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AUTOCASK (AUTOmatic Generation of 3-D CASK Models)

A Microcomputer Based System for Shipping Cask Design Review Analysis

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DISCLAIMER

AUTOCASK (*AUTO*matic Generation of 3-D *CASK* models) is a microcomputer-based system of computer programs and databases developed at the Lawrence Livermore National Laboratory (LLNL) for the structural analysis of shipping casks for radioactive material. Model specification is performed on the microcomputer, and the analyses are performed on an engineering workstation or mainframe computer.

AUTOCASK is based on 80386/80486 compatible microcomputers. The system is composed of a series of menus, input programs, display programs, a mesh generation program, and archive programs. All data is entered through fill-in-the-blank input screens that contain descriptive data requests.

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The authors thank the following people for their contributions to the development of *AUTOCASK*.

Henry Lee, Li Yang, and Daniel Huang of the U.S. Nuclear Regulatory Commission for their financial support and technical direction.

Gerald Mok of Lawrence Livermore National Laboratory for his technical contributions.

Lawrence Livermore National Laboratory has developed a microcomputer-based analysis preparation system to assist the Nuclear Regulatory Commission in performing structural analyses of shipping casks for radioactive material. The cask model is specified and the analysis input is generated on the microcomputer. Then the three-dimensional quasi-static impact analysis is performed on an engineering workstation or mainframe computer. ***AUTOCASK*** documentation includes the ***AUTOCASK*** user's manual, including the program reference, and Lawrence Livermore National Laboratory documents for NIKE3D and TAURUS.

1

Introduction

AUTOCASK —— *AUTO*matic Generation of 3-D *CASK* models *

From the inception of commercial nuclear power production to this day, spent fuel has been accumulating in reactor fuel pools across the country. When a permanent nuclear waste repository is established, as required by Federal law, this fuel will be shipped from the reactor sites to the repository. In anticipation of increased license submittals for spent-fuel shipping casks, the U.S. Nuclear Regulatory Commission requested the Lawrence Livermore National Laboratory to develop an integrated software system to conduct confirmatory analyses of the casks. The purpose of the analyses is to ensure structural integrity under a series of normal operating loads and hypothetical accident loads as specified in Title 10 of the *Code of Federal Regulations* (1983).

AUTOCASK is a microcomputer based system of computer programs developed by LLNL for the structural analysis of shipping casks for radioactive material. *AUTOCASK* is composed of a series of menus, input programs, display programs, a mesh generation program, and archive programs. After the necessary input data is provided, *AUTOCASK* generates a finite element analysis input file which is then transferred to an engineering workstation or mainframe computer. On the workstation or mainframe, a quasi-static analysis is performed using an LLNL developed finite element program, and the results are displayed graphically on the workstation monitor. Graphic output can also be printed.

* This work was supported by the United States Nuclear Regulatory Commission under a Memorandum of Understanding with the United States Department of Energy.

AUTOCASK uses a series of menus to coordinate input programs, geometry display programs, terminal programs, data archive programs, and databases. **Figure 1-1** illustrates the menu structure. The menus are ordered according to the stages of an analysis.

AUTOCASK requires only the press of a single key to make menu and subtask selections. *AUTOCASK* indicates the available selections on each display screen and describes what action *AUTOCASK* will take. For example: on the main menu *AUTOCASK* indicates that the appropriate keys to press are **1 2 3 4 5** and **Q**; the action taken after pressing key **Q** is to return to DOS.

Data is entered through fill-in-the-blank input screens. Full editing features are available (insert, delete, move cursor, overtype, etc.), and data items are accepted when the cursor is moved to another data field.

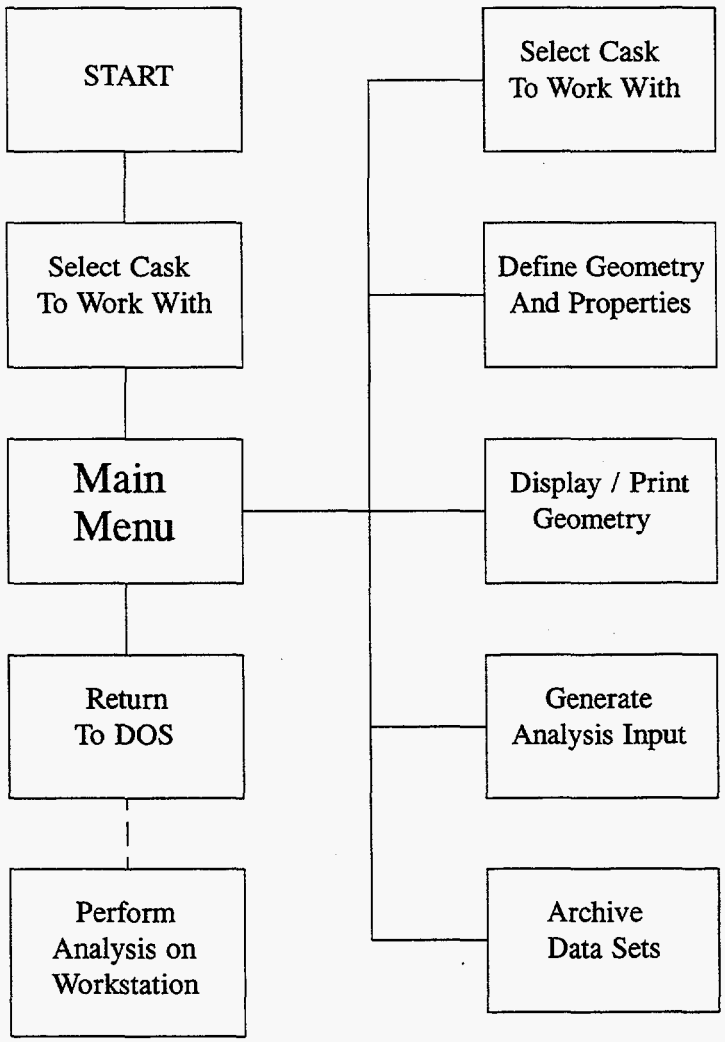

Figure 1-1. *AUTOCASK* menu structure.

AUTOCASK is designed for 80386 DOS based microcomputers. The minimum required hardware configuration is:

80386 based DOS microcomputer
- 40 Mbyte hard disk drive
- 1.44 Mbyte 3½ inch floppy disk (high density)
- 2 Mbyte RAM
- CGA Board (Color Graphics Adapter)
- Color Graphics Monitor
- IBM or EPSON Graphics printer

AUTOCASK performance is improved by using an 80387 math co-processor or an 80486 class of machine. A typical upgraded configuration is:

80486 DX-66 based DOS microcomputer
- 420 Mbyte hard disk drive
- 1.44 Mbyte 3½ inch floppy disk (High Density)
- 1.2 Mbyte 5¼ inch floppy disk (High Density)
- 8 Mbyte RAM
- VGA Board (Video Graphics Array)
- VGA Color Monitor
- HP LaserJet Series III or Series 4 printer

AUTOCASK requires the operating system DOS version 3.1 or later. The DOS command files listed below must be present in the root directory of the booting hard disk drive.

AUTOEXEC.BAT ANSI.SYS CONFIG.SYS COMMAND.COM

The DOS file COMMAND.COM must be in the root directory of the hard disk drive which will contain *AUTOCASK*.

The DOS programs listed below must be available through the current PATH.

MODE.COM BACKUP.COM RESTORE.COM

The file CONFIG.SYS must include the following lines:

```
DEVICE=ANSI.SYS
BREAK ON
FILES=15
BUFFERS=15
```

The file AUTOEXEC.BAT must include the following path:

PATH *x*:\ where *x* is the hard disk drive which contains *AUTOCASK*.

The files CONFIG.SYS and AUTOEXEC.BAT and the command PATH are described in the DOS reference manual.

The ***AUTOCASK*** release package contains one 3½-inch high-density diskette for 1.44Mb disk drives. The programs and control files on the distribution diskette occupy approximately 2.84Mb of disk space and must be installed on a hard disk drive. **NOTE:** The DOS file COMMAND.COM must be in the root directory of the hard disk drive which will contain ***AUTOCASK***.

To install ***AUTOCASK***:

(1) Insert diskette number 1 into drive **A:** or **B:** and type **A:INSTALL** if using drive **A:**. If using drive **B:**, type **B:INSTALL**.
(2) INSTALL presents two choices:
    Press **S** to select the hard disk drive where ***AUTOCASK*** will reside
    Press **Q** to QUIT and return to DOS
(3) INSTALL displays the available hard disk drives on your system. Press the indicated letter to select the drive where ***AUTOCASK*** will reside, or press **Q** to QUIT and return to DOS.
(4) INSTALL displays the space remaining on the selected hard disk drive, creates the **\ACASK** subdirectory, and prompts for ***AUTOCASK*** diskette number 1.
(5) Insert each diskette as requested into either drive **A:** or **B:**. Press **A** or **B** as required to install that disk. Repeat for all distribution diskettes (if more than 1).
(6) Select video display type and printer settings.

NOTE: Press **Q** at any time to abandon installation of ***AUTOCASK***. INSTALL will ask for verification before de-installing ***AUTOCASK***.

The program INSTALL is provided to perform the installation operations listed below:

(1) INSTALL determines how many hard disk drives exist on the system, lists the hard disk drives, and asks for the drive that will contain ***AUTOCASK***.
(2) INSTALL checks the selected hard disk drive for enough space. ***AUTOCASK*** cannot be partially installed. If there is not enough space, either remove files from the hard disk drive to create room or select a different hard disk drive (if available).
(3) INSTALL creates the subdirectory **\ACASK** on the selected hard disk. If an older version of ***AUTOCASK*** is already installed, **\ACASK** is renamed to **\ACASKnn** (where **nn** is the previous ***AUTOCASK*** version number) before **\ACASK** is created. If the same version of ***AUTOCASK*** is already installed, INSTALL asks if you want to reinstall ***AUTOCASK***.
(4) INSTALL copies the program and control files from the distribution diskettes. INSTALL asks for each ***AUTOCASK*** diskette in order.
(5) INSTALL selects a default display type and allows the user to select the printer type and printer-plot resolution and to change the display type.
(6) INSTALL updates the ***AUTOCASK*** procedure to identify the selected hard disk.

Once installation is completed, start ***AUTOCASK*** by typing:

AUTOCASK (followed with Enter or Return)

AUTOCASK will display the title and disclaimer screen shown in **Figure 1-2**. Press any key to continue. ***AUTOCASK*** automatically initiates the **Select Cask** process and searches for cask data sets that already exist. The number of existing data sets is displayed and two choices are given:

Press **Q** to QUIT and return to DOS
Press any other key to proceed with cask selection

If no data sets exist, ***AUTOCASK*** requests entry of a new CASKID. The CASKID is a four digit number that identifies the cask data set. All four digits are required. For example, to specify a CASKID of 77, enter **0077**. Enter **Q** to QUIT and return to DOS.

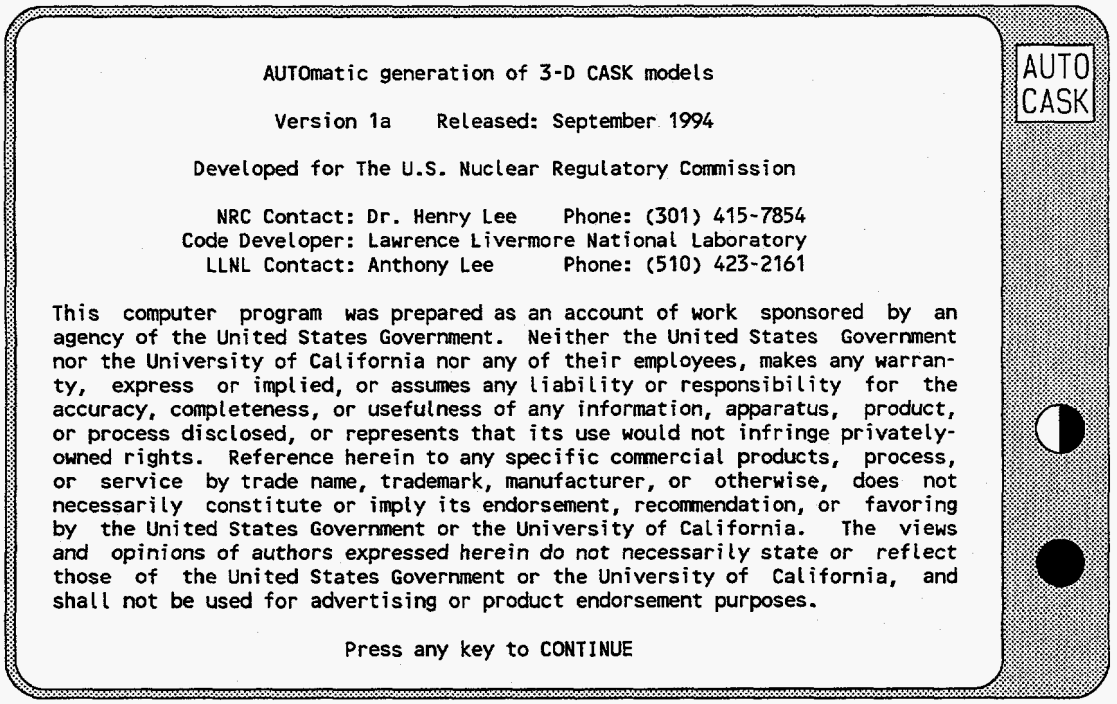

Figure 1-2. Title and disclaimer screen. Displayed when *AUTOCASK* is started.

AUTOCASK displays a list of CASKIDs with titles and dates and indicates several options:

Press **N** to select a new CASKID by direct entry
Press **S** to select the highlighted CASKID
Press **Q** to QUIT and return to DOS
Press ↑ to highlight the previous CASKID
Press ↓ to highlight the next CASKID

After the CASKID is selected, *AUTOCASK* displays the Main Menu. The first step for a new data set is to define the basic geometry. Once the geometry definitions exist, the general sequence of operations is to graphically verify the cask geometry, specify the loading and impact conditions, and construct the model file, generating the analysis input file. Each of these operations is selected from the Main Menu.

Finally, the analysis input file is uploaded to an engineering workstation or mainframe computer to perform the analysis and display the analysis results.

2

Main Menu

The Main Menu (**Figure 2-1**) is the central hub of *AUTOCASK*. It provides access to four task menus and the select cask facility. The task menus are connected only through the Main Menu. They cannot call each other directly.

PRESS 1 to Select a new CASK ID

The select cask facility is similar to the select cask process when *AUTOCASK* is started. The only difference is that pressing **Q** returns to the Main Menu instead of leaving *AUTOCASK* and returning to DOS.

PRESS 2 to Specify/Modify the cask geometry model

Select this task first for a new cask data set. *AUTOCASK* displays the Geometry Menu which provides tasks for: (1) creating new (or modifying previous) geometry definitions; (2) copying geometry from a different cask data set; and (3) modifying material data sets.

PRESS 3 to Display/Print summary of cask geometry

AUTOCASK displays the Display Menu which provides tasks for: (1) displaying the outline of the cask geometry; (2) reviewing the cask data check summary on the screen; and (3) printing the cask data check summary on the printer.

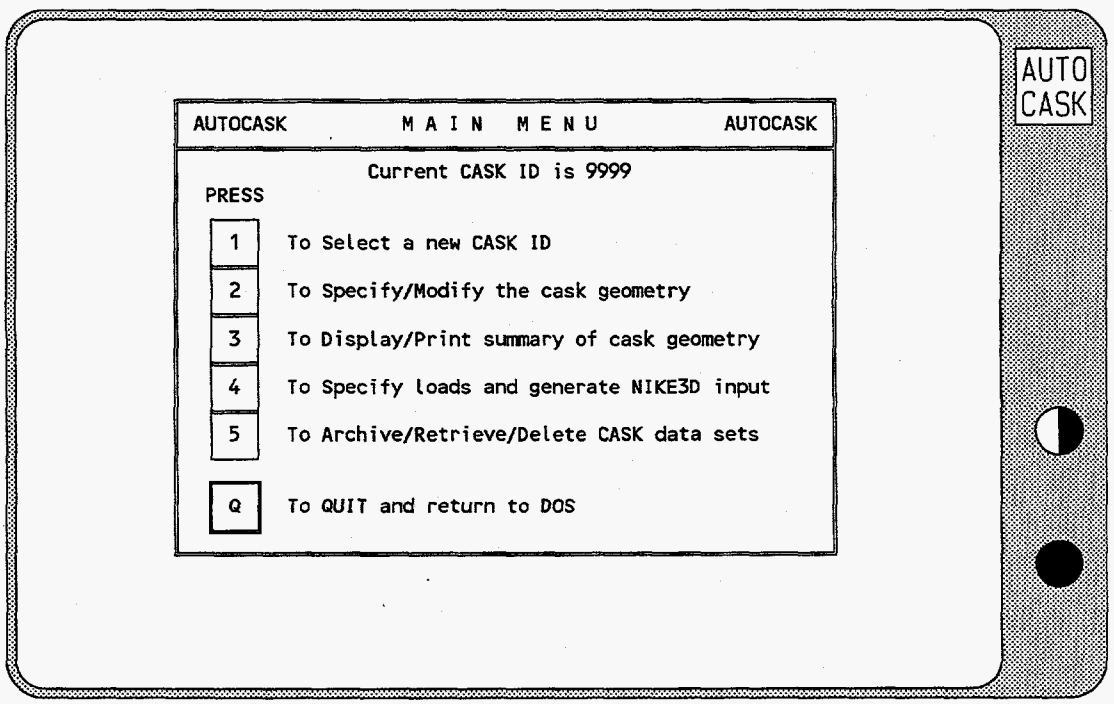

Figure 2-1. *AUTOCASK* Main Menu.

PRESS 4 to Specify loads and generate NIKE3D input

Specifies the G-load (gravity load), cask end which impacts the ground, end cap support for end-on impacts, and the impact angle. After the analysis conditions are specified, *AUTOCASK* creates a model file which is passed to the mesh generator. The mesh generator produces a complete, ready-to-run NIKE3D input file. The analysis program NIKE3D and its use are described in Chapter 7.

PRESS 5 to Archive/Retrieve/Delete CASK data sets

AUTOCASK displays the Archive Menu which provides tasks for:
(1) archiving cask data sets; (2) retrieving previously archived data sets; and (3) deleting cask data sets from the hard disk.

PRESS Q to QUIT and return to DOS

AUTOCASK terminates the session and returns to DOS in the root directory of the hard disk which contains *AUTOCASK*.

3

Geometry Menu

The Geometry Menu (**Figure 3-1**) provides tasks for creating new (or modifying previous) cask geometry definitions and material data sets.

PRESS 1 to Create/Modify cask geometry

If the cask geometry definition data set exists, editing is initiated. If the cask geometry data does not exist, *AUTOCASK* creates a new data set with default values, and editing is initiated. When the cask geometry is saved, *AUTOCASK* automatically performs a data check. Cask geometry definitions must be completed and pass the data check before *AUTOCASK* will generate an analysis input file.

PRESS 2 to Copy cask geometry from different cask

Use this feature to create the cask geometry definition data set by copying it from the existing data set for a different cask. Then, modify the data set to resolve any differences between the casks.

AUTOCASK lists the available cask geometry definition data sets from other casks. Use the cursor keys to highlight the data set to copy, then press **S**. If a cask geometry data set already exists for the current cask, *AUTOCASK* asks for confirmation before copying the selected data set over the current one.

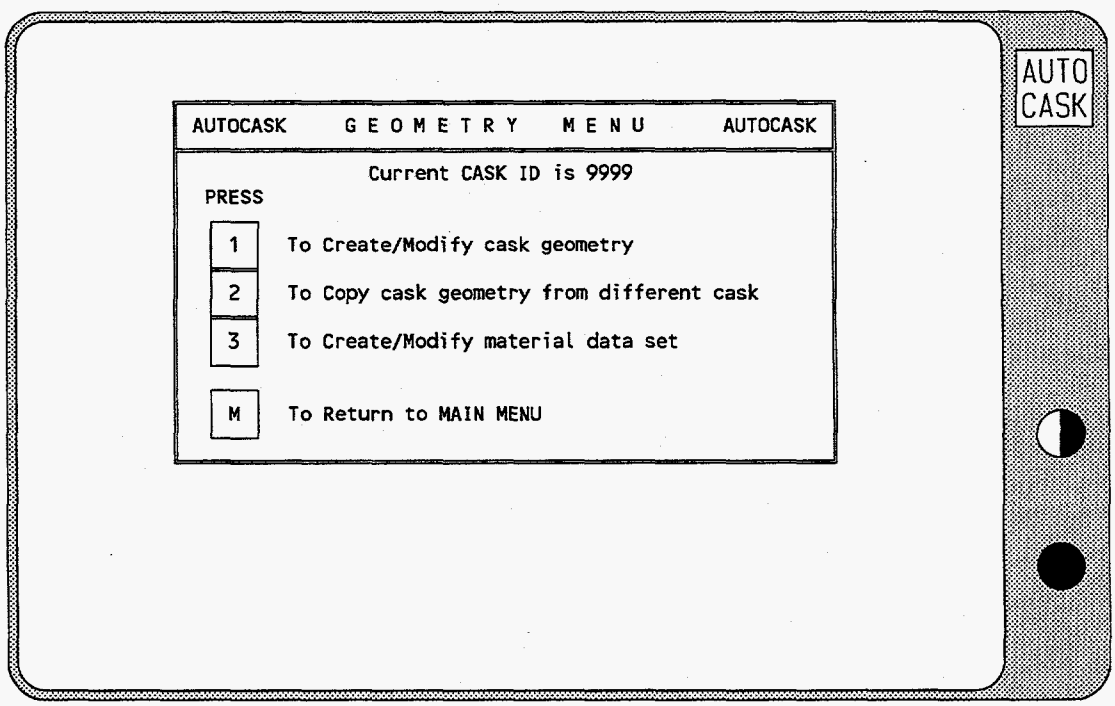

Figure 3-1. *AUTOCASK* Geometry Menu.

PRESS 3 to Create/Modify material data set

AUTOCASK displays a list of material data sets, indicating if the data set is locked. Locked data sets may be copied but not edited. When the material data set is saved, *AUTOCASK* automatically performs a data check. Material data sets that are referenced in the cask geometry definition must be completed and pass the data check before *AUTOCASK* will generate an analysis input file.

PRESS M to Return to MAIN MENU

AUTOCASK returns to the Main Menu display.

AUTOCASK uses a general purpose fill-in-the-blank type editor to enter data for the cask geometry definition and material data set definition. Appendix A has a complete description of the editor features, displays, and usage. A condensed description of how to use the editor is included here.

When editing the cask geometry, the editor title screen indicates the status of the data set. To abandon editing at this point, press **Q** to quit and return to the Geometry Menu. If the data set does not exist, press any other key to create the data set using default values. If the data exists, press **D** to delete the data set and create a new one or press any other key to edit the existing data set. When **D** is selected, *AUTOCASK* asks for confirmation before proceeding.

The editor reads a template which describes the editor screens and, if creating a new data set, identifies each editor page as it is created with the appropriate default values. The editor then displays the first editor page. Each page contains related data, and each data field has a descriptive label indicating what to enter (units are indicated if appropriate). All fields displayed in light blue are required inputs; fields displayed in green have default values which can be changed or accepted as is.

On each page display, in the upper left-hand corner, the editor displays the number of pages which must be accessed. These pages have fields that must be filled in before the data set is considered complete. The page list display also identifies these pages. Be sure to move to each field that is labeled in light blue. If necessary, enter the appropriate data.

Use the following keys to edit a field:

Characters, numbers, and special symbols to enter the appropriate data.
Keypad left and right arrow keys to position the cursor.
DEL and backspace keys to delete characters.
INS key to toggle between insert and overtype modes.

Use the following keys to accept a field and go to another:

Keypad up and down arrow keys or **ENTER** to move to previous or next field on current page.
Keypad **PgUp** and **PgDn** to move to first field on previous or next page.

Use the following keys for help, redefaulting, and special control:

ESC to display help relating to the current field and a description of all the editing keys.

F1 to display list of all the pages in the data set. Use the keypad up and down arrow keys to highlight the desired page and then press **F1** again to move to the indicated page. The page list screen indicates which pages have data fields that must be filled in.

F2 saves the data set, terminates the editor, and returns to the current menu.

F3 abandons editing. *AUTOCASK* asks for confirmation before proceeding.

F4 saves the data set and continues editing.

F5 prints the displayed page on the printer. Make sure the printer is on-line.

F6 resets the current field to its default value.

F7 resets all fields on the current page to their default values.

If the entered data is invalid for the specified field, the editor displays an error message at the bottom of the screen and indicates any restrictions on the data item. Press **ENTER** to clear the error message and return to editing.

See Appendix A for a more complete description of the editor and its features.

AUTOCASK uses a simplified cask model comprised of five components: (1) cask cavity; (2) shell; (3) bottom end cap; (4) top end cap; and (5) top end cap closure bolts. The general form of this cask model is shown in **Figure 3-2**. The shell and end caps can be either solid (single layer) or laminated (three layers). Mesh division values are used to generate the three-dimensional finite-element mesh. The geometry definition is described in the context of the editor pages that follow.

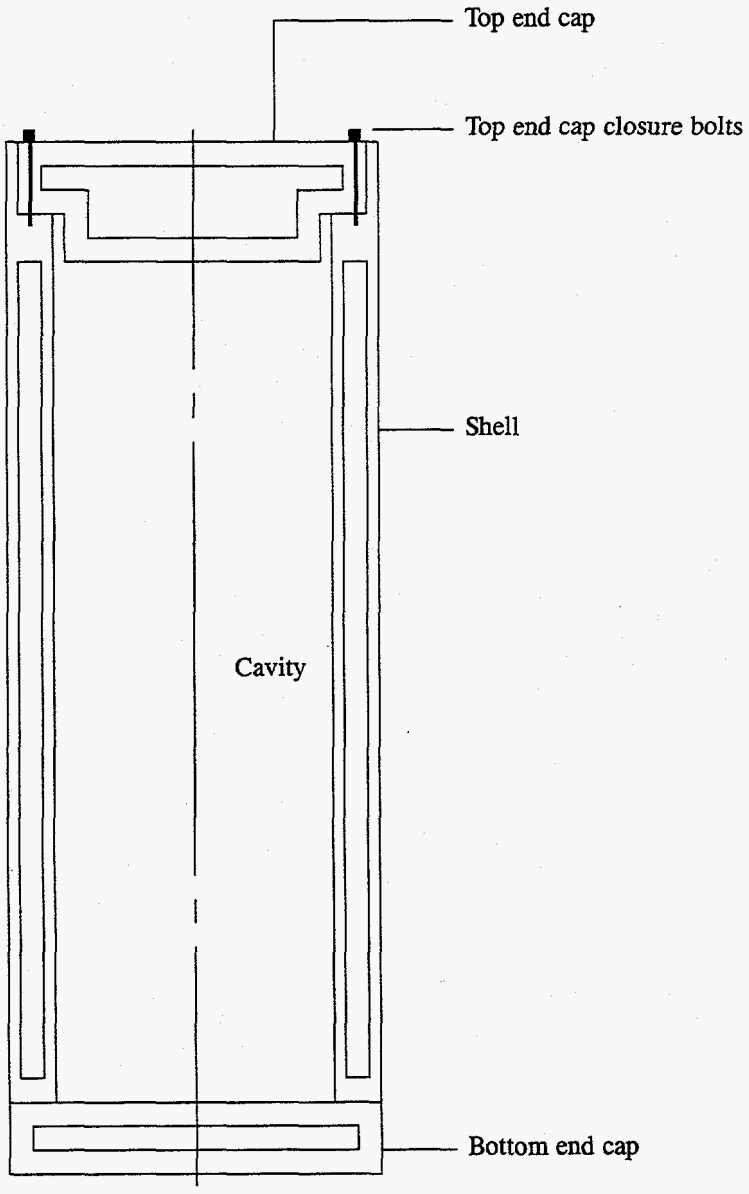

Figure 3-2. *AUTOCASK* simplified cask model.

Title and Cavity Specifications *Cask Geometry PAGE 1*

The cask input is identified with a descriptive title, and the cask cavity is specified by its inner radius and length. **Figure 3-3** shows the dimensions required to specify the cavity.

Cask Title **Required**. A descriptive label of up to 48 characters.
Cavity inner radius (inches) **Required**. Must be positive and less than 200.
Cavity length (inches) **Required**. Must be positive and less than 1000.
Number of mesh divisions along cavity length. Range is 4 to 99.
Weight of spent fuel contents and internal structures (lbs). Must be non-negative.

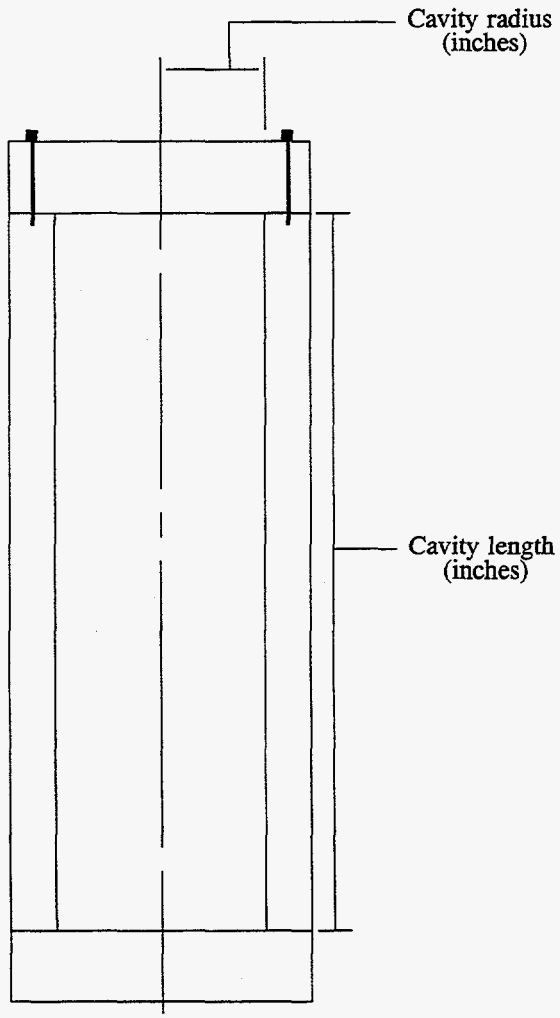

Figure 3-3. Dimensions required to specify the cavity.

Cask Configurations *Cask Geometry PAGE 2*

The default cask configuration has a solid shell and solid end caps. Enter **L** to specify a laminated shell or end caps. **Figure 3-4** shows several possible configurations.

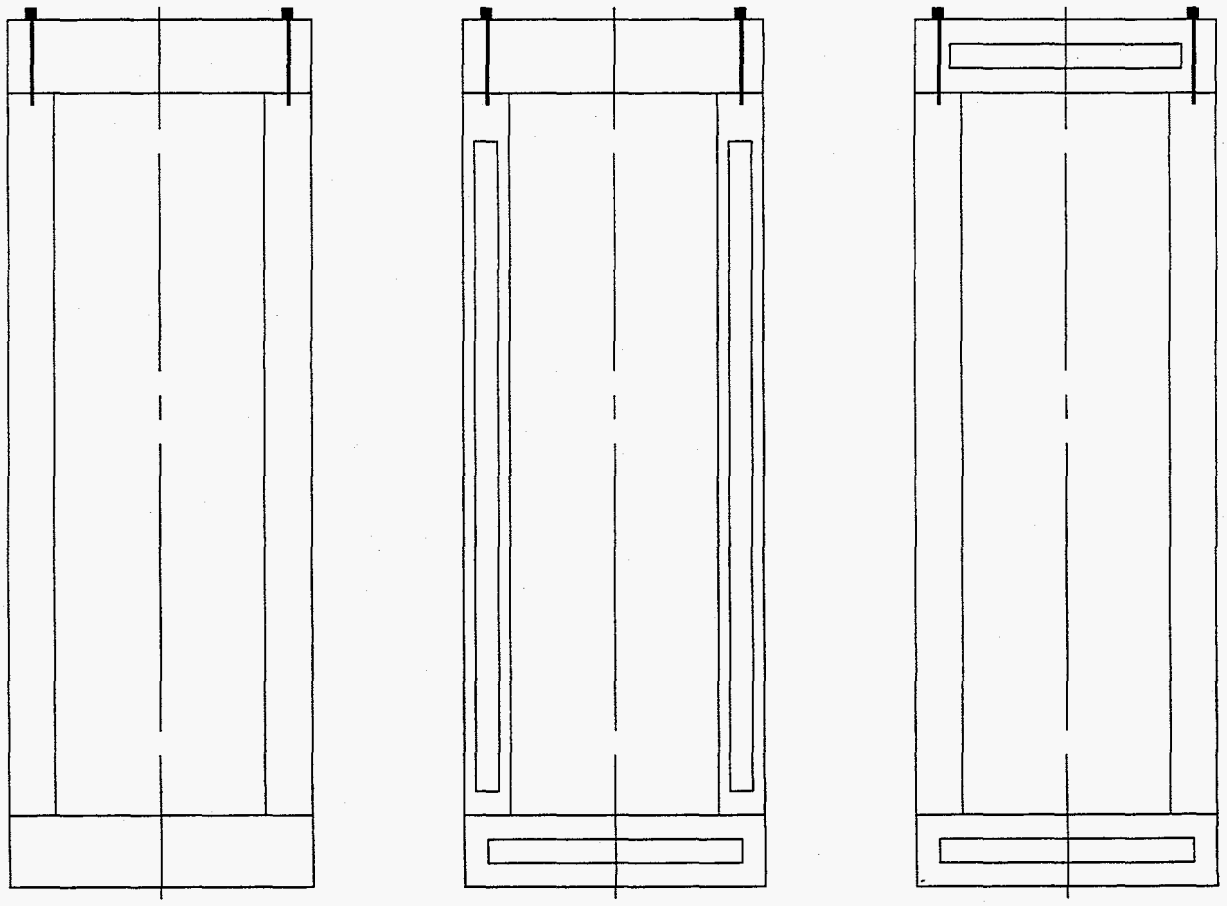

Figure 3-4. Sample cask configurations.

Cask Shell Specifications *Cask Geometry Page 3*

Page 3a is displayed when a solid shell is specified and page 3b is displayed when a laminated shell is specified. **Figure 3-5** shows the dimensions required to specify a solid shell. **Figure 3-6** shows the dimensions required to specify a laminated shell.

Solid Shell

Shell material name. Select from displayed list of materials.
Shell thickness (inches) **Required**. Total thickness of the shell. Range is 0.1 to 60.
Number of mesh divisions through shell. Range is 3 to 20.

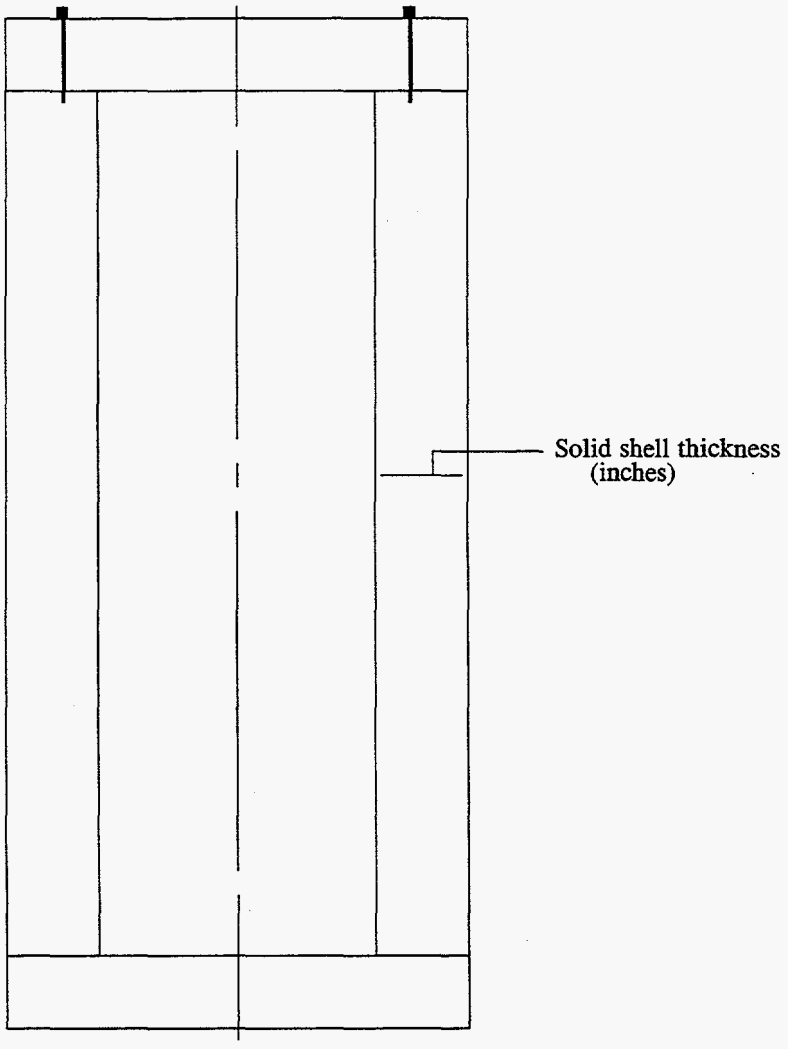

Figure 3-5. Dimensions required to specify a solid shell.

Laminated Shell

Shell inner layer material name. Select from displayed list of materials.
Shell inner layer thickness (inches) **Required**. Range is 0.1 to 60.
Number of mesh divisions through shell inner layer. Range is 1 to 20.
Shell shield layer material name. Select from displayed list of materials.
Shell shield layer thickness (inches) **Required**. Range is 0.1 to 60.
Number of mesh divisions through shell shield layer. Range is 2 to 20.
Distance from bottom of shell to shield (inches). Range is 0. to 100.
Distance from top of shell to shield (inches) **Required**. Range is 0.1 to 100. **Note:** The cavity length must be greater than the sum of the distance from the bottom of the shell and the distance from the top of the shell.
Shell outer layer material name. Select from displayed list of materials.
Shell outer layer thickness (inches) **Required**. Range is 0.1 to 60.
Number of mesh divisions through shell outer layer. Range is 1 to 20.

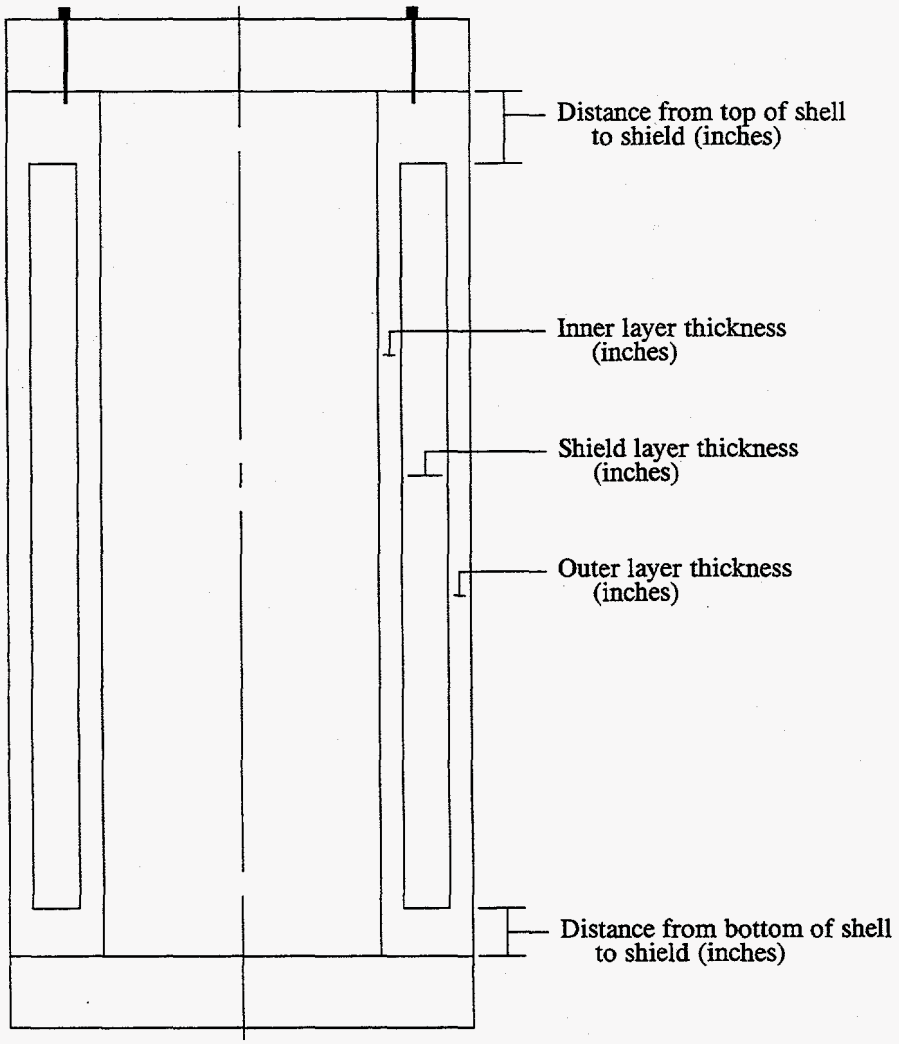

Figure 3-6. Dimensions required to specify a laminated shell.

Bottom End Cap Specifications *Cask Geometry Page 4*

Page 4a is displayed when a solid bottom end cap is specified. Page 4b is displayed when a laminated bottom end cap is specified. **Figure 3-7** shows the dimensions required to specify a solid bottom end cap. **Figure 3-8** shows the dimensions required to specify a laminated bottom end cap.

Solid Bottom End Cap

Bottom end cap material name. Select from displayed list of materials.
Bottom end cap thickness (inches) **Required**. Total thickness of the end cap. Range is 0.1 to 60.
Number of mesh divisions through bottom end cap. Range is 1 to 20.

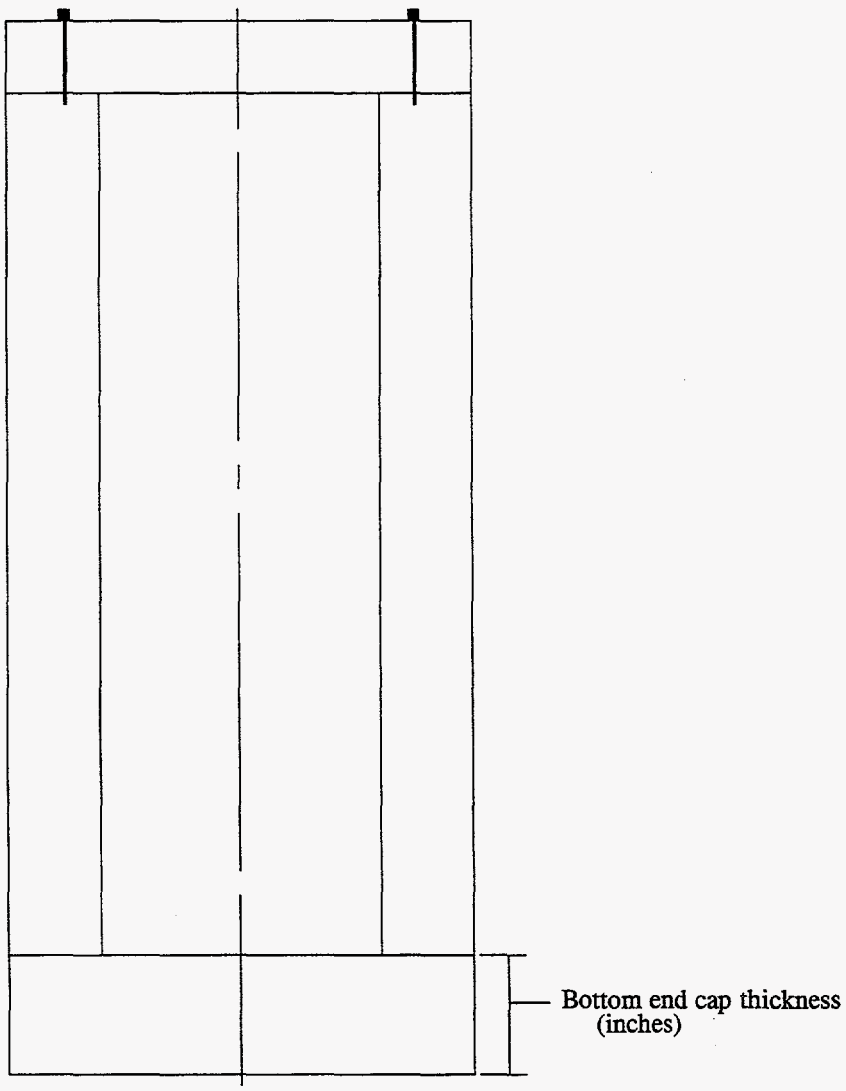

Figure 3-7. Dimensions required to specify a solid bottom end cap.

Laminated Bottom End Cap

Bottom end cap inner layer material name. Select from displayed list of materials.

Bottom end cap inner layer thickness (inches) **Required**. Range is 0.1 to 60.

Number of mesh divisions through bottom end cap inner layer. Range is 1 to 20.

Bottom end cap shield layer material name. Select from displayed list of materials.

Bottom end cap shield layer thickness (inches) **Required**. Must be non-negative and less than 2000. Set to 0.0 to eliminate the shield layer.

Number of mesh divisions through bottom end cap shield layer. Range is 2 to 20.

Bottom end cap shield radius (inches) **Required**. Range is 0.1 to 300. Must not exceed the cask body outer radius (cavity radius plus shell thickness).

Bottom end cap outer layer material name. Select from displayed list of materials.

Bottom end cap outer layer thickness (inches) **Required**. Range is 0.1 to 60.

Number of mesh divisions through bottom end cap outer layer. Range is 1 to 20.

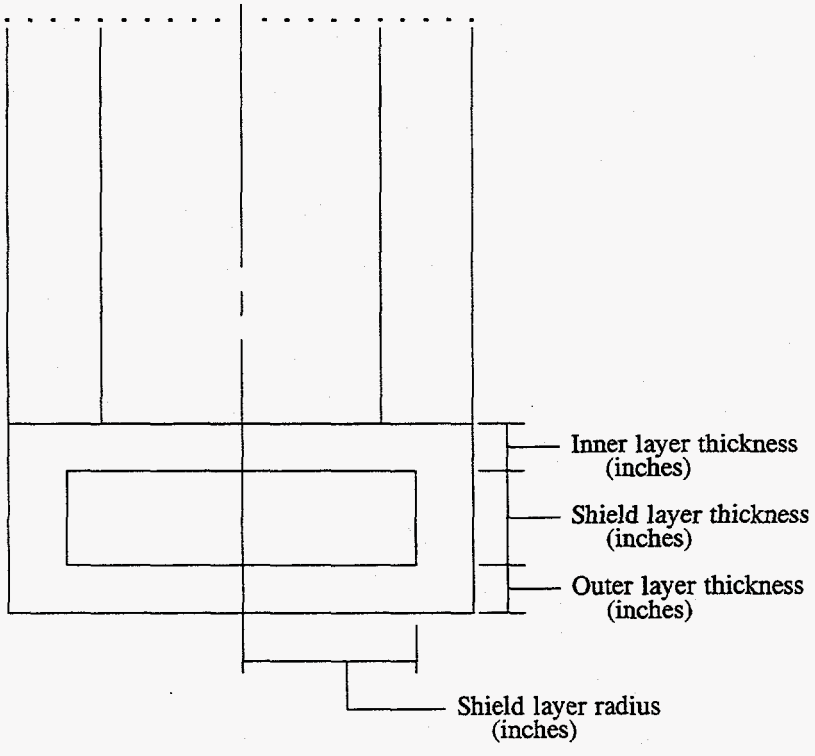

Figure 3-8. Dimensions required to specify a laminated bottom end cap.

Top End Cap Specifications *Cask Geometry Page 5*

Page 5a is displayed when a solid top end cap is specified. Page 5b is displayed when a laminated top end cap is specified. **Figure 3-9** shows the dimensions required to specify a solid top end cap. **Figure 3-10** shows the dimensions required to specify a laminated top end cap.

Solid Top End Cap

Top end cap material name. Select from displayed list of materials.
Top end cap thickness (inches) **Required**. Total thickness of the end cap. Range is 0.1 to 60.
Number of mesh divisions through top end cap. Range is 1 to 20.
Top end cap lip in the cavity. Enter **Y** if the top end cap has a lip extending into the cavity. The lip is specified on page 6a.

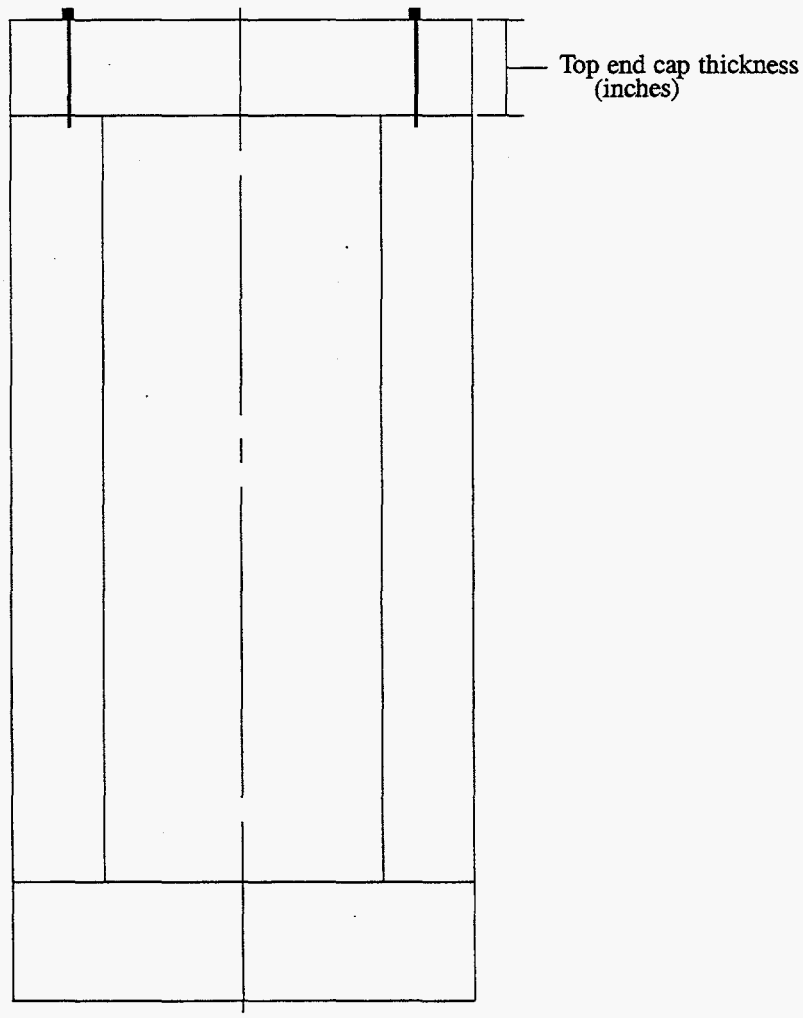

Figure 3-9. Dimensions required to specify a solid top end cap.

Laminated Top End Cap

Top end cap inner layer material name. Select from displayed list of materials.

Top end cap inner layer thickness (inches) **Required**. Range is 0.1 to 60.

Number of mesh divisions through top end cap inner layer. Range is 1 to 20.

Top end cap shield layer material name. Select from displayed list of materials.

Top end cap shield layer thickness (inches) **Required**. Must be non-negative and less than 2000. Set to 0.0 to eliminate the shield layer.

Number of mesh divisions through top end cap shield layer. Range is 2 to 20.

Top end cap shield radius (inches) **Required**. Range is 0.1 to 300. Must not exceed the bolt circle radius less 1 bolt diameter.

Top end cap outer layer material name. Select from displayed list of materials.

Top end cap outer layer thickness (inches) **Required**. Range is 0.1 to 60.

Number of mesh divisions through top end cap outer layer. Range is 1 to 20.

Top end cap lip in the cavity. Enter **Y** if the top end cap has a lip extending into the cavity. The lip is specified on page 6b.

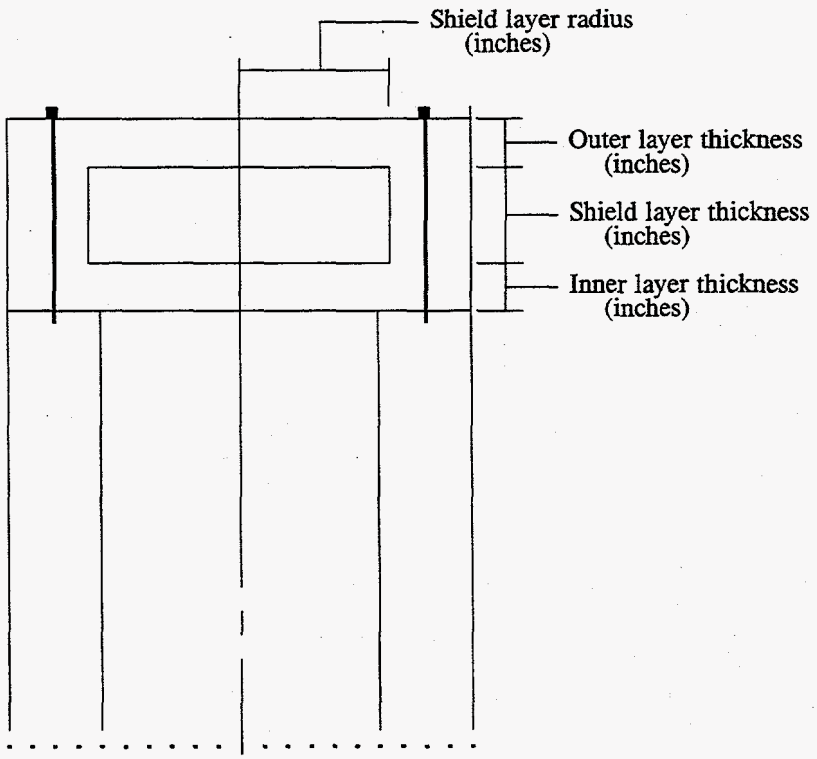

Figure 3-10. Dimensions required to specify a laminated top end cap.

Top End Cap Lip Specifications *Cask Geometry Page 6*

Page 6a is displayed when a lip for a solid top end cap is specified. Page 6b is displayed when a lip for a laminated top end cap is specified. **Figure 3-11** shows the dimensions required to specify the lip for a solid top end cap. **Figure 3-12** shows the dimensions required to specify the lip for a laminated top end cap.

Solid Top End Cap Lip

Lip thickness (inches) **Required**. Amount the cap extends into the cavity from the top of the shell. Range is 0.1 to 200. Must not exceed the cavity length.

Gap from shell wall (inches). Range is 0 to 50. Must not exceed the cavity radius.

Lip contact with shell wall. Enter **Y** to include a contact surface between the lip and the shell wall. Enter **N** to ignore contact between the lip and the shell wall.

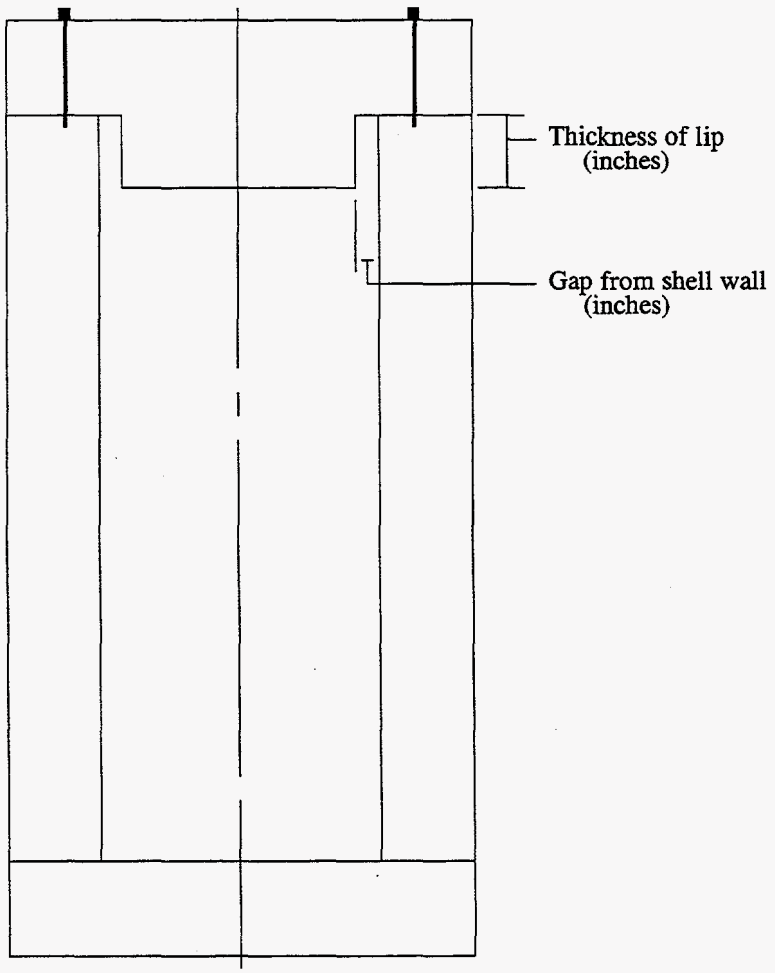

Figure 3-11. Dimensions required to specify the lip for a solid top end cap.

Laminated Top End Cap Lip

Lip thickness (inches) **Required**. Amount the cap extends into the cavity from the top of the shell. Range is 0.1 to 200. Must not exceed the cavity length.

Additional thickness of shield in lip (inches). Amount the shield extends into the lip from the shield layer. Range is 0.1 to 200. Must not exceed the sum of the top end cap inner layer thickness and the lip thickness.

Radius of shield in lip (inches). Range is 0.1 to 200. Must not exceed the shield layer radius and must not exceed the cavity radius less the gap from the shell wall (radius of the lip).

Gap from shell wall (inches). Range is 0 to 50. Must not exceed the cavity radius.

Lip contact with shell wall. Enter **Y** to include a contact surface between the lip and the shell wall. Enter **N** to ignore contact between the lip and the shell wall.

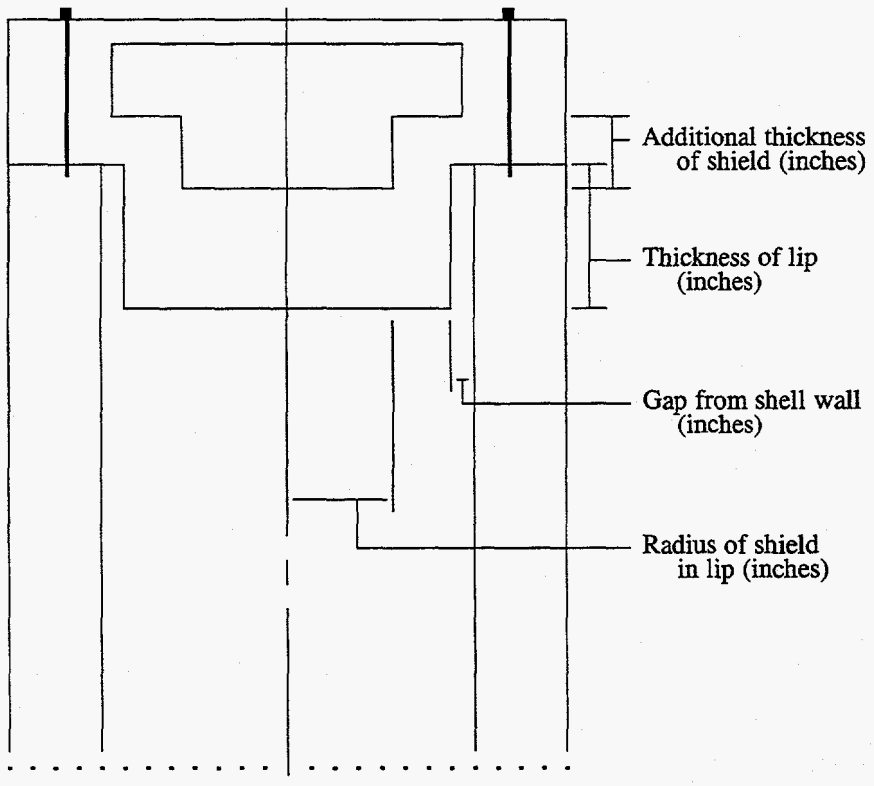

Figure 3-12. Dimensions required to specify the lip for a laminated top end cap.

Top End Cap Inset *Cask Geometry Page 7*

Figure 3-13 shows the dimensions required to specify an inset top end cap.

Inset top end cap. Enter **Y** to inset the top end cap by extending the shell. Enter **N** if the top end cap overlays the shell and is not inset.

Thickness of cask wall outside the end cap (inches) **Required**. Range is 0.1 to 60.

Gap between end cap and cask wall (inches). Range is 0 to 50.

End cap contact with cask wall. Enter **Y** to include a contact surface between the top end cap and the shell wall where the end cap is inset. Enter **N** to ignore contact between the lip and the shell wall.

Note: The radius of the inset top end cap (cask outer radius minus cask wall thickness minus gap) must be greater than the bolt circle radius plus one bolt diameter.

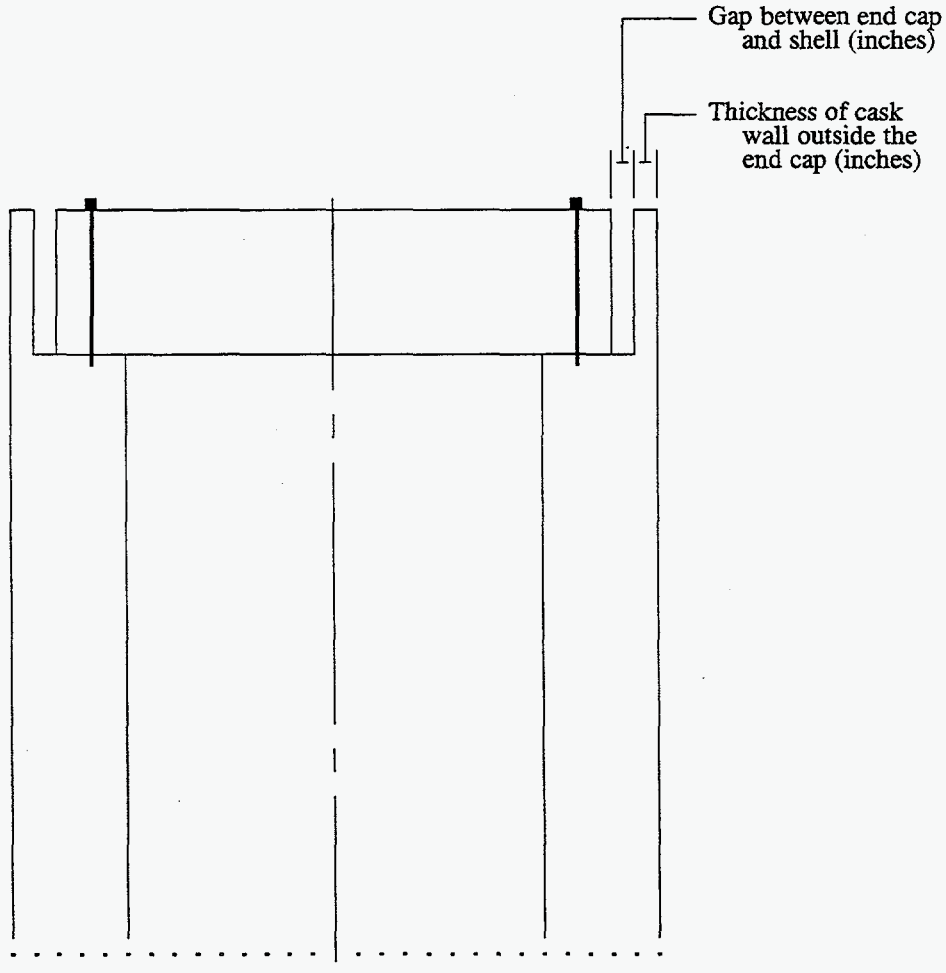

Figure 3-13. Dimensions required to specify an inset top end cap.

Top End Cap Cask Closure Bolts Information *Cask Geometry Page 8*

Figure 3-14 shows the dimensions required to specify the bolt circle.

Bolt material name. Select from displayed list of materials.
Number of closure bolts **Required**. Range is 4 to 98. Must be even.
Number of mesh divisions between bolts. Range is 1 to 20. **Note:** If the number of bolts is less than 8, the minimum number of mesh divisions between bolts is 2.
Diameter of closure bolts (inches) **Required**. Range is .01 to 20.
Closure bolt circle radius (inches) **Required**. Range is 1 to 300. Must be greater than the cavity radius plus one bolt diameter and less than the cask outer radius (or top end cap outer radius if the end cap is inset) less one bolt diameter.

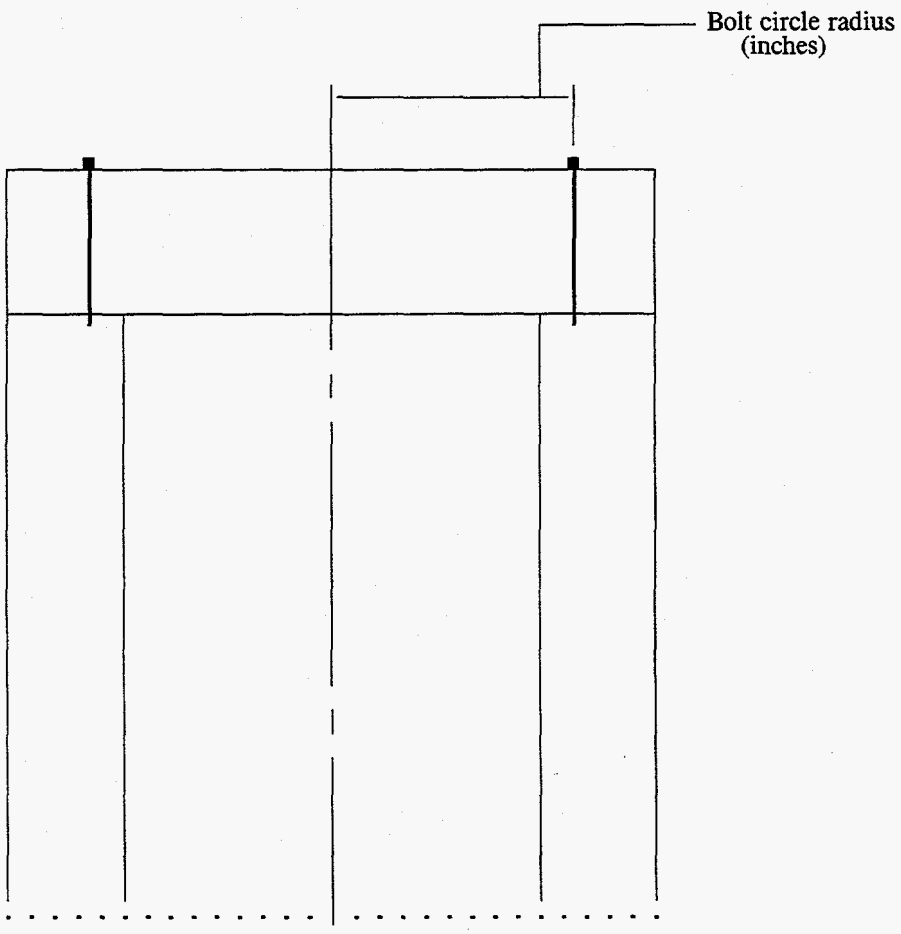

Figure 3-14. Dimensions required to specify the bolt circle.

AUTOCASK is distributed with a set of material files for the different cask components. These material files cannot be modified and are *LOCKED*. However, these material files may be *copied* to a new material file name and then modified. New material files are added by copying an existing material file to a new name and then modifying the material specification.

The Edit A Material Data Set title screen indicates the number of material sets that exist. Press **Q** to QUIT and return to the Geometry Menu, or press any other key to select a material set. *AUTOCASK* displays the Select Material File Screen (**Figure 3-15**) and lists the following options:

Press **Q** to QUIT and return to the Geometry Menu
Press **C** to Copy the indicated data set
Press **E** to Edit the indicated data set (if not *LOCKED*)
Press ↑ to move to the previous data set
Press ↓ to move to the next data set

When a file is selected to edit, *AUTOCASK* initiates editing. When a file is selected to copy, *AUTOCASK* displays a summary of the selected file indicating the file name, the material name, the cask component the material file is associated with, and the date the file was last modified. Enter the name for the new material file, or enter **Q** to QUIT and return to the Geometry Menu or **S** to select a different material file to copy.

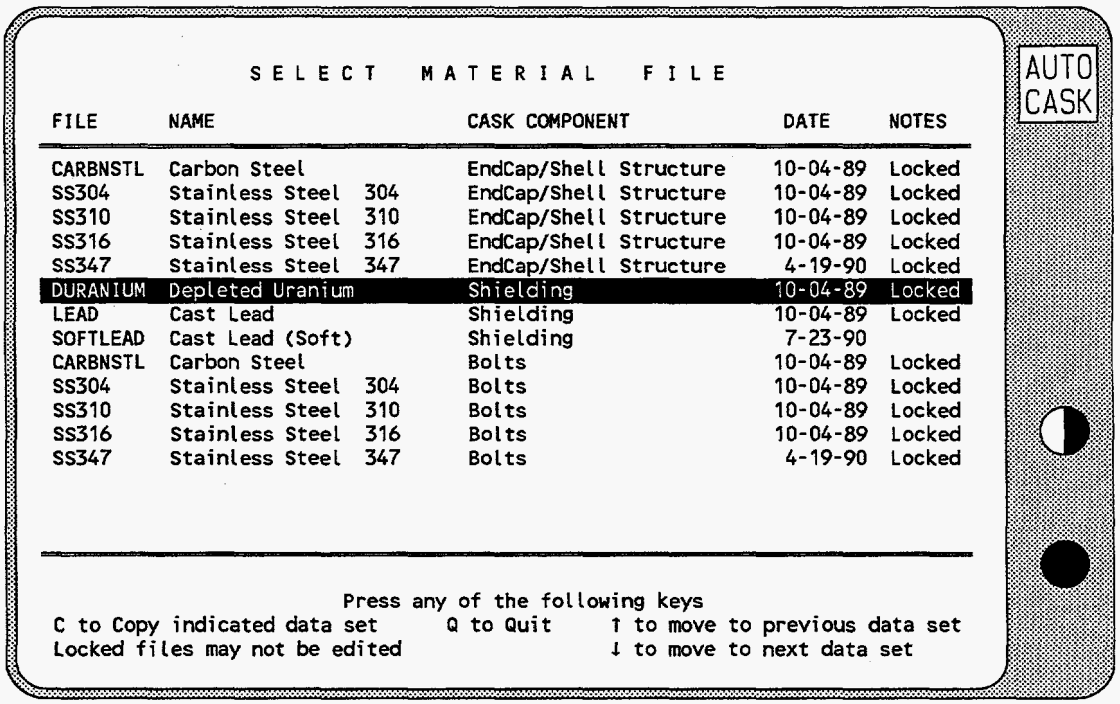

Figure 3-15. Select Material File to copy or edit.

When a new material file name is entered, *AUTOCASK* lists the following options (**Figure 3-16**):

Press **F1** to associate the material file with end cap and shell structural components (inner and outer layers)
Press **F2** to associate the material file with shield layers
Press **F3** to associate the material file with bolts
Press **Q** to QUIT and return to the Geometry Menu
Press **N** to enter a new file name
Press **C** to copy the file and return to the Geometry Menu
Press **E** to copy the file and then initiate editing

Note: Material files are associated with a particular cask component. Thus, it may be necessary to have several duplicate versions of a material file, one for each desired cask component. For example, the distribution material data sets include SS304 for end cap and shell structural components and SS304 for the bolts. These are separate material files. When a material file exists for several cask components, modifying the material file for one cask component does not automatically modify the material files for the other cask components.

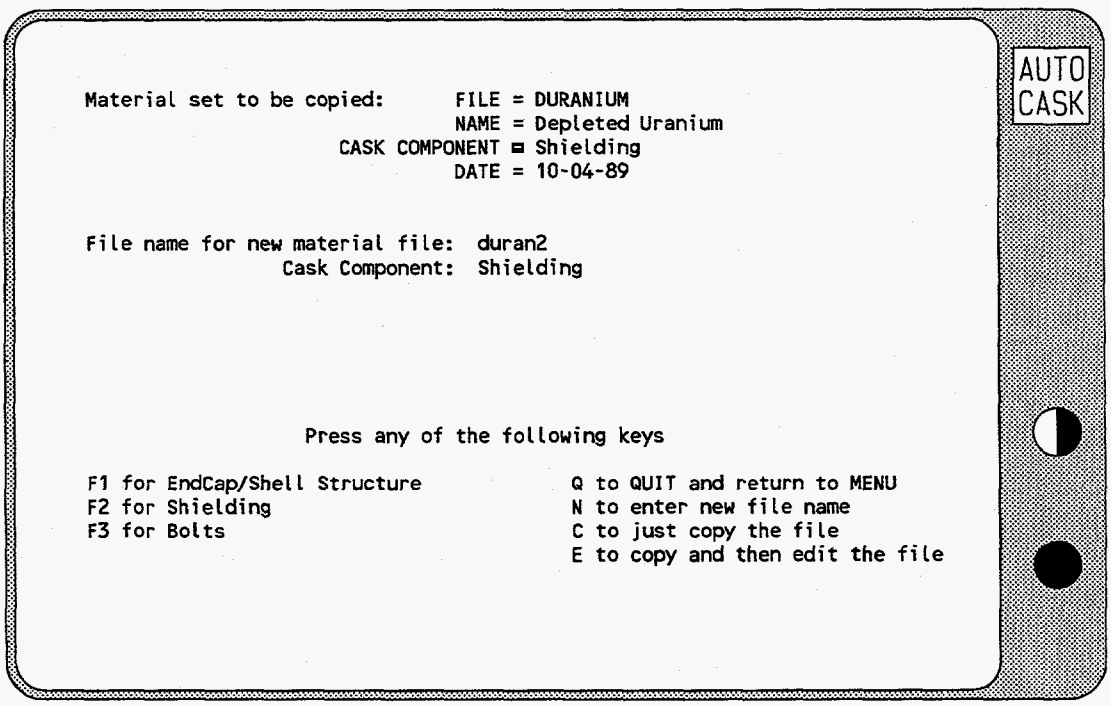

Figure 3-16. Ready to copy Material file to a new file name.

The material specifications are described in the context of the editor pages that follow.

Material Name and material density *Material Specification PAGE 1*

Material Name **Required**. A descriptive label of up to 24 characters.
Density (lbm/in^3) **Required**. Must be positive.

Impact, Puncture, Buckling Analysis Properties *Material Specification PAGE 2*

In this section *AUTOCASK* only uses the Yield Stress and Plastic Modulus. The Young's Moduls and Poisson's Ratio are specified in the Temperature-Dependent Properties section.

Impact Young's Modulus (psi) **Required**. Must be positive. Not currently used by *AUTOCASK*.
Impact Poisson's Ratio **Required**. Range is 0.001 to 0.499. Not currently used by *AUTOCASK*.
Yield Stress (psi). Must be non-negative. If a positive value is entered, *AUTOCASK* will treat the material as Elastic-Plastic.
Plastic Modulus (psi). Must be non-negative. Used only if the yield stress is positive.
Ultimate Stress (psi). Must be non-negative. Not currently used by *AUTOCASK*.

The following properties are used for buckling analyses and are not currently used by *AUTOCASK*. $\mathbf{e_o}$ and **m** define the stress-strain relation at stress levels above the proportional stress limit according to: $\mathbf{e = e_o n^m}$.

Proportional stress limit (psi). Must be non-negative.
e_o (psi). Must be non-negative.
m. Must be non-negative.

Temperature-Independent Properties *Material Specification PAGE 3*

Number of temperature sets **Required**. Range is 1 to 8.
Material type. Must be 3.

Temperature-Dependent Properties *Material Specification PAGEs 4a-4h*

Complete for each temperature set. NOTE: *AUTOCASK* uses properties at 68° and will interpolate between temperature sets if necessary.

Temperature (°F) **Required**. Must be greater or equal to -459.
Young's Modulus (psi) **Required**. Must be positive.
Poisson's Ratio **Required**. Range is 0.001 to 0.499.
Coefficient of thermal expansion (inch/inch °F). Not currently used by *AUTOCASK*.
Thermal conductivity (Btu/inch min °F). Must be positive. Not currently used by *AUTOCASK*.
Specific heat capacity (Btu/lbm °F). Must be positive. Not currently used by *AUTOCASK*.

4

Display Menu

The Display Menu (**Figure 4-1**) provides options for displaying the outline of the cask geometry, reviewing the data check cask summary on the screen, and printing the data check cask summary.

PRESS 1 to Display outline of the cask geometry

Display the outline of the cask geometry as a vertical cross-section or top view, with or without an approximation of the mesh grading.

PRESS 2 to Review data check / summary on the screen

Review the data check cask summary on the screen. The output may also be printed from this option.

PRESS 3 to Print data check / summary

Print the data check cask summary on the printer.

PRESS M to Return to MAIN MENU

AUTOCASK returns to the Main Menu display.

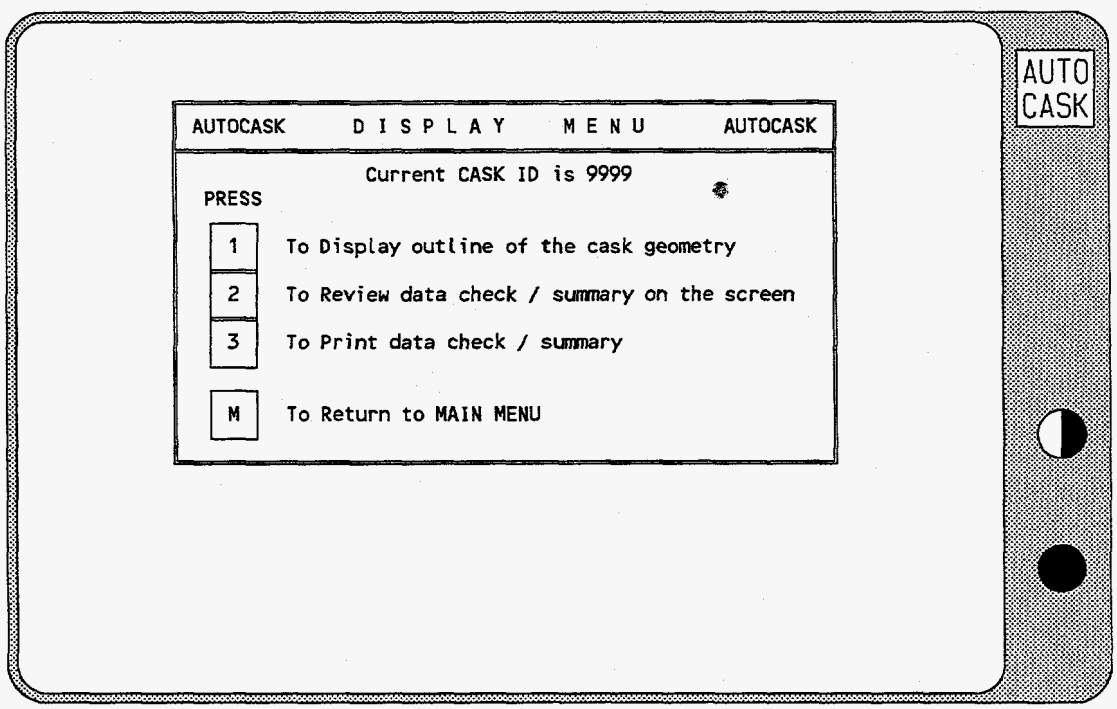

Figure 4-1. *AUTOCASK* Display Menu.

AUTOCASK displays the Plot Graphic Summary of Cask Title Screen. Press **Q** to QUIT and return to the Display Menu, or press any other key to select the plot to display. *AUTOCASK* displays the screen shown in **Figure 4-2** and lists the following options:

Press **Q** to QUIT and return to the Display Menu
Press ↑ to move to the previous choice box
Press ↓ to QUIT to the next choice box

Selecting the Plot to Display or Print

Highlight the *Select Plot to Display* field to display plots. Highlight the *Select Plot to Print* field to display and print plots. Press one of the following function keys to display the desired plot.

F1 to plot a vertical cross-section outline of the geometry **(Figure 4-3)**
F2 to plot a top view outline of the geometry **(Figure 4-4)**
F3 to plot a vertical cross-section with approximate mesh grading **(Figure 4-5)**
F4 to plot a shell cross-section at mid-length with approximate mesh grading **(Figure 4-6)**

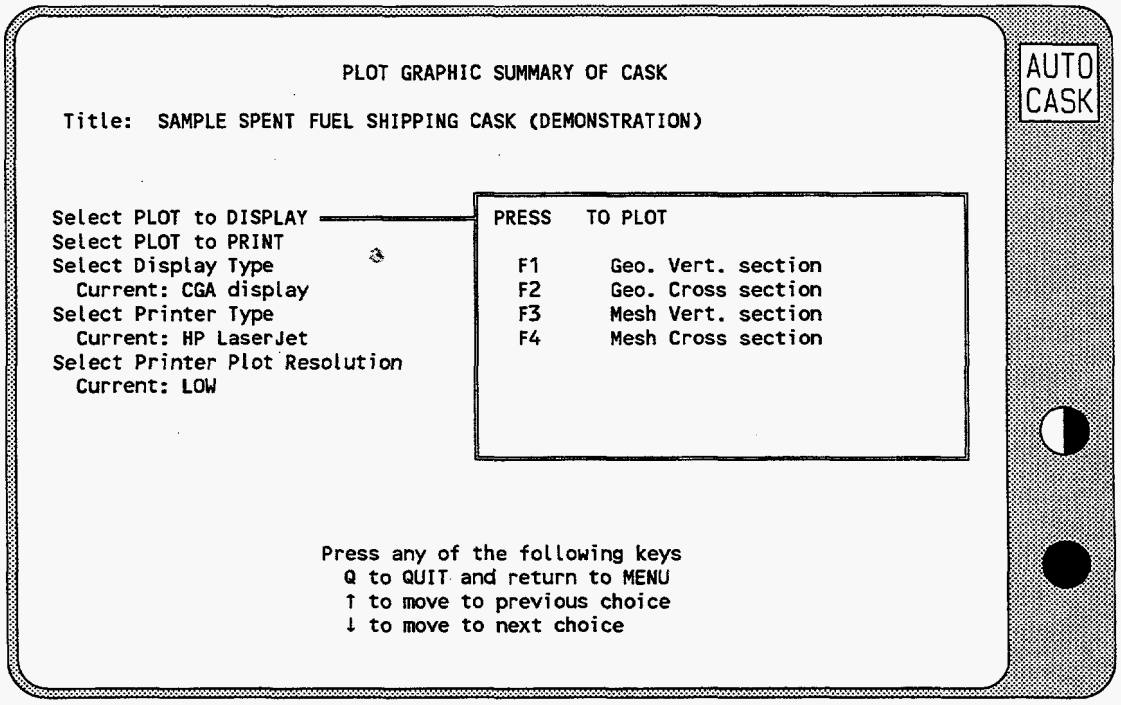

Figure 4-2. Plot a graphic summary of the cask.

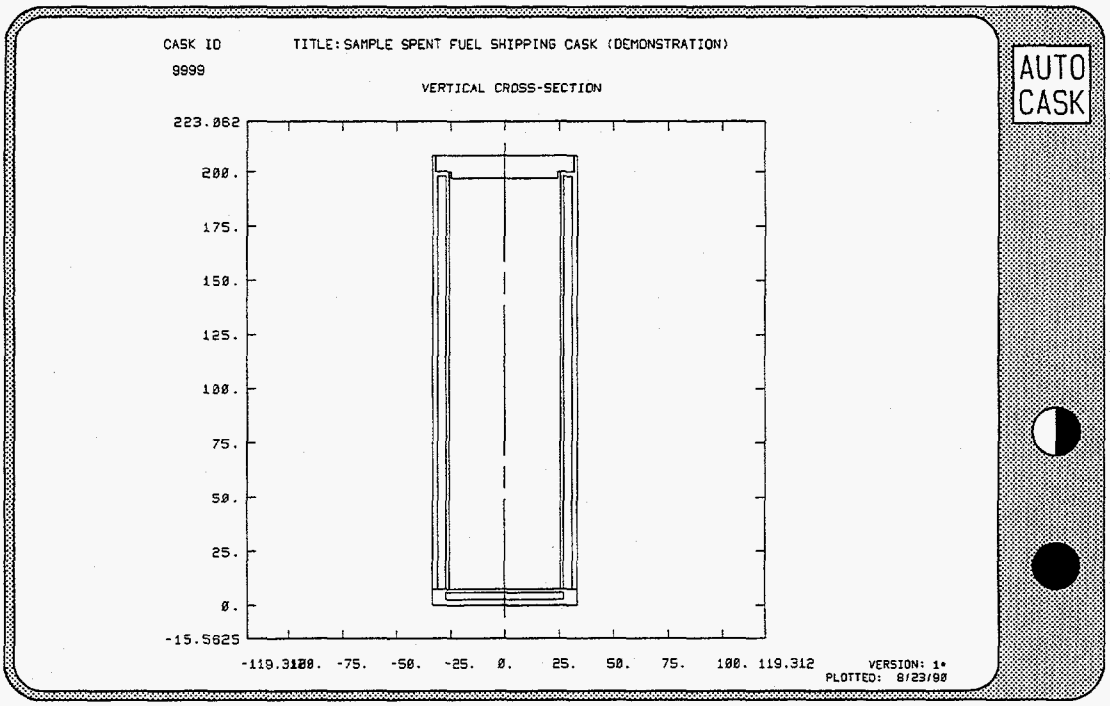

Figure 4-3. Vertical cross-section outline of cask.

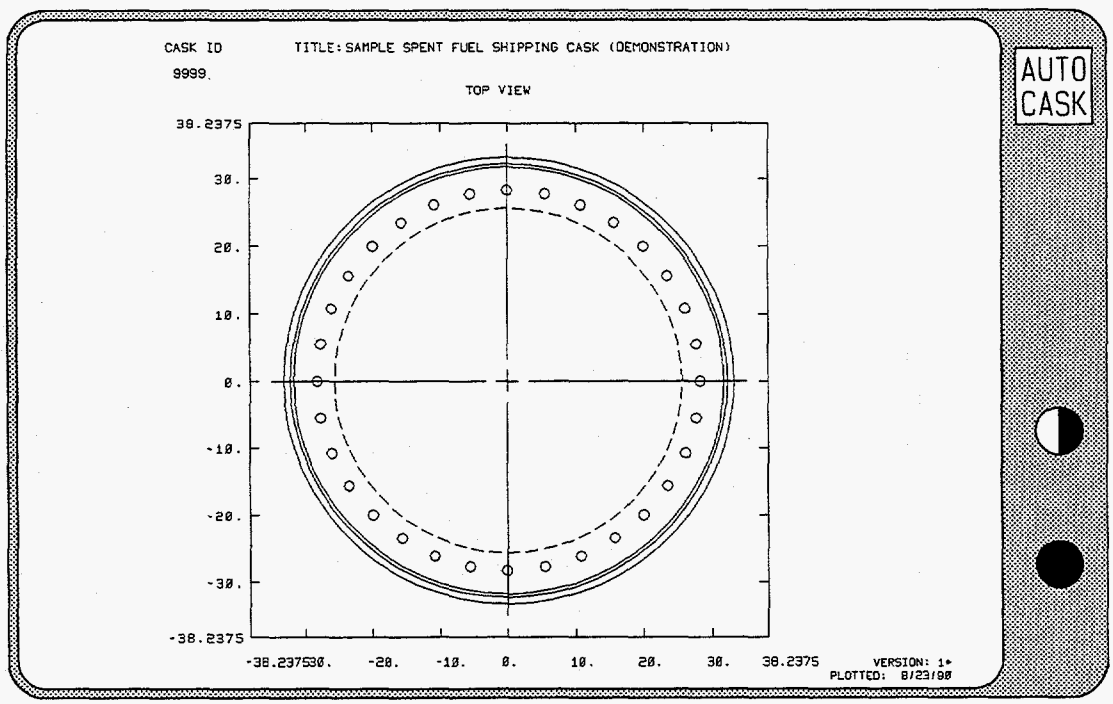

Figure 4-4. Top view outline of cask. Dashed circle is cavity.

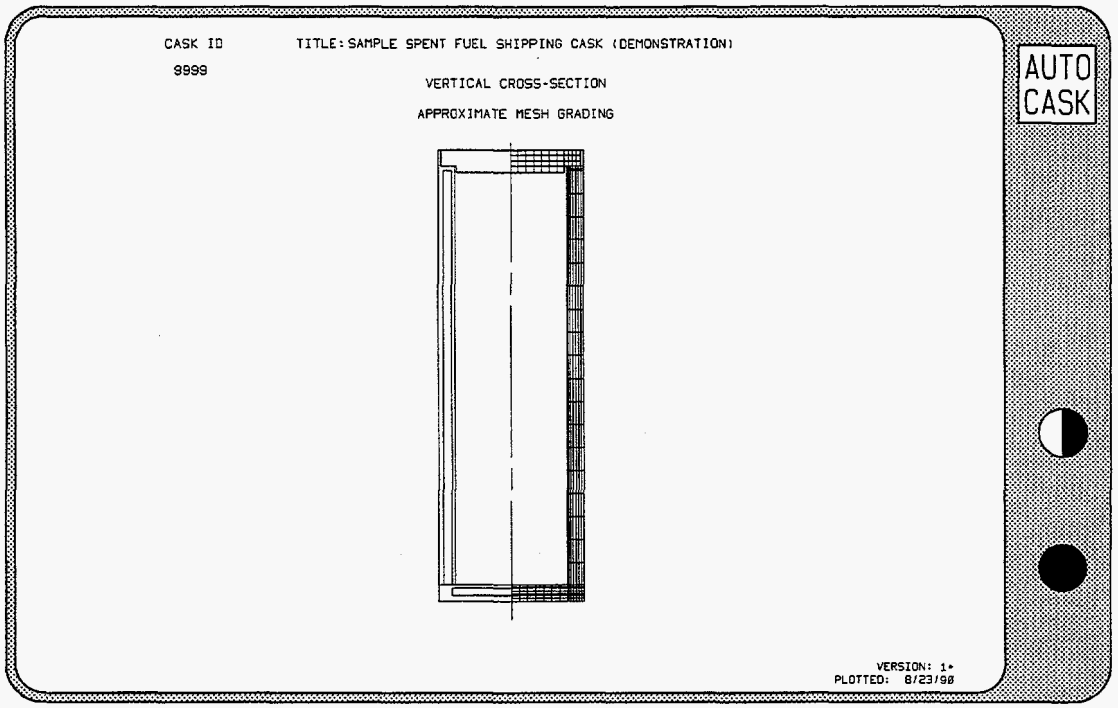

Figure 4-5. Vertical cross-section of cask with approximate mesh grading.

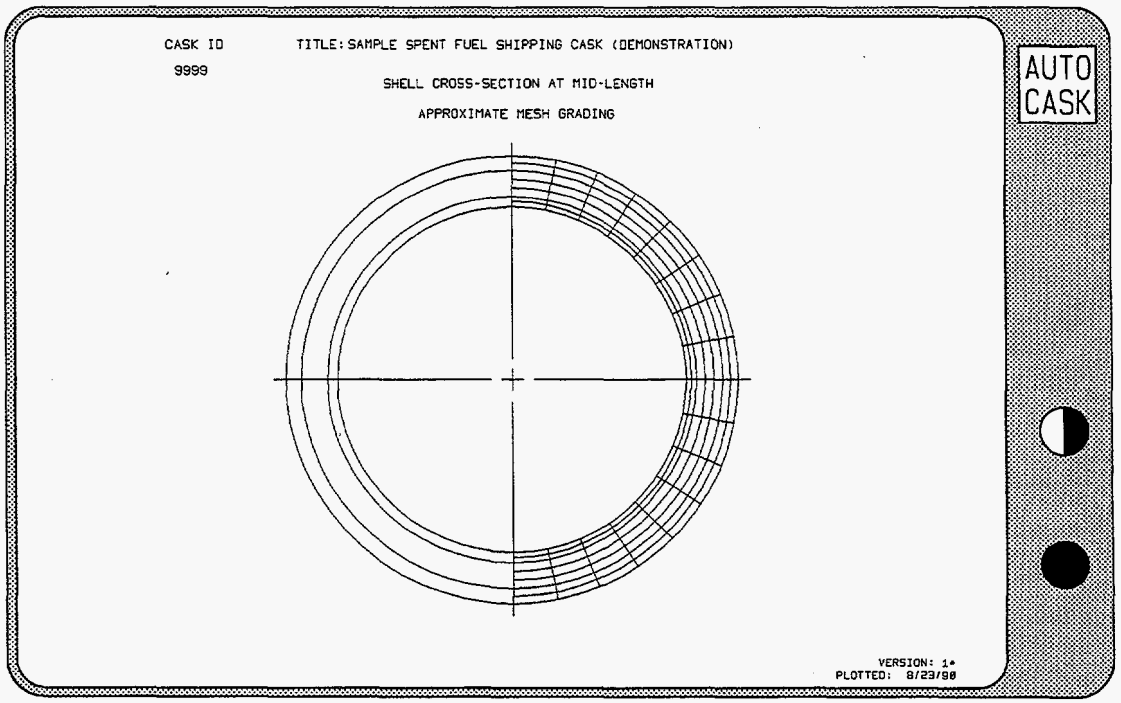

Figure 4-6. Shell cross-section at mid-length with approximate mesh grading.

Selecting the Display Type

Highlight the *Select Display Type* field to select the display type. *AUTOCASK* automatically detects the various valid display options. Press one of the following function keys (if listed by *AUTOCASK*) to select the desired display type.

F1 for a CGA display (one color, 640 x 200 pixels)
F2 for a EGA display (three colors, 640 x 350 pixels)
F3 for a VGA display (three colors, 640 x 480 pixels)
F4 for a HGC display (Hercules monochrome, 720 x 348 pixels)

Selecting the Printer Type

Highlight the *Select Printer Type* field to select the printer type. Press one of the following function keys to select the desired printer type.

F1 for an HP LaserJet or compatible laserjet printer
F2 for an IBM/EPSON or compatible 9-pin dot matrix graphics printer

AUTOCASK can utilize any dot matrix printer that uses the same graphics commands as the IBM Proprinter and Epson FX-85.

AUTOCASK supports the use of Hewlett Packard PCL compatible laserjet printers in a limited fashion. Printed output is in the standard Courier font (10 characters per inch), LOW resolution plots are drawn using 150 dpi (dots per inch) graphics mode, and HIGH resolution plots are drawn using 300 dpi graphics mode. Older laserjet models which have limited memory may print HIGH resolution plots piecemeal on several pages, and in the case of the original LaserJet, may even print LOW resolution plots piecemeal on several pages.

Selecting the Printer Plot Resolution

Highlight the *Select Printer Plot Resolution* field to select the printer plot resolution. Press one of the following function keys to select the desired printer plot resolution.

F1 for LOW resolution
F2 for HIGH resolution

Printer plots are for graphics displays and require a printer that supports graphics. High resolution plots take up to 10 times longer to print than low resolution plots.

Hint:
Use low resolution plots until report-quality plots are required. Switch to high resolution for report-quality plots, then return to low resolution.

AUTOCASK displays the first 20 lines of data check cask summary on the screen (**Figure 4-7**). *AUTOCASK* can review up to 4000 lines in a file (the entire file can be printed). The review control options are:

Press	**S**	to print the 20 lines displayed on the screen
Press	**ESC**	to exit (end review and return to the Display Menu)
Press	**P**	to print the output (see **Printing the Output**)
Press	**↑**	to scroll screen down, displaying previous line at top
Press	**↓**	to scroll screen up, displaying next line at bottom
Press	**Home**	to display first 20 lines of output
Press	**End**	to display last 20 lines of output
Press	**PgUp**	to display previous 20 lines of output
Press	**PgDn**	to display next 20 lines of output

The symbol **<FF>** represents form feeds used to paginate the output. Press **ESC** to terminate reviewing the data check cask summary and return to the Display Menu.

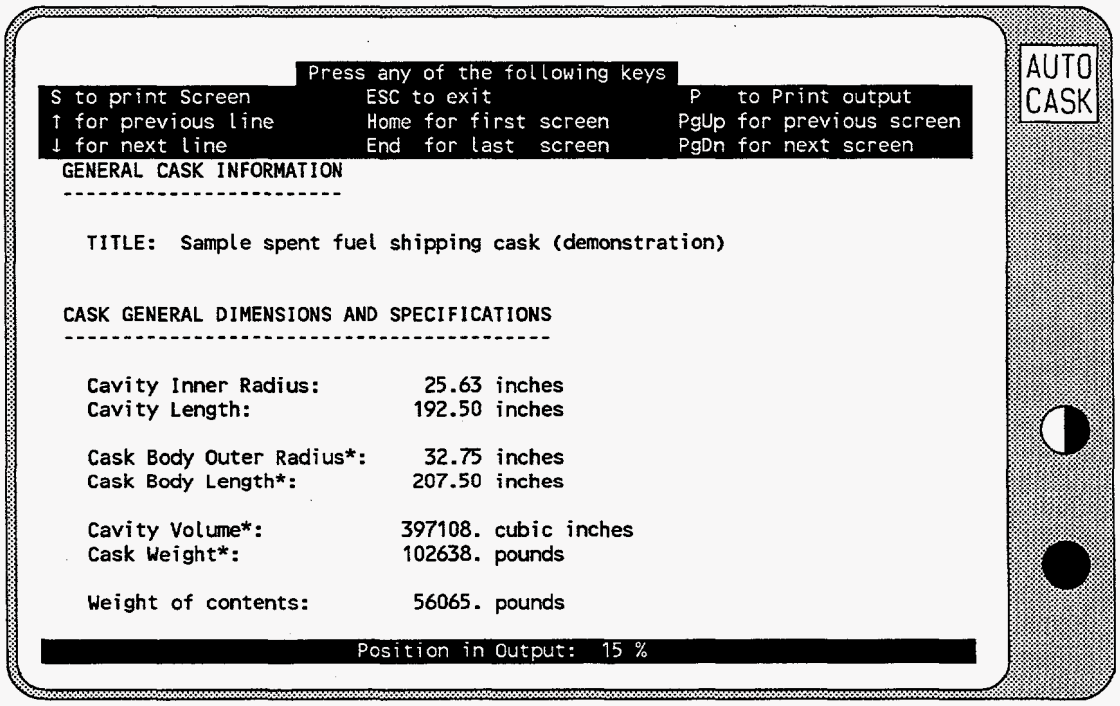

Figure 4-7. Reviewing the Data Check Cask Summary.

AUTOCASK displays an Output Summary Screen indicating the number of pages in the output with a reminder to make sure the printer is ON-LINE and set to the TOP-OF-PAGE (**Figure 4-8**). *AUTOCASK* lists the following options:

Press **P** to Print the Data Check Cask Summary
Press **Q** to QUIT and return to the Display Menu

As the output is printed, *AUTOCASK* indicates the current page being printed. Press any key to suspend printing. When printing is halted, *AUTOCASK* lists the following options:

Press **C** to Continue
Press **Q** to QUIT and return to the Display Menu

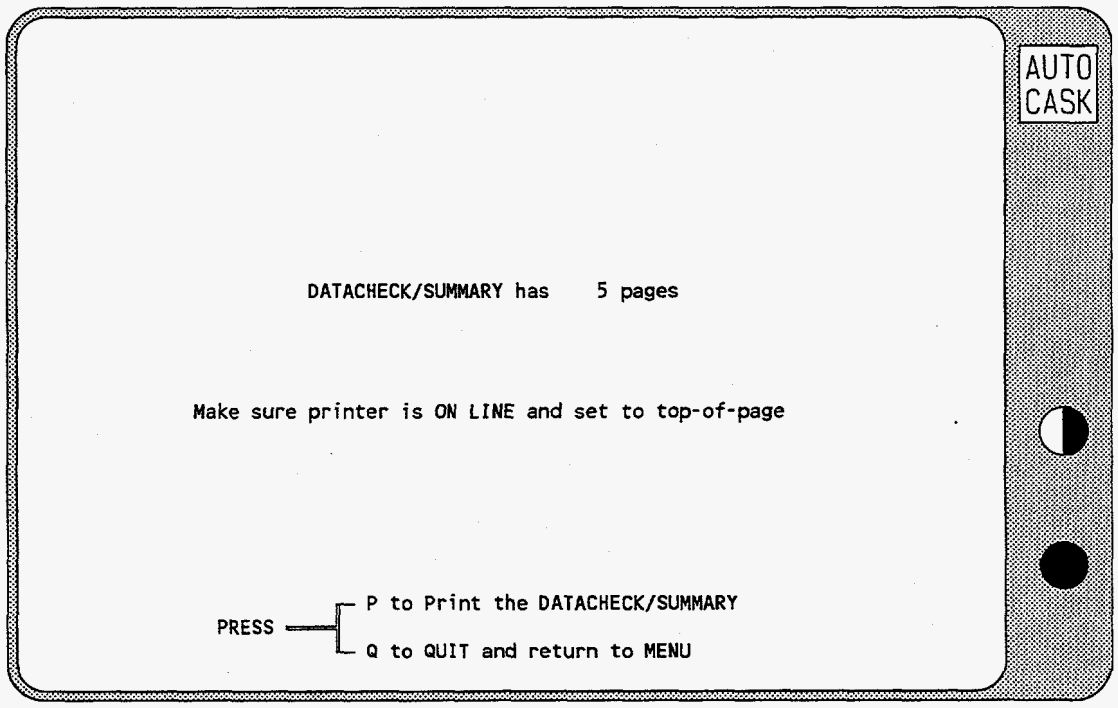

Figure 4-8. Printing the Data Check Cask Summary.

5

Generate Analysis Input

AUTOCASK displays the Specify Loads and Orientation Title Screen. Press **Q** to QUIT and return to the MAIN Menu, or press any other key to select the analysis conditions. *AUTOCASK* displays the screen shown in **Figure 5-1** and lists the following options:

Press **Q** to QUIT and return to the MAIN Menu
Press **M** to Make the MODEL file
Press ↑ to move to the previous choice box
Press ↓ to QUIT to the next choice box

Specifying the G-Load

Highlight the *G-Load* field. Enter a value for the G-Load (in Gs). Range is 0. to 1000000.

Specifying the Impact End

Highlight the *Impact End* field. Press one of the following function keys to select the desired impact end. **Note:** Impact end only applies to end-on and oblique impacts, not side impacts.

F1 for an impact on the cask bottom
F2 for an impact on the cask top

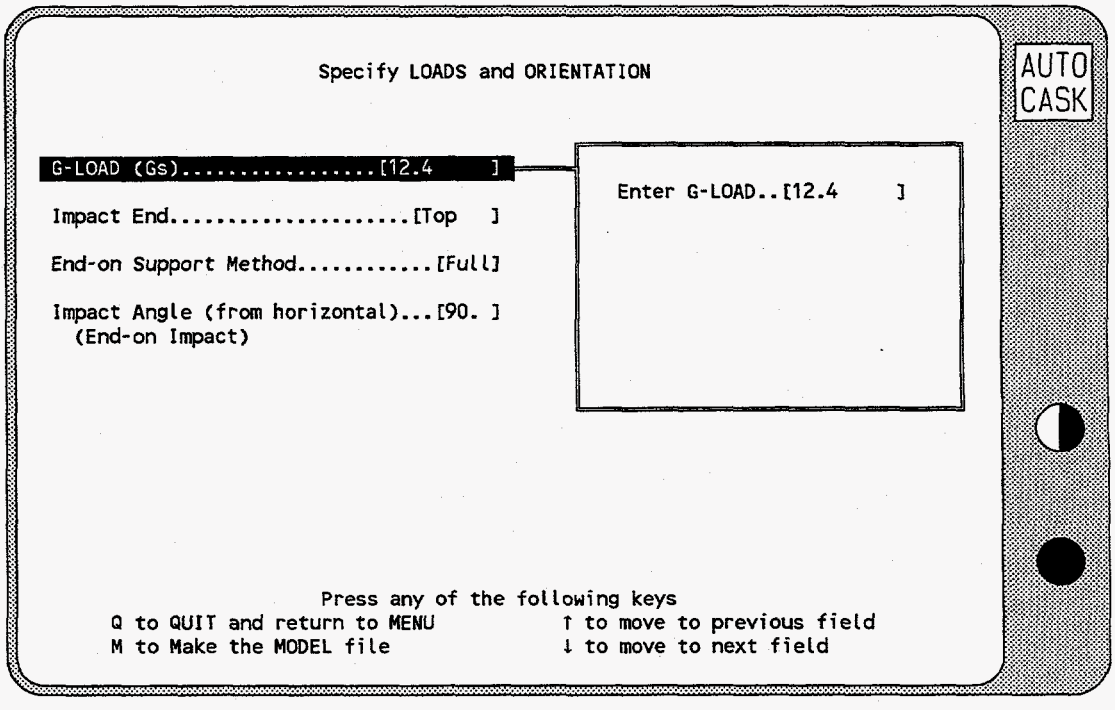

Figure 5-1. Specify Loads and Orientation of the cask.

Specifying the End-on Support Method

Highlight the *End-on Support Method* field. Press one of the following function keys to select the desired impact end. **Note:** End-on support method only applies to end-on impacts.

F1 for full support of the impacting end cap. The entire end cap surface is included in the contact condition.

F2 for a ring support of the impacting end cap. For a **bottom** impact the ring is the area under the shell. For a **top** impact the ring is the area outside the bolt circle.

Specifying the Impact Angle

Highlight the *Impact Angle* field. Press one of the following function keys to select the desired impact angle. **Note:** All angles are measured from the horizontal; an angle of 0. degrees is a side impact, an angle of 90 degrees is an end-on impact. For an arbitrary angle the model is over constrained and the results may be questionable for the end of the cask away from the impact point.

F1 for a side impact (0 degrees)

F2 for an end-on impact (90 degrees)

F3 for a CG impact (CG-over-corner)

F4 for an arbitrary impact angle. Enter the impact angle. Range is 0. to 90. An angle of 0. selects a side impact, and an angle of 90. selects an end-on impact.

Making the Model File and generating the Analysis Input file

After all analysis conditions are selected, press **M** to make the model file. This file contains mesh generator commands to create the three-dimensional finite element model. After the model file is complete, press **Q** to QUIT and return to the MAIN Menu or press any other key to generate the analysis input file. *AUTOCASK* uses a stand-alone mesh generator package to generate a complete, ready-to-run analysis input file, including all control parameters, material properties, and loading conditions.

The name of the model file is of the form **MFxxxx** and the name of the analysis input file for NIKE3D is of the form **NKxxxxI**, where **xxxx** is the associated CASK ID.

6

Archive Menu

The Archive Menu (**Figure 6-1**) provides options for archiving cask data sets to diskettes, retrieving archived cask data sets, and deleting cask data sets from the hard disk.

PRESS 1 to Archive CASK data set on diskettes

Creates a compressed data set archive containing the cask geometry, data check cask summary, and data check flag file for the selected cask. Then writes the data set archive to diskettes.

PRESS 2 to Retrieve CASK data set from diskettes

Retrieves a compressed data set archive from diskettes and uncompresses it, restoring the data set to the hard disk.

PRESS 3 to Delete CASK data set from hard disk

Deletes the complete data set for the selected cask.

PRESS M to Return to MAIN MENU

AUTOCASK returns to the Main Menu display.

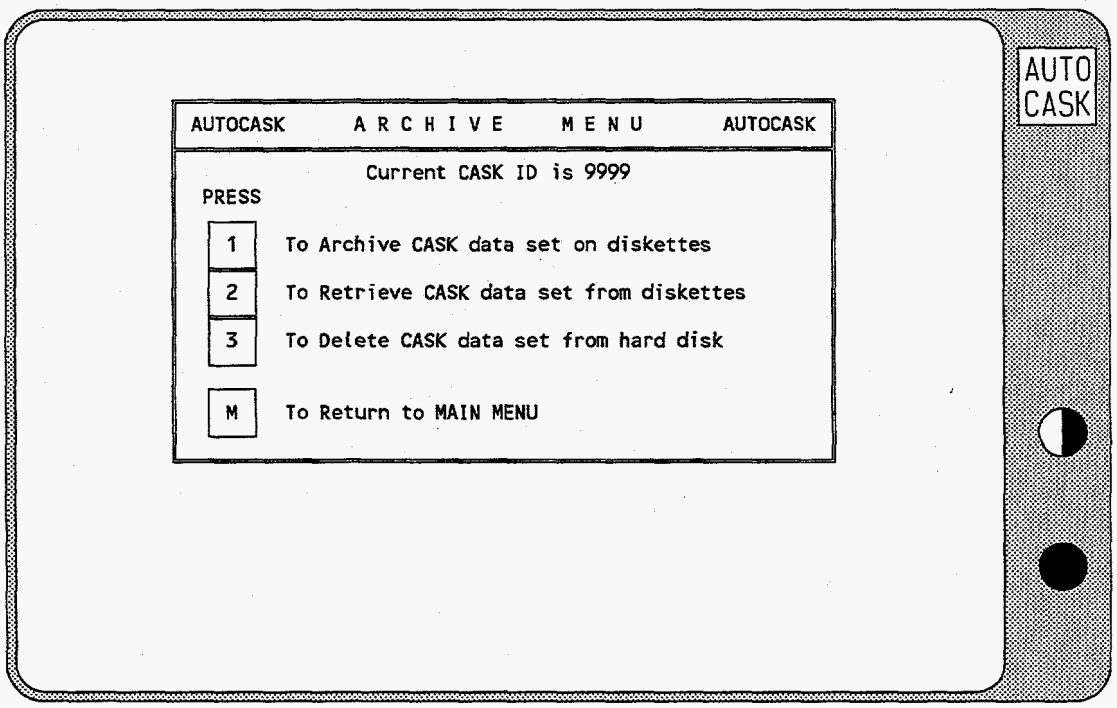

Figure 6-1. *AUTOCASK* Archive Menu.

AUTOCASK archives data sets by creating a compressed data set archive and then writing the archive to a diskette. If the archive is larger than a single diskette, ***AUTOCASK*** automatically uses the DOS utility *BACKUP* to save the archive on more than one diskette. All existing data sets can be archived from the Archive Menu. The number of existing data sets is indicated on the Archive Data Sets Title Screen. Press **Q** to QUIT and return to the Archive Menu, or press any other key to select the data set to archive. ***AUTOCASK*** displays a list of CASKIDs and indicates several options (**Figure 6-2**):

Press **Q** to QUIT and return to the Archive Menu
Press **A** to Archive the summarized data set
Press ↑ to move to previous CASK
Press ↓ to move to next CASK

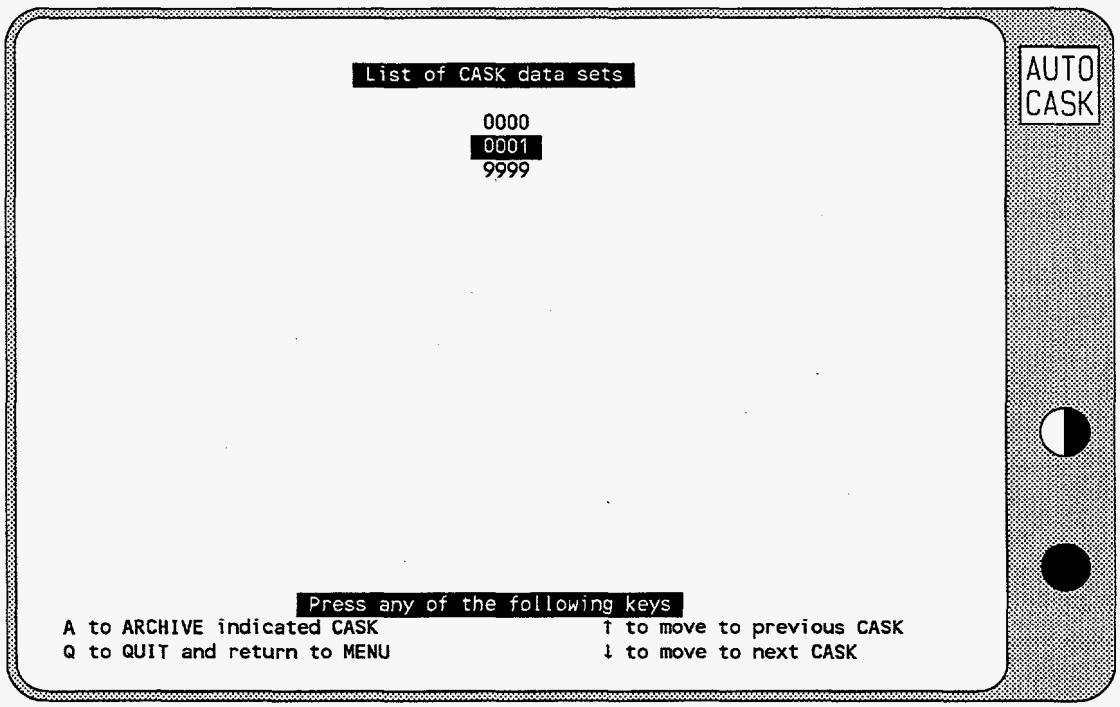

Figure 6-2. List of cask data sets to Archive.

AUTOCASK starts the archive process by creating a compressed data set archive. The resulting compressed archive requires only 60 percent of the space the complete data requires. After the compressed archive is created, *AUTOCASK* asks for a **formatted** diskette in drive **A:** or **B:**. Because of potential drive/diskette incompatibility, do not use a 360Kb diskette in a 1.2Mb drive. To proceed:

Press **A** to Select DRIVE **A:**
Press **B** to Select DRIVE **B:**
Press **Q** to QUIT and return to the Archive Menu

AUTOCASK checks the selected drive and compares the space requirements for the archive with the available space on the diskette. The error conditions that can occur are listed in **Table 6-1**. Archiving will not proceed until all error conditions are satisfied.

If the compressed archive will fit on a single diskette, *AUTOCASK* will use *COPY* to write the archive to the diskette. If the archive will not fit on a single diskette, *AUTOCASK* will use *BACKUP* to write the archive to multiple diskettes (*AUTOCASK* indicates how many formatted diskettes of similar density are required). If the archive exists on the diskette, *AUTOCASK* displays the date and time of the hard disk version and the diskette version of the archive. Press the appropriate key to continue with archiving:

Press **ENTER** to write the Archive to diskette
(using *COPY* if the archive will fit on one diskette)
(using *BACKUP* if the archive will not fit on one diskette)
Note: If archive exists on diskette, it is pre-deleted
Press **S** to Select different Diskette or Drive
Press **Q** to QUIT and return to the Archive Menu

BACKUP will request necessary number of diskettes to complete the *BACKUP* process. Be sure to label the diskettes with the order in which they were processed. *RESTORE* will request *BACKUP* diskettes in the order they were written.

When *AUTOCASK* finishes writing the archive to diskettes, the following options are presented:

Press **C** to Continue (to select other data sets to archive)
Press **D** to DELETE cask data set (from the hard disk)
(*AUTOCASK* asks for confirmation before deleting)

AUTOCASK asks for confirmation before deleting any data set. Press **F1** to delete the data set, or press **F9** to continue without deleting. After archiving the data set is complete, *AUTOCASK* displays the number of data sets remaining on the hard disk that may potentially be archived. If no data sets remain on disk, press **ENTER** to return to the Archive Menu. If one or more data sets remain on disk, press **A** to archive additional data sets, or press **Q** to QUIT and return to the Archive Menu.

Table 6-1. Possible Error Messages during Archiving.

There is NO diskette in drive *X:*

Possible causes: wrong drive selected, or drive door is not closed. Make sure a diskette is in drive **A:** or **B:** and that the drive door is closed.

Diskette is UNFORMATTED or a 1.2Mb diskette is in a 360K drive

Possible causes: diskette is unformatted, diskette is damaged and unreadable, or 1.2Mb diskette is in a 360K drive. Make sure the diskette is formatted and of the correct density.

General ERROR on drive *X:*

Possible causes: diskette is reversed, diskette is damaged and unreadable, or drive is malfunctioning. Try a different drive and/or diskette.

Not enough space on the diskette

The compressed archive will fit on the diskette if other data is not on the diskette. Either remove data from the diskette or provide a diskette that has more space.

Diskette is a BACKUP diskette, ARCHIVE will fit on one diskette

AUTOCASK will use *COPY* to write the archive on a single diskette. Existing data on the diskette was written by *BACKUP*. Use a non-*BACKUP* diskette.

Diskette is a BACKUP diskette NOT for this ARCHIVE

AUTOCASK will use *BACKUP* to write the archive on multiple diskettes. Existing data on the diskette was written by *BACKUP* for data other than this archive. Use a different diskette.

Diskette is BACKUP diskette for DOS versions 3.2 and higher
Current DOS versions is x.xx

AUTOCASK will use *BACKUP* to write the archive on multiple diskettes. Existing data on the diskette was written by a DOS 3.2 or higher version of *BACKUP* and current version of DOS is less than 3.2. Use a different diskette.

These files will be LOST during BACKUP of ARCHIVE if you proceed

AUTOCASK will use *BACKUP* to write the archive on multiple diskettes. The diskette contains the listed files and is NOT a *BACKUP* diskette. These files will be lost if you proceed with this diskette. Use a different diskette or lose the files.

ARCHIVE is already on DISKETTE

Archive has already been saved. *AUTOCASK* displays the time and date for the data set on the hard disk and on the diskette. Use a different diskette, overwrite the existing archive, or quit.

AUTOCASK retrieves compressed data sets from diskettes and then unpacks the archive, restoring the data set to the hard disk. *AUTOCASK* lists two options on the Retrieve Data Sets title screen:

Press **Q** to QUIT and return to the Archive Menu
Press any other key to start retrieval of data set

Place the diskette containing the compressed data set archive (or the first *BACKUP* diskette for the archive) in either drive **A:** or **B:** and press one of the following keys:

Press **A** to find data sets on diskette in Drive **A:**
Press **B** to find data sets on diskette in Drive **B:**
Press **Q** to QUIT and return to the Archive Menu

AUTOCASK checks the selected drive and searches for archived data sets. The error conditions that can occur are listed in **Table 6-2**. Retrieval will not proceed until all error conditions are satisfied.

If the diskette contains only one archived data set, *AUTOCASK* selects that data set for retrieval. If the diskette contains more than one archived data set, *AUTOCASK* displays a list of CASKIDs for the archived data sets and lists several options:

Press **S** to Select the highlighted CASKID for retrieval
Press **Q** to QUIT and return to the Archive Menu
Press ↑ to highlight the previous CASKID
Press ↓ to highlight the next CASKID

AUTOCASK displays the date and time of the selected archive on the diskette and warns if this data set will replace an existing data set on the hard disk. *AUTOCASK* lists the following options:

Press **ENTER** to retrieve the Archive
(using *COPY* if the archive was saved with *COPY*)
(using *RESTORE* if the archive was saved with *BACKUP*)
Press **S** to Select different Diskette or Drive
Press **Q** to QUIT and return to the Archive Menu

AUTOCASK asks for confirmation before deleting the existing data set. Press **F1** to delete the data set from the hard disk, or press **F9** to QUIT and return to the Archive Menu. After deleting the data set (if necessary), *AUTOCASK* starts retrieving the archived data set. If the archive was saved using *BACKUP*, *AUTOCASK* uses *RESTORE* for retrieval. *RESTORE* will request the archive *BACKUP* diskettes in the order they were written. After the archive is retrieved from the diskette, *AUTOCASK* unpacks the data from the archive. Be patient, this process may take a little while. When unpacking is complete, press **R** to retrieve additional data sets, or press **Q** to QUIT and return to the Archive Menu.

Table 6-2. Possible Error Messages during Retrieving.

There is NO diskette in drive *X:*

Possible causes: selected the wrong drive; drive door is not closed. Make sure a diskette is in drive **A:** or **B:** and that the drive door is closed.

Diskette is UNFORMATTED or a 1.2Mb diskette is in a 360K drive

Possible causes: diskette is unformatted; diskette is damaged and unreadable; 1.2Mb diskette is in a 360K drive. Make sure the diskette is formatted and of the correct density.

General ERROR on drive *X:*

Possible causes: diskette is reversed; diskette is damaged and unreadable; drive is malfunctioning. Try a different drive and/or diskette.

NO Archives on diskette

Diskette does not contain any compressed data set archives. Archive names have the form **xxxxDATA.CSK**, where **xxxx** is the four digit CASKID. Try a different diskette.

DATA set exists on HARDDISK and will be LOST if you proceed

The selected data set already exists on the hard disk. *AUTOCASK* displays the time and date for the data set on the diskette and for the data set on the hard disk. If you proceed, the data on the hard disk will be overwritten.

Unable to retrieve cask data set xxxx

Unable to retrieve the selected data set from the diskette. The diskette may have been corrupted.

Data sets consist of the cask geometry descriptions, data check cask summary, and the data check flag file. All existing data sets can be deleted from this menu. *AUTOCASK* indicates the number of existing data sets. Press **Q** to QUIT and return to the Archive Menu, or press any other key to select the data set to delete. *AUTOCASK* displays a list of CASKIDs and indicates several options:

Press **D** to Delete the highlighted CASKID
Press **Q** to QUIT and return to the Archive Menu
Press ↑ to highlight the previous CASKID
Press ↓ to highlight the next CASKID

AUTOCASK asks for confirmation before deleting the data set or output as shown in **Figure 6-3**. Press **F1** to delete the data set or output. Press **F9** to QUIT and return to the Archive Menu without deleting. If no data sets remain on disk, press **ENTER** to return to the Archive Menu. When *AUTOCASK* has completed deleting the data set or output, if one or more data sets remain on disk, *AUTOCASK* lists the following options:

Press **D** to Delete additional data sets
(redisplays the data set list screen)
Press **Q** to QUIT and return to the Archive Menu

Caution ! ! !

Once a data set or its output is deleted, it is not recoverable unless it was archived on diskettes. **Be careful when deleting data sets.**

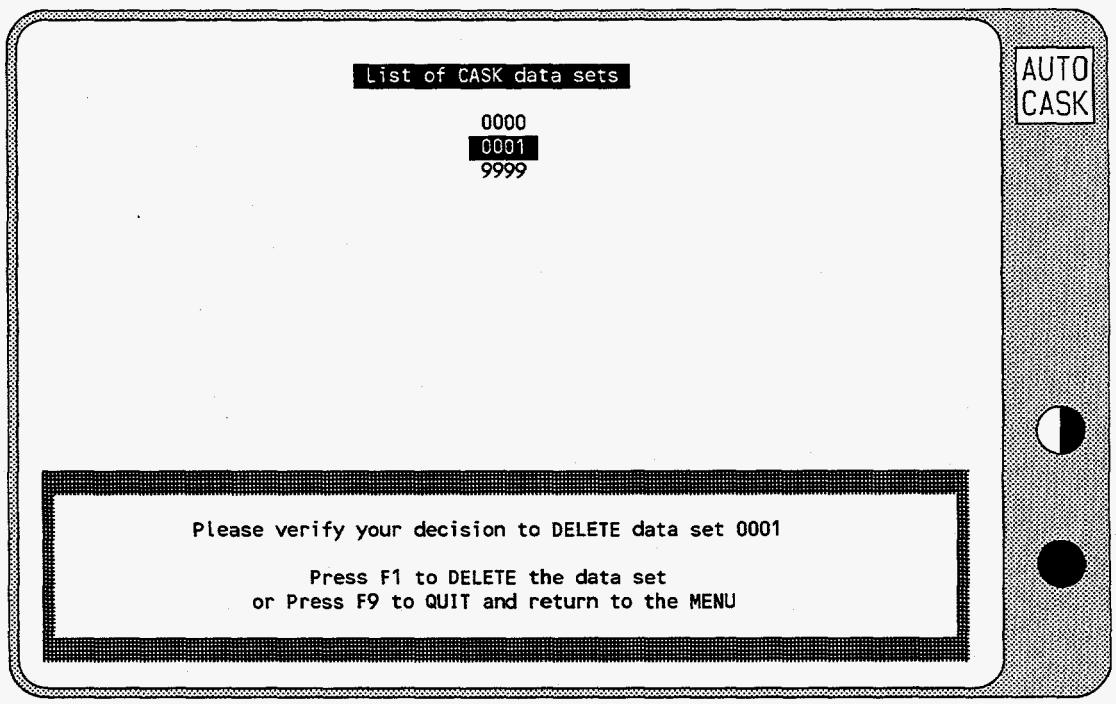

Figure 6-3. Confirm decision to DELETE screen.

7

Performing an Analysis

Performing an analysis involves the following steps:

(1) Transfer the analysis input file to the workstation or mainframe computer. The form of the NIKE3D input file name is **NKxxxxI**, where **xxxx** is the CASK ID.
(2) Run the structural analysis program NIKE3D [1].
(3) Review the structural analysis results. TAURUS [2] is used to display NIKE3D results graphically. The NIKE3D text output may be printed or displayed using an editor.

Transferring the Analysis Input File to the Workstation or Mainframe Computer

Transfer the analysis input file to the workstation or mainframe computer either using a floppy diskette or electronically over a network connection using ftp.

Running the Analysis Program

NIKE3D is an implicit, finite-deformation, finite element program for analyzing the static and dynamic response of three-dimensional solids. NIKE3D calculates the quasi-static response of the cask to an applied G-load. Since contact/impact analyses may have difficulty converging with large load steps, the quasi-static G-load is applied to the cask over a series of ten load steps. To run NIKE3D, enter the program execute line shown below. An example of running NIKE3D is shown in **Figures 7-1** and **7-2**. NIKE3D indicates the status of each load step as the analysis progresses.

nike3d i=nkxxxxi o=nxxxxo g=nxxxxp

where: **nkxxxxi** is the name of the input file for NIKE3D
nxxxxo is the name of the NIKE3D printable output file (text)
nxxxxp is the name of the NIKE3D plotable output file (database)
xxxx is the CASK ID

```
nike3d i=nk9999i o=n9999o g=n9999p

**********************************************************************

    *      **  ******  **    **   *********  *********  *******
    **     **  ******  **   **    *********  ********   ********
    ***    **    **    **  **     **             **     **   ***
    ****   **    **    ** **      **           ***      **    **
    ** **  **    **    ****       *******     *****     **    **
    **  ** **    **    *****      *******       ***     **    **
    **   ****    **    **  **     **            **      **    **
    **    ***    **    **   **    **          ***   ***   **   ***
    **     **  ******  **    **   *********   *******   ********
    **      *  ******  **     **  *********    *****    *******

          NIKE3D  -  VERSION  2.3.5     COMPILED 05/06/94

**********************************************************************


file names used :

i=nk9999i    o=n9999o     d=n3dump     g=n9999p
f=n3runr     t=thrxyz     c=itrcnt


ANALYSIS TITLE
==============================================================
Sample spent fuel shipping cask (demonstration)              AUG 31, 1994


MEMORY available
==============================================================
                                 total        this job
                 (Mbyte):       17.600        17.600

               . . .
                . . .
                 . . .


CONSTITUTIVE history data
==============================================================
    type       # elements       size (words)       blocks
    ----       ----------       ------------       ------
    solid          1224              147456            3
    beam             27               49152            1


LINEAR EQUATION SOLVER data
==============================================================
    number of equations                          =      5605
    available working space                      =   4394395
    working space used                           =   2214964
    number of words in stiffness matrix          =   2203751
         maximum column height                   =      4162
         average column height                   =       393
    number of blocks in out-of-core solution     =         1
```

Figure 7-1. NIKE3D initialization messages.
User input is shown as inverse print, white-on-black.

```
======= beginning time step #   1 =======
iterating:  1
Nonlinear solution status: time=  1.0000E-01  step #    1  iteration #  1
   stiffness updates              =  0
   right hand side evaluations    =  2
   stiffness  matrix reformations =  0
   step size from line search     =  1.0000E+00
   convergence norms:   INITIAL      CURRENT      REQUIRED
     residual         6.9203E+07    1.2423E+09    6.9203E+17
     energy           5.5953E+03    5.5953E+03    5.5953E+01
     displacement     9.5835E-01    9.5835E-01    9.5835E-07

   iteration process diverging . . . . . commence reformation # 1

              . . .
               . . .
                . . .

Nonlinear solution status: time=  1.0000E+00  step #   10  iteration #  1
   stiffness updates              =  0
   right hand side evaluations    =  9
   stiffness  matrix reformations =  2
   step size from line search     =  1.0000E+00
   convergence norms:   INITIAL      CURRENT      REQUIRED
     residual         1.3801E+09    8.5044E+08    1.3801E+19
     energy           6.0016E+03    5.8158E+01    6.0016E+01
     displacement     1.0405E+00    1.0404E-04    1.0500E-04

 . . . . . . . . . . . . . . . . . . . . . . . augmentation  #  2
   slide surfaces:      FORCE          GAP         REQUIRED
   stonewalls:         CURRENT        CHANGE       REQUIRED
     #  1             2.6446E+06    1.3005E-09    1.0000E-02
 . . . . . . . . . . . . . . . . . . . . . . . augmentation  loop converged
------- converged at time= 1.0000E+00


RESTART file  n3dump    written


LINEAR EQUATION SOLVER data
============================================================
    number of equations                          =     5605
    available working space                      =  4394395
    working space used                           =  2216002
    number of words in stiffness matrix          =  2204789
         maximum column height                   =     4162
         average column height                   =      393
    number of blocks in out-of-core solution     =        1


n o n l i n e a r   i t e r a t i o n   i n f o r m a t i o n

    number of time steps completed . . . . . .      10

    total number of equilibrium iterations . . . . . .     142

    average number of equilibrium iterations . . . . .   14.20

    total number of stiffness formations . . . . . .      40

total time charged for run (unweighted) =       2881.650


n o r m a l   t e r m i n a t i o n
```

Figure 7-2. NIKE3D solution messages.

Reviewing the Structural Analysis Results

NIKE3D produces both a printable output file and a plotable output file. If these files are very large, they are *familied* as a series of files with the root name specified on the NIKE3D execute line and a two-digit sequence number. An example of a set of *familied* files is shown below.

Specified graphics file name	*Family* of files created
g=n9999p	**n9999p**
	n9999p01
	n9999p02
	n9999p03

The printable output file may be either printed or examined using an editor. The section titles in the printable output file are shown in **Table 5-1**. These may be used with an editor *find* command to locate the various parts of the output. The plotable output may be graphically displayed using TAURUS.

Table 5-1. Section titles in the NIKE3D printable output file.

control information	
material definitions	
nodal point data	
element information	
beam element information	
slide surface information	
generated nodal data	
rigid wall definitions	
load curves	
at time 1.0	(top of each page of results, step 10 at time 1.0)
nodal print out	(top of each page of nodal results)
element stress calculations	(top of each page of element stress results)
resultants and stresses	(occurs once at beginning of beam results)

Using TAURUS to Display Graphic Output

TAURUS is an interactive, graphic, post-processor for NIKE3D. The default display is an X-Window. TAURUS can also direct the graphic output to a Post Script disk file for portrait or landscape orientations and for black and white or color printers.

The model is displayed in three-dimensions with perspective, and can be rotated and moved about on the screen. Rotations are defined about axes fixed to the display screen: the **X** axis is along the bottom of the screen to the right; the **Y** axis is along the left edge of the screen, upward; and the **Z** axis points out from the screen. Global rotations and translations are defined using these axes.

Several of the most useful TAURUS commands are shown in **Table 5-2**. Commands may be stacked on a single line by separating them with a space.

Table 5-2. TAURUS commands.

end	Terminate TAURUS.
state #	Select analysis solution state to display, where # is the state number. Select the last state, normally state 11.
zv	Display the geometry with hidden lines removed (faster than **view**)
view	Display the geometry with hidden lines removed
triad	Toggle the display of a model coordinate triad in the lower left corner of the screen, indicating the orientation of model.
rx ang	Rotate the model **ang** degrees about the screen X axis.
ry ang	Rotate the model **ang** degrees about the screen Y axis.
rz ang	Rotate the model **ang** degrees about the screen Z axis.
dist d	Set the distance to the model to **d**. Use **summary** to display the current **d**. Increase **d** to make the model appear smaller, decrease **d** to make the model appear larger.
xtrans x	Move the model **x** along the screen X axis.
ytrans y	Move the model **y** along the screen Y axis.
ztrans z	Move the model **z** along the screen Z axis.
center	Center the model on the screen.
dsf s	Set the displacement scale factor to **s**, default is 1. Useful for viewing deformed shapes.
angle ang	Set the perspective angle to **ang** degrees, default is 45. Increase **ang** for more perspective, decrease **ang** for less perspective.
summary	List the view settings, including the range of model coordinates, location of the view center, distance to the model, and the perspective angle.
restore	Restore the view settings to the default settings.

m a Display only material **a**.

dam Display all materials, default.

dms n a b c ... Display a subset of materials. **n** is the count of materials to be displayed, and **a b c ...** are the materials to display.

Table 5-2. TAURUS commands. *continued*

contour c	Plot contours of **c** on all displayed materials, using hidden-lines.
fringe c	Plot fringes of **c** on all displayed materials, using hidden-lines.

c	**Contour or fringe of**
1	x normal stress
2	y normal stress
3	z normal stress
4	xy shear stress
5	yz shear stress
6	zx shear stress
7	effective plastic strain
9	von Mises stress
13	maximum shear stress
14	1st principal maximum stress
15	2nd principal stress
16	3rd principal minimum stress

NOTE: Materials are numbered in the following component sequence. If a component is laminated, the outer layer is numbered first, followed by the inner layer, and then the shield layer.
(a) Bottom end cap. Starts with material 1.
(b) Top end cap.
(c) Shell.
(d) Bolts. Half bolts at symmetry plane first, then full bolts.
(e) Contents.

An example of using TAURUS to display the results of an analysis is shown in **Figure 7-3**. The resulting TAURUS plots are show in **Figures 7-4** to **7-7**. The first two rotate commands orient the model with the top end cap up. The next two rotate commands orient the cask for an isometric view. The perspective angle is reduced to 22.5° for the first view (**Figure 7-4**). The two rotate commands orient the model so the symmetry plane is parallel to the screen. Solution state 11 (at time 1.0, reflecting the full G-load) is read and the perspective angle is reduced to 1, eliminating virtually all perspective. The model has eight materials. The **dms** command selects the first five materials which represent the bottom end cap (material 1), the shell (materials 2, 3, and 4), and the top end cap (material 5). The bolts (materials 6 and 7) and the cavity contents (material 8) will not appear in subsequent views. The displacement scale factor is set to magnify the displacements by 400. The model is displayed with contours of Z stress superimposed (**Figure 7-5**). Next, material 1 (bottom end cap) is selected, and two rotate commands are used to provide an isometric view. Perspective is restored by setting the perspective angle to 22.5, material 1 is centered on the screen for the view, and the displacement scale factor is increased to 1000 (**Figure 7-6**). The displacement scale factor is set to 1, removing any magnification, and material 1 is displayed with contours of von Mises stress (**Figure 7-7**). Then TAURUS is terminated.

```
taurus g=n9999p

     TAURUS
     Revision  3.1.94
     Date compiled : 9/07/94
     Operating System :  AIX
     Blank common available :  2000000 words

      ***** ANALYSIS TITLE *****
     Sample spent fuel shipping cask (demonstra

     ***** ANALYSIS SUMMARY *****

     Number of nodal points :        2029
     Analysis code :                 nike3d
     Global variables per state:       51
     Nodal data options:
          Temperture (1=inc):           0
          Cur Geometry :                1
          Velocities :                  1
          Accelerations:                0
     Number of Brick Elements :      1224
     Number of Brick Materials :        6
     Number of Brick Variables :        7
     Number of Beam Elements :         27
     Number of Beam Materials :         2
     Number of Beam Variables :         6
     Number of States:                 11
     Final valid time:             1.0000
     Default Color Levels:
          X11:                       128
          Gray Scale PostScript:       8
          Color PostScript:           16

     Geometry range:
          Xmin: -1.18008E-01 Xmax:  3.27500E+01
          Ymin: -3.27500E+01 Ymax:  3.27500E+01
          Zmin:  0.00000E+00 Zmax:  2.07500E+02
          Umin:  0.00000E+00 Umax:  0.00000E+00

     Origin (x,y,z):              1.6316E+01  -5.7220E-06   1.0375E+02
     Initial dist from eye to object:         4.02028E+02
     Initial field of view (deg) :                  45.00
     Initial zmin (dist to near clip plane):  1.00000E-01
     Initial zmax (dist to far clip plane):   8.30000E+02

phs1> ry 90 rz 90 ry 35 rx 20 angle 22.5 zv                          Figure 7-4
phs1> rx -20 ry -35 state 11 angle 1 dms 5 1 2 3 4 5 dsf 400 cont 3  Figure 7-5
 time =   1.0000
phs1> m 1 ry 35 rx 20 angle 22.5 center dsf 1000 zv                  Figure 7-6
    Geometry range:
         Xmin: -2.95639E+01 Xmax:  3.03034E+01
         Ymin: -1.22488E+01 Ymax:  1.21669E+01
         Zmin: -2.59031E+01 Zmax:  2.50644E+01
         Umin: -9.47773E-03 Umax:  1.80559E-03

    Origin (x,y,z):              7.1712E+00  -2.1613E+00   3.5681E+00
    Initial dist from eye to object:         2.23866E+02
    Initial field of view (deg) :                  22.50
    Initial zmin (dist to near clip plane):  1.00000E-01
    Initial zmax (dist to far clip plane):   5.98673E+03
phs1> xtrans -5 dsf 1 frin 9                                         Figure 7-7
phs1> end
```

Figure 7-3. Displaying the analysis results using TAURUS. User input is shown as inverse print, white-on-black.

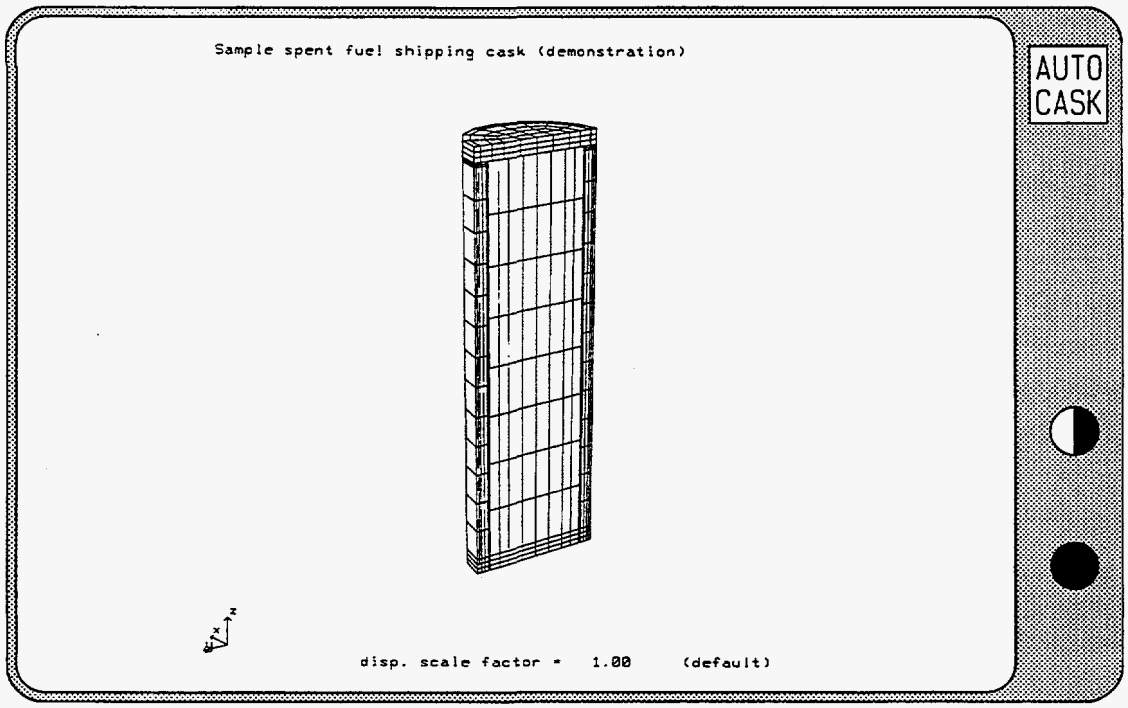

Figure 7-4. Isometric view of the cask model.

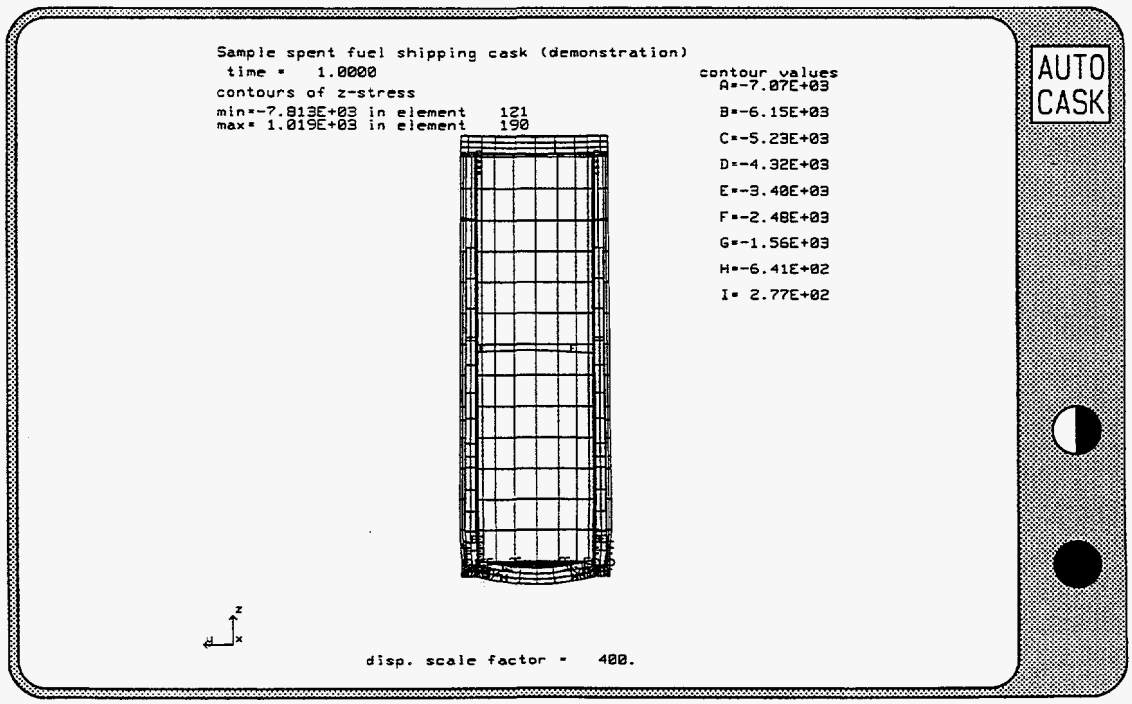

Figure 7-5. Cross-section view of cask body with contours of Z stress. Displacements are magnified 400 times.

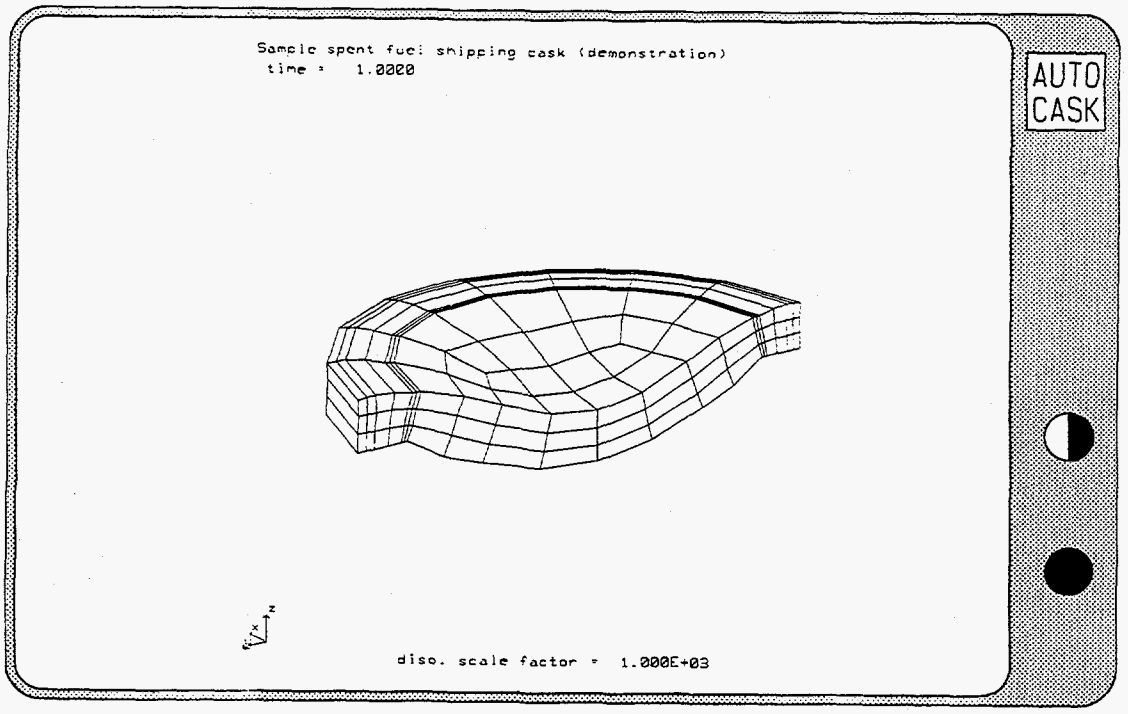

Figure 7-6. Isometric view of bottom end cap. Displacements are magnified 1000 times.

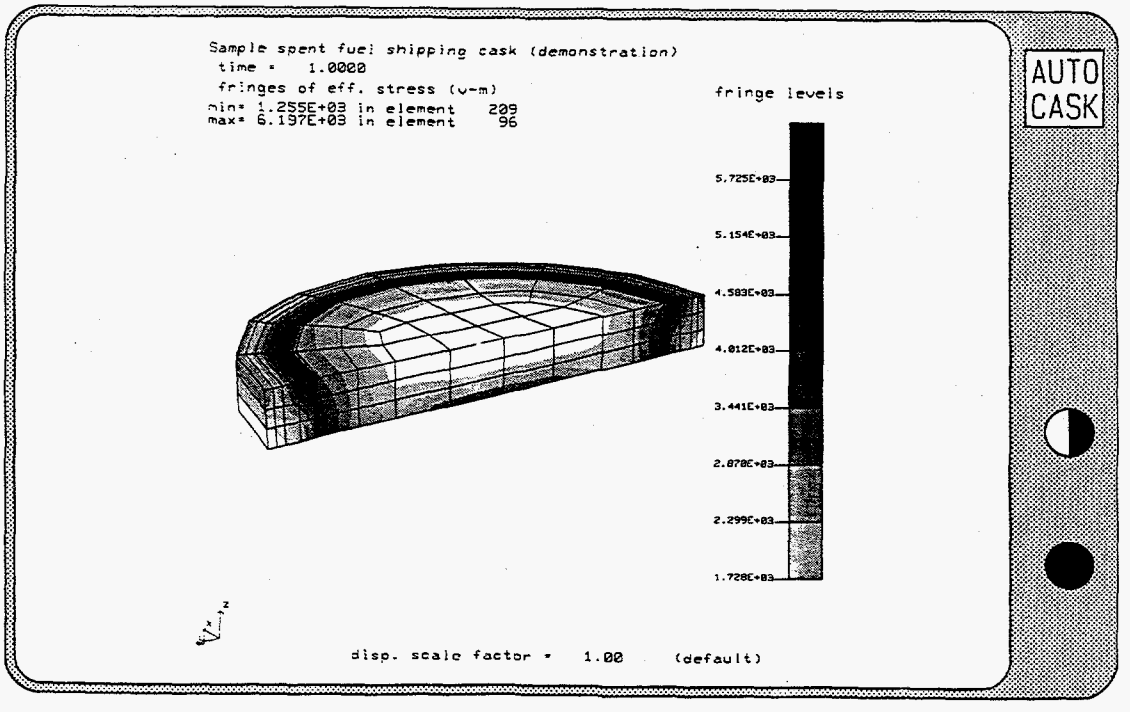

Figure 7-7. Isometric view of bottom end cap with contours of von Mises stress. Displacements are not magnified.

References

1. Bradley N. Maker, *NIKE3D: A Nonlinear, Implicit, Three-Dimensional Finite Element Code for Solid and Structural Mechanics, User's Manual*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-MA-105268 (1991).

2. Thomas Spelce, *TAURUS: An Interactive Post-Processor for the Analysis Codes NIKE3D, DYNA3D, and TOPAZ3D*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-MA-105401 (1991).

Appendix A

The Editor

AUTOCASK uses a general purpose fill-in-the-blank type editor to enter data for the basic geometry definition and impact limiter force-deflection curve definitions. The editor title screen indicates the status of the data set. If the data set does not exist, *AUTOCASK* lists the following options:

Press **Q** to QUIT and return to the Menu
Press any other key to proceed with editing (creates a new data set)

If the data set already exists, *AUTOCASK* lists the following options:

Press **Q** to QUIT and return to the Menu
Press **D** to delete current data set and create a new data set
Press any other key to proceed with editing (edit the current data set)

Delete the data set to start with a fresh data set with all data set to default values. *AUTOCASK* asks for confirmation before deleting the existing data set:

Press **F1** to delete the data set and create a new data set
(edit the new data set)
Press **Q** to QUIT and return to the Menu
Press **F2** to proceed with editing (edit the current data set)

AUTOCASK reads a template which describes the editor pages and how data values are saved in the data set. If creating a new data set, *AUTOCASK* displays a status screen which indicates each editor page as it is created. As pages are created, all values are set to appropriate defaults. *AUTOCASK* then displays the first editor page.

Description of Editor Pages

Each data set is divided into pages of related items. For example, all the items necessary to define the cask shell are on the same editor page. All pages have the same format (**Figure A-1**). The top line indicates the name of the data set [**A**], the CASK ID [**B**], and the current date [**C**]. The second line indicates the name of the editor page [**D**], the current page number of how many [**E**], and the date any item on the page was last changed [**F**]. The third line is a double green bar the full width of the screen. This line also indicates how many pages remain which must be accessed [**G**] and Insert Mode (if applicable) [**H**]. Below the second double green bar is a list of available function keys and their applications [**I**].

Between the double green bars are the item requests [**J**]. Each item request has a descriptive label indicating what to enter (units are included if appropriate) [**K**], and an item field delimited by square brackets [**L**]. Item descriptions displayed in *light blue* require an entry, while item descriptions displayed in *green* have default values which can be accepted as is. The count of pages remaining which must be accessed indicates pages which have items requiring an entry. Once entries are made on a page for *ALL* items requiring an entry, the page need not be accessed.

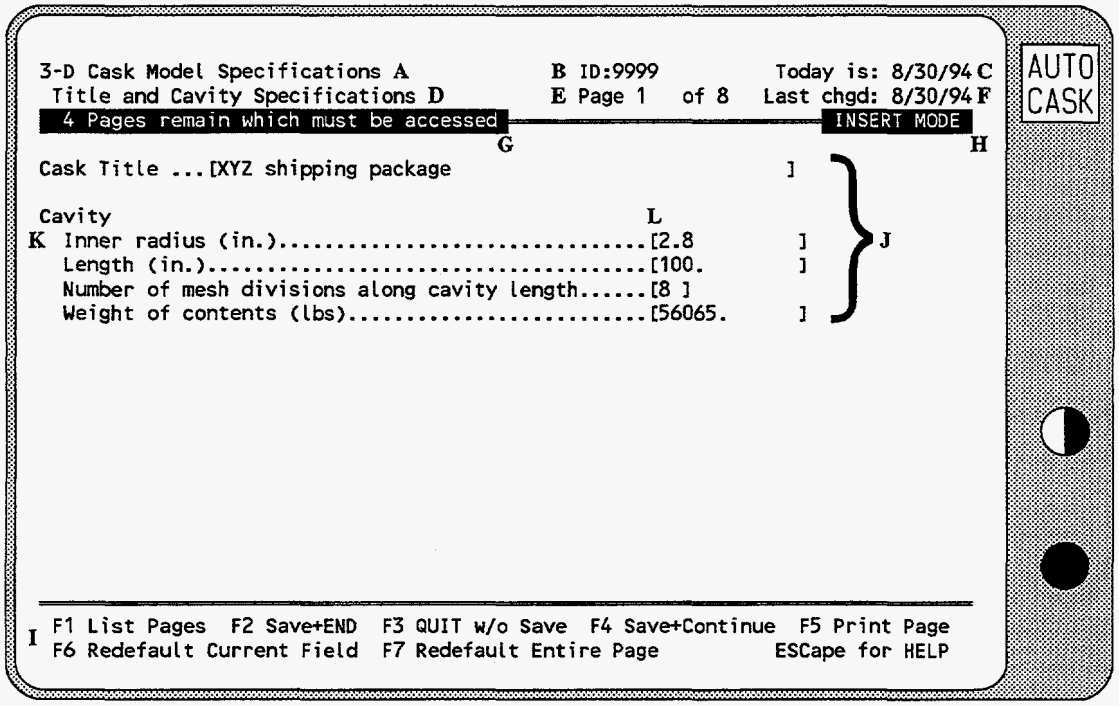

Figure A-1. *AUTOCASK* Editor Page Layout.

Getting Help

Press the **ESC** key to display the *HELP* screens. The first screen indicates the *AUTOCASK* current item type and restrictions placed on the item and describes the use of the function keys. The second *HELP* screen indicates the data entry and editing keys. The third *HELP* screen indicates the keys used to move between item fields and editor pages.

Saving the Edits

Save the changes made during the editing session using the following keys. The value in the current item field must be a valid item before *AUTOCASK* will save the edits.

F2 (function key)
Save the data set as is, end the editing session, and return to the current menu.

F4 (function key)
Save the data set as is and redisplay the current page to continue editing. Use this feature to save the edits periodically during a protracted editing session. *AUTOCASK will lose all edits not saved if a power failure interrupts the operation of the PC.*

Ending the Edit Session

End the editing session by pressing one of the following function keys:

F2 (function key)
Save the data set as is, end the editing session, and return to the current menu.

F3 (function key)
Abandon all edits during this session (or since the previous save), end the editing session, and return to the current menu. *AUTOCASK* asks for confirmation before proceeding: press **F1** to QUIT, abandoning the edits; or press **F9** to return to editing.

Moving Around

The blinking solid cursor identifies the current item field expecting an entry. The entry in the item field is checked for validity when the cursor is moved from this field to another. The entry must be valid before *AUTOCASK* will allow the cursor to leave the current item field. Use the following keys to accept the current entry and move to another item field:

UP Arrow (on the keypad)
Move to the previous item field on the current page. If the current item field is the FIRST on the page, move to the LAST item field.

DOWN Arrow (on the keypad) or **ENTER**
Move to the next item field on the current page. If the current item field is the LAST on the page, move to the FIRST item field.

PgUp (on the keypad)
Move to the FIRST item field on the previous page. If the current page is the FIRST editor page, move to the FIRST item field on the current page.

PgDn (on the keypad)
Move to the FIRST item field on the next page. If the current page is the LAST editor page, move to the FIRST item field on the current page.

F1 (function key)
Display list of all pages in the data set. Use the keypad **UP Arrow** and **DOWN Arrow** keys to highlight the desired page, and then press **F1** to move to the FIRST item field on the indicated page. The page list indicates which pages have items requiring an entry.

Entering a Value

Enter values by typing in the item field (typing in the first character position clears the field). Enter character string type items using letters, numerical digits and special characters ($,%,#, etc.). Enter integer-number type items using the form **±nnn**. The sign is optional; **n** is any numerical digit (0-9). Enter real-number type items using either the form **±nn.mmm** or **±nn.mmmE±jj** (scientific notation). The sign, decimal point and exponent are optional; **n**, **m**, and **j** are any numerical digit (0-9). Use the following keys to assist editing values in the item field.

LEFT Arrow (on the keypad)
Accept the character under the cursor and move the cursor to the left one character (can move as far left as the first character position).

RIGHT Arrow (on the keypad)
Accept the character under the cursor and move the cursor to the right one character (can move as far right as the last character position).

DEL (on the keypad)
Delete the character under the cursor and shift the remaining characters to the left.

BACKSPACE (above **ENTER**)
Delete the character to the left of the cursor and shift the remaining characters to the left.

INS (on the keypad)
Toggle insert mode on and off. When insert mode is on, **INSERT** appears in the upper right corner of the screen on the double green bar. All new characters are inserted at the cursor, shifting the remaining characters to the right. When insert mode is off, new characters are inserted at the cursor, and they write over previous characters.

F6 (function key)
Set the current item to the *AUTOCASK* default (NOT the previous saved value).

F7 (function key)
Set all items on the current page to the *AUTOCASK* defaults (NOT the previous saved values).

Making Selections from a List

Certain items are restricted to values presented in a list (**Figure A-2**). Use the following keys to change the selection indicated in the item field:

N or **n** Move blinking highlight cursor to the *NEXT* list item.
P or **p** Move blinking highlight cursor to the *PREVIOUS* list item.
S or **s** Select the item indicated by the blinking highlight cursor.

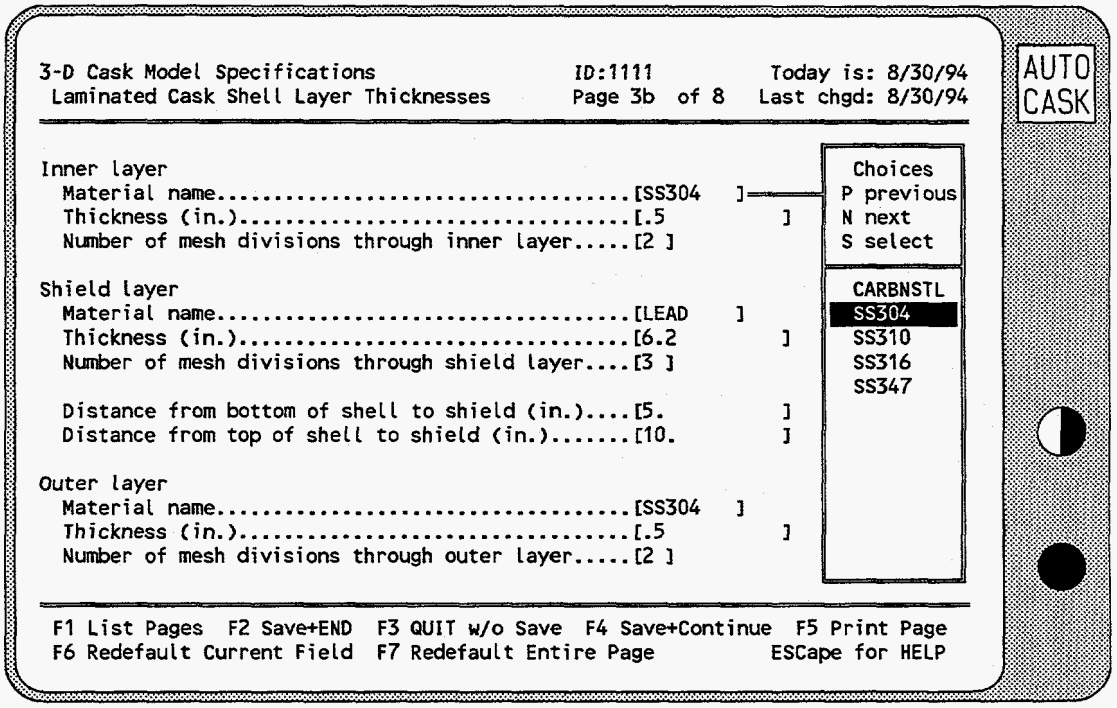

Figure A-2. Select Item from a List.

Copying Data from Another Editor Page

If the item requests displayed on the current editor page are the same as those on another editor page, press **F10** to copy data from another page. *AUTOCASK* displays a list of all pages that are appropriate for copying and indicates the current page. Use the **UpArrow** and **DnArrow** keys to indicate the page to copy from, and then press **C** to perform the copy. Press **R** to return without performing a copy.

Printing an Editor Page

Press the **F5** function key to print a copy of the current page. Make sure the printer is on-line and ready before printing the page.

Handling Errors

If an entry is invalid for the specified item, *AUTOCASK* displays an error message at the bottom of the screen and indicates any restrictions on the item. Press **ENTER** to clear the error message and return to editing.

Appendix B

Material Properties

The material sets used in *AUTOCASK* contain all the information required to perform NIKE3D impact analyses. These materials are built into *AUTOCASK* and cannot be modified. However, they may be copied and then modified by selecting **3** on the Geometry Menu. All properties are interpolated to 68 °F for the analyses.

Material	References
Structural and Bolt Materials	
Carbon Steel	1, 2
Stainless Steel 304	1, 2, 6
Stainless Steel 310	3, 4, 5, 6
Stainless Steel 316	3, 4, 5, 6
Stainless Steel 347	3, 4, 5, 6
Shielding Materials	
Lead	1, 2, 7

Structural and Bolt Materials

Carbon Steel Set name: *CARBNSTL*

Density: .2820 lb/cu.inch
Young's Modulus: 2.800E+07 psi (at 68 °F)
Poisson's ratio: .290 (at 68 °F)

Temp (°F)	Thermal Conductivity (BTU/in.min°F)	Specific Heat Capacity (BTU/lbm°F)	Young's Modulus (psi)	Poisson's Ratio	Coefficient of Thermal Expansion (in./in.°F)
-100.	.035000	.1130	2.900E+07	.2900	6.600E-06
68.	.034700	.1130	2.790E+07	.2900	6.639E-06
200.	.034700	.1130	2.770E+07	.2900	6.670E-06
300.	.034000	.1130	2.740E+07	.2900	6.870E-06
400.	.033300	.1130	2.700E+07	.2900	7.070E-06
500.	.032600	.1130	2.640E+07	.2900	7.250E-06
600.	.031500	.1130	2.570E+07	.2900	7.420E-06
700.	.029600	.1130	2.480E+07	.2900	7.590E-06

Stainless Steel 304 Set name: *SS304*

Density: .2841 lb/cu.inch
Young's Modulus: 2.840E+07 psi (at 68 °F)
Poisson's ratio: .290 (at 68 °F)

Temp (°F)	Thermal Conductivity (BTU/in.min°F)	Specific Heat Capacity (BTU/lbm°F)	Young's Modulus (psi)	Poisson's Ratio	Coefficient of Thermal Expansion (in./in.°F)
-58.	.011250	.1200	2.910E+07	.2900	8.700E-06
68.	.011400	.1230	2.840E+07	.2900	8.700E-06
212.	.012083	.1238	2.760E+07	.2900	8.700E-06
392.	.012083	.1275	2.660E+07	.2900	8.700E-06
572.	.013056	.1312	2.560E+07	.2900	8.700E-06
752.	.013889	.1350	2.390E+07	.2900	8.700E-06
1112.	.015278	.1425	2.250E+07	.2900	8.700E-06
1472.	.018056	.1500	2.250E+07	.2900	8.700E-06

Structural and Bolt Materials *(continued)*

Stainless Steel 310 Set name: *SS310*

Density: .2870 lb/cu.inch
Young's Modulus: 2.820E+07 psi (at 68 °F)
Poisson's ratio: .290 (at 68 °F)

Temp (°F)	Thermal Conductivity (BTU/in.min°F)	Specific Heat Capacity (BTU/lbm°F)	Young's Modulus (psi)	Poisson's Ratio	Coefficient of Thermal Expansion (in./in.°F)
-50.	.010400	.0880	2.820E+07	.2900	7.576E-06
68.	.010600	.0880	2.820E+07	.2900	8.056E-06
300.	.012200	.0880	2.820E+07	.2900	9.001E-06
600.	.014800	.1055	2.820E+07	.2900	9.159E-06
900.	.017700	.1200	2.820E+07	.2900	9.175E-06
1200.	.021100	.1300	2.820E+07	.2900	9.230E-06
1600.	.025400	.1310	2.820E+07	.2900	9.531E-06
2000.	.025400	.1310	2.820E+07	.2900	9.889E-06

Stainless Steel 316 Set name: *SS316*

Density: .2870 lb/cu.inch
Young's Modulus: 2.810E+07 psi (at 68 °F)
Poisson's ratio: .290 (at 68 °F)

Temp (°F)	Thermal Conductivity (BTU/in.min°F)	Specific Heat Capacity (BTU/lbm°F)	Young's Modulus (psi)	Poisson's Ratio	Coefficient of Thermal Expansion (in./in.°F)
-50.	.010100	.0980	2.810E+07	.2900	7.997E-06
68.	.010900	.1080	2.810E+07	.2900	8.321E-06
300.	.012600	.1170	2.810E+07	.2900	8.958E-06
600.	.015200	.1310	2.810E+07	.2900	9.605E-06
900.	.016700	.1360	2.810E+07	.2900	9.921E-06
1200.	.019200	.1400	2.810E+07	.2900	1.028E-05
1600.	.021600	.1550	2.810E+07	.2900	1.051E-05
2000.	.021600	.1620	2.810E+07	.2900	1.173E-05

Structural and Bolt Materials *(continued)*

Stainless Steel 347 Set name: *SS347*

Density: .2860 lb/cu.inch
Young's Modulus: 2.820E+07 psi (at 68 °F)
Poisson's ratio: .290 (at 68 °F)

Temp (°F)	Thermal Conductivity (BTU/in.min°F)	Specific Heat Capacity (BTU/lbm°F)	Young's Modulus (psi)	Poisson's Ratio	Coefficient of Thermal Expansion (in./in.°F)
-50.	.011400	.0980	2.820E+07	.2900	8.502E-06
68.	.011900	.1080	2.820E+07	.2900	8.786E-06
300.	.012700	.1200	2.820E+07	.2900	9.345E-06
600.	.015100	.1310	2.820E+07	.2900	9.831E-06
900.	.016700	.1370	2.820E+07	.2900	1.019E-05
1200.	.018800	.1440	2.820E+07	.2900	1.044E-05
1600.	.020500	.1590	2.820E+07	.2900	1.086E-05
2000.	.020500	.1640	2.820E+07	.2900	1.229E-05

Shielding Materials

Cast Lead Set name: *LEAD*

Density: .4110 lb/cu.inch
Young's Modulus: 2.000E+06 psi (at 68 °F)
Poisson's ratio: .420 (at 68 °F)
Yield Stress: 4.300E+03 psi (at 68 °F)
Plactic Modulus: 2.400E+03 psi (at 68 °F)

Temp (°F)	Thermal Conductivity (BTU/in.min°F)	Specific Heat Capacity (BTU/lbm°F)	Young's Modulus (psi)	Poisson's Ratio	Coefficient of Thermal Expansion (in./in.°F)
-58.	.028888	.0300	2.000E+06	.4200	1.600E-05
68.	.028000	.0307	2.000E+06	.4200	1.600E-05
212.	.026800	.0315	2.000E+06	.4200	1.600E-05
392.	.025278	.0326	2.000E+06	.4200	1.600E-05
572.	.023889	.0337	2.000E+06	.4200	1.600E-05
630.	.016806	.0340	2.000E+06	.4200	1.600E-05
717.	.013472	.0339	2.000E+06	.4200	1.600E-05
1276.	.012028	.0337	2.000E+06	.4200	1.600E-05

Material References

1. W.M. Rohsenow and J.P. Hartnett, ed., *Handbook of Heat Transfer*, McGraw-Hill, New York, NY (1973).

2. A.L. Edwards, *A Compilation of Thermal Property Data for Computer Heat-Conduction Calculations*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-50589 (1969).

3. Y.S. Touloukian, et al., *Thermophysical Properties of Matter, Volume 1, Thermal Conductivity, Metallic Elements and Alloys*, IFI/Plenum, New York, NY (1970).

4. Y.S. Touloukian, et al., *Thermophysical Properties of Matter, Volume 4, Specific Heat, Metallic Elements and Alloys*, IFI/Plenum, New York, NY (1970).

5. Y.S. Touloukian, et al., *Thermophysical Properties of Matter, Volume 12, Thermal Expansion, Metallic Elements and Alloys*, IFI/Plenum, New York, NY (1970).

6. American Society of Metals, *Metals Handbook Ninth Edition, Volume 3, Properties and Selection: Stainless Steels, Tool Materials and Special Purpose Metals*, Metals Park, OH (1978).

7. C.R. Adams, et al, *A Comparison of Analytical Techniques for Analyzing a Nuclear-Spent-Fuel Shipping Cask Subjected to an End-On Impact*, Sandia National Laboratories, Albuquerque, NM, NUREG/CR-2018, SAND80-1870 RT (1981).

Appendix C

Sample Cask Analysis

Description of Sample Cask

This sample spent fuel shipping cask is included in the *AUTOCASK* release. The CASKID is 9999. The cask geometry includes a long cylindrical cask body and top and bottom end caps. The cask body has an inner shell layer of Stainless Steel 304, a Lead shielding layer, and an outer shell layer of Stainless Steel 304. Both end caps are solid Stainless Steel 304. Cask dimensions are shown in **Figure C-1**. Component weights and closure bolt information are listed below:

Weights

Contents/internals:	56065	lbs

Closure Bolts (for Top End Cap)

Bolt Material:	SS304	
Number of bolts:	16	
Bolt diameter:	1.5	inches
Bolt circle radius:	29.5	inches

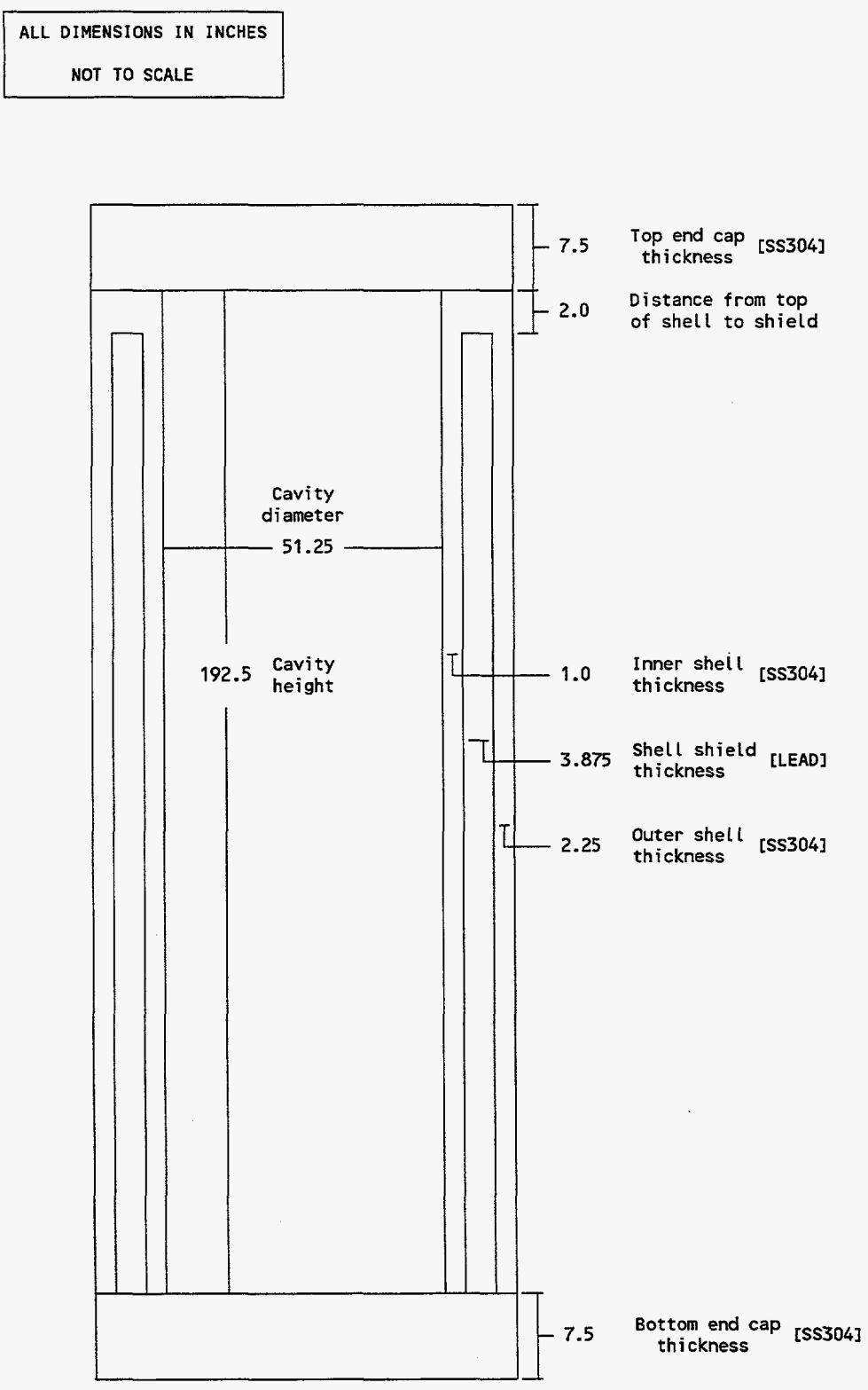

Figure C-1. Sample Cask Geometry and Dimensions.

Cask Summary and Data Check Output

This output is produced during the data check performed when the cask geometry is saved (Geometry Menu). It is a complete summary of all specifications for the cask. Warning and error messages appear when geometry dimensions are inconsistent. This output does not have any warning messages. The output format follows.

(1) **Header**
Indicates Geometry Data Summary, page number of how many, date and time the output was generated, and *AUTOCASK* version number. The header shown in **Figure C-2** is printed at the top of every page of output.

(2) **Data Set Status**
Indicates the status of the Cask Geometry data set: *COMPLETE* or *INCOMPLETE* (**Figure C-2**). If the status indicates *INCOMPLETE*, the data set has items requiring an entry.

(3) **Cask General Dimensions and Specifications**
Lists general cask dimensions and contents specifications (**Figure C-2**).

(4) **Cask Configuration**
Summary of the configuration of the shell, bottom end cap, and top end cap (**Figure C-2**).

(5) **Component Specifications**
Summary of geometry specifications for the shell, bottom end cap, and top end cap (**Figure C-3**).

(6) **Closure Bolts**
Lists the bolt material name, number of bolts, bolt diameter, and bolt circle radius (**Figure C-3**).

(7) **Material Properties**
Tables listing properties for each material (**Figure C-4**). The output also indicates the components using the material.

```
GEOMETRY DATA SUMMARY FOR CASK 9999                          Page   1 of   5
GENERATED ON  8/30/94 AT 17:47:07                  AUTOCASK VERSION: 1a



Cask geometry data set is COMPLETE

 GENERAL CASK INFORMATION
 ------------------------

   TITLE:  Sample spent fuel shipping cask (demonstration)

 CASK GENERAL DIMENSIONS AND SPECIFICATIONS
 ------------------------------------------

   Cavity Inner Radius:          25.63 inches
   Cavity Length:               192.50 inches

   Cask Body Outer Radius*:      32.75 inches
   Cask Body Length*:           207.50 inches

   Cavity Volume*:             397108. cubic inches
   Cask Weight*:               102638. pounds

   Weight of contents:          56065. pounds

   Number of Mesh Divisions Along Cavity Length:  15

 CASK CONFIGURATION
 ------------------

   Shell is Laminated (3 Layers)

   Bottom End Cap is Solid (1 Layer)

   Top End Cap is Solid (1 Layer)
       Top End Cap is not Inset
       Lip is not Included

                    ************************************
                    *                                  *
                    *   * indicates a derived quantity *
                    *                                  *
                    ************************************
```

Figure C-2. Cask Summary and Data Check Output General Dimensions and Specifications, Cask Configuration.

SHELL DESCRIPTION

Layer	Material Name	Thickness (Inches)	Inner Radius* (Inches)	Outer Radius* (Inches)	Mesh Div
Inner Layer	SS304	1.00	25.63	26.63	2
Shield Layer	LEAD	3.88	26.63	30.50	2
Outer Layer	SS304	2.25	30.50	32.75	2
Totals		7.13			6

Layer	X-Section Area* (Sq Inches)	Volume* (Cu Inches)	Weight* (Lbs)
Inner Layer	164.1	31598.5	8978.4
Shield Layer	695.4	132477.7	54448.3
Outer Layer	447.1	87455.3	24849.5
Totals	1306.7	251531.5	88276.3

Distance from Bottom of Shell to Shield: .00 inches
Distance from Top of Shell to Shield: 2.00 inches

Shield Height*: 190.50 inches

BOTTOM END CAP DESCRIPTION

Layer	Material Name	Thickness (Inches)	Volume* (Cu Inches)	Weight* (Lbs)	Mesh Divisions
End Cap	SS304	7.50	25271.7	7180.7	3

TOP END CAP DESCRIPTION

Layer	Material Name	Thickness (Inches)	Volume* (Cu Inches)	Weight* (Lbs)	Mesh Divisions
End Cap	SS304	7.50	25271.7	7180.7	3

CLOSURE BOLTS

Material Name: SS304
Number of Bolts: 16
Bolt Diameter: 1.50 inches
Bolt Circle Radius: 29.50 inches

Number of Mesh Divisions between Bolts: 1

Figure C-3. Cask Summary and Data Check Output Component Specifications and Closure Bolts.

```
MATERIAL PROPERTIES
-------------------

    This model uses  3 different materials


    SS304      (Stainless Steel  304    )

        Used in: Shell inner layer
                 Shell outer layer
                 Bottom end cap
                 Top end cap

        Properties for the Finite Element Analysis

             Density:              .2841  lb/cu.inch
             Young's Modulus:  2.840E+07  psi (at 68 F)
             Poisson's ratio:       .290      (at 68 F)

                                                              Coefficient
               Thermal       Specific      Young's  Poisson's  of Thermal
    Temp  Conductivity  Heat Capacity      Modulus      Ratio    Expansion
      F   BTU/in min F    BTU/lbm F          psi                  in/in F
    ----  -----------  -------------  -------  ---------  -----------
     -58.    .011250         .1200   2.910E+07    .2900     8.700E-06
      68.    .011400         .1230   2.840E+07    .2900     8.700E-06
     212.    .012083         .1238   2.760E+07    .2900     8.700E-06
     392.    .012083         .1275   2.660E+07    .2900     8.700E-06
     572.    .013056         .1312   2.560E+07    .2900     8.700E-06
     752.    .013889         .1350   2.390E+07    .2900     8.700E-06
    1112.    .015278         .1425   2.250E+07    .2900     8.700E-06
    1472.    .018056         .1500   2.250E+07    .2900     8.700E-06


    LEAD       (Cast Lead              )

        Used in: Shell shield layer

        Properties for the Finite Element Analysis

             Density:              .4110  lb/cu.inch
             Young's Modulus:  2.000E+06  psi (at 68 F)
             Poisson's ratio:       .420      (at 68 F)
             Yield Stress:     4.300E+03  psi (at 68 F)
             Plastic Modulus:  2.400E+03  psi (at 68 F)

                                                              Coefficient
               Thermal       Specific      Young's  Poisson's  of Thermal
    Temp  Conductivity  Heat Capacity      Modulus      Ratio    Expansion
      F   BTU/in min F    BTU/lbm F          psi                  in/in F
    ----  -----------  -------------  -------  ---------  -----------
     -58.    .028888         .0300   2.000E+06    .4200     1.600E-05
      68.    .028000         .0307   2.000E+06    .4200     1.600E-05
     212.    .026800         .0315   2.000E+06    .4200     1.600E-05
     392.    .025278         .0326   2.000E+06    .4200     1.600E-05
     572.    .023889         .0337   2.000E+06    .4200     1.600E-05
     630.    .016806         .0340   2.000E+06    .4200     1.600E-05
     717.    .013472         .0339   2.000E+06    .4200     1.600E-05
    1276.    .012028         .0337   2.000E+06    .4200     1.600E-05

                          . . .
                          . . .
                          . . .
```

Figure C-4. Cask Summary and Data Check Output Material Properties.

Performing the Analysis

Select **4** from the MAIN Menu to specify loads and generate the analysis input file. This sample analysis specifies a 34.2 g impact with the cask oriented with the cask CG over the bottom corner. The end-on support method is defaulted to FULL and does not play a part in a CG-over-corner impact. **Figure C-5** shows the LOADS and ORIENTATION specification screen. Press **M** to make the model file and generate the analysis input file.

After the analysis input file is generated, transfer it to the workstation or mainframe computer which will be used to perform the analysis. **Figures C-6** and **C-7** show performing the analysis with NIKE3D. **Figure C-8** shows examining the results with TAURUS. The plots produced by TAURUS are show in **Figures C-9** to **C-13**.

Excerpts from the NIKE3D printable output file are shown in **Figures C-14** to **C-16**. These portions show the nodal point displacements, solid element stresses, and the resultants and stresses for the beams. **Note:** stresses are printed for each integration point in an element.

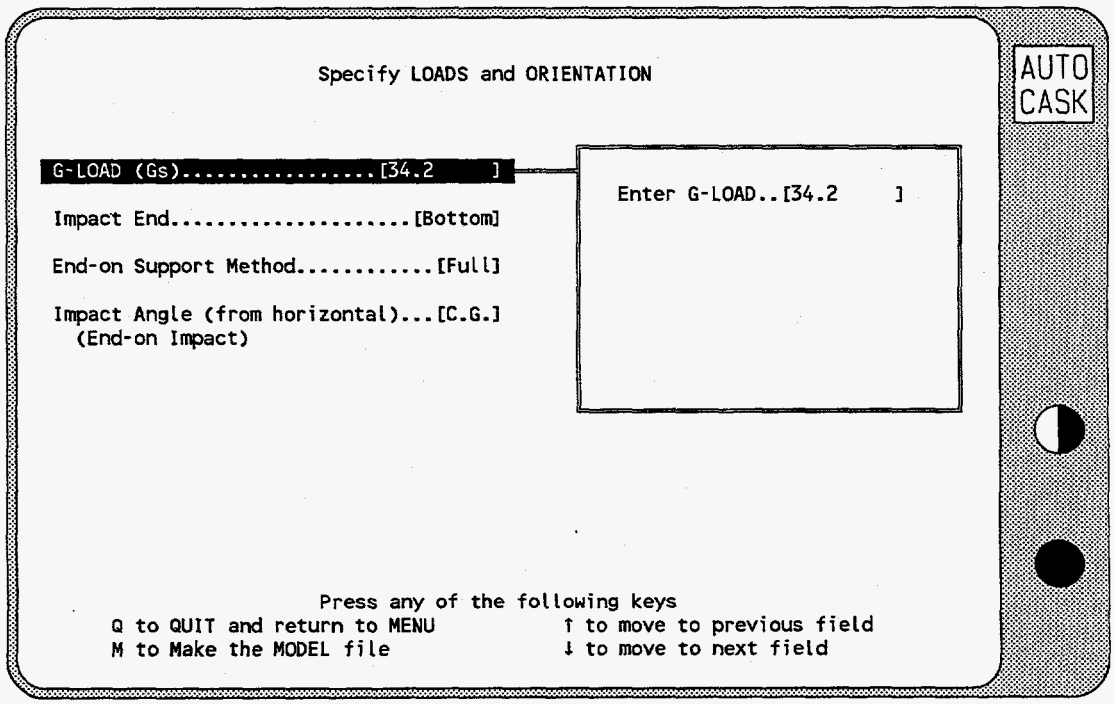

Figure C-5. Specify Loads and Orientation of the cask for sample analysis.

```
nike3d i=nk9999i o=n9999o g=n9999p

**********************************************************************

    *      **  ******  **    **   *********  *********  *******
    **     **  ******  **   **    *********  ********   ********
    ***    **    **    **  **     **             **     **   ***
    ****   **    **    ** **      **           ***      **    **
    ** **  **    **    ****       *******      *****    **    **
    **  ** **    **    *****      *******        ***    **    **
    **   ****    **    **  **     **             **     **    **
    **    ***    **    **   **    **           ***   ***   **   ***
    **     **  ******  **    **   *********    *******   ********
    **      *  ******  **     **  *********     *****    *******

         NIKE3D  -  VERSION  2.3.5     COMPILED 05/06/94

**********************************************************************


file names used :

i=nk9999i    o=n9999o    d=n3dump    g=n9999p
f=n3runr     t=thrxyz    c=itrcnt


ANALYSIS TITLE
==============================================================
Sample spent fuel shipping cask (demonstration)            AUG 31, 1994


MEMORY available
==============================================================
                                  total       this job
                (Mbyte):        17.600       17.600

              . . .
               . . .
                . . .


CONSTITUTIVE history data
==============================================================
    type      # elements      size (words)      blocks
    ----      ----------      ------------      ------
    solid         1224             147456           3
    beam            27              49152           1


LINEAR EQUATION SOLVER data
==============================================================
    number of equations                          =      5605
    available working space                      =   4394395
    working space used                           =   2214964
    number of words in stiffness matrix          =   2203751
         maximum column height                   =      4162
         average column height                   =       393
    number of blocks in out-of-core solution     =         1
```

Figure C-6. NIKE3D initialization messages.
User input is shown as inverse print, white-on-black.

```
======= beginning time step #   1 =======
iterating:  1
Nonlinear solution status: time=  1.0000E-01  step #    1  iteration #  1
   stiffness updates              =  0
   right hand side evaluations    =  2
   stiffness  matrix reformations =  0
   step size from line search     =  1.0000E+00
   convergence norms:   INITIAL      CURRENT      REQUIRED
     residual         6.9203E+07    1.2423E+09    6.9203E+17
     energy           5.5953E+03    5.5953E+03    5.5953E+01
     displacement     9.5835E-01    9.5835E-01    9.5835E-07

   iteration process diverging . . . . . commence reformation # 1

              . . .
               . . .
                . . .

Nonlinear solution status: time=  1.0000E+00  step #   10  iteration #  1
   stiffness updates              =  0
   right hand side evaluations    =  9
   stiffness  matrix reformations =  2
   step size from line search     =  1.0000E+00
   convergence norms:   INITIAL      CURRENT      REQUIRED
     residual         1.3801E+09    8.5044E+08    1.3801E+19
     energy           6.0016E+03    5.8158E+01    6.0016E+01
     displacement     1.0405E+00    1.0404E-04    1.0500E-04

 . . . . . . . . . . . . . . . . . . . . . . augmentation  #  2
   slide surfaces:      FORCE          GAP         REQUIRED
   stonewalls:         CURRENT        CHANGE       REQUIRED
     #  1             2.6446E+06    1.3005E-09    1.0000E-02
 . . . . . . . . . . . . . . . . . . . . . . augmentation  loop converged
------- converged at time= 1.0000E+00


RESTART file  n3dump    written


LINEAR EQUATION SOLVER data
============================================================
    number of equations                          =     5605
    available working space                      =  4394395
    working space used                           =  2216002
    number of words in stiffness matrix          =  2204789
         maximum column height                   =     4162
         average column height                   =      393
    number of blocks in out-of-core solution     =        1


n o n l i n e a r   i t e r a t i o n   i n f o r m a t i o n

    number of time steps completed . . . . . .      10

    total number of equilibrium iterations . . . . . .    142

    average number of equilibrium iterations . . . . .   14.20

    total number of stiffness formations . . . . . .      40

total time charged for run (unweighted) =       2881.650


n o r m a l   t e r m i n a t i o n
```

Figure C-7. NIKE3D solution messages.

```
taurus g=n9999p

      TAURUS
      Revision  3.1.94
      Date compiled : 9/07/94
      Operating System :  AIX
      Blank common available :  2000000 words

       ***** ANALYSIS TITLE *****
      Sample spent fuel shipping cask (demonstra

      ***** ANALYSIS SUMMARY *****

      Number of nodal points :        2029
      Analysis code :                 nike3d
      Global variables per state:       54
      Nodal data options:
           Temperture (1=inc):           0
           Cur Geometry :                1
           Velocities :                  1
           Accelerations:                0
      Number of Brick Elements :      1224
      Number of Brick Materials :        6
      Number of Brick Variables :        7
      Number of Beam Elements :         27
      Number of Beam Materials :         2
      Number of Beam Variables :         6
      Number of States:                 11
      Final valid time:              1.0000
      Default Color Levels:
           X11:                       128
           Gray Scale PostScript:       8
           Color PostScript:           16

      Geometry range:
           Xmin: -1.18008E-01 Xmax:  3.27500E+01
           Ymin: -3.27500E+01 Ymax:  3.27500E+01
           Zmin:  0.00000E+00 Zmax:  2.07500E+02
           Umin:  0.00000E+00 Umax:  0.00000E+00

      Origin (x,y,z):              1.6316E+01  -5.7220E-06   1.0375E+02
      Initial dist from eye to object:         4.02028E+02
      Initial field of view (deg) :                  45.00
      Initial zmin (dist to near clip plane):  1.00000E-01
      Initial zmax (dist to far clip plane):   8.30000E+02

phs1> angle 22.5 dms 7 1 2 3 4 5 6 7 ry 90 rz 90 ry 30 rx 15 zv        Figure C-9
phs1> rx -15 ry -30 rz -17 angle 1 state 11 zv                         Figure C-10
 time =   1.0000
phs1> angle 22.5 ry -25 ytrans 80 xtrans 10 dist 270 dsf 10 zv         Figure C-11
phs1> range 10000 30000  fringe 9                                      Figure C-12
phs1> m 1  center  xtrans -10  fringe 9                                Figure C-13
     Geometry range:
          Xmin: -5.36635E+01 Xmax:  8.31247E+00
          Ymin: -3.00038E+01 Ymax: -4.31440E+00
          Zmin: -3.09514E+01 Zmax:  1.57305E+01
          Umin: -2.16859E-01 Umax:  6.18725E-02

     Origin (x,y,z):              9.4042E+00   2.9893E+00   1.2376E+00
     Initial dist from eye to object:         2.31751E+02
     Initial field of view (deg) :                  22.50
     Initial zmin (dist to near clip plane):  1.00000E-01
     Initial zmax (dist to far clip plane):   6.19759E+03
phs1> end
```

Figure C-8. Examining the results with TAURUS. User input is shown as inverse print, white-on-black.

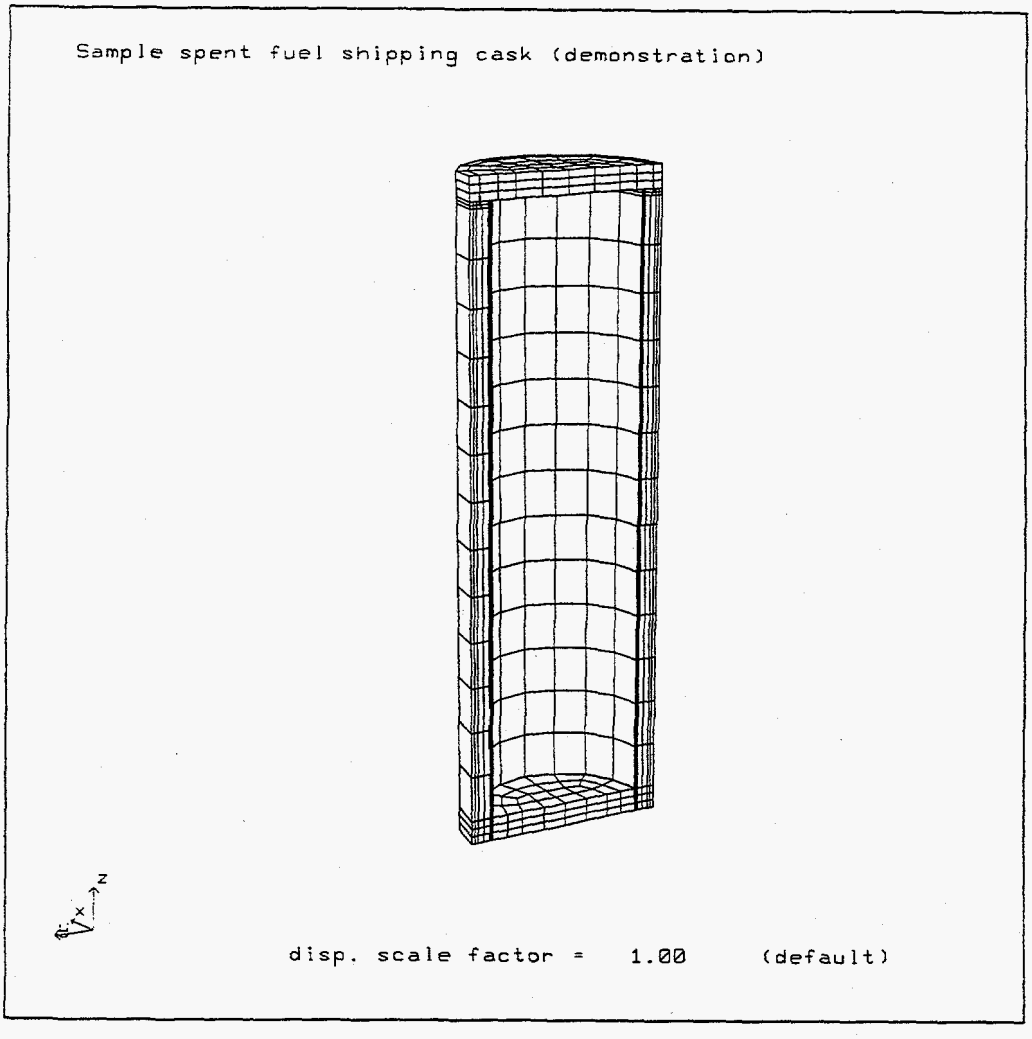

Figure C-9. Isometric view of the cask.
The contents material has been removed.

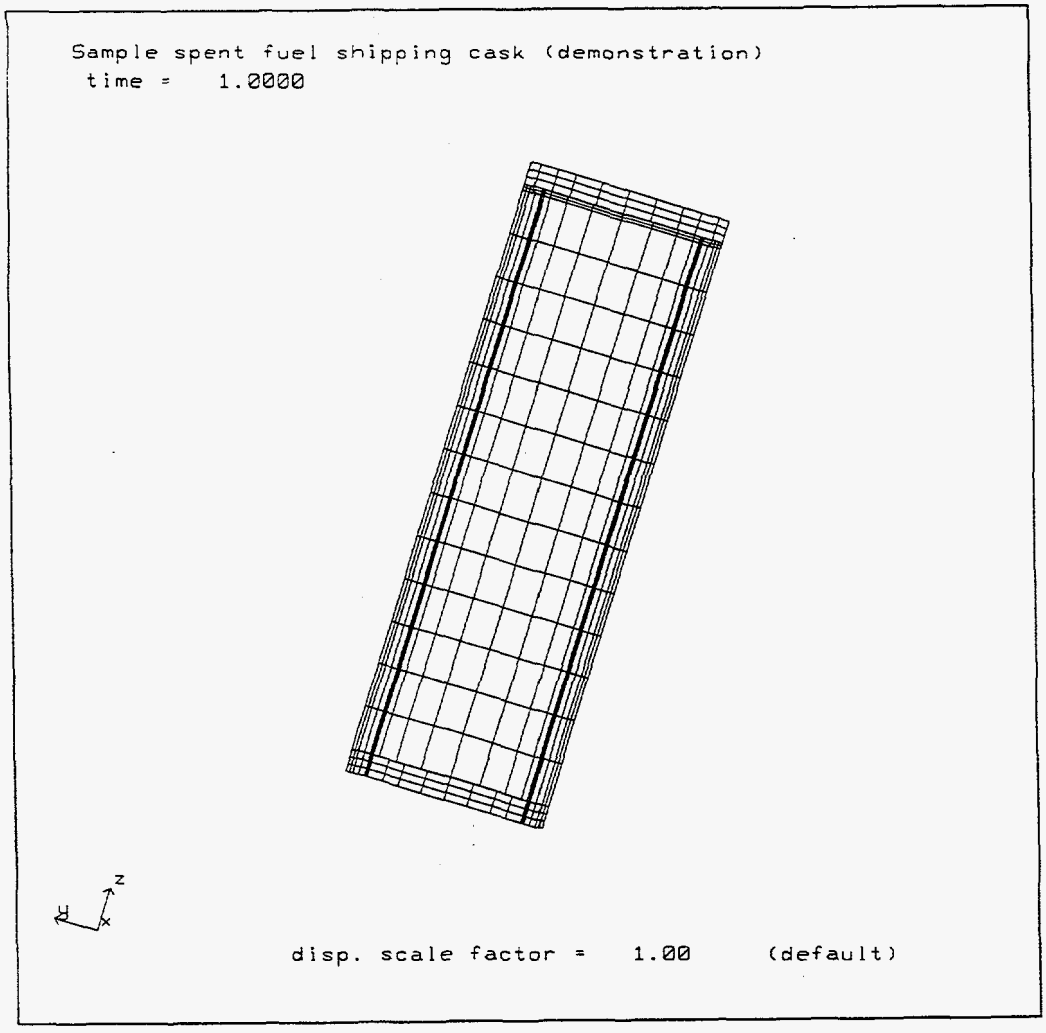

Figure C-10. Cask rotated to CG-over-corner orientation.

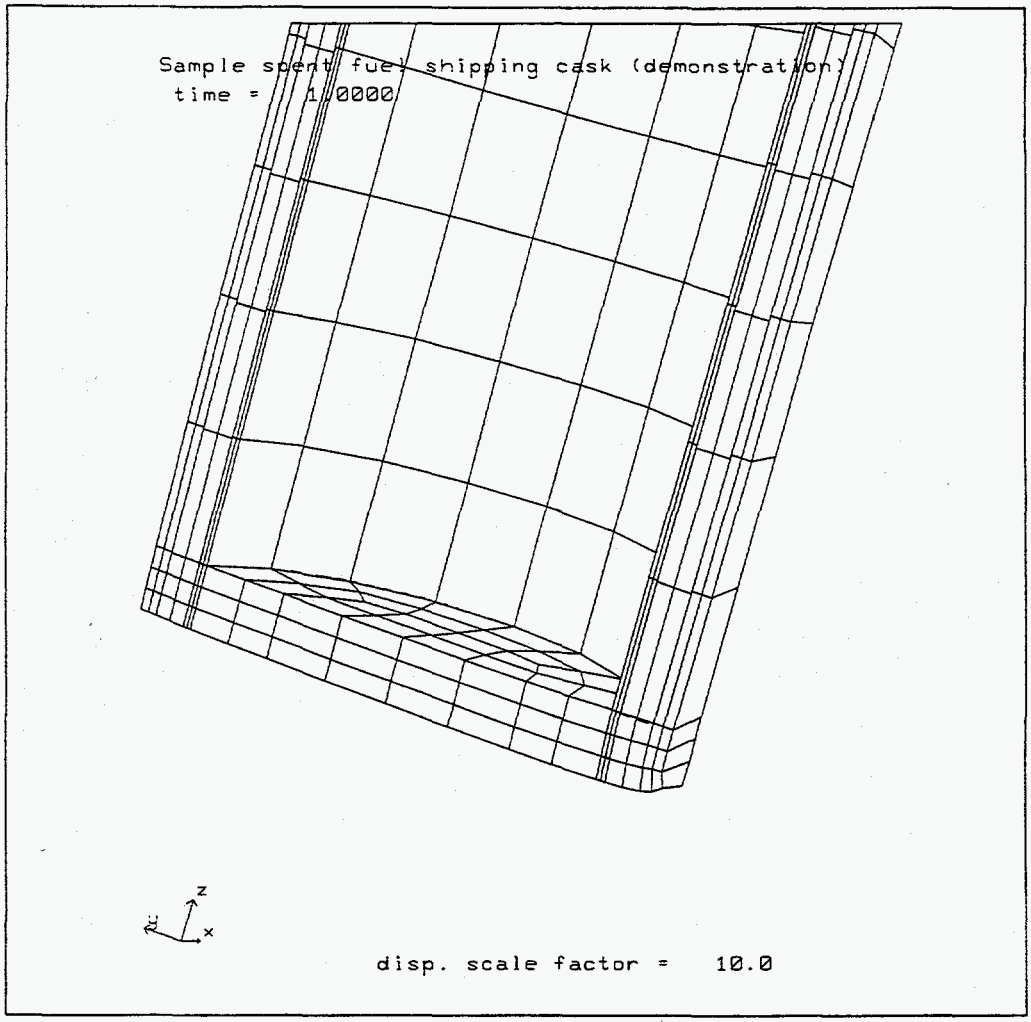

Figure C-11. Close-up of contact corner. Displacements have been magnified 10 times.

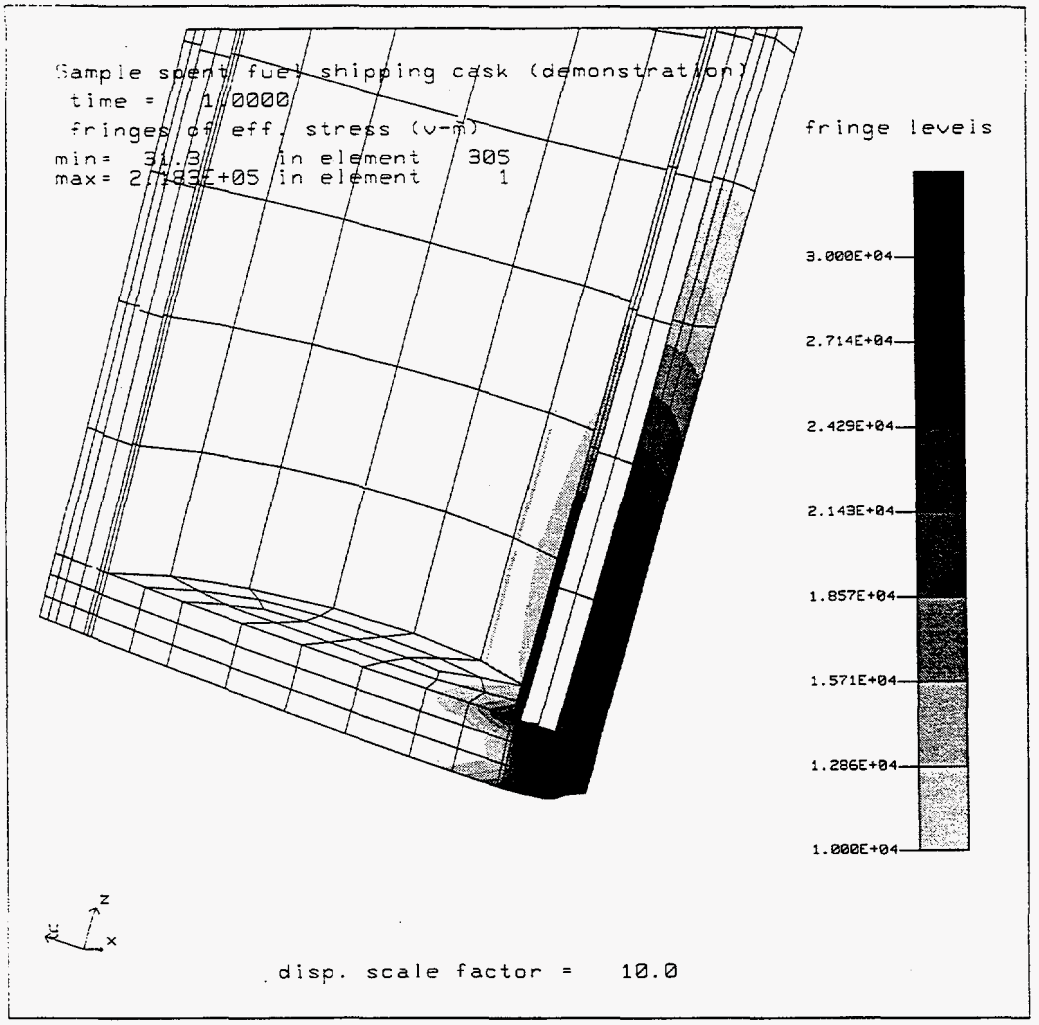

Figure C-12. Fringes of effective stress (von Mises) from 10ksi to 30ksi. Displacements have been magnified 10 times.

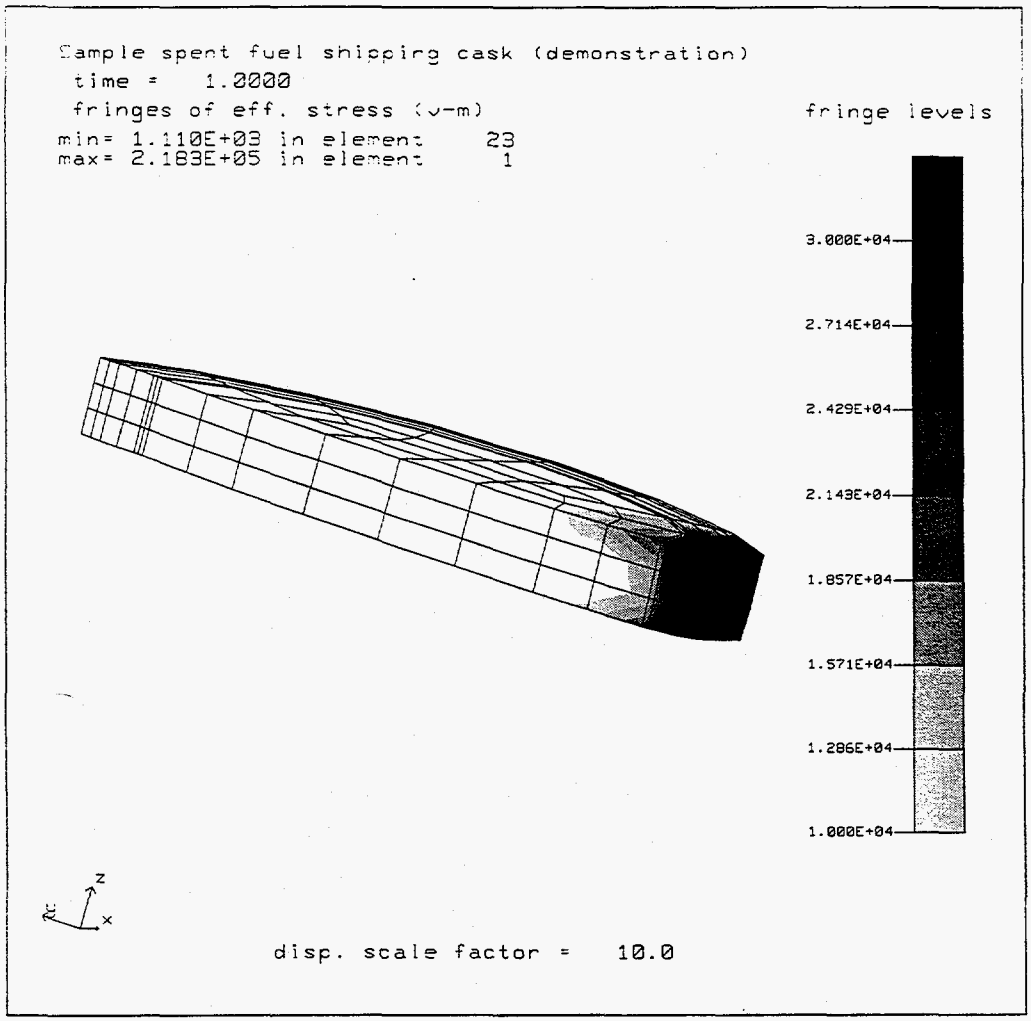

Figure C-13. Fringes of effective stress (von Mises) on the bottom end cap from 10ksi to 30ksi. Displacements have been magnified 10 times.

Sample spent fuel shipping cask (demonstration) AUG 31, 19
nike3d (version 2.3.5) compiled 05/06/94

n o d a l p r i n t o u t f o r t i m e s t e p 10 (at time 1.0000E+00)

node	x-disp	y-disp	z-disp	x-rot	y-rot	z-rot
1	0.00000E+00	1.89911E-11	-8.29299E-12	0.00000E+00	0.00000E+00	0.00000E+00
2	0.00000E+00	-6.83421E-03	-7.91826E-02	0.00000E+00	0.00000E+00	0.00000E+00
3	0.00000E+00	-6.59199E-04	-1.13233E-01	0.00000E+00	0.00000E+00	0.00000E+00
4	0.00000E+00	1.01062E-02	-1.43279E-01	0.00000E+00	0.00000E+00	0.00000E+00
5	0.00000E+00	1.81653E-02	-1.58828E-01	0.00000E+00	0.00000E+00	0.00000E+00
6	0.00000E+00	1.98134E-02	-1.61636E-01	0.00000E+00	0.00000E+00	0.00000E+00
7	0.00000E+00	2.11922E-02	-1.64180E-01	0.00000E+00	0.00000E+00	0.00000E+00
8	0.00000E+00	2.81325E-02	-1.85208E-01	0.00000E+00	0.00000E+00	0.00000E+00
9	0.00000E+00	3.17920E-02	-1.98068E-01	0.00000E+00	0.00000E+00	0.00000E+00
10	-1.14737E-02	3.03907E-02	-2.12244E-01	0.00000E+00	0.00000E+00	0.00000E+00
11	-1.18170E-02	3.86636E-02	-1.89905E-01	0.00000E+00	0.00000E+00	0.00000E+00
12	-1.07213E-02	3.73331E-02	-1.79488E-01	0.00000E+00	0.00000E+00	0.00000E+00
13	-8.00546E-03	3.35784E-02	-1.74910E-01	0.00000E+00	0.00000E+00	0.00000E+00
14	-5.54994E-03	3.10095E-02	-1.76608E-01	0.00000E+00	0.00000E+00	0.00000E+00
15	-4.99977E-03	3.05517E-02	-1.77506E-01	0.00000E+00	0.00000E+00	0.00000E+00
16	-4.45882E-03	3.01551E-02	-1.78542E-01	0.00000E+00	0.00000E+00	0.00000E+00
17	-8.08521E-04	3.05155E-02	-1.90840E-01	0.00000E+00	0.00000E+00	0.00000E+00
18	3.56792E-04	3.25940E-02	-2.00896E-01	0.00000E+00	0.00000E+00	0.00000E+00
19	-1.56487E-03	3.43890E-02	-1.75049E-01	0.00000E+00	0.00000E+00	0.00000E+00
20	1.26716E-04	2.87741E-02	-1.84200E-01	0.00000E+00	0.00000E+00	0.00000E+00

. . .
. . .
. . .

Figure C-14. NIKE3D Output — Nodal Displacements.

Sample spent fuel shipping cask (demonstration) AUG 31, 19
nike3d (version 2.3.5) compiled 05/06/94

e l e m e n t s t r e s s c a l c u l a t i o n s f o r s t e p 10 (time = 1.0000E+00)

element num/ipt	stress state	sig-xx	sig-yy	sig-zz	sig-xy	sig-yz	sig-zx	effsg	yield function
1- 1									
1		-1.846E+05	-6.919E+04	-1.039E+05	3.695E+03	-1.160E+04	-9.208E+04	1.908E+05	0.000E+00
2		3.906E+04	-1.868E+03	-3.949E+05	2.298E+04	-3.095E+05	-4.331E+04	6.833E+05	0.000E+00
3		4.026E+04	2.339E+04	-4.213E+05	-7.850E+03	-1.419E+04	-4.850E+04	4.619E+05	0.000E+00
4		-1.611E+05	-1.010E+05	-9.554E+04	-1.986E+04	-1.703E+04	-3.825E+04	1.021E+05	0.000E+00
5		-1.796E+05	-5.945E+04	-1.186E+05	1.034E+04	-5.173E+03	-5.599E+04	1.437E+05	0.000E+00
6		-4.879E+04	-8.713E+04	-2.218E+05	3.062E+04	-2.920E+05	-3.592E+03	5.323E+05	0.000E+00
7		-4.732E+04	-6.264E+04	-2.477E+05	-4.144E+03	-2.365E+03	-3.583E+04	2.031E+05	0.000E+00
8		-1.558E+05	-9.275E+04	-1.091E+05	-1.646E+04	-1.882E+04	-2.765E+04	8.589E+04	0.000E+00
2- 1									
1		-7.022E+04	-3.434E+04	-6.410E+04	-2.525E+04	-1.178E+04	-5.619E+04	1.136E+05	0.000E+00
2		8.096E+03	5.612E+01	-1.768E+05	-1.863E+04	-4.296E+04	-5.590E+04	2.207E+05	0.000E+00
3		4.545E+03	8.058E+03	-1.813E+05	-1.590E+04	-1.970E+04	-4.114E+04	2.054E+05	0.000E+00
4		-6.636E+04	-4.287E+04	-5.943E+04	-1.597E+04	-4.617E+03	-3.842E+04	7.547E+04	0.000E+00
5		-7.128E+04	-3.381E+04	-6.357E+04	-2.338E+04	-1.458E+04	-5.211E+04	1.077E+05	0.000E+00
6		1.195E+03	-6.085E+03	-1.638E+05	-1.660E+04	-4.011E+04	-5.345E+04	2.007E+05	0.000E+00
7		-1.802E+03	1.541E+03	-1.684E+05	-1.501E+04	-1.699E+04	-4.017E+04	1.863E+05	0.000E+00
8		-6.672E+04	-4.304E+04	-5.890E+04	-1.509E+04	-7.856E+03	-3.572E+04	7.164E+04	0.000E+00

. . .
. . .
. . .

Figure C-15. NIKE3D Output — Element Stresses.

```
Sample spent fuel shipping cask (demonstration)              AUG 31, 19
                  nike3d (version  2.3.5  ) compiled 05/06/94



r e s u l t a n t s   a n d   s t r e s s e s   f o r   t i m e   s t e p   10       ( at time 1.0000E+00 )



beam/truss #  =    1      material #  =  7

resultants    axial       shear-s      shear-t      moment-s     moment-t     torsion
           -7.20703E+02 -3.69940E+03 -6.02709E-04  2.27374E-13  0.00000E+00  9.09495E-13

integration point stress in global coordinates
  sigma 11     sigma 22     sigma 33     sigma 12     sigma 23     sigma 13    plastic eps
 0.00000E+00  3.73245E+00 -8.18963E+02 -6.95108E-21 -4.18381E+03  1.73472E-17  0.00000E+00
 0.00000E+00  3.73245E+00 -8.18963E+02 -6.95108E-21 -4.18381E+03  1.73472E-17  0.00000E+00
 0.00000E+00  3.73245E+00 -8.18963E+02 -6.95108E-21 -4.18381E+03  1.73472E-17  0.00000E+00
 0.00000E+00  3.73245E+00 -8.18963E+02 -6.95108E-21 -4.18381E+03  1.73472E-17  0.00000E+00



beam/truss #  =    2      material #  =  6

resultants    axial       shear-s      shear-t      moment-s     moment-t     torsion
           -1.29643E+03 -6.76149E+03  3.52839E+03  2.72848E-12  0.00000E+00  0.00000E+00

integration point stress in global coordinates
  sigma 11     sigma 22     sigma 33     sigma 12     sigma 23     sigma 13    plastic eps
 3.02751E-02  3.93766E+00 -7.37690E+02  3.45287E-01 -4.29871E+03 -3.80412E+02  0.00000E+00
 3.02751E-02  3.93766E+00 -7.37690E+02  3.45287E-01 -4.29871E+03 -3.80412E+02  0.00000E+00
 3.02751E-02  3.93766E+00 -7.37690E+02  3.45287E-01 -4.29871E+03 -3.80412E+02  0.00000E+00
 3.02751E-02  3.93766E+00 -7.37690E+02  3.45287E-01 -4.29871E+03 -3.80412E+02  0.00000E+00

                                    . . .
                                     . . .
                                      . . .
```

Figure C-16. NIKE3D Output — Beam Resultants and Stresses.

Appendix D

Program Reference

Contents of Distribution Diskettes

The *AUTOCASK* release package contains one 3½-inch high-density (1.44Mb) distribution diskette, listed below. Each file is identified and its function explained.

Distribution Disk (4 files)

File Name	Function
ACASK.VER	*AUTOCASK* Version File
TERMPROG.EXE	Archive Containing the *AUTOCASK* programs and files
ACASKV1A.D1	*AUTOCASK* Distribution Disk Identification File
INSTALL.EXE	Program to Install *AUTOCASK*

Once *AUTOCASK* is installed, the subdirectory **\ACASK** contains the files listed below. Each file is identified and its function explained

Installed *AUTOCASK* Files (47 files)

File Name	Function
9999CASK.CHK	Sample Cask Data Check Summary File
9999CASK.GEI	Sample Cask Geometry File
9999DATA.FLG	Sample Cask Data Check Flag File
ACAM.COM	*AUTOCASK* Archive Menu
ACASK.VER	*AUTOCASK* Version File
ACBLDBLK.BEC	Geometry Model Building Block File for Bottom End Cap
ACBLDBLK.HED	Geometry Model Building Block Header File
ACBLDBLK.SHL	Geometry Model Building Block File for Shell
ACBLDBLK.TEC	Geometry Model Building Block File for Top End Cap
ACBLDBLK.TRL	Geometry Model Building Block Trailing Information File
ACDM.COM	*AUTOCASK* Display Menu
ACGM.COM	*AUTOCASK* Geometry Menu
ACMM.COM	*AUTOCASK* Main Menu
ALLDONE.EXE	Program for Termination Message
AUTOCASK.BAT	*AUTOCASK* Main Control Batch File
CARBNSTL.BLM	Bolt Material File, Carbon Steel
CARBNSTL.STM	Shell/End Cap Material File, Carbon Steel
CASKGEOM.EDT	Editor Template File for Basic Geometry
COPYFL.EXE	Program to Copy Geometry Data Files
CURSOR.COM	Program to Set Cursor Size
DATACK.EXE	Program to Create Cask Summary and Data Check
DISCLAIM.EXE	Program to Display Disclaimer
DSPLAY.EXE	Program to Display Cask Geometry
DSPNMS.EXE	Program to Display Names of Model File and Analysis Input File
EDG.EXE	Program to Initialize Editor for Geometry Editing
EDITOR.EXE	Program to Edit Geometry and Material Data Files
EDMAT.EXE	Program to Initialize Editor for Material Editing
GETID.EXE	Program to Select CASK ID
LEAD.SHM	Shield Material File, Lead

Installed *AUTOCASK* Files *(continued)*

File Name	Function
MAKMSH.EXE	Program to Select Loading/Orientation and Make Model File
MATCK.EXE	Program to Data Check Material Files After Editing
MATERIAL.EDT	Editor Template File for Materials
PLOTRES.LOW	Flag File for Printer Plot Resolution
PRINTER.EPS	Flag File for Printer Type
PRNTVU.EXE	Program to Print and Review the Data Check Cask Summary File
SAVER.EXE	Program to Archive/Retrieve/Delete Data Sets
SLCHLP.HLP	Help File for Mesh Generator
SLIC.EXE	Mesh Generator Program
SS304.BLM	Bolt Material File, Stainless Steel 304
SS304.STM	Shell/End Cap Material File, Stainless Steel 304
SS310.BLM	Bolt Material File, Stainless Steel 310
SS310.STM	Shell/End Cap Material File, Stainless Steel 310
SS316.BLM	Bolt Material File, Stainless Steel 316
SS316.STM	Shell/End Cap Material File, Stainless Steel 316
SS347.BLM	Bolt Material File, Stainless Steel 347
SS347.STM	Shell/End Cap Material File, Stainless Steel 347
VIDEO.CGA	Flag File for Video Display Type

System Details

AUTOCASK uses a DOS *BATCH* command file to coordinate the menus, input programs, cask analysis programs, output programs, data archive programs, and databases. A *BATCH* file is a file containing commands that DOS executes one at a time. The *AUTOCASK BATCH* file is controlled using menu programs. Each menu program displays a list of options and waits until one of the indicated keys is pressed. After accepting the key, the menu program sets the DOS ERRORLEVEL to indicate which key was pressed. The *AUTOCASK BATCH* file branches, based on ERRORLEVEL, to perform the selected task.

AUTOCASK has four menu programs. Each menu program is written in Assembly Language, making it small, fast, and flexible. All other programs in *AUTOCASK* are written in FORTRAN. The FORTRAN programs use a set of FORTRAN callable Assembly Language routines to provide access to DOS and BIOS functions. These functions include manipulating the video screen, sending data to the printer, managing disk files, and obtaining disk space and directory information.

The *AUTOCASK BATCH* file is listed below with comments identifying the flow of control.

```
C:                                          | Switch to hard disk containing AUTOCASK
SET JUNQUE=%PROMPT%                         | Save the current prompt in variable JUNQUE
PROMPT  $e[1;37;40m                         | Clear prompt, set white text over black background
ECHO OFF                                    | Turn off echo feature of batch file
MODE CO80                                   | Set video mode to CGA with 80 columns of text

REM  ***** TEST FOR COMMAND.COM ON AUTOCASK DRIVE *****

IF EXIST \COMMAND.COM  GOTO CHNGDIR         | Check for COMMAND.COM on AUTOCASK drive

ECHO                                        | Display error message indicating COMMAND.COM
ECHO                                        |  does not exist
ECHO
ECHO  ERROR -- CANNOT INITIALIZE AUTOCASK
ECHO
ECHO       COMMAND.COM DOES NOT EXIST IN THE ROOT DIRECTORY OF THE
ECHO       DRIVE WHICH CONTAINS AUTOCASK
ECHO
ECHO

SET PROMPT=%JUNQUE%                         | Restore prompt
GOTO END2                                   | Jump to end of batch command file

REM ************************************************************

REM  **** CHANGE TO AUTOCASK DIRECTORY ****

:CHNGDIR
CD\ACASK                                    | Change to ACASK subdirectory
```

```
REM  **** DISPLAY DISCLAIMER AND GET THE CASK ID

DISCLAIM                                    | Display AUTOCASK disclaimer
GETID                                       | Select CASK ID
IF NOT EXIST CASK.ID  GOTO END              | If no CASK ID selected, go to end AUTOCASK

REM ************************************************************

REM  ***** MAIN MENU *****

:MAIN
ACMM                                        | Display MAIN MENU
IF ERRORLEVEL 6 GOTO END                    | Check ERRORLEVEL and branch
IF ERRORLEVEL 5 GOTO SAVE
IF ERRORLEVEL 4 GOTO MAKMODEL
IF ERRORLEVEL 3 GOTO DISPLAY
IF ERRORLEVEL 2 GOTO GEOMETRY
:INIT
GETID                                       | Select CASK ID
GOTO MAIN                                   |  and return to MAIN MENU

REM ************************************************************

REM  ***** GEOMETRY MENU *****

:GEOMETRY
IF EXIST EDITOR.EDM DEL EDITOR.EDM          | Delete EDITOR control file
ACGM                                        | Display GEOMETRY MENU
IF ERRORLEVEL 4 GOTO MAIN                   | Check ERRORLEVEL and branch
IF ERRORLEVEL 3 GOTO EDITM
IF ERRORLEVEL 2 GOTO COPYG

REM      EDIT THE CASK GEOMETRY DATA FILE AND PERFORM DATA CHECK

:EDITG
EDG                                         | Set up to edit GEOMETRY
IF NOT EXIST EDITOR.EDM GOTO GEOMETRY       | If control file missing, return to GEOMETRY MENU
EDITOR                                      | Edit GEOMETRY
IF NOT EXIST DATACHCK GOTO GEOMETRY         | If not doing data check, return to GEOMETRY MENU
DATACK                                      | Perform data check on GEOMETRY
GOTO GEOMETRY                               |  and return to GEOMETRY MENU

REM      COPY CASK GEOMETRY FROM DIFFERENT CASK

:COPYG
COPYFL                                      | Copy GEOMETRY from different data set
GOTO GEOMETRY                               |  and return to GEOMETRY MENU
```

```
REM       EDIT MATERIAL DATA SET

:EDITM
EDMAT A                                          | Set up to edit AUTOCASK materials
IF NOT EXIST EDITOR.EDM GOTO GEOMETRY            | If control file missing, return to GEOMETRY MENU
EDITOR                                           | Edit MATERIALS
IF NOT EXIST DATACHCK GOTO GEOMETRY              | If not doing data check, return to GEOMETRY MENU
MATCK                                            | Perform data check on MATERIALS
GOTO GEOMETRY                                    |  and return to GEOMETRY MENU

REM ************************************************************

REM  ***** DISPLAY / REVIEW GEOMETRY MENU *****

:DISPLAY
ACDM                                             | Display DISPLAY MENU
IF ERRORLEVEL 4 GOTO MAIN                        | Check ERRORLEVEL and branch
IF ERRORLEVEL 3 GOTO PRNTIT
IF ERRORLEVEL 2 GOTO REVU

REM       DISPLAY OUTLINE OF THE CASK

:DISPLY
DSPLAY                                           | Display geometry outline
GOTO DISPLAY                                     |  and return to DISPLAY MENU

REM       REVIEW THE CASK SUMMARY

:REVU
PRNTVU R                                         | Review Cask Summary Data Check on screen
GOTO DISPLAY                                     |  and return to DISPLAY MENU

REM       PRINT THE CASK SUMMARY

:PRNTIT
PRNTVU P                                         | Print Cask Summary Data Check
GOTO DISPLAY                                     |  and return to DISPLAY MENU

REM ************************************************************

REM  ***** MAKE MODEL PROCESS *****

REM       SELECT LOADING AND MAKE UPLOAD FILE

:MAKMODEL
MAKMSH                                           | Specify loads/orientation, make model file
```

```
REM       GENERATE NIKE3D INPUT FILE IF REQUESTED

IF NOT EXIST SLICIN.CMD GOTO MAIN        | If model file missing, return to MAIN MENU

REM       RUN SLIC  (PRE-DELETE NK3DIN)

IF EXIST NK3DIN DEL NK3DIN > NUL         | Delete temporary NIKE3D input file if it exists

SLIC READ SLICIN.CMD                     | Generate the mesh and NIKE3D input file

REM       DELETE THE SLICIN.CMD FILE

DEL SLICIN.CMD > NUL                     | Delete the model file

REM       DELETE THE RERUN AND SLCLST FILES

DEL RERUN*.CMD > NUL                     | Delete the command recap file RERUN.CMD
DEL SLCLST*.LST > NUL                    | Delete the mesh generation log file SLCLST.LST

REM       DISPLAY THE MODEL AND NIKE3D INPUT FILE NAMES

DSPNMS                                   | Display Model file and NIKE3D input file names

GOTO MAIN                                | Return to the MAIN MENU


REM ************************************************************

REM  ***** ARCHIVE MENU *****

:SAVE
ACAM                                     | Display ARCHIVE MENU
IF ERRORLEVEL 4 GOTO MAIN                | Check ERRORLEVEL and branch
IF ERRORLEVEL 3 GOTO DELETE
IF ERRORLEVEL 2 GOTO GET

REM      ARCHIVE CASK DATA SET

:PUT
SAVER A                                  | ARCHIVE data sets
GOTO SAVE                                |  and return to ARCHIVE MENU

REM      RETRIEVE CASK DATA SET

:GET
SAVER R                                  | RETRIEVE data sets
GOTO SAVE                                |  and return to ARCHIVE MENU

REM      DELETE CASK DATA SET

:DELETE
SAVER D                                  | DELETE data sets
GOTO SAVE                                |  and return to ARCHIVE MENU
```

```
REM ************************************************************

REM  ***** END OF THE AUTOCASK PROCESS *****

:END                                    Terminate AUTOCASK
IF EXIST CASK.ID DEL CASK.ID            Delete CASK ID identification file
SET PROMPT=%JUNQUE%                     Restore the prompt
ALLDONE                                 Display termination message
CD\                                     Change to root directory
:END2                                   End of batch file when COMMAND.COM is missing
SET JUNQUE=                             Clear the variable JUNQUE
ECHO ON                                 Restore ECHO
```

Description of Databases

AUTOCASK uses integrated databases to pass information between various programs. These databases describe the cask geometry, loading conditions, and material properties. All databases, with the exception of printable output, are *random access* files with fixed record lengths. Thus, each program that utilizes the database has access to individual elements in the data base, identified by record number. Following is a description of each *random access* database.

Geometry Database

Purpose: Contains all geometry specifications for the cask.
Record Length: 12

NOTE: Record types are as follows:
Real = Real Number
Int = Integer Number
Char = Character string
List = Single Character which must match specific choices
Name = Value is selected from a file name list

Header

Record	Description	Type	Length	Restrictions	Default
1	Id			Must be 'ACASK gei'	
2 \					
3 |					
4 |--	Database name	Char	60		
5 |					
6 /					
8	File creation date	Char	8	Form 'mm/dd/yy'	
9	File creation time	Char	8	Form 'hh:mm:ss'	
10	Editor code name	Char	8	Editor	
11	Editor version no.	Char	3	2.1	
12	Editor compile date	Char	8	Form 'mm/dd/yy'	
13	Geometry template file name	Char	12	Caskgeom.edt	
14	*** Unused ***				
15	Data file status	Char	12	'Complete' or 'Incomplete'	
16	Page 1 mod date, PGACC, PGREQ	Char	8 1 1	Form 'mm/dd/yy AR'	
17	Page 2 mod date, PGACC, PGREQ	Char	8 1 1	Form 'mm/dd/yy AR'	
	. NOTE: See TEMPLATE for definition of PGACC & PGREQ				
45	Page 30 mod date, PGACC, PGREQ	Char	8 1 1	Form 'mm/dd/yy AR'	

Title and Cavity Specifications

Record	Description	Type	Length	Restrictions	Default
46 \					
47 |	Title	Char	48		(blank)
48 |					
49 /					
50	Cavity radius (CAVR)	Real	12	$1. \leq X \leq 200.$	0.
51	Cavity length (CAVL)	Real	12	$1. \leq X \leq 1000.$	0.
52	Cavity length zoning (ZCAVL)	Int	2	$4. \leq X \leq 99.$	10.
53	Weight of contents (WTCON)	Real	12	$0. \leq X$	0.
54	*** Unused ***				

Cask Configuration

Record	Description	Type	Length	Restrictions	Default
55	Shell configuration (LSLAM)	List	1	L or S	S
56	Bottom end cap configuration (LBLAM)	List	1	L or S	S
57	Top end cap configuration (LTLAM)	List	1	L or S	S
58	*** Unused ***				
59	*** Unused ***				

Solid Shell Thickness

Record	Description	Type	Length	Restrictions	Default
60	Solid shell material name (SHLM)	Name	8	*.stm	SS304
61	Solid shell thickness (SHLT)	Real	12	$.1 \leq X \leq 60.$	0.
62	Solid shell zoning (ZSHLT)	Int	2	$3. \leq X \leq 20$	3.
63	*** Unused ***				
64	*** Unused ***				

Laminated Shell Layer Thicknesses

Record	Description	Type	Length	Restrictions	Default
65	Inner layer material name (SHLIM)	Name	8	*.stm	SS304
66	Inner layer thickness (SHLIT)	Real	12	$.1 \leq X \leq 60.$	0.
67	Inner layer zoning (ZSHLIT)	Int	2	$1. \leq X \leq 20$	2.
68	Shield layer material name (SHLLM)	Name	8	*.shm	LEAD
69	Shield layer thickness (SHLLT)	Real	12	$.1 \leq X \leq 60.$	0.
70	Shield layer zoning (ZSHLLT)	Int	2	$2. \leq X \leq 20$	3.
71	Shell bottom to shield distance (SHLLBD)	Real	12	$0. \leq X \leq 100.$	0.
72	Shell top to shield distance (SHLLTD)	Real	12	$.1 \leq X \leq 100.$	0.
73	Outer layer material name (SHLOM)	Name	8	*.stm	SS304
74	Outer layer thickness (SHLOT)	Real	12	$.1 \leq X \leq 60.$	0.
75	Outer layer zoning (ZSHLOT)	Int	2	$1. \leq X \leq 20$	2.
76	*** Unused ***				
77	*** Unused ***				

Solid Bottom End Cap Thickness

Record	Description	Type	Length	Restrictions	Default
78	Solid bottom end cap material name (BECM)	Name	8	*.stm	SS304
79	Solid bottom end cap thickness (BECT)	Real	12	.1≤X≤60.	0.
80	Solid bottom end cap zoning (ZBECT)	Int	2	1.≤X≤20	3.
81	*** Unused ***				
82	*** Unused ***				

Laminated Bottom End Cap Thicknesses

Record	Description	Type	Length	Restrictions	Default
83	Inner layer material name (BECIM)	Name	8	*.stm	SS304
84	Inner layer thickness (BECIT)	Real	12	.1≤X≤60.	0.
85	Inner layer zoning (ZBECIT)	Int	2	1.≤X≤20	2.
86	Shield layer material name (BECLM)	Name	8	*.shm	LEAD
87	Shield layer thickness (BECLT)	Real	12	.1≤X≤60.	0.
88	Shield layer zoning (ZBECLT)	Int	2	2.≤X≤20	3.
89	Shield layer radius (BECLR)	Real	12	.1≤X≤300.	0.
90	Outer layer material name (BECOM)	Name	8	*.stm	SS304
91	Outer layer thickness (BECOT)	Real	12	.1≤X≤60.	0.
92	Outer layer zoning (ZBECOT)	Int	2	1.≤X≤20	2.
93	*** Unused ***				
94	*** Unused ***				

Solid Top End Cap Thickness

Record	Description	Type	Length	Restrictions	Default
95	Solid top end cap material name (TECM)	Name	8	*.stm	SS304
96	Solid top end cap thickness (TECT)	Real	12	.1≤X≤60.	0.
97	Solid top end cap zoning (ZTECT)	Int	2	1.≤X≤20	3.
98	Lip in cavity ? (LLIP)	List	1	Y or N	N
99	*** Unused ***				
100	*** Unused ***				

Laminated Top End Cap Thicknesses

Record	Description	Type	Length	Restrictions	Default
101	Inner layer material name (TECIM)	Name	8	*.stm	SS304
102	Inner layer thickness (TECIT)	Real	12	.1≤X≤60.	0.
103	Inner layer zoning (ZTECIT)	Int	2	1.≤X≤20	2.
104	Shield layer material name (TECLM)	Name	8	*.shm	LEAD
105	Shield layer thickness (TECLT)	Real	12	.1≤X≤60.	0.
106	Shield layer zoning (ZTECLT)	Int	2	2.≤X≤20	3.
107	Shield layer radius (TECLR)	Real	12	.1≤X≤300.	0.
108	Outer layer material name (TECOM)	Name	8	*.stm	SS304
109	Outer layer thickness (TECOT)	Real	12	.1≤X≤60.	0.
110	Outer layer zoning (ZTECOT)	Int	2	1.≤X≤20	2.
111	Lip in cavity ? (LLIP)	List	1	Y or N	N
112	*** Unused ***				
113	*** Unused ***				

Solid Top End Cap Lip

Record	Description	Type	Length	Restrictions	Default
114	Lip thickness (TLIP)	Real	12	.1≤X≤200.	0.
115	Lip gap from shell wall (GLIP)	Real	12	0.≤X≤50.	0.
116	Allow contact with shell ? (LLCON)	List	1	Y or N	Y
117	*** Unused ***				
118	*** Unused ***				

Laminated Top End Cap Lip

Record	Description	Type	Length	Restrictions	Default
119	Lip thickness (TLIP)	Real	12	.1≤X≤200.	0.
120	Shield thickness in lip (TSLIP)	Real	12	0.≤X≤200.	0.
121	Shield radius in lip (RSLIP)	Real	12	0.≤X≤200.	0.
122	Lip gap from shell wall (GLIP)	Real	12	0.≤X≤50.	0.
123	Allow contact with shell ? (LLCON)	List	1	Y or N	Y
124	*** Unused ***				
125	*** Unused ***				

Top End Cap Inset

Record	Description	Type	Length	Restrictions	Default
126	Is the top end cap inset ? (LINSET)	List	1	Y or N	N
127	Shell wall thickness outside end cap (SHLXT)	Real	12	.1≤X≤60.	0.
128	Gap between end cap and shell (GEC)	Real	12	0.≤X≤50.	0.
129	Allow contact with shell ? (LECON)	List	1	Y or N	Y
130	*** Unused ***				
131	*** Unused ***				

Top End Cap Closure Bolts Information

Record	Description	Type	Length	Restrictions	Default
132	Bolt material name (BOLTSM)	Name	8	*.blm	SS304
133	Number of bolts (NBOLTS)	Int	2	4.≤X≤98 (even)	0.
134	Number of zones between bolts (ZBOLTS)	Int	2	1.≤X≤20	1.
135	Bolt diameter (BDIA)	Real	12	.01≤X≤20.	0.
136	Bolt circle radius (BCR)	Real	12	1.≤X≤300.	0.
137	*** Unused ***				
138	*** Unused ***				
139	*** Unused ***				
140	*** Unused ***				

Loading and Orientation Information

Record	Description	Type	Length	Restrictions	Default
141	G-Load	Real	12	0.≤X	0.
142	Angle of Impact	Real	12	-1. or 0.≤X≤90.	0.
143	Name of impact orientation	Char	4	side, end, cg, or oblq	side
144	Impact end	Char	6	Bottom or Top	Bottom
145	End-on impact support condition	Char	4	Full or Ring	Full

146-150 *** Unused ***

Material Database

Purpose: Contains thermal/structural material properties
Record Length: 12
File Type: Distributed files are in binary format. User modifiable files are ASCII.

NOTE: Record types are as follows:
Real = Real Number
Int = Integer Number
Char = Character string
List = Single Character which must match specific choices
Name = Value is selected from a file name list

Header

Record	Description	Type	Length	Restrictions	Default
1	Id			Must be 'ACASK mat'	
2 \					
3 |					
4 |--	Database name	Char	60		
5 |					
6 /					
8	File creation date	Char	8	Form 'mm/dd/yy'	
9	File creation time	Char	8	Form 'hh:mm:ss'	
10	Editor code name	Char	8	Editor	
11	Editor version no.	Char	3	2.1	
12	Editor compile date	Char	8	Form 'mm/dd/yy'	
13	Material template file name	Char	12	material.edt	
14	*** Unused ***				
15	Data file status	Char	12	'Complete' or 'Incomplete'	
16	Page 1 mod date, PGACC, PGREQ	Char	8 1 1	Form 'mm/dd/yy AR'	
17	Page 2 mod date, PGACC, PGREQ	Char	8 1 1	Form 'mm/dd/yy AR'	
.					
.	NOTE: See TEMPLATE for definition of PGACC & PGREQ				
.					
45	Page 30 mod date, PGACC, PGREQ	Char	8 1 1	Form 'mm/dd/yy AR'	

Material name

Record	Description	Type	Length	Restrictions	Default
46 \ 47 /	Material name	Char	24		(blank)
48	*** Unused ***				
49	*** Unused ***				
50	*** Unused ***				

Global Properties-- Impact and Temperature Independent

Record	Description	Type	Length	Restrictions	Default
51	Density (lbm/in.**3)	Real	12	Positive	.1
52	Impact Young's Modulus (psi)	Real	12	Positive	1.
53	Impact Poisson's Ratio	Real	12	$.001 \leq X \leq .499$	.3
54	Impact Yield Stress (psi)	Real	12	$0. \leq X$	0.
55	Impact Plastic Modulus (psi)	Real	12	$0. \leq X$	0.
56	Ultimate stress	Real	12	$0. \leq X$	0.
57	Proportional limit	Real	12	$0. \leq X$	0.
58	eo	Real	12	$0. \leq X$	0.
59	m	Real	12	$0. \leq X$	0.
60	*** Unused ***				
61	Melt Temperature (F)	Real	12	$-459. \leq X$	10000.
62	Heat of Fusion (Btu/lbm)	Real	12	Positive	1.
63	Internal heat generation (Btu/in.**3 min)	Real	12	$0. \leq X$	0.
64	*** Unused ***				
65	Material type	Int	1	$x = 3$	3.
66	Number of temperatures	Int	1	$1 \leq X \leq 8$	1.
67	*** Unused ***				
68	*** Unused ***				
69	*** Unused ***				
70	*** Unused ***				

Temperature-Dependent Properties

Record	Description	Type	Length	Restrictions	Default
71	Temperature 1 (F)	Real	12	$-459. \leq X$	0.
72	Young's Modulus (psi)	Real	12	Positive	1.
73	Poisson's Ratio	Real	12	$.001 \leq X \leq .499$	.3
74	Coefficient of thermal expansion (in./in.F)	Real	12		0.
75	Thermal conductivity (Btu/in.min F)	Real	12	Positive	1.
76	Specific heat capacity (Btu/lbm F)	Real	12	Positive	1.
77	Thermal emissivity for radiation	Real	12	$0. \leq X \leq 1.$	1.
78	*** Unused ***				
79	*** Unused ***				
80	*** Unused ***				

Record	Description	Type	Length	Restrictions	Default
81	Temperature 2 (F)	Real	12	-459.≤X	0.
82	Young's Modulus (psi)	Real	12	Positive	1.
83	Poisson's Ratio	Real	12	.001≤X≤.499	.3
84	Coefficient of thermal expansion (in./in.F)	Real	12		0.
85	Thermal conductivity (Btu/in.min F)	Real	12	Positive	1.
86	Specific heat capacity (Btu/lbm F)	Real	12	Positive	1.
87	Thermal emissivity for radiation	Real	12	0.≤X≤1.	1.
88	*** Unused ***				
89	*** Unused ***				
90	*** Unused ***				
91	Temperature 3 (F)	Real	12	-459.≤X	0.
92	Young's Modulus (psi)	Real	12	Positive	1.
93	Poisson's Ratio	Real	12	.001≤X≤.499	.3
94	Coefficient of thermal expansion (in./in.F)	Real	12		0.
95	Thermal conductivity (Btu/in.min F)	Real	12	Positive	1.
96	Specific heat capacity (Btu/lbm F)	Real	12	Positive	1.
97	Thermal emissivity for radiation	Real	12	0.≤X≤1.	1.
98	*** Unused ***				
99	*** Unused ***				
100	*** Unused ***				
101	Temperature 4 (F)	Real	12	-459.≤X	0.
102	Young's Modulus (psi)	Real	12	Positive	1.
103	Poisson's Ratio	Real	12	.001≤X≤.499	.3
104	Coefficient of thermal expansion (in./in.F)	Real	12		0.
105	Thermal conductivity (Btu/in.min F)	Real	12	Positive	1.
106	Specific heat capacity (Btu/lbm F)	Real	12	Positive	1.
107	Thermal emissivity for radiation	Real	12	0.≤X≤1.	1.
108	*** Unused ***				
109	*** Unused ***				
110	*** Unused ***				
111	Temperature 5 (F)	Real	12	-459.≤X	0.
112	Young's Modulus (psi)	Real	12	Positive	1.
113	Poisson's Ratio	Real	12	.001≤X≤.499	.3
114	Coefficient of thermal expansion (in./in.F)	Real	12		0.
115	Thermal conductivity (Btu/in.min F)	Real	12	Positive	1.
116	Specific heat capacity (Btu/lbm F)	Real	12	Positive	1.
117	Thermal emissivity for radiation	Real	12	0.≤X≤1.	1.
118	*** Unused ***				
119	*** Unused ***				
120	*** Unused ***				

Record	Description	Type	Length	Restrictions	Default
121	Temperature 6 (F)	Real	12	-459. ≤X	0.
122	Young's Modulus (psi)	Real	12	Positive	1.
123	Poisson's Ratio	Real	12	.001 ≤X≤ .499	.3
124	Coefficient of thermal expansion (in./in.F)	Real	12		0.
125	Thermal conductivity (Btu/in.min F)	Real	12	Positive	1.
126	Specific heat capacity (Btu/lbm F)	Real	12	Positive	1.
127	Thermal emissivity for radiation	Real	12	0. ≤X≤ 1.	1.
128	*** Unused ***				
129	*** Unused ***				
130	*** Unused ***				
131	Temperature 7 (F)	Real	12	-459. ≤X	0.
132	Young's Modulus (psi)	Real	12	Positive	1.
133	Poisson's Ratio	Real	12	.001 ≤X≤ .499	.3
134	Coefficient of thermal expansion (in./in.F)	Real	12		0.
135	Thermal conductivity (Btu/in.min F)	Real	12	Positive	1.
136	Specific heat capacity (Btu/lbm F)	Real	12	Positive	1.
137	Thermal emissivity for radiation	Real	12	0. ≤X≤ 1.	1.
138	*** Unused ***				
139	*** Unused ***				
140	*** Unused ***				
141	Temperature 8 (F)	Real	12	-459. ≤X	0.
142	Young's Modulus (psi)	Real	12	Positive	1.
143	Poisson's Ratio	Real	12	.001 ≤X≤ .499	.3
144	Coefficient of thermal expansion (in./in.F)	Real	12		0.
145	Thermal conductivity (Btu/in.min F)	Real	12	Positive	1.
146	Specific heat capacity (Btu/lbm F)	Real	12	Positive	1.
147	Thermal emissivity for radiation	Real	12	0. ≤X≤ 1.	1.
148	*** Unused ***				
149	*** Unused ***				
150	*** Unused ***				

Description of Editor Templates

The *AUTOCASK* editor uses a *template* to describe the editor pages and how data values are saved in the data sets. The *template* is a *random access* ASCII file. It is divided into three sections: control information, page headers, and descriptions of each editor page. The record length for the *template* is 150. The format of the *template* and the function of *template* parameters are described below.

Control Information

Record	Description [*format*]	
1	Scans Id 'Scans edt'	[*9a1*]
2	Name of the Template	[*65a1*]
3	Date of last modification	[*20a1*]
4	RECTOT, PAGTOT, TRECL, MAXREC, RECLN	[*5i6*]
	where RECTOT = Number of records in the template file	
	PAGTOT = Number of editor pages	
	TRECL = Template file record length (unused)	
	MAXREC = Number of records to create in data file	
	RECLN = Data file record length	
5	FORTRAN read format for body of template	[*a127*]

Page Headers

Record	Variable	Columns	Format	Comments
6	HDPGNO	1-3	I3	Sequential page number (unused)
	PAGNUM	5-7	A3	Page number displayed with editor page
	PGNAME	9-53	A45	Page identification line (end with \)
	NPRECS	55-57	I3	Number of records used to describe this page (If NPRECS<0, then this editor page is a copy of page IABS(NPRECS))
	PGACC	70	A1	Page access flag (reported in data file header) (Y=page always on, otherwise toggle A=on, N=off)
	PGREQ	72	A1	Required access flag (reported in data file) (R=page must be accessed, O=optional access)
	CBYPGN	74-75	I2	Page which has data which controls this page (0=this page not controlled by another)
	CBYRCN	77-78	I2	Record on page CBYPGN which controls this page
	CPON	80	A1	Character which defines page accessibility if record CBYRCN is character type and data is CPON
	IPON	82-83	I2	Number which defines page accessibility if record CBYRCN is integer type and data $\geq$ IPON
	GRCOFF	85-87	I3	Global record offset in data file added to the data global record if page is copy (NPRECS<0)
	FL1OFF	89-91	I3	1st default file data offset for copy pages
	FL1EXT	93-95	A3	1st default file extension to use FL1OFF
	FL2OFF	89-91	I3	2nd default file data offset for copy pages
	FL2EXT	93-95	A3	2nd default file extension to use FL2OFF

Repeat record 6 for each editor page (PAGTOT)

Description of Editor Pages

Record	Variable	Columns	Format	Comments
ii	NPG	1-2	I2	Page number (reference only)
	NLINE	4-5	I2	Description line number (reference only)
	GRBASE	6-9	I3	Global record in data file for data item (0=description line on screen is comment, GRCOFF is added to GRBASE if page is copy)
	REQDAT	11	A1	Is this required data ? (must be filled in) (Y=yes, display cyan; N=no, display green)
	CNTRL	13	A1	Control flag for displaying rest of page If CNTRL=blank and DTYPE=C or L, then if data item matches CNTRL rest of page is avail.
	LROW	15-16	I2	Row to display description (3 to 21)
	LCOL	18-19	I2	Column to display description (0 to 65)
	LABEL	21-94	A74	Data item description (must end with \)
	DTYPE	96	A1	Data item type ' ' (blank) = comment, not a data item 'c' = Character string 'n' = Data item selected from name list 'l' = Single character which must match list 'i' = Integer number 'r' = Real number
	DLEN	98-99	I2	Length of data item field
	DROW	101-102	I2	Row for data item field (0=use LROW) (3-21)
	DCOL	104-105	I2	Column for data item field (0-70)
	NUMCHK	107-108	A2	Numeric data item validation requirement ' ' (blank) = No checking 'NC' = No checking 'GT' = must be greater than NUM1 'LT' = must be less than NUM1 'GE' = must be greater than or equal to NUM1 'LE' = must be less than or equal to NUM1 'RG' = must be in range NUM1 to NUM2 inclusive 'PS' = must be positive 'ER' = must be even and in range NUM1 to NUM2 NOTE: NUM1 and NUM2 are contained in CHK
	CHK	110-130	var	For DTYPE='l' list of appropriate characters (end list with a blank character) For DTYPE='i' or 'r' NUM1 and NUM2 are in CHK READ (CHK, 'f10.0,1x,f10.0') NUM1,NUM2 For DTYPE='n' mask for file names (i.e. '*.mat')
	DFLT	131-145	var	For DTYPE='c', 'l' or 'n' default characters For DTYPE='i' or 'r' numeric default is in CHK READ (CHK, 'f10.0') RDVAL
	DFLTRC	147-150	I4	Record in default data file to find default value 0 = default is specified as DFLT in template >0 = default data file name is in DFLT and DFLTRC is record number in default data file

Repeat record ii for each line describing the editor page (NPRECS)

Repeat the set of records for each editor page (PAGTOT)

Cask Geometry Template

```
ACASK get
Template for AUTOCASK  Cask Geometry
Modified on July 2, 1990  at  11:25am by Michael Gerhard
   108    12   163   150    12
(bn,5x,i4,2(1x,a1),2(1x,i2),1x,a74,1x,a1,3(1x,i2),1x,a2,1x,a21,1x,a14,1x,i4)
  1 1    Title and Cavity Specifications          \   6          Y R  0  0
  2 2    Cask Configuration                       \   9          Y O  0  0
  3 3a   Solid Shell Thickness                    \   4          N R  2  1 S
  4 3b   Laminated Shell Layer Thicknesses        \  14          N R  2  1 L
  5 4a   Solid Bottom End Cap Thickness           \   4          N R  2  4 S
  6 4b   Laminated Bottom End Cap Layer Thicknesses \ 13          N R  2  4 L
  7 5a   Solid Top End Cap Thickness              \   5          N R  2  7 S
  8 5b   Laminated Top End Cap Layer Thicknesses   \  14          N R  2  7 L
  9 6a   Solid Top End Cap Lip                    \   4          N R  7  5 Y
 10 6b   Laminated Top End Cap Lip                \   6          N R  8 14 Y
 11 7    Top End Cap Inset                        \   4          Y O  0  0
 12 8    Top End Cap Closure Bolts Information    \   8          Y R  0  0
 1  1  46 R    4  0 Cask Title\                                  c 48   15                                                    0
 1  2          6  0 Cavity\                                                                                                  0
 1  3  50 R    7  0   Inner radius (in.)\                       r 12   52 RG 1.          200.      0.0                      0
 1  4  51 R    8  0   Length (in.)\                            r 12   52 RG 1.          1000.     0.0                      0
 1  5  52      9  0   Number of mesh divisions along cavity length\ i  2   52 RG 4.          99.       10.                      0
 1  6  53     10  0   Weight of contents (lbs)\                r 12   52 GE 0.                    0.0                      0
 2  1  55      4  0 Shell configuration\                        l  1   52    SL                    S                        0
 2  2   0      5  0      S=solid (1 layer)\                                                                                 0
 2  3   0      6  0      L=laminated (3 layers)\                                                                            0
 2  4  56      8  0 Bottom end cap configuration\              l  1   52    SL                    S                        0
 2  5   0      9  0      S=solid (1 layer)\                                                                                 0
 2  6   0     10  0      L=laminated (3 layers)\                                                                            0
 2  7  57     12  0 Top end cap configuration\                 l  1   52    SL                    S                        0
 2  8   0     13  0      S=solid (1 layer)\                                                                                 0
 2  9   0     14  0      L=laminated (3 layers)\                                                                            0
 3  1   0      4  0 Solid shell\                                                                                            0
 3  2  60      5  0   Material name\                           n  8   52    *.stm                 SS304                    0
 3  3  61 R    6  0   Thickness (in.)\                         r 12   52 RG .1          60.       0.                       0
 3  4  62      7  0   Number of mesh divisions through shell\ i  2   52 RG 3.          20.       3.                       0
 4  1   0      4  0 Inner layer\                                                                                            0
 4  2  65      5  0   Material name\                           n  8   52    *.stm                 SS304                    0
 4  3  66 R    6  0   Thickness (in.)\                         r 12   52 RG .1          60.       0.                       0
 4  4  67      7  0   Number of mesh divisions through inner layer\ i  2   52 RG 1.          20.       2.                       0
 4  5   0      9  0 Shield layer\                                                                                           0
 4  6  68     10  0   Material name\                           n  8   52    *.shm                 LEAD                     0
 4  7  69 R   11  0   Thickness (in.)\                         r 12   52 RG .1          60.       0.                       0
 4  8  70     12  0   Number of mesh divisions through shield layer\ i  2   52 RG 1.          20.       3.                       0
 4  9  71     14  0   Distance from bottom of shell to shield (in.)\ r 12   52 RG 0.          100.      0.                       0
 4 10  72 R   15  0   Distance from top of shell to shield (in.)\ r 12   52 RG .1          100.      0.                       0
```

Cask Geometry Template *continued*

```
4 11   0      17  0 Outer layer\                                                                                    0
4 12  73      18  0   Material name\                          n  8   52    *.stm            SS304                 0
4 13  74 R    19  0   Thickness (in.)\                        r 12   52 RG .1        60.     0.                    0
4 14  75      20  0   Number of mesh divisions through outer layer\  i  2   52 RG 1.         20.     2.           0
5  1   0       4  0 Solid bottom end cap\                                                                          0
5  2  78       5  0   Material name\                          n  8   52    *.stm            SS304                 0
5  3  79 R     6  0   Thickness (in.)\                        r 12   52 RG .1        60.     0.                    0
5  4  80       7  0   Number of mesh divisions through end cap\  i  2   52 RG 1.         20.     3.           0
6  1   0       4  0 Inner layer\                                                                                   0
6  2  83       5  0   Material name\                          n  8   52    *.stm            SS304                 0
6  3  84 R     6  0   Thickness (in.)\                        r 12   52 RG .1        60.     0.                    0
6  4  85       7  0   Number of mesh divisions through inner layer\  i  2   52 RG 1.         20.     2.           0
6  5   0       9  0 Shield layer\                                                                                  0
6  6  86      10  0   Material name\                          n  8   52    *.shm            LEAD                  0
6  7  87 R    11  0   Thickness (in.)\                        r 12   52 RG .1        60.     0.                    0
6  8  88      12  0   Number of mesh divisions through shield layer\  i  2   52 RG 1.         20.     3.           0
6  9  89 R    13  0   Radius (in.)\                           r 12   52 RG .1        300.    0.                    0
6 10   0      15  0 Outer layer\                                                                                   0
6 11  90      16  0   Material name\                          n  8   52    *.stm            SS304                 0
6 12  91 R    17  0   Thickness (in.)\                        r 12   52 RG .1        60.     0.                    0
6 13  92      18  0   Number of mesh divisions through outer layer\  i  2   52 RG 1.         20.     2.           0
7  1   0       4  0 Solid top end cap\                                                                             0
7  2  95       5  0   Material name\                          n  8   52    *.stm            SS304                 0
7  3  96 R     6  0   Thickness (in.)\                        r 12   52 RG .1        60.     0.                    0
7  4  97       7  0   Number of mesh divisions through end cap\  i  2   52 RG 1.         20.     3.           0
7  5  98       9  0 Does the end cap have a lip in the cavity? [Y/N]\  l  1   52    YN               N             0
8  1   0       4  0 Inner layer\                                                                                   0
8  2 101       5  0   Material name\                          n  8   52    *.stm            SS304                 0
8  3 102 R     6  0   Thickness (in.)\                        r 12   52 RG .1        60.     0.                    0
8  4 103       7  0   Number of mesh divisions through inner layer\  i  2   52 RG 1.         20.     2.           0
8  5   0       9  0 Shield layer\                                                                                  0
8  6 104      10  0   Material name\                          n  8   52    *.shm            LEAD                  0
8  7 105 R    11  0   Thickness (in.)\                        r 12   52 RG .1        60.     0.                    0
8  8 106      12  0   Number of mesh divisions through shield layer\  i  2   52 RG 1.         20.     3.           0
8  9 107 R    13  0   Radius (in.)\                           r 12   52 RG .1        300.    0.                    0
8 10   0      15  0 Outer layer\                                                                                   0
8 11 108      16  0   Material name\                          n  8   52    *.stm            SS304                 0
8 12 109 R    17  0   Thickness (in.)\                        r 12   52 RG .1        60.     0.                    0
8 13 110      18  0   Number of mesh divisions through outer layer\  i  2   52 RG 1.         20.     2.           0
8 14 111      20  0 Does the end cap have a lip in the cavity? [Y/N]\  l  1   52    YN               N             0
9  1   0       4  0 End cap lip\                                                                                   0
9  2 114 R     5  0   Thickness (in.)\                        r 12   52 RG .1        200.    0.                    0
9  3 115       6  0   Gap from shell wall (in.)\              r 12   52 RG 0.        50.     0.                    0
9  4 116       7  0   Allow contact with the shell? [Y/N]\    l  1   52    YN               Y                     0
```

Cask Geometry Template *continued*

```
10  1   0      4  0 End cap lip\                                                                                  0
10  2 119 R    5  0   Thickness (in.)\                    r 12   52 RG .1          200.      0.                  0
10  3 120      6  0   Additional thickness of shield in lip (in.)\  r 12   52 RG 0.          200.      0.        0
10  4 121      7  0   Radius of shield in lip (in.)\      r 12   52 RG 0.          200.      0.                  0
10  5 122      8  0   Gap from shell wall (in.)\          r 12   52 RG 0.          50.       0.                  0
10  6 123      9  0   Allow contact with the shell? [Y/N]\  l  1   52    YN                    Y                 0
11  1 126   Y  4  0 Is the end cap inset? [Y/N]\          l  1   52    YN                    N                 0
11  2 127 R    6  0   Thickness of cask wall outside end cap (in.)\  r 12   52 RG .1          60.       0.        0
11  3 128      7  0   Gap between end cap and cask wall (in.)\  r 12   52 RG 0.          50.       0.          0
11  4 129      8  0   Allow contact with the shell? [Y/N]\  l  1   52    YN                    Y                 0
12  1   0      4  0 Closure bolts\                                                                                0
12  2 132      5  0   Material name\                      n  8   52    *.blm                 SS304             0
12  3 133 R    6  0   Number of bolts (must be even)\     i  2   52 ER 4.          98.       0.                  0
12  4 134      7  0   Number of mesh divisions between bolts\  i  2   52 RG 1.          20.       1.          0
12  5   0      8  0     NOTE: If number of bolts is less than 8, the minimum\                                     0
12  6   0      9  0           number of mesh divisions between bolts is 2\                                        0
12  7 135 R   10  0   Bolt diameter (in.)\                 r 12   52 RG .01         20.       0.                  0
12  8 136 R   11  0   Bolt circle radius (in.)\           r 12   52 RG 1.          300.      0.                  0
```

Material Template

```
ACASK mat
Template for AUTOCASK  Cask Geometry
Modified on 28 Nov 89  at  3:00pm by Michael Gerhard
    50    12   163   150    12
(bn,5x,i4,2(1x,a1),2(1x,i2),1x,a74,1x,a1,3(1x,i2),1x,a2,1x,a21,1x,a14,1x,i4)
  1 1    Material Name and material density        \   2          Y R  0  0
  2 2    Impact, Puncture, Buckling Analysis Props  \  12          Y R  0  0
  3 3    Temperature-Independent Properties         \   2          Y R  0  0
  4 4a   Temperature 1 Properties                   \   6          N R  3  1    1
  5 4b   Temperature 2 Properties                   \  -4          N R  3  1    2  10
  6 4c   Temperature 3 Properties                   \  -4          N R  3  1    3  20
  7 4d   Temperature 4 Properties                   \  -4          N R  3  1    4  30
  8 4e   Temperature 5 Properties                   \  -4          N R  3  1    5  40
  9 4f   Temperature 6 Properties                   \  -4          N R  3  1    6  50
 10 4g   Temperature 7 Properties                   \  -4          N R  3  1    7  60
 11 4h   Temperature 8 Properties                   \  -4          N R  3  1    8  70
```

1	1	46	R	4	0	Material name\	c	24	45					0
1	2	51	R	6	0	Density (lbm/in.**3)\	r	12	45	PS		.1		0
2	1	52	R	4	0	Impact Young's Modulus (psi)\	r	12	45	PS		1.		0
2	2	53	R	5	0	Impact Poisson's Ratio\	r	12	45	RG	.001	.499	.3	0
2	3			7	0	The following properties are used for puncture and lead slump\								0
2	4	54		9	0	Yield Stress (psi)\	r	12	45	GE	0.		0.0	0
2	5	55		10	0	Plastic Modulus (psi)\	r	12	45	GE	0.		0.0	0
2	6	56		11	0	Ultimate stress (psi)\	r	12	45	GE	0.		0.0	0
2	7			13	0	The following properties are used for buckling\								0
2	8			14	0	eo and m define the stress-strain relation at stress levels\								0
2	9			15	0	above the proportional stress limit according to e = eo * n**m\								0
2	10	57		17	0	Proportional stress limit (psi)\	r	12	45	GE	0.		0.0	0
2	11	58		18	0	eo (psi)\	r	12	45	GE	0.		0.0	0
2	12	59		19	0	m\	r	12	45	GE	0.		0.0	0
3	1	66	R	4	0	Number of temperature sets (max is 8)\	i	1	45	RG	1.	8.	1.	0
3	2	65		6	0	Material type (Only type 3 is available)\	i	1	45	RG	3.	3.	3.	0
4	1	71	R	4	0	Temperature (F)\	r	12	45	GE	-459.		0.0	0
4	2	72	R	6	0	Young's Modulus (psi)\	r	12	45	PS			1.	0
4	3	73	R	7	0	Poisson's Ratio\	r	12	45	RG	.001	.499	.3	0
4	4	74		8	0	Coefficient of thermal expansion (in./in.F)\	r	12	45				0.	0
4	5	75		10	0	Thermal conductivity (Btu/in.min F)\	r	12	45	PS			1.	0
4	6	76		11	0	Specific heat capacity (Btu/lbm F)\	r	12	45	PS			1.	0

Data Set File Naming Conventions

AUTOCASK data sets consist of three files plus a model file and analysis input file. The names of these files are shown below. Each file name includes the associated CASK ID, xxxx.

xxxxCASK.GEI	Geometry Database
xxxxCASK.CHK	Geometry Data Check and Cask Summary Print File
xxxxDATA.FLG	Data Check Flag for Geometry
MFxxxx	Model file with mesh generation commands
NKxxxxi	Input file for NIKE3D

NRC FORM 335 (2-89) NRCM 1102, 3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

(See instructions on the reverse)

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U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

10. SUPPLEMENTARY NOTES

11. ABSTRACT *(200 words or less)*

AUTOCASK (AUTOmatic Generation of 3-D CASK Models) is a microcomputer-based system of computer programs and databases developed at the Lawrence Livermore National Laboratory for the structural analysis of shipping casks for radioactive material. Model specification is performed on the microcomputer, and the analyses are performed on the engineering workstation or mainframe computer. AUTOCASK is based on 80386-60486 compatible microcomputers. The system is composed of a series of menus, input programs, display programs, a mesh generation program, and archive programs. All data is entered through fill-in-the-blank input screens that contain descriptive data requests.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*
shipping casks, structural analysis, computer codes, NIKE3D

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