water and sludge) using the SDS were completed. Thus, the amount of radioactivity which reached the sump during the accident has not been determined. The current best-estimate of the fission product transport from the reactor building is via the letdown system.

Analysis of an RCS surface sample obtained from a resistance temperature detector (RTD) removed from the hot leg of the A steam generator has led to the conclusion that RCS surfaces do not now represent a significant repository for for fission products.

Two control rod drive leadscrews have been examined for surface deposits of radionuclides. If fission products had been deposited on these surfaces during the accident, they were largely removed since the accident. It is concluded that surfaces of the reactor vessel represent only a minor fission repository.

The reactor core is believed to be a principal repository for fission products. The analysis results from samples taken from the upper debris bed reveal that high-volatility products like iodine and cesium were retained to a much higher degree and the medium-volatile fission products like ruthenium and antimony were retained to a lower degree than expected based on the temperatures which were reached by the core during the accident and the volatilities of these fission products. Low-volatile fission products, such as europium and cerium, were essentially completely retained, as expected, within the accuracy of the analyses.

Note for UP. GRID DAMAGE

Damage to the upper fuel assembly grid was determined from video inspections performed after removal of the assembly from the reactor vessel. Two major damage zones exist and indicate the presence of multidimensional steam/gas

TABLE A-4: NOTES ASSOCIATED WITH CB DIAGRAMS

Note for UP. GRID DAMAGE

flow within the reactor core during the period of high core temperatures. Within each damage zone, localized variations in damage are evident. For example, within the limited area above only one fuel assembly, localized ablation of the stainless steel structure is observed; however, grid structures adjacent to the ablated zone appear to be undamaged. Also, in some regions, the molten grid material appears to have a foamy-like, high-porosity texture which occurs when stainless steel oxidizes near the melting temperature. Previously molten material within a few inches of the foamy-like structure appears essentially unoxidized, suggesting that some of the hot gases exiting the core were oxygen deficient, probably high in hydrogen. Thus, the upper fuel assembly grid damage suggests that highly non-uniform flow patterns were present at the time of grid damage; and localized gas conditions (composition, flow rate and temperature) varied significantly within the flow stream.